Aquaculture Round-Table

Report 1: collation of background information

August 2014

Hauraki Gulf Marine Park
Ko te Pataka kai o Tikapa Moana
Te Moananui a Toi

In partnership with mana whenua and the following agencies:

Hauraki Gulf Forum Tikapa Moana Te Moananui a Toi
Ministry for Primary Industries Manatū Ahu Matua
Department of Conservation Te Papa Atawhai
Waikato Regional Council Te Kaunihera ā Rohe o Waikato
Auckland Council Te Kaunihera o Tāmaki Makaurau

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Aquaculture Round-Table
Report 1: collation of information

This paper is a collation of relevant documents. Section 1 provides an introduction and brief overview of the legal planning framework that applies to marine farming. Section 2 contains extracts from technical reports that discuss marine farming and its effects on the environment. Most of this material has been copied directly from the documents and electronic links to the full documents have been provided.

Contents

1 Context

1.1 Round-tables and information needs

The Sea Change – Tai Timu Tai Pari is a stakeholder led project to improve the health and productivity of the Hauraki Gulf. A Stakeholder Working Group (SWG) leads this process and is supported by agencies. Round-tables (RTs) composed of stakeholders and focusing on specific topics (such as aquaculture) are a way for the SWG to break down the task of building understanding of the issues into smaller areas of enquiry. Adding more stakeholder representatives to the RTs allows the SWG to build deeper relationships and engagement with interest groups which themselves may not otherwise feel directly engaged in the process.

The SWG and the RTs need to be provided with technical and other information relevant to their work. The first part of this is information gathering. The second is synthesis and issues, the third part is exploring solutions and the final part is developing the plan. This document collates the technical information relevant for the information gathering phase. Other information required for this first stage, such as from public surveys and other engagement will be part of other reports.

1.2 Sources of expertise

List of potential sources of expertise with their affiliation and field of expertise.

Andrew Forsythe	NIWA, Bream Bay	aquaculture and biotechnology
Jeanie Stenton-Dozey	NIWA, Christchurch	marine ecology
Don Morrisey	NIWA, Nelson	marine ecologist
Paul Sagar	NIWA, Christchurch	seabird ecologist
Jane Symonds	NIWA, Bream Bay	aquaculture broodstock
Sean Handley	NIWA, Nelson	marine biologist
John Zeldis	NIWA, Christchurch	marine ecology/water quality
David Plew	NIWA, Christchurch	hydrodynamics
Mark Morrison	NIWA, Auckland	marine scientist
Niall Broekhuizen	NIWA, Hamilton	ecosystem modeller
Jacquie Reed	Cawthron Institute, Nelson	aquaculture group manager
Chris Cornelisen	Cawthron Institute, Nelson	coastal group manager
Paul Gillespie	Cawthron Institute, Nelson	coastal and estuarine ecosystems
Nigel Keeley	Cawthron Institute, Nelson	aquaculture monitoring and research
Deanna Clement	Cawthron Institute, Nelson	marine mammals
Barrie Forrest	Cawthron Institute, Nelson	marine ecology and biosecurity
Kevin Heasman	Cawthron Institute, Nelson	species development
Ben Knight	Cawthron Institute, Nelson	marine biophysics
Dave Taylor	Cawthron Institute, Nelson	aquaculture monitoring
Rochelle Constantine	University of Auckland	marine mammals
Chris Battershill	Waikato University	coastal and marine ecosystems
Shane Kelly	Coast & Catchment Ltd	marine ecology
Mark James	Consultant	marine biology and ecology
Richard Ford	MPI	fisheries scientist

1.3 Statutory documents

These documents contain policy guidance that management agencies have a legal obligation to implement, including some extracts from policies and plans prepared by the agencies themselves. Key parts of the documents are highlighted.

1.3.1 Relevant legislation

Marine farming is mainly managed by the Resource Management Act 1991 (RMA) and the plans that Auckland Council and Waikato Regional Council prepare under that legislation.

Other relevant legislation includes:

Fisheries Act – this requires the Ministry of Primary Industries to assess the impact of a marine farm on commercial, customary and recreational fishing.

Maori Commercial Aquaculture Claims Settlement Act –requires that the equivalent of 20% of any new marine farming space is allocated to the iwi of the region (as an equivalent amount of space or cash or a combination or other equivalent as agreed by negotiation)..

Biosecurity Act – this requires marine farmers to report any unwanted organisms that they observe on their farms or vessels.

Marine Mammal Act – this makes it an offense to harm, harass or disturb any marine mammal.

Wildlife Act – this protects most species, including most birds and makes it an offense to kill or have possession of any protected species.

Food Act and Animal Products Act – these acts manage food safety.

1.3.2 New Zealand Coastal Policy Statement 2010

The New Zealand Coastal Policy Statement (NZCPS) contains policies relating to coastal management and includes a specific policy on aquaculture. Planning documents prepared by councils must give effect to the NZCPS. This includes regional policy statements, regional plans, district plans and unitary plans.

It is important to recognise that no policy in the NZCPS should be considered in isolation from the rest, and they have equal weighting depending on the specific wording of the policy. The use, development and protection of the coastal environment must give effect to all relevant policies of the NZCPS.

Policy 8 Aquaculture

Recognise the significant existing and potential contribution of aquaculture to the social, economic and cultural well-being of people and communities by:

(a) including in regional policy statements and regional coastal plans provision for aquaculture activities in appropriate places in the coastal environment, recognising that relevant considerations may include:

(i) the need for high water quality for aquaculture activities; and

(ii) the need for land-based facilities associated with marine farming;

(b) taking account of the social and economic benefits of aquaculture, including any available assessments of national and regional economic benefits; and

(c) ensuring that development in the coastal environment does not make water quality unfit for aquaculture activities in areas approved for that purpose.

http://www.doc.govt.nz/documents/conservation/marine-and-coastal/coastal-management/nz-coastal-policy-statement-2010.pdf

1.3.3 The Waikato Regional Policy Statement

The proposed Regional Policy Statement (RPS) for the Waikato Region provides an overview of the resource management issues of the region and describes how the integrated management of natural and physical resources will be achieved. Regional and District Plans are required to give effect to the RPS. The proposed RPS is expected to become operative in early 2015, once Environment Court appeals have been resolved.

Policy 7.1 Interests in the coastal marine area
The coastal marine area is recognised as generally being public space and its efficient use is ensured by allocating space to activities in a way that:

a) recognises the Crown's interest in the coastal marine area;
b) recognises conflicting uses;
c) provides for protected customary rights; and
d) provides for ecosystem values as well as people's social, economic and cultural aspirations.

Method 7.1.1 Allocation of space within the coastal marine area
The regional coastal plan shall establish criteria to determine the appropriateness of different activities within the coastal marine area and where necessary identify areas that are appropriate for different purposes or activities including areas to be protected from development. Particular regard will be had to:

a) opportunities for recreational access across a range of experiences;
b) opportunities for electricity generation from renewable sources;
ba) **opportunities for the development of aquaculture**;
c) the functional necessity for activities to locate in the coastal marine area;
d) avoiding the effects of natural hazards;
e) the public benefits of the use of natural resources and from any development in public space;
f) changes projected as a result of climate change;
g) avoiding sprawling and sporadic development;
h) economic, cultural and social uses of the coastal marine area; and
i) linking activities taking place in the marine area to land-based infrastructure necessary for its support; and
j) avoiding adverse effects, including cumulative effects on:
   i) areas of significance to tāngata whenua;
   ii) open space and amenity values;
   iii) public access;
   iv) existing/future marine transport corridors;
   v) marine water quality;
   vi) indigenous biodiversity values;
   vii) natural character and landscape values; and

viii) physical coastal processes (hydrodynamic and sediment dynamics).

Method 7.1.4 Aquaculture strategy
Waikato Regional Council will develop an aquaculture strategy in consultation with relevant stakeholders to recognise the existing and future contribution of aquaculture to the region. This will form part of the wider Coastal Marine Strategy in Method 7.1.4A.

http://www.waikatoregion.govt.nz/PageFiles/10522/2320314_RPS_Decisions_1_Feb_2013.pdf

1.3.4 The Auckland Unitary Plan

Marine farming activities in the Auckland region will be managed by the proposed Auckland Unitary Plan when it becomes operative. This is expected to occur in late 2016.

The objectives of the proposed Auckland Unitary Plan for aquaculture are:

5.1.14 Aquaculture
Objectives

1. The cultural, social and economic benefits of aquaculture are recognised, and aquaculture is developed in appropriate locations that avoid, or where appropriate minimise, conflicts with other uses and values of the CMA.
2. Established aquaculture is not compromised by other uses or activities that degrade water quality.
3. Aquaculture activities are managed to minimise the risk of introducing or spreading harmful aquatic organisms.

http://unitaryplan.aucklandcouncil.govt.nz/pages/plan/Book.aspx

In the meantime the plans of the old Auckland Regional Council also apply. These are complicated by existence of several variations to the Auckland Regional Plan: Coastal and a Ministry of Agriculture and Fisheries gazette notice dating from 1984.

The effect of these is to prohibit marine farming in most of the part of the Hauraki Gulf. Specifically, the gazette notice prohibits aquaculture within that part of the Gulf that falls within the area of the old Auckland Regional Authority (shown in figure 1).

The gazette notice (and therefore the prohibition on marine farming in this area) will expire when the proposed Auckland Unitary Plan becomes operative.

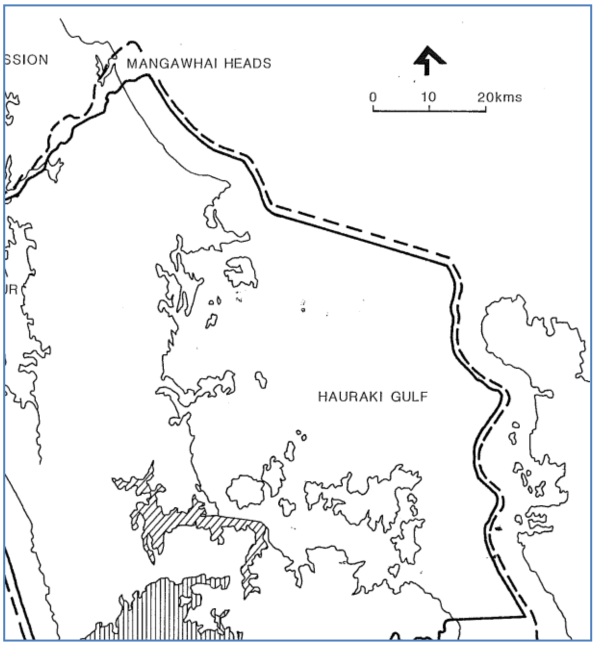


Figure 1: Extent of the Auckland Regional Authority

http://www.aucklandcity.govt.nz/council/documents/regionalplans/coastal/aucklandregionalcoastalplanwholeplan.pdf

1.3.5 The Waikato Regional Coastal Plan

Marine farming activities in the Waikato region are managed by the Waikato Regional Coastal Plan. The Plan became operative in 2005 and a review of it will start in 2015, following the completion of the Sea Change Tai Timu Tai Pari marine spatial plan for the Hauraki Gulf.

In general terms, aquaculture is prohibited in all areas in the Waikato region outside of the marine farming zones, except for minor extensions to existing farms outside the zones, inter-tidal oyster farms and spat catching. Fish farming is prohibited except within Area C of the Wilson Bay Marine Farming Zone and in the Coromandel Marine Farming Zone. No fish farms are currently operating or consented.

> **Waikato Regional Coastal Plan**
> **6.1 Marine Farming**
> **Objective**
>
> Marine faming developed in an efficient and sustainable manner which avoids adverse effects on the coastal environment as far as practicable.

http://www.waikatoregion.govt.nz/Council/Policy-and-plans/Rules-and-regulation/Regional-Coastal-Plan/

1.4 Strategic documents

These are non-statutory documents that describe short and long term aspirations for the aquaculture industry. Strategies have been prepared by Aquaculture New Zealand and by the Ministry for Primary Industries.

1.4.1 The New Zealand Aquaculture Strategy 2006

(extract from Aquaculture NZ website hosting the report)

The New Zealand Aquaculture Strategy is the blueprint to becoming a Billion-dollar sector by 2025.

It will see aquaculture's revenue rival that produced by New Zealand's wool and wine industries.

The Strategy was prepared in conjunction with participants from all sectors of the seafood industry, iwi, government ministries, research providers and NGOs. It focuses on actions that are within the control of the industry acting cooperatively as a sector, working in partnership with iwi, regions, communities, science, education, training providers and government and guided by the following principles:

- The strategy is market-driven, industry-led, commercially viable, and sector-wide
- It requires the collective action of industry participants
- Growth will be driven by innovations in existing and new space, species, products and markets
- Growth will take place within an environmentally sustainable framework
- The strategy will be implemented through a partnership between industry and government, communities, iwi, regions, and research/education/training providers

http://aquaculture.org.nz/about-us/strategy/

http://aquaculture.org.nz/wp-content/uploads/2011/05/Strategy.pdf

1.4.2 The Government's Aquaculture Strategy 2012

(extract from MPI website hosting the report)

In 2012 the Government adopted the Aquaculture Strategy and a Five-year Action Plan. The strategy and action plan establishes a whole-of-government pathway to enable the aquaculture sector to grow.

This strategy and action plan aligns with both the aquaculture industry's strategy and the Ministry for Primary Industries' 2030 Strategy, setting out how the government can support the growth ambitions established by the sector. It also complements existing government environmental and economic initiatives and upholds the Crown's obligations under the Treaty of Waitangi.

Through the strategy and action plan the government will support industry in achieving its goals while acting in the public interest to ensure an appropriate balance of economic, social, cultural and ecological values.

Through the strategy and action plan the government will:

- implement the new aquaculture law and work with councils and the public to plan for sensible and sustainable future aquaculture growth in accordance with New Zealand's laws and regulations;
- ensure the laws and frameworks governing the establishment and operation of marine and land-based aquaculture are effective and responsive, and enable industry investment;
- deliver on the Crown's aquaculture settlement obligations to Māori and identify opportunities for improving Māori wellbeing though aquaculture development;
- build our knowledge of environmental effects and ensure a healthy aquatic environment;
- maintain and build our world-leading animal health and welfare, food safety, and biosecurity standards;
- encourage investment and adoption of innovation; and
- facilitate continued discussion between industry, government, Māori and the public as to how aquaculture should grow and be managed in New Zealand.

(extract from the foreword to the Strategy)

Our primary industries are the engine room of our economy. We need to enable primary industry growth underpinned by strong environmental performance. The Ministry for Primary Industries' vision for our primary sectors is "Growing and Protecting New Zealand".

Government supports well-planned and sustainable aquaculture growth in New Zealand and is committed to enabling the 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 users and values of our waterways and marine environment.

http://www.fish.govt.nz/en-nz/Commercial/Aquaculture/Aquaculture+Strategy/default.htm

http://www.fish.govt.nz/NR/rdonlyres/20A0ED89-A20B-4975-9E63-6B302187840D/0/AQUAStrat5yrplan2012.pdf

2 Technical Information

This section includes sources of information on the effects of aquaculture. This collection is not exhaustive as there is a very large body of research and information available, but an attempt has been made to provide a comprehensive coverage. No commentary on these references has been included. Any notes added to this section are given in *italics*. All other text in this sections has been copied and pasted directly from the sources. In most cases it is the abstract or executive summary, or part of it.

All these documents are available online in full and links have been included.

2.1 Global context and economic effects

UNFAO Fisheries and Aquaculture Department, 2014. **The State of World Fisheries and Aquaculture, 2014: Opportunities and challenges**. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-i3720e/index.html

(extract from Part 1 of the report)

Overview
Global fish production has grown steadily in the last five decades (Figure 1), with food fish supply increasing at an average annual rate of 3.2 percent, outpacing world population growth at 1.6 percent. World per capita apparent fish consumption increased from an average of 9.9 kg in the 1960s to 19.2 kg in 2012 (preliminary estimate) (Table 1 and Figure 2, all data presented are subject to rounding). This impressive development has been driven by a combination of population growth, rising incomes and urbanization, and facilitated by the strong expansion of fish production and more efficient distribution channels.

China has been responsible for most of the growth in fish availability, owing to the dramatic expansion in its fish production, particularly from aquaculture. Its per capita apparent fish consumption also increased an average annual rate of 6.0 percent in the period 1990–2010 to about 35.1 kg in 2010. Annual per capita fish supply in the rest of the world was about 15.4 kg in 2010 (11.4 kg in the 1960s and 13.5 kg in the 1990s).

Figure 1

World capture fisheries and aquaculture production

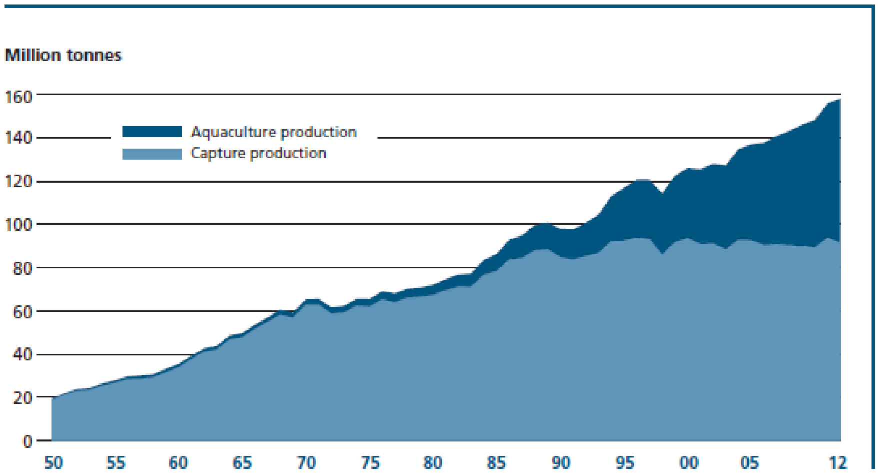


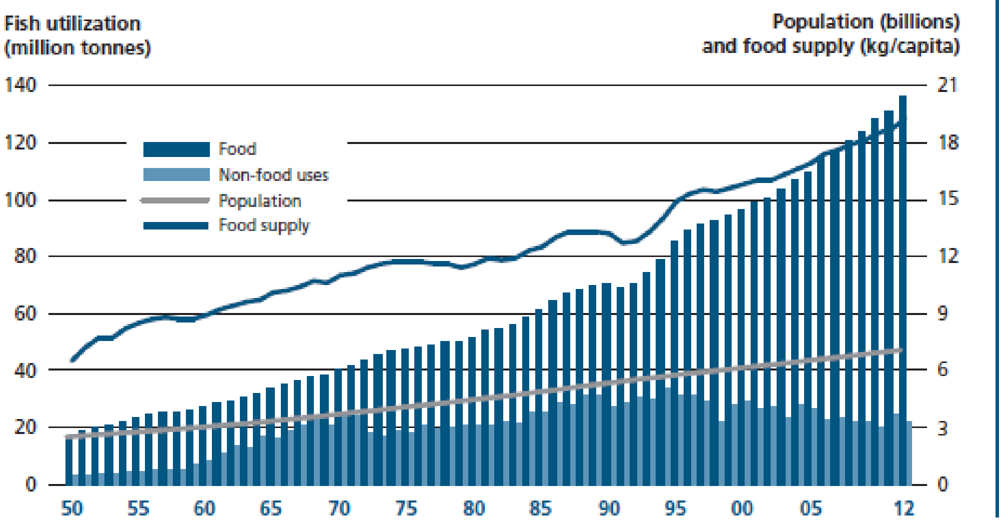
Table 1
World fisheries and aquaculture production and utilization

	2007	2008	2009	2010	2011	2012
	(Million tonnes)					
PRODUCTION						
Capture						
Inland	10.1	10.3	10.5	11.3	11.1	11.6
Marine	80.7	79.9	79.6	77.8	82.6	79.7
Total capture	**90.8**	**90.1**	**90.1**	**89.1**	**93.7**	**91.3**
Aquaculture						
Inland	29.9	32.4	34.3	36.8	38.7	41.9
Marine	20.0	20.5	21.4	22.3	23.3	24.7
Total aquaculture	**49.9**	**52.9**	**55.7**	**59.0**	**62.0**	**66.6**
TOTAL WORLD FISHERIES	**140.7**	**143.1**	**145.8**	**148.1**	**155.7**	**158.0**
UTILIZATION[1]						
Human consumption	117.3	120.9	123.7	128.2	131.2	136.2
Non-food uses	23.4	22.2	22.1	19.9	24.5	21.7
Population (*billions*)	6.7	6.8	6.8	6.9	7.0	7.1
Per capita food fish supply (*kg*)	17.6	17.9	18.1	18.5	18.7	19.2

Note: Excluding aquatic plants. Totals may not match due to rounding.
[1] Data in this section for 2012 are provisional estimates.

Figure 2

World fish utilization and supply



Total capture fisheries production

According to final data, total global capture production of 93.7 million tonnes in 2011 was the second-highest ever, slightly below the 93.8 million tonnes of 1996. Moreover, 2012 showed a new maximum production (86.6 million tonnes) when the highly variable anchoveta (Engraulis ringens) catches are excluded.

However, these recent results should not raise expectations of significant catch increases. Rather, they represent a continuation of the generally stable situation reported previously.1 Variations in production by country, fishing area and species are buffered at the global level through compensatory developments in different fisheries. In 1998, extremely low anchoveta catches reduced the total catch to 85.7 million tonnes. Thereafter, the widest deviations from the annual average of 91.1 million tonnes in the best and worst years (2011 and 2003 at 93.7 and 88.3 million tonnes, respectively) have been only about 3 percent.

Aquaculture

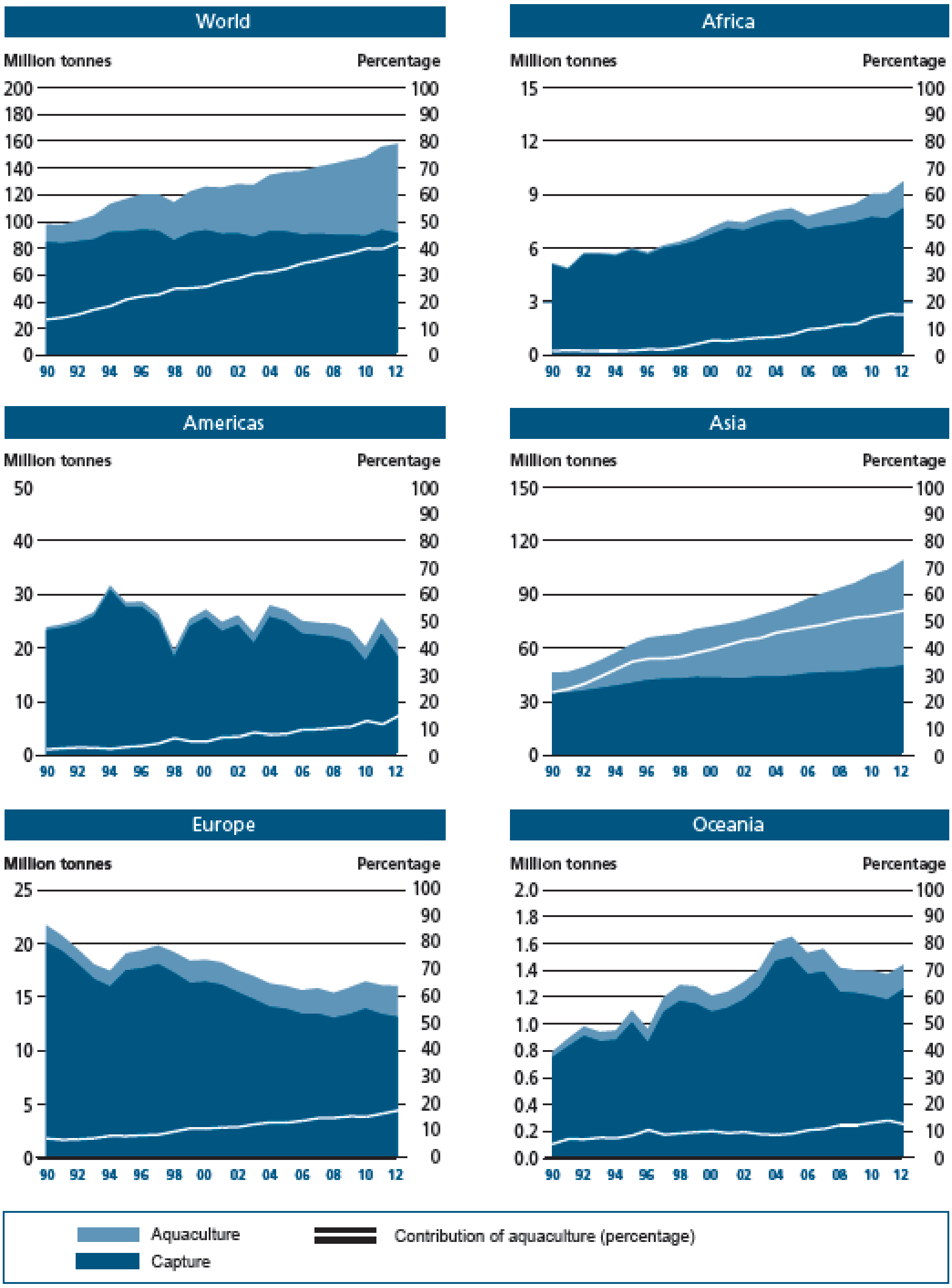
World aquaculture production continues to grow, albeit at a slowing rate. According to the latest available statistics collected globally by FAO, world aquaculture production attained another all-time high of 90.4 million tonnes (live weight equivalent) in 2012 (US$144.4 billion), including 66.6 million tonnes of food fish (US$137.7 billion) and 23.8 million tonnes of aquatic algae (mostly seaweeds, US$6.4 billion). In addition, some countries also reported collectively the production of 22 400 tonnes of non-food products (US$222.4 million), such as pearls and seashells for ornamental and decorative uses. For this analysis, the term “food fish” includes finfishes, crustaceans, molluscs, amphibians, freshwater turtles and other aquatic animals (such as sea cucumbers, sea urchins, sea squirts and edible jellyfish) produced for the intended use as food for human consumption. At the time of writing, some countries (including major producers such as China and the Philippines) had released their provisional or final official aquaculture statistics for 2013. According to the latest information, FAO estimates that world food fish aquaculture production rose by 5.8 percent to 70.5 million tonnes in 2013, with production of farmed aquatic plants (including mostly seaweeds) being estimated at 26.1 million tonnes. In 2013, China alone produced 43.5 million tonnes of food fish and 13.5 million tonnes of aquatic algae.

The total farmgate value of global aquaculture has probably been overstated owing to factors such as some countries reporting retail, product or export prices instead of prices at first sale. Nonetheless, when used at aggregated levels, the value data are useful in showing the development trend and for comparison of the relative importance of economic benefit among different types of aquaculture and different groups of farmed aquatic species.

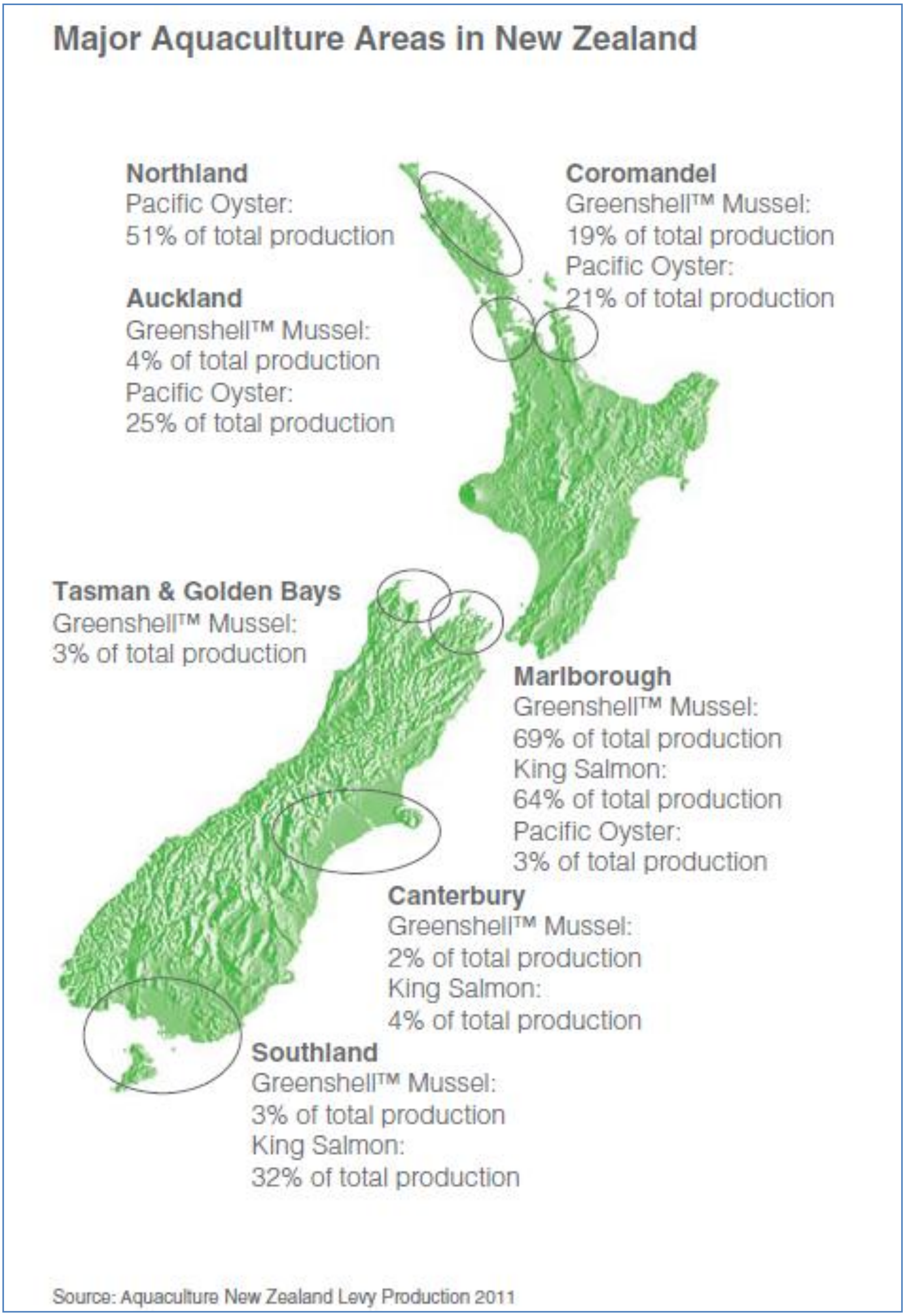
The global trend of aquaculture development gaining importance in total fish supply has remained uninterrupted. Farmed food fish contributed a record 42.2 percent of the total 158 million tonnes of fish produced by capture fisheries (including for non-food uses) and aquaculture in 2012 (Figure 5). This compares with just 13.4 percent in 1990 and 25.7 percent in 2000. Asia as a whole has been producing more farmed fish than wild catch since 2008, and its aquaculture share in total production reached 54 percent in 2012, with Europe at 18 percent and other continents at less than 15 percent.

Figure 5

Share of aquaculture in total fish production



New Zealand Aquaculture, 2012. **A sector overview with key facts, statistics and trends**.
http://aquaculture.org.nz/wp-content/uploads/2012/05/NZ-Aquaculture-Facts-2012.pdf



New Zealand Aquaculture Statistics

Production and revenue metrics for 2011

	Mussels	Salmon	Oysters
Harvested product (greenweight tonnage)	101,311	14,037	1,804
Export revenue NZ$ (millions)	218.1	63.4	16.6
Domestic revenue NZ$ (millions) (estimated)	35.0	65.0	8.0

Due to a lack of robust domestic consumption information being available for the three species, a focus has been placed on presenting an analysis around the export statistics. These are official export figures collected by New Zealand Customs. All export revenue information is reported in FoB (Free on Board) pricing.

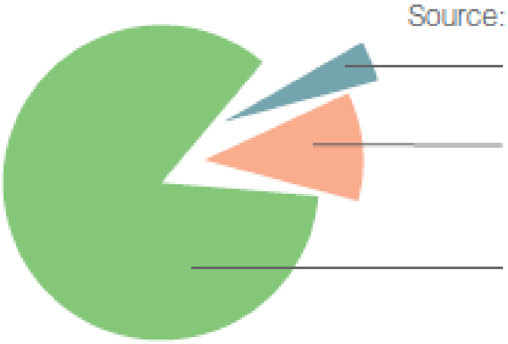
New Zealand Aquaculture Exports

Aquaculture exports in 2011 equated to NZ$298 million.

New Zealand had 79 active export markets in 2011 for Greenshell™ Mussels, Pacific Oysters and King Salmon.

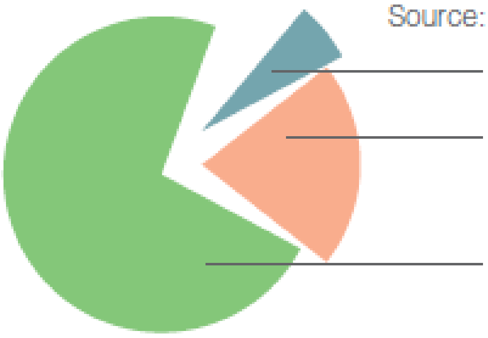
Proportion of aquaculture exports for 2011 by Volume

Source: New Zealand Seafood Exports 2011



Proportion of aquaculture exports for 2011 by Value

Source: New Zealand Seafood Exports 2011



James, M.A. and Slaski, R. J (2009) **A strategic review of the potential for aquaculture to contribute to the future security of food and non-food products and services in the UK and specifically England**. Report commissioned by the Department for the Environment and Rural Affairs, 121pp.
http://archive.defra.gov.uk/foodfarm/fisheries/documents/aquaculture-report0904.pdf

(extract from executive summary)

Strategic projections of supply and demand for fish and shellfish
There is much evidence to show that on a global scale, fish and shellfish production from wild fisheries has plateaued. The Food and Agriculture Organization of the United Nations (FAO) has classified most wild fisheries as either fully exploited or over exploited.

In 2006 wild fisheries produced 91m tonnes and aquaculture 67m tonnes – approximately 42% of global production. About 93% of aquaculture production occurs in Asia. More than 60% of production takes place in freshwater. In the coming decades aquaculture is likely to be the greatest source of increased fish and shellfish production.

To achieve 1.5 meals per week of seafood the EU27 will require an additional 3.7 million tonnes of whole fish equivalent seafood supply by 2035 – an increase of some 35% over the 2006 supply.

UK population is forecast to grow to almost 71 million by 2035. The implications for seafood products are: that at an increased level of 1.5 seafood meals per week, total seafood requirement would grow from 1.1 million tonnes whole fish equivalent (2006) to some 1.9 million tonnes by 2035.

Unlike the overall global trend, EU27 capture fisheries have declined over recent years, with the balance of supplies coming from aquaculture production and from increased imports.

The prices of many animal-origin foods have declined steeply over the past several decades because of increased production and stagnating demand. In contrast, consumers have experienced a longterm increase in the real prices of fresh and frozen fish and this trend is likely to continue.

Food Security - fish and shellfish production
Governments have a responsibility to ensure that everyone has enough to eat. Food needs to be available, accessible and affordable through a resilient and reliable supply system.

The capacity of some developed economies to respond effectively to chronic insults on food security is questionable in the face of Global changes in economies, climate, the energy gap and anticipated population growth.

Developed economies such as the UK rely heavily on their ability to import goods and services. The capacity and desirability of doing so in the future with respect to seafood is discussed.

A framework of indicators is used to assess UK food security with respect to seafood and is presented as a summary below.

Overall, the assessment suggests that it would be desirable and strategically important for the UK and, where appropriate, England to develop aquaculture as a means of reducing our projected increasing reliance on imports – ensuring that seafood remains accessible and affordable, is

produced sustainably and offers the potential for the export of healthy and relatively high value produce.

...

Drivers for aquaculture trends

The strategic drivers for the continued growth of global aquaculture are the requirement for it to continue bridging the gap between maximum sustainable wild seafood harvests and the requirements of a growing and more nutritionally aspirational world population. A future potentially significant driver may be to produce biofuels and other non-food products.

A range of potential constraints that have affected trends in aquaculture production are considered including:

- Physical availability of environmental resources for aquatic production
    - Finite resources in absolute terms
    - Increased public interest in sustainable utilisation of environmental resources
    - Competing requirements for environmental resources
- Environmental carrying capacity in terms of nutrients
- Biological, social and economic competition with other aquatic sectors
- Availability of essential raw materials

Irvine, R., Robinson, M., & Carboni, A., 2007, **Economic Impact of Aquaculture in the Waikato Region**, Environment Waikato technical report 2007/33, prepared by Covec Limited.
http://www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/Economic-Impact-of-Aquaculture-in-the-Waikato-Region/

(extract from executive summary)

Aquaculture industry

The total value of aquaculture production throughout New Zealand was approximately $289 million in 2004. Mussels accounted for $181 million, with 645 farms encompassing 4,747 ha of marine space. This produced around 95,000 tonnes, over three quarters of which was exported, bringing in around $120 million in export earnings.

Oysters accounted for $26 million, with 230 farms covering 750 ha of marine space. This produced just under 3,000 tonnes, two-thirds of which was exported, bringing in close to $15 million in export earnings.

Regional production

The aquaculture industry in the Waikato region consists of around 40 core businesses that carry out a range of activities. The dominant form of aquaculture in the Waikato region is mussel farming, with around 900 ha of active mussel farms producing over 21,000 tonnes annually. Thus, mussel farming in the Waikato region accounts for around 20 per cent of national mussel production. Oyster farming in the Waikato region is relatively small in comparison, with less than 70 ha of farms producing around 640,000 dozen oysters per year, accounting for around 10 per cent of national oyster production.

Most aquacultural activity occurs in the waters around the Coromandel Peninsula, although there are a few small farms on the west coast.

The total mussel harvest size across the region has been increasing over the past few years. The total harvest in Coromandel in 2006 was around 21,000 tonnes of mussels, compared with 17,600 in 2005 and around 16,000 in 2004. 2007 began with greater harvest sizes than the corresponding months in 2006.

Economic impacts

Aquaculture contributes approximately $27 million to Waikato's annual regional GDP. This is the total value, or wealth, added to the regional economy because of aquacultural activity. This impact of aquaculture can be broken down between the impacts resulting from farming activities (including harvesting) and those from processing activities. The farming of mussels and oysters accounts for around 70 per cent of the industry's impact on regional GDP ($19.1 million), while processing accounts for the remaining 30 per cent ($7.8 million).

Economic impacts can also be broken down by direct, indirect and induced impacts. The majority ($18.9 million) of the $27 million contribution to regional GDP comes from the direct impact of revenue earned from within the aquaculture industry itself. Indirect impacts include the value-added by those who provide inputs to the aquaculture industry, eg fuel, utilities, professional services (accountancy, legal services, etc). These indirect impacts contribute $3.7 million to regional GDP. Induced impacts, arising largely from the spending of households who receive wages and salaries resulting from aquacultural activity, contribute a further $4.3 million.

Direct employment within the aquaculture industry itself equates to around 270 full time equivalent (FTE) positions. Because a large proportion of jobs are seasonal, especially within the processing sector, just under one-third (140) of the approximately 400 individuals directly employed in the industry are employed on a permanent full-time basis. Total wages and other remuneration received by employees within the industry is around $10 million.

Murray, C.; and McDonald, G.; (2010). **Aquaculture: Economic impact in the Auckland region**. Jointly prepared by the Auckland Regional Council and Market Economics Ltd for Auckland Regional Council. Auckland Regional Council Document. Technical Report no. 009, 2010.
http://www.aucklandcouncil.govt.nz/SiteCollectionDocuments/aboutcouncil/planspoliciespublications/technicalpublications/tr2010009aquacultureeconomicimpactintheaucklandregion.pdf

(extract from executive summary)

In the 2008-2009 year, the Auckland region harvested 2,648 tonnes of mussels and 890 tonnes of oysters. This equates with 3 per cent of national mussel production and 26 per cent of oyster production. For that period, the region processed nearly seven times the amount of mussels harvested (17,426 tonnes). It processed (853 tonnes) slightly less than that harvested in the region, indicating that this is done in other regions or oysters are exported live. The food processing facilities in Auckland are very important for the industry, and also service contiguous regions. Aquaculture contributed an estimated $200472 million of output to Auckland's economy in 2009. This corresponds to $200428.2 million of value added, or regional gross domestic product (GDP), or 0.06per cent of Auckland's total regional GDP. The contribution to GDP is comprised of aquaculture farming impacts (approximately 20 percent of total) and aquaculture processing impacts (approximately 80 percent of GDP impact). Thus, for the region, aquaculture processing is highly significant. The processing facilities are not just important for the Auckland region, but also for adjoining regions' harvests.

Economic impacts of the aquaculture industry 2008-2009 year

	Aquaculture Farming Impacts[1]	Aquaculture Processing Impacts[2]	Total Economic Impact
*Output ($$_{2004}$mil)**			
Direct	6.6	42.2	48.7
Indirect	4.5	14.2	18.7
Induced	0.8	4.1	5.0
Total	**11.9**	**60.5**	**72.4**
Value Added ($$_{2004}$mil)			
Direct	3.1	13.7	16.8
Indirect	2.2	6.7	8.9
Induced	0.4	2.0	2.5
Total	**5.7**	**22.4**	**28.2**
Employment (FTEs)			
Direct	66	275	341
Indirect	37	104	141
Induced	4	21	25
Total	**107**	**400**	**507**

*prices are given in 2004 dollar terms, which is the base year for the input-output table (See section 3.3 for details).

Economic impact assessment recognises that one form of economic activity almost always leads to others. Direct impacts are the initial immediate economic activities resulting within the target industry from an investment. These are the first round of expenditure in an economy. Indirect impacts are the changes that occur in other businesses or industries that supply inputs into the industry where the investment has taken place. Induced impacts are those which occur due to increased total household expenditure, as a result of an investment. The sum of the direct indirect and induced effects is the total effect on the economy – the effects of an initial investment is compounded or multiplied throughout the economy.

In terms of employment, there are an estimated 507 full time equivalents (FTEs) resulting from aquaculture in the region. These are comprised of 341 in direct farming and processing jobs, 141 indirect jobs as a result of activity in other industries, and 25 induced jobs in the region. Again, 80 percent of these are in the processing industry, reinforcing its relative importance within the industry.

Wyatt, S., 2011. **Economic Impact of Coromandel Aquaculture**, Sapere Research Group report prepared for the Hauraki-Coromandel Development Group.
http://www.srgexpert.com/Coromandel%20EIS_Final_9%20Sept%202011.pdf

(executive summary)

Current economic impacts

In the 2010/11 year, farms in the Coromandel district harvested an estimated 31,000 green weight tonnes (GWT) of mussels and half a million dozen oysters. Aquaculture New Zealand estimates that the Coromandel district produces 24 per cent of national mussel production and 20 per cent of oyster production. For that period, processors in the Coromandel district processed about 30 per cent of the volume of mussels harvested while processing facilities in Auckland and Tauranga

processed the remainder. Almost all the oysters harvested in the Coromandel were either processed in Coromandel or sold fresh to consumers and wholesalers.

Aquaculture contributed an estimated $31.4 million of value added, or regional gross domestic product (GDP), to the Waikato region in 2010/11. This is 0.2 percent of Waikato's total gross regional product (GRP); by comparison dairy farming and dairy factories contribute around 10.8 percent of GRP. The contribution to GDP is comprised of aquaculture farming impacts (approximately 43 percent of total) and aquaculture processing impacts (approximately 57 percent of GDP impact). In terms of employment, there are an estimated 432.3 full time equivalents (FTEs) resulting from aquaculture and its supplying industries located in the Waikato region. These are comprised of 297.4 in direct farming and processing jobs, 72.5 indirect jobs as a result of activity in other industries, and 62.4 induced jobs.

The Coromandel does not support many ancillary services (i.e fuel supply, spat supply, research, marketing, legal services), which means that the economic impact is relatively lower than it is in regions where such ancillary services exist. For this reason, the Coromandel industry's contribution to the national economy should not be overlooked.

When measured for its value to the national economy, the Coromandel aquaculture industry contributes $77.4 million in GDP to the national economy – and generates a total of 1,193full-time equivalent jobs. These results show that Coromandel production generates significant impacts from aquaculture processing in adjoining regions, and from inputs sourced in other regions.

As well as generating direct employment for 270 FTEs within the industry, with employment split roughly evenly between farming and processing, aquaculture generates the equivalent of an additional 100 jobs throughout the region as a result of flow-on effects to other activities and industries. Accounting for both indirect employment effects as well as employment within the industry itself, aquaculture generates employment for a total of 370 FTEs throughout the entire Waikato region. Around half of this total employment impact is the result of farming activity, the other half results from processing activity.

This study highlights the relative importance of aquaculture processing in the generation of economic impacts from aquaculture. The processing facilities in the Coromandel district and surrounding regions are dependent on local aquaculture farms, so a symbiotic relationship exists between the farms and processing facilities.

Economic impact of the Coromandel aquaculture industry – Waikato Region 2010/11 financial year (NZD_{2010}$)

Waikato region	*Shellfish Farming*	*Shellfish Processing*	*Total Impact*
Output			
Direct	$21.8	$26.2	$48.0
Indirect	$3.9	$9.2	$13.1
Induced	$5.1	$5.8	$10.9
	$30.8	**$41.1**	**$71.9**
Value Added (GDP)			
Direct	$11.8	$7.6	$19.4
Indirect	$1.8	$4.5	$6.3
Induced	$2.7	$3.1	$5.7
	$16.2	**$15.2**	**$31.4**
Gross Household Income			
Direct	$5.4	$5.2	$10.5
Indirect	$1.3	$2.3	$3.6
Induced	$1.2	$1.4	$2.5
	$7.8	**$8.8**	**$16.6**
Employment (FTEs)			
Direct	121.2	176.3	297.4
Indirect	10.5	62.0	72.5
Induced	26.3	36.0	62.4
	158.0	**274.2**	**432.3**

Economic impact of the Coromandel aquaculture industry – National 2010/11 financial year (NZD_{2011}$)

National (total)	*Shellfish Farming*	*Shellfish Processing*	*Total Impact*
Output			
Direct	$21.8	$73.8	$95.6
Indirect	$15.4	$34.8	$50.1
Induced	$11.6	$29.3	$40.9
	$48.8	**$137.9**	**$186.7**
Value Added (GDP)			
Direct	$11.8	$22.4	$34.1
Indirect	$6.4	$16.2	$22.6
Induced	$5.9	$14.9	$20.7
	$24.1	**$53.4**	**$77.4**
Gross Household Income			
Direct	$5.4	$13.6	$18.9
Indirect	$3.8	$9.3	$13.1
Induced	$2.9	$7.4	$10.3
	$12.1	**$30.3**	**$42.4**
Employment (FTEs)			
Direct	121.2	430.0	551.2
Indirect	117.7	259.7	377.4
Induced	75.4	189.5	264.8
	314.2	**879.2**	**1193.4**

Future growth scenario
This report considers the impact of future aquaculture developments in the Coromandel. Development in this area is highly likely because new marine farming zones have been established as part of recent law reforms and further shellfish farming consents were issued in 2011. Production at a point in the future, 2025, has been chosen because it allows for consideration of the impact of full development of shellfish farms, the introduction of finfish farms and to allow for comparison with the sector strategy and other industry projections.

The scenario presented in this report assumes that mussel production from the region has increased to 60,000 green weight tonnes. This estimate takes account of new zones and numerous small farm extensions, namely:

- Full development in Wilson Bay A (additional 70.5 ha becoming operational)
- Full development in Wilson Bay B (520 ha becoming operational)
- Various small extensions and realignments (net additional 50 ha becoming operational)
- BUT Leaving aside the potential conversion of spat space in the Western Firth

The scenario for mussels assumes that the location of mussel processing will continue in Whitianga, Tauranga and Auckland, in roughly the same proportion as currently.

The scenario for oyster production assumes that the hectarage for oysters will remain largely unchanged but that farmers in the region will likely convert production from racks to basket technology. This, alongside widespread selective breeding practises, is expected to double the output of the region's oyster farms by 2025. The scenario also assumes, perhaps optimistically, that disease incursions such as the herpes outbreak experienced earlier this year will not be regular features.

This study estimates that the growth in production of mussels and oysters is expected to see the mussel and oyster industry contributing a total of $60.7 million in GDP7 to the regional economy by 2025, and bringing in 835 full-time jobs (in other words, creating 403 new full-time equivalent jobs across the region). At the national economy level, the Coromandel mussel and oyster industry will generate $149.3 million in GDP by 2025, and generate 2,301 full-time equivalent jobs.

The Government has passed legislation to allow for finfish farming in the Hauraki Gulf and in the new Coromandel Marine Farming Zone. While there is potential to farm a greater volume given approved discharge limits, a conservative estimate is of production of 6,000 tonnes of Kingfish (5,175 tonnes head off, gilled and gutted (HoGG)) from the region by 2025. This will generate an extra $56.3 million of revenue (direct output8) per annum for the entity or entities involved in farming and processing fish. The scenario assumes that processing and export of the fish will occur at a facility in the Coromandel district. It further assumes that the farming and processing facilities will be vertically integrated and the bulk of the product will be exported.

This study estimates a contribution of an additional $34.9 million in GDP to the regional economy from finfish farming. Assuming that the finfish processing can be done on the Peninsula (either at the existing fish factory in Whitianga, or at new plants built at Coromandel or Thames), this will create an additional 354.4 full-time equivalent jobs. At the national level, finfish farming in the Coromandel is predicted to bring in an additional $45.6 million in GDP to the New Zealand economy, and create 473.6 new full-time equivalent jobs.

In summary, this study estimates that:

- Aquaculture contributed an estimated $31.4 million of value added, or regional gross domestic product (GDP), to the Waikato region in 2010/11.
- The contribution to GDP is comprised of aquaculture farming impacts (approximately 43 percent of total) and aquaculture processing impacts (approximately 57 percent of GDP impact).
- In terms of employment, there are an estimated 432.3 full time equivalents (FTEs) resulting from aquaculture and its supplying industries located in the Waikato region.
- The Coromandel aquaculture industry contributes $77.4 million in GDP to the national economy – and generates a total of 1,193 full-time equivalent jobs.
- The combined contribution from mussels, oysters and finfish to the regional economy by 2025 will be $95.6 million in GDP, with the generation of 1,190 full-time equivalent jobs.
- At the national level, the Coromandel industry will contribute $194.9 million in GDP by 2025, and generate a total of 2,775 full-time equivalent jobs.

Barbera, M. 2012. **Towards an economic valuation of the Hauraki Gulf: a stock-take of activities and opportunities**. Auckland Council technical report TR2012/035
https://www.aucklandcouncil.govt.nz/EN/AboutCouncil/representativesbodies/haurakigulfforum/Documents/tr2012035towardsaneconomicvaluationofthehaurakigulf.pdf

(extract from executive summary, page iii)

Table B presents a summary of the existing empirical research of the economic and cultural activities provided by the Hauraki Gulf. The estimated total value added (ie, contribution to GDP) is presented, along with a breakdown of direct and indirect value added effects when this information is available. To provide a broader picture the employment effects have also been included. The information presented in Table B is collated from a variety of sources and research papers. As such, comparing the results between the economic and cultural activities is fraught. Specifically, the estimated impacts:

- do not refer to the same year
- are the result of different valuations, techniques, and methods
- have different assumptions that underpin the analysis
- are not necessarily independent/mutually exclusive of each other.

Phase 1 has identified that the economic and cultural activities in Table B contribute positively to the Auckland and Waikato regions, creating a wealth of value added. These activities also sustain significant employment opportunities. The results indicate that tourism, the recreational marine cluster and the Ports of Auckland generate significant economic impact. However, it is important to clarify what conclusions and inferences can be drawn from these estimates.

The estimates of value added do not consider any depletion of capital stock and trade-offs of these activities. In addition, the analysis does not consider, or imply, which activities could generate the biggest returns on any future investment. This means that the focus of current and future policy should not be based solely off these results. Policy should be developed after gaining an appreciation of:

- The return on investment relative to alternatives (opportunity costs)
- The scale of investment required
- The complex interaction between the activities

Table B. Assessed economic activities in Auckland and the Hauraki Gulf.

	Year	Direct value added $_{2011}$ million[1]	Indirect + induced value added $_{2011}$ million[1]	Total value added $_{2011}$ million[1]	Employment[2]	
Tourism	2008	656	281	937	15,742	FTEs
Marine recreational[3]	2008	na	na	550	5781	FTEs
Recreational fishing	2010	na	na	81	na	
Aquaculture[4]	2008/2010	49	50	99	939	FTEs
Commercial fishing[5]	2010	41	na	41	1183	FTEs
Ports of Auckland	2008	113	143	257	2027	ECs
Cruise industry	2009	35	34	69	928	ECs
Sand mining	2010	na	na	10	100	FTEs

1. Direct impacts are initial injections of revenue and expenditure that accrue to that specific sector; Indirect impacts are the net increase of economic activity generated by the provision of goods and services to the study sector; Induced impacts are the net increase of economic activity due to increased household expenditure in the study sector.
2. Employment Counts (ECs) are not directly comparable to Full-Time Equivalents (FTEs) as they count equally both full- and part-time jobs. Therefore, they tend to be higher than FTEs.
3. Value added includes some indirect impacts within the marine cluster but not induced impacts.
4. Values for Auckland refer to 2008, values for the Waikato refer to 2010.
5. Including processing.

However, the results of Phase 1 present a useful picture. The tentative picture provided by this study shows a complex relationship between the environment and the economy. The study shows that the environment underpins all the values realised by humans, but also that the relationship between the economy and the environment in the Hauraki Gulf is mainly synergistic. This means that a thriving ecosystem is necessary to support the Auckland and Waikato economies, while thriving Auckland and Waikato economies are necessary to realise the vast untapped economic potential of the Hauraki Gulf.

The Hauraki Gulf has always been one of the most powerful economic, environmental, social, and cultural clusters for Auckland and the Coromandel. These preliminary results show that the Hauraki Gulf is home to a cluster of economic activities that have the environment at the very core of their value proposition. These share a common interest in protecting the environment as they have a critical dependence on the flow of ecological goods and services provided by the Gulf. In other words, the Hauraki Gulf supports a complex eco-cluster.

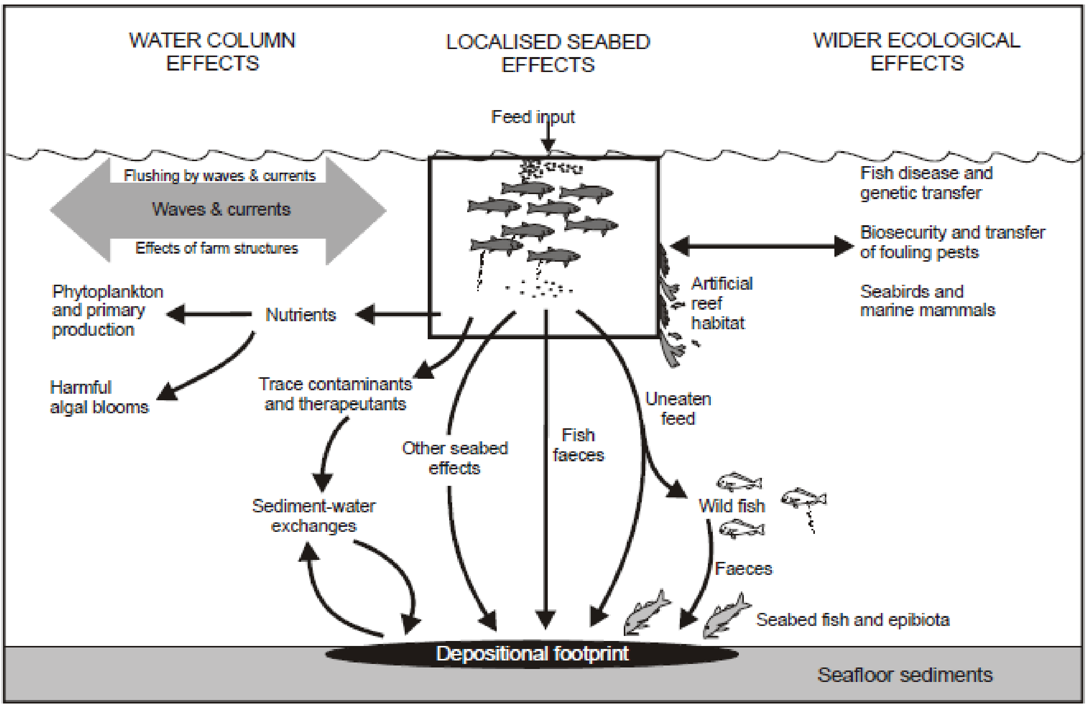
These economic activities could further increase their value through deeper collaboration while the economic relevance of the Hauraki Gulf could grow if its ecosystems are preserved and the potential of an eco-cluster is clearly identified and valued both by the private and public sectors.

2.2 Ecological effects

Forrest, B., Keeley, N., Gillespie, P., Hopkins, G., Knight, B., & Govier, D., 2007, **Review of the Ecological Effects of Marine Finfish Aquaculture**, Cawthron Report No. 1285, prepared for the Ministry of Fisheries.
http://www.fish.govt.nz/NR/rdonlyres/7AE41C40-5AFF-46AA-B345-252F794038F9/0/Reviewecologicaleffects_marinefinfish.pdf

(executive summary)

OVERVIEW
The marine finfish aquaculture industry in New Zealand is small by comparison with many other countries, and based primarily around sea-cage farming of King salmon (Oncorhynchus tshawytscha) at sites in the Marlborough Sounds, Akaroa Harbour, and Big Glory Bay (Stewart Island). There has been recent interest in expansion of the finfish industry to new areas and new species such as yellowtail kingfish and groper, among others. A trial kingfish farm is already established in the Marlborough Sounds. This report reviews existing information on the ecological effects of finfish farming, providing background knowledge that will assist with resource management decisions in relation to future development. However, this review is not intended to be an assessment of environmental effects that could be used directly in relation to a resource consent application; any assessment for such purposes would need to consider a range of site-specific issues.



The ecological effects of finfish farms have been intensively studied world-wide, primarily in relation to the development of the salmon farming industry. Finfish held in aquaculture are fed artificial diets in the form of food pellets, and early work highlighted significant effects on the seabed beneath farm structures, which arose from the deposition of waste (i.e., uneaten) feed and faecal material from the farmed stock. There is now a considerable amount of scientific literature on the seabed effects of salmon farms from both New Zealand and overseas. More recently a range of other potential effects and interactions have also been recognised, most of which are represented in the

following diagram. Below we provide a summary of our findings for each of these issues, along with management and mitigation approaches.

ECOLOGICAL EFFECTS OF FINFISH FARMS AND OPTIONS FOR MITIGATION

Seabed and water column effects: The deposition of uneaten feed and faeces can have pronounced effects directly beneath finfish cages, but there is a rapid improvement in environmental conditions with increasing distance from farm structures (over tens or hundreds of metres). Seabed effects are largely reversible, although recovery is likely to take many months or years, depending on water flushing characteristics. Nutrient enrichment in the water column occurs in the vicinity of finfish farms. Although nutrient enrichment has the potential to stimulate algal blooms, studies in New Zealand and overseas have not linked blooms to fish farming activities; presently, finfish farming in New Zealand is of a low intensity and appears to be well within the carrying capacity of the environment. Seabed and water column effects can be reduced by locating farms in well-flushed areas, in areas where species and habitats of special value are not present, or where flushing characteristics alter deposition patterns to a point where adverse effects do not occur. A range of other steps to mitigate effects have already been implemented at salmon farms in New Zealand. For example, feed wastage is minimised and stocking densities managed at levels that ensure the environment is maintained in a condition that is considered, by stakeholder consensus, to be acceptable.

Habitat creation and biosecurity: Finfish farms and other artificial structures in marine environments provide a three-dimensional suspended reef habitat for colonisation by fouling communities. The aggregation of wild fish around artificial structures is well recognised, and fish in the vicinity of fish farms may feed on waste feed, thereby attracting larger fish. Several studies have highlighted the possible role played by fouled structures within the ecosystem, such as enhancement of local biodiversity and productivity. The role of aquaculture structures as reservoirs for the establishment of pest organisms (e.g., fouling pests) is also recognised. The development of finfish farming in New Zealand therefore has the potential to exacerbate the domestic spread of pest organisms, although various management approaches can be implemented to reduce such risks. Some of these approaches (e.g., codes of practice, treatments for infected structures) have already been implemented by aquaculture companies in New Zealand in response to existing pests.

Seabirds and marine mammals: Potential effects on seabirds and marine mammals (seals, dolphins and whales) relate mainly to habitat modification, entanglement in structures and habitat exclusion. For seabirds a range of potential effects are recognised, but none are well understood. New Zealand fur seals are a problematic species around salmon farms, leading to use of predator exclusion nets around most sea-cages. In approximately 25 years of sea-cage salmon farming in New Zealand there have been four entanglements of marine mammals (2 seals, 2 dolphins) in predator nets. Subsequent management responses (e.g., changes to net design, development of protocols for net changing) mean that entanglement is unlikely to be a significant ongoing issue. Exclusion of marine mammals from critical habitat by finfish farms is highly unlikely at present in New Zealand given the small scale of the industry, and risks from future development could be minimised by appropriate site selection.

Genetics, disease transfer and effects of escaped fish: Potential interactions between farmed and wild fish populations include: competition for resources with wild fish and related ecosystem effects from escapee fish, alteration of the genetic structure of wild fish populations by escapee fish, and transmission of pathogens from farmed stocks to wild fish populations. These risks have been highlighted in overseas studies (primarily in relation to salmon farming), but appear to be relatively minor issues for New Zealand at present. For example, effects from escapee salmon are likely to be minimal given the small scale of the industry, and the limited salmon numbers in wild populations

within existing grow-out regions. For species such as kingfish, and other candidate species that may be trialled in New Zealand, significant ecosystem effects from escapees are unlikely. For kingfish, significant genetic influences on wild stocks are unlikely, but for other species would need to be considered on a case-by-case basis. Disease is not a significant issue within the New Zealand salmon industry, however issues could arise with kingfish or other new species. This situation could lead to the use of therapeutants (i.e., pharmaceutical medicines) to manage disease risks.

Therapeutants and trace contaminants: Most therapeutants have limited environmental significance as they are usually water soluble and break down readily. However, some are administered as feed additives, hence they can be deposited on the seabed. Increased levels of trace metals (zinc and copper) can be found in sediments beneath fish cages in New Zealand and overseas. Zinc is a nutritional supplement necessary for maintaining fish health, and copper comes from antifouling paint whose use is necessary to minimise the build-up of fouling organisms. Both zinc and copper are likely to bind with sediments and organic material, which will naturally mitigate their risk to the environment. Other chemical contaminants such as dioxins, polychlorinated biphenyls (PCBs) and heavy metals like mercury, are globally ubiquitous compounds that accumulate in animal tissue (including humans) via the food chain. In New Zealand PCB and dioxin levels in sea-cage salmon are well within health guidelines stipulated by various regulatory agencies, and are unlikely to be a risk to the wider ecosystem. The New Zealand salmon industry and feed supply companies implement various measures to minimise contaminant inputs to the environment, which will likely lead to reduced contaminant loads in the future. With the further development of the finfish farming industry, it is important that similar mitigation measures are encouraged as part of 'best management practice'.

SYNTHESIS AND CONCLUSIONS

Although there will always be a site-specific element to the magnitude and significance of finfish farm impacts, most of the main effects are reasonably well understood, reflecting the considerable research and monitoring that has been conducted in New Zealand and overseas in relation to the salmon industry. Collectively, this work indicates that the effects of salmon and other finfish farms are often highly localised and largely reversible, and can be managed in various ways to meet acceptable standards. Hence, at the present low level of finfish production in New Zealand the wider ecological significance of many of the issues we describe in this report is likely to be minor. Nonetheless, there are some exceptions to these general statements. Using criteria to gauge the relative ecological significance of the various issues identified, we highlight that biosecurity risks relating to the spread of pest organisms are an important consideration. Although the magnitude of pest-related effects may be less than in the case of seabed impacts, by comparison with all other ecological stressors the spread of pest organisms by finfish farming activities can occur at regional scales, and potentially lead to irreversible changes to coastal ecosystems. The magnitude of seabed impacts is also relatively high, but seabed effects are highly localised and largely reversible in the medium to long term.

Furthermore, while the ecological significance of seabed impacts may be high in a relative sense, in absolute terms the broader consequences can be mitigated by appropriate site selection. For issues other than those relating to pest organisms and seabed effects, ecological significance is arguably less, at least at the present level of finfish (primarily salmon) aquaculture in New Zealand. In some instances this reflects low likelihood events that are presently well-managed, such as adverse effects on marine mammals. Similarly, in the case of disease transfer and genetic alteration of wild stock, the ecological effects of present developments are either minor or can be effectively managed.

Changes in ecological risk associated with fish farming, and in the relative importance of the different ecological issues, are likely to result from future developments that involve the aquaculture

of new species or a significant increase in the number or size of finfish farms. In relation to new species, interactions between farmed and wild fish stocks, and the associated potential for genetic alteration and disease should be carefully considered, as should the use of chemical therapeutants to manage disease risk. For the other issues discussed in the report, ecological consequences are likely to be similar for most of the candidate species that may be farmed in the future, with effects related primarily to the local intensity and geographic scale of farming (assuming procedures for appropriate site selection and effective management are in place to mitigate any adverse effects). Note, however, that for large-scale new developments, cumulative and threshold effects will also need to be considered. For example, high intensity finfish farming within individual embayments could lead to nutrient enrichment at levels of greater significance (in relation to algal bloom formation) than presently appears to be the case.

Where new developments are proposed it is almost inevitable that some areas of uncertainty will arise for which answers regarding ecological risk are not straightforward. At the farm scale, mitigation of poorly understood risks may rely on industry 'best management practice' or adherence to internationally accepted guidelines, at a level of effort that is reasonable within the context of sources of risk from other activities. The New Zealand salmon farming industry already has codes of practice for many aspects of its operations. In relation to future finfish farming activities, consideration should be given to development of a more comprehensive environmental code of practice for the industry as a whole. At greater scales of development (i.e., where multiple farms or atypically large farms are proposed) it may be appropriate for development to proceed in a staged manner within an adaptive management and monitoring framework. Staged development will be of particular importance for issues where potential cumulative effects are recognised.

Finally, we note that judgements as to the ecological significance of finfish farming should ideally be made in relation to other sources of environmental risk to coastal systems, so that the effects of finfish aquaculture are placed in context. A risk-based framework (the 'Relative Risk Model') for this purpose was recently applied in relation to mussel farm development in the Firth of Thames. In that approach, the relative risks to predefined endpoints (particular species and populations, and habitats) from a number of sources and stressors (agricultural land use, climate change, marine farming, fishing, urban development, etc.) were investigated. The outcome of the Firth of Thames work was that relative risks were identified for all of the habitats in question from all of the stressors. Such methods can be applied in a defined area (e.g., a harbour) or across multiple regions, and provide a defensible basis for making resource management decisions.

Keeley, N., et. al., 2009. **Review of the Ecological Effects of Farming Shellfish and Other Non-finfish Species**, Cawthron Report No. 1476 prepared for the Ministry of Fisheries.
http://www.fish.govt.nz/NR/rdonlyres/E9BCB125-9FC6-4CB1-B3F8-DB64F11E75C6/0/Reviewecologicaleffects_farmingshellfish.pdf

(executive summary)

Purpose and scope

Regional councils and the marine farming industry have identified a lack of publicly available information summarising the ecological effects of non-finfish marine farming in New Zealand (e.g. culture of mussels and oysters) as a critical information gap in relation to regional aquaculture planning and development. Although a large amount of research and monitoring has been conducted in New Zealand (especially with regards to Greenshell™ mussels), the information is generally not readily available to the public (e.g. Fisheries Resources Impact Assessment (FRIA) documents), or in a form that is easily assimilated by non-scientists. Hence, the Ministry of Fisheries

(MFish) contracted Cawthron Institute (Cawthron) to conduct a review of existing information and to summarise knowledge of ecological effects associated with non-finfish species.

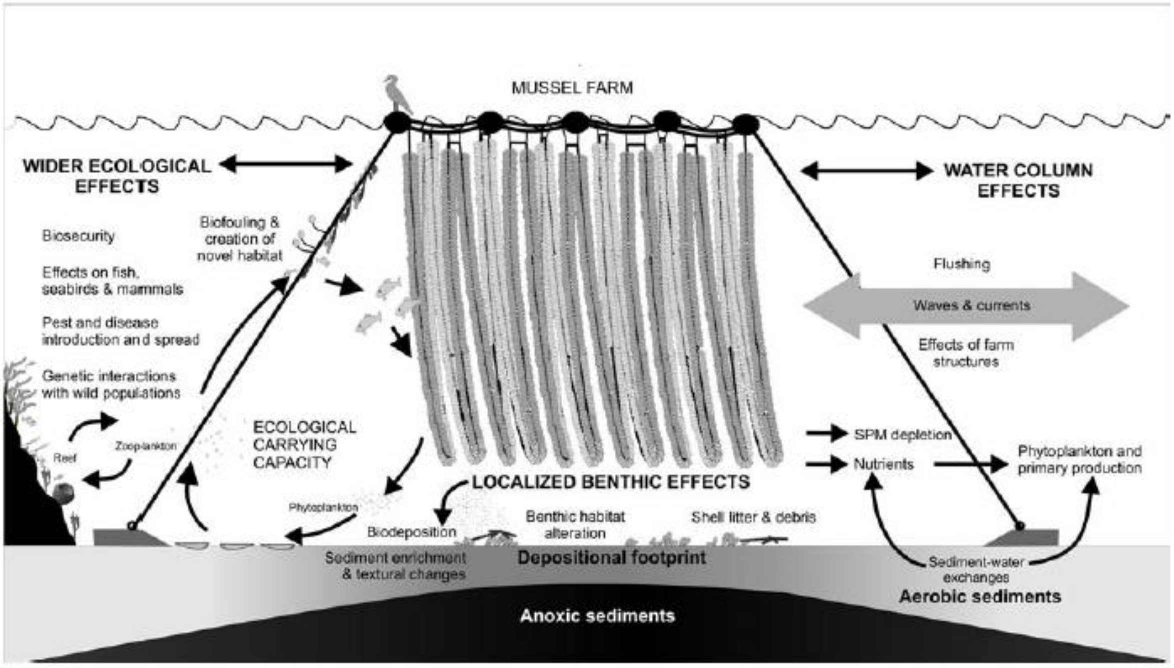
The scope and structure of this review reflects three specific objectives as prescribed by MFish; these are to collate and review information on the ecological effects of farming (1) Greenshell™ mussels including spat catching, (2) intertidal oysters, and (3) other non-finfish species. The other species considered include: dredge oysters, scallops, blue mussels, black-foot paua, sponges, crayfish, kina, sea cucumber and seaweeds. Greenshell™ mussel farming is, by far, New Zealand's largest aquaculture activity (~85% by area) and information pertaining to environmental effects is accordingly extensive. Oysters comprise a much smaller industry and locally derived literature is less common. The ecological effects of new and developing culture species are often unknown; in which case the guidance provided in this report is general in nature and based more on overseas examples and comparable species.

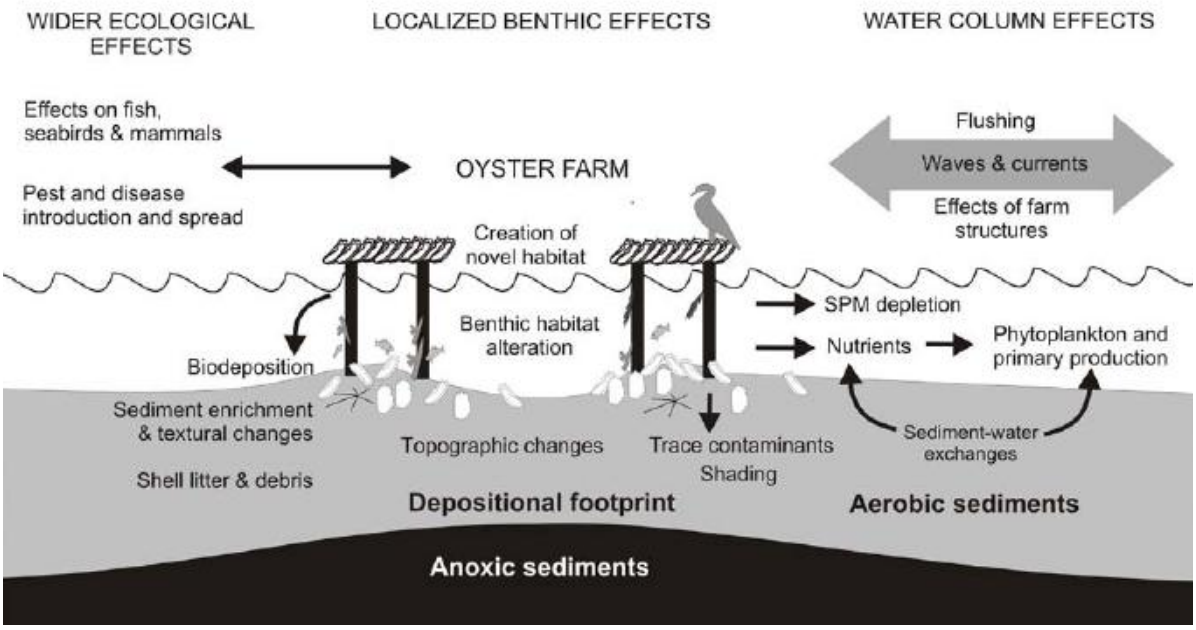
This report focuses on ecological effects only, whereas a broader range of effects and benefits on the coastal environment and communities will be relevant to resource management decisions (e.g. social and cultural aspects). The scope is limited to sea-based aquaculture and does not include managed wild fisheries like scallop enhancement. The review also focuses on coastal issues relating to farm structures and operations (including sea-rearing stages and spat catching) and does not consider wider 'off-site' effects (i.e. land-based hatchery rearing and product processing).

Overview of effects

The ecological issues of non-finfish farming are broadly classified into three main areas, including (1) those associated with effects on the seabed, (2) those associated with effects on the water column, and (3) wider ecological issues such as effects on fish, mammals and the spread of invasive species or disease (see figure over page). The typical effects associated with each of these categories are summarised in very general terms below. We encourage the reader to visit the relevant section of the report to obtain more detailed descriptions.

Through this review we identify that the environmental effects that arise from aquaculture are largely common to organisms that share cultivation methods (e.g. backbone suspended culture) and/or feeding strategies (e.g. filter-feeding bivalves). This is because most of the effects stem from either feeding and waste products or the physical presence of the structures themselves. In particular, our review highlights several commonalities among ecological effects arising from the subtidal cultivation of Greenshell™ mussels and intertidal cultivation of Pacific oysters, particularly with regard to the seabed and water column. Moreover, farming of other filter-feeding bivalve species (i.e. scallops, flat oysters, blue mussels and subtidal Pacific oyster culture) are expected to have analogous effects on the marine environment, whereas the cultivation of organisms that require the addition of feed (e.g. paua, crayfish) may lead to different types or magnitudes of effects. The nature and magnitude of wider ecological effects such as the spread of pest species, disease outbreaks, or effects on the genetic makeup of natural populations will often depend on the species.





Seabed effects

The main ecological effects on the seabed from farming mussels, oysters and other filter-feeding bivalves arise from biodeposits and drop-off of shell and associated biota. In most instances, the severity of seabed effects has been assessed as low to moderate. The effects exhibit as minor enrichment of the seabed sediments (organic content increases by ~7.5%), increased build up of shell litter directly beneath the site, and in some instances increased aggregations of starfish and other epifauna taxa. Sediment enrichment, in-turn, affects the composition of sediment dwelling biota with productivity generally enhanced (i.e. some smaller species become more prolific). Changes to the surface dwelling biota (e.g. starfish) have been documented but are difficult to quantify and vary significantly between sites. Seabed effects are most pronounced directly beneath farm sites, reduce rapidly with distance, and are usually difficult to detect within 20-50 m away. The most important factors influencing the magnitude of effects are water depth and current speeds;

hence severity of effects is very much site-specific and effects are minimised by locating farms in well-flushed areas, where species and habitats of special value are not present.

Seabed effects from intertidal oyster farms are comparable to those from mussel farms, with the exception that there is increased scope for topographical changes to the seabed due to the positioning of structures within the shallow intertidal zone. The potential for species other than mussels and oysters to affect the seabed has not been well studied, but we recognise that paua, crayfish and kina farming all require external feed inputs and will therefore have greater biodeposition and enrichment potential. At the other end of the spectrum, the seabed effects of algal culture are expected to be relatively benign, but there is potential for shading, or light limitation effects on the seabed.

Water column effects

Effects of mussel cultivation on the water column are less well defined than for the seabed, because water column characteristics are more dynamic and inherently harder to quantify. The physical presence of farms can alter and reduce current speeds, which affects water residence times and has implications for associated biological processes. Farm structures can also attenuate short-period waves, which can affect inshore ecology, but these issues are not considered significant at the present scale of development in New Zealand. Bivalves and other associated fauna release dissolved nitrogen (e.g. ammonium) directly into the water column, which can cause localised enrichment and stimulate phytoplankton growth. Toxic microalga blooms may lead to ecological or health problems, but there is no evidence of this being exacerbated by mussel farming in New Zealand waters. Filtration pressure by mussels is sufficient to potentially alter the composition of the phytoplankton and zooplankton/mesoplankton communities through feeding, but the extent to which this occurs and its ecological consequences are poorly understood. Despite the recognised knowledge gaps, the fact that no significant water column related issues have been documented suggests that effects associated with traditional inshore farming practices are minor.

Oysters and other bivalve species interact with the water column in a similar manner to mussels and hence the scope for nutrient enrichment, seston alteration and toxic microalgae bloom potential remains roughly equivalent. Differences in phytoplankton depletion potential can be estimated from equivalent farming densities (per m^2) and filtration rates. However, intertidal culture of oysters is thought to have slightly more profound effects on hydrodynamics due to the structures occupying a cross section of the water column. Species that require atypical cage structures or additional feed (e.g. crayfish and paua) will likely interact with the water differently; the extent to which their effects will differ remains undetermined.

Carrying capacity

There are no definitive studies that provide a clear answer to the question of carrying capacity in relation to New Zealand mussel farming. Spatial modelling tools offer a way of estimating the extent to which the cumulative effects of mussel farming may be approaching ecological carrying capacity on “bay-wide” and “regional” scales. However, knowledge gaps are still evident in these models; particularly in the biological aspects, which are still areas of active research. Production is closely linked to Southern Oscillation Index (SOI) and can be projected from climate data; before this relationship was understood there were concerns that carrying capacity had been reached within the Marlborough Sounds system. However, mussel growth and production have subsequently recovered, suggesting that farming levels were not the driving factor. The present farming intensity in New Zealand is still considered low-moderate in an international context. There are anecdotal reports that Pacific oyster production has approached carrying capacity in some New Zealand estuaries, although this has not been conclusively proven. The potential for such effects is situation-specific and temporally variable.

Wider ecological issues
The wider ecological issues that are assessed include: habitat creation and alteration, effects on fish, seabirds and mammals, biosecurity risks, disease and genetics. These issues are generally less well studied than seabed and water column effects, due either to logistical difficulties in obtaining quantitative data, lack of awareness, or because the need has not arisen (i.e. potential for adverse effects is generally perceived to be low).

Habitat creation recognises the fact that, in addition to growing the culture species, farms function as mid-water artificial reefs. Artificial structures provide novel foraging habitat, detrital food sources, breeding habitat, and refuge from predators for some species, and can contribute to seabed enrichment issues through biodeposits and drop off. As well as changing habitat characteristics, and with it, the composition of the wild fish assemblages, marine farms can affect fish populations through changing fishing pressures and aggregation behaviour. In addition, recruitment of fish larvae to wild fish populations could theoretically be affected by the filtration pressures of large bivalve farms. The role of aquaculture structures as reservoirs for the establishment of pest organisms (e.g. fouling pests) is also recognised. The development of aquaculture in New Zealand therefore has the potential to exacerbate the domestic spread of pest organisms, although various management approaches can be implemented to reduce such risks. Some of these approaches (e.g. codes of practice, treatments for infected seed stock) have already been implemented by aquaculture companies in New Zealand in response to existing pests.

Potential effects on seabirds and marine mammals (seals, dolphins and whales) relate mainly to habitat modification, entanglement in structures and habitat exclusion. For seabirds, a range of potential effects are recognised, but these are generally not well understood. The few overseas studies describing seabird interaction with oyster culture sites provide no evidence of adverse effects. Our review only revealed one reported case of marine mammal entanglement in mussel (spat) farm structures in an industry that now comprises ~900 farms, and there remains some uncertainty over whether the death was the result of entanglement. Hence, scope for marine mammal interactions and/or exclusion has been low, possibly due to the historical 'coastal ribbon' style development, but this may change with the advent of large offshore mussel farming sites. The potential for adverse interaction between intertidal oyster culture and marine mammals is minor in New Zealand, as there is probably minimal overlap between sites of intertidal cultivation and typical marine mammal habitat.

The risk of transmission of pathogens or parasites from cultured to wild mussels to other species is considered minimal at present. With the exception of one protozoan parasite, all other diseases reported in cultured mussels have been less prevalent than from wild mussels. No mussels in New Zealand have been reported with any recognised important pathogens. Likewise, there have been no documented serious (OIE listed) parasites/pathogens of Pacific oysters in New Zealand. But several other less severe diseases and parasites have been reported to occur. Most of these are also globally ubiquitous and may pose some commercial threat to oyster production, but not the wider ecology. Overall, disease has not been a significant issue with New Zealand aquaculture, but disease propensity is species-specific and therefore needs careful consideration with the introduction of other new culture species.

One of the less recognised effects of non-finfish aquaculture concerns maintenance of genetic diversity. Studies of genetic structuring within populations of Perna canaliculus have consistently demonstrated high levels of genetic variation, and more recently, introgression and viable hybridisation between northern and southern populations has been identified. However, the predisposition of Greenshell™ mussels to genetic issues is likely to be mitigated by high connectivity

among mussel populations, and the industry being based on wild-sourced progeny. Furthermore there is already a high pre-existing level of inter-regional mussel seed-stock transfer. Therefore, the continued transfer of wild-sourced mussels within and between the northern and southern groups is unlikely to adversely affect fitness of wild stocks in the future. However, this conclusion does not hold if the mussel industry were to increase its dependence on hatchery-supplied spat. In the case of Pacific oyster cultivation, ecological effects on wild populations are not as relevant since Pacific oysters are non-indigenous to New Zealand. Furthermore, recent advances in breeding and the future production of triploid oyster spat that are sterile will likely eliminate the potential for genetic interactions.

Synthesis of findings

A case study of environmental risk associated with oyster farming was used to evaluate the relative significance of the different ecological effects. Overall, environmental risks to the seabed and water column were considered low, with the largest risks associated with moderate effects to the seabed in close proximity to the farms. With regard to the wider ecosystem effects, biosecurity issues relating to the spread of pest organisms received the highest risk ranking. The spread of pest organisms by aquaculture activities can occur at regional scales, potentially leading to ecologically significant and irreversible changes to coastal ecosystems. The potential for disease also scored relatively high; even though the likelihood was scored as relatively low, the overall score was inflated by the fact that the consequences of an outbreak could be significant, the effects long-term or irreversible and at greater than local scales. There are a range of remaining effects categories relating mainly to water column and wider ecosystem change for which ecological significance was on average scored as low or very low.

The results from the risk assessment of oyster farming are broadly transferable to the subtidal cultivation of Greenshell™ mussels and other bivalve species. Perhaps the main point of difference would be in relation to seabed effects and changes in topography, which are different for intertidal versus subtidal cultivation due in large part to the proximity of the structures to the seabed and the water depth. The magnitude, spatial extent and duration of effects arising from the spread of pest species and/or disease is considered high for all cultured non-finfish species; however, the pests and/or diseases involved are likely specific to the type of cultivation or species.

While the notion of ecological 'risk' tends to imply negative or adverse effects, there are some ecological effects from farming shellfish that could subjectively be considered 'neutral' or 'beneficial'. Furthermore, when the range of effects is considered as a whole it could be argued that some nominally 'adverse' effects may be compensated to some extent by more 'positive' effects. For example, although natural seabed sediments and benthos may be altered beneath oyster and mussel farms, local biodiversity and production may be enhanced through provision of habitat for fouling. Hence, these types of considerations need to be part of management discussions in relation to aquaculture developments.

Future mitigation and management

Possible effects associated with likely future developments in the aquaculture industry such as the imminent move to larger offshore areas and the conceptual implementation of integrated (multispecies) culture are considered. These developments are considered to have some potential for managing and mitigating the effects that are conventionally associated with inshore, single species aquaculture. However, possible scale-related effects of offshore aquaculture remain undetermined and difficult to predict. Another key management and mitigation measure that is identified throughout this review, is careful site selection; i.e. sites that have strong currents to aid waste dissipation, good food supplies in the case of extractive culture (i.e. suspension feeding bivalves) and are removed from sensitive habitats. It is also recognised however, that in near-shore

regions, areas that have strong current tend to coincide with ecologically significant or sensitive habitats, creating a trade-off between waste-dispersion potential and localised effects on such areas.

Effects can also be mitigated through adopting management strategies for pest species, disease and genetic diversity. Approaches to managing pest species are likely to be transferable across different forms of aquaculture. However, in the cases of disease and genetics, management will differ between species and more research may be required before appropriate protocols can be developed. This is especially the case with the minor and potential culture species in New Zealand, for which relatively little is known.

Overall, this review highlights that our present knowledge of ecological effects arising from New Zealand's two most widely practiced forms of aquaculture (Greenshell™ mussel and Pacific oyster farming) is reasonably good. This is especially true for the more recognised effects associated with the seabed, and, to a lesser degree, water column processes. It is also apparent that the level of knowledge is high when put in the context of effects associated with other coastal activities (e.g. fishing and trawling, habitat loss and non-point source pollution). However, through this review we have also identified areas where our knowledge is lacking or can be improved and these are listed toward the end of the document.

Even more broadly, we suggest that management responses to farm developments be made in relation to other sources of environmental risk to estuarine systems at a bay-wide or regional scale, so that the effects of aquaculture are placed in context. Such an approach can be applied in defined regions (e.g. estuaries) or across multiple regions, providing a robust basis for developing plans for research and prioritising management according to the greatest sources of risk.

Ministry for Primary Industries, 2013. **Overview of Ecological Effects of Aquaculture**
http://www.mpi.govt.nz/Default.aspx?TabId=126&id=1950

Ministry for Primary Industries, 2013. **Literature Review of Ecological Effects of Aquaculture**
http://www.fish.govt.nz/en-nz/Commercial/Aquaculture/Marine-based+Aquaculture/Aquaculture+Ecological+Guidance.htm

These reports were commissioned by the Ministry for Primary Industries and prepared by a large team of researchers from the National Institute of Water and Atmospheric Research and the Cawthron Institute. The overview report summaries the findings of the literature review. A copy of the overview report will be provided to the Aquaculture Round Table.

(extract from MPI webpage hosting the overview report)

This report summarises the key potential ecological effects of aquaculture in New Zealand, gives comment on their likely significance, and suggests management and mitigation options. The purpose of this Overview is to communicate, in an easy-to-understand manner, the key technical details of the Literature Review of Ecological Effects of Aquaculture

(extract from MPI webpage hosting the literature review report)

The foundation of the Aquaculture Ecological Guidance Package is the Literature Review of Ecological Effects of Aquaculture, a review which brings together existing scientific knowledge on the main potential ecological effects of aquaculture in New Zealand and identifies uncertainties and

knowledge gaps. The review focuses on the potential ecological effects of existing commercial aquaculture species in New Zealand, and those species that are likely to be developed over the next five years.

Literature Review of Ecological Effects of Aquaculture by chapter:

1. Preamble and Introduction (includes cover page, contents, preamble) (PDF 5.1mb)
2. Pelagic Effects (PDF 1.7MB)
3. Benthic Effects (PDF 2.3mb)
4. Effects on Marine Mammals (PDF 1.3mb)
5. Effects on Wild Fish (PDF 1.3mb)
6. Seabird Interactions (PDF 1.6mb)
7. Biosecurity (PDF 1.8MB)
8. Escapee Effects (PDF 1.3mb)
9. Effects from Genetic Modification or Polyploidy (PDF 1.6mb)
10. Effects from Additives (PDF 1.4MB)
11. Hydrodynamic Effects (PDF 1.5MB)
12. Cumulative Effects (PDF 2.1)

Du Fresne, S., 2008. **Evaluation of Experimental Aquaculture Impacts on Marine Mammals**, Environment Waikato technical report 2008/27 prepared by Du Fresne Ecology Limited. http://www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/TR-200827-Evaluation-of-the-Impacts-of-Finfish-Farming-on-Marine-Mammals-in-the-Firth-of-Thames/

(abstract)

Aquaculture in New Zealand is dominated by the GreenshellTM mussel, however it is expected that finfish aquaculture will expand in coming years. Environmental Waikato is scoping a plan change that would allow finfish aquaculture to be developed within existing aquaculture management areas (AMA) currently used for mussel farming. This report seeks to identify those marine mammal species most likely to be at risk from such activities. Impacts, associated risks, and ecological consequences are identified and discussed.

The marine mammal species most likely to be encountered in the Firth of Thames include: short-beaked common dolphins (Delphinus delphis); bottlenose dolphins (Tursiops truncates); killer whales (orca; Orcinus orca); Bryde's whales (Balaenoptera edeni/brydei); and various species of beaked whales. Additionally, the neighbouring Hauraki Gulf contains a high diversity of marine mammals, including those already listed, as well as: humpback whales (Megaptera novaeangliae); southern right whale (Eubalena australis); pilot whales (Globicephala sp.); and minke whales (Balaenoptera acutorostrata/bonaerensis).

Three possible effects of finfish aquaculture on marine mammals were identified: entanglement; habitat exclusion; and vessel disturbance.

Entanglement will be a greater risk for small cetaceans such as short-beaked common dolphins and bottlenose dolphins. Entanglement risk is currently well-managed by the aquaculture industry in areas of New Zealand where salmon farms exist, and there have been only three known cases of dolphin fatalities after becoming entangled in predator nets in over 25 years. Operational practices and net designs have improved such that entanglement should be a minor risk, however this will need to be monitored.

Habitat exclusion and vessel disturbance are potential risks for many marine mammals that utilise the Firth. A paucity of data makes assessment difficult; however clear mitigation strategies exist should future surveys and monitoring determine these risks to be significant.

Lloyd, B.D. 2003: **Potential effects of mussel farming on New Zealand's marine mammals and seabirds: a discussion paper**. Department of Conservation.
http://www.doc.govt.nz/Documents/science-and-technical/musselfarms01.pdf

(abstract)

Mussel farming is an important and expanding industry in New Zealand. In the year 2000, there were nearly 3000 ha of mussel farms, with proposals for a further 39 000 ha including offshore farms of up to 4000 ha each. There have been no concerted attempts to investigate the effects of mussel farms on marine mammals and seabirds. However, there is growing evidence of adverse effects as these animals are in direct competition for space in the most productive coastal waters. Mussel farms deplete phytoplankton and zooplankton; modify the benthic environment, species assemblages, and local hydrodynamics; increase marine litter; and facilitate the spread of unwanted organisms. Thus, the establishment of mussel farms may lead to loss and degradation of wildlife habitat, either by exclusion or as a consequence of changes to the ecosystem. Thus far, the only adverse effects reported within New Zealand are the exclusion of dusky dolphins from mussel farms areas, and the entanglement and deaths of two Bryde's whales in mussel spat-catching lines. Because of the limited extent of mussel farms to date, effects on wildlife were dismissed as inconsequential. However, the proposed increase in the area used for mussel farming changes the scale of effects and prompts concern. The construction of large offshore farms across the seasonal migration routes of large whales is particularly worrying. An ecologically sustainable mussel farming industry requires a programme to monitor the industry's effects on wildlife and other forms of marine biodiversity. This report provides a resource to assist the mussel farming industry, coastal planners and researchers in the development of an ecologically sustainable industry.

Forrest, B., Hopkins, G., Webb, S., Tremblay, L., 2011. **Overview of Marine Biosecurity Risks from Finfish Aquaculture Development in the Waikato Region**, Waikato Regional Council technical report 2011/22 prepared by Cawthron Institute.
http://www.waikatoregion.govt.nz/TR201122

(extract from executive summary)

Sources of biosecurity risk
Biosecurity hazards from specific finfish culture activities could arise in a number of ways. Transfer pathways associated with finfish culture could introduce new pests or disease agents to finfish farms from external source regions. Potential risk pathways include juvenile fish stock and associated transport water, transfers of equipment (e.g. fouled sea cages or harvesting gear), transfers of feed, and vessel movements (e.g. fouled hulls or contaminated bilge water). International transfers of kingfish stock (from Australia) and finfish feed are controlled by Import Health Standards that outline stringent quarantine and control procedures to minimise the risk of disease transfer. Other pathways are largely uncontrolled at present, but a number of simple mitigation approaches are possible.

Finfish farms could also become infected from local or external sources that are unrelated to culture activities, such as natural dispersal from established populations or as a result of other

anthropogenic pathways. In relation to marine pests, the Waikato region already has two non-indigenous species that have been designated as Unwanted Organisms under the Biosecurity Act 1993, namely the sea squirt Styela clava and the Asian kelp Undaria pinnatifida. Both species are likely to infect the structures of any finfish farms that are developed. In the case of pathogens and parasites, local infection sources are probably more important than external sources, as cultured fish will be susceptible to the same disease agents as their wild conspecifics. In the case of kingfish, diseases of commercial importance are relatively well understood, whereas for hapuku there remains considerable uncertainty regarding which pathogens or parasites will become commercially significant to culture operations.

As well as the potential for a range of adverse effects on culture operations, an infected finfish farm may pose a biosecurity risk to other uses and values by acting as a reservoir from which marine pests or disease agents spread to the environment, potentially leading to irreversible regional-scale effects. A range of mechanisms could contribute to spread; including the natural dispersal of risk organisms via planktonic life-stages that drift with water currents, the transport or risk organisms by anthropogenic pathways such as vessel movements, and pathogen or parasite transfer as a result of interactions between cultured fish and wild finfish or other wildlife (e.g. sea birds). An additional way that a finfish farm could give rise to wider biosecurity risk is by creating environmental conditions that facilitate the establishment of pest species; for example nutrient enrichment may initiate or exacerbate blooms of harmful algal species that are already established in the region

Giles, H., 2007. **Bayesian Network Analysis Exploring the Benthic Carrying capacity for Finfish Farming Within the Firth of Thames**, Environment Waikato technical report 2007/50 prepared by NIWA
http://www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/Bayesian-Network-Analysis-Exploring-the-Benthic-Carrying-Capacity-for-Finfish-Farming-Within-the-Firth-of-Thames/

(extract from abstract)

The Bayesian network analysis suggested that of the examined input parameters the free water depth below fish cages has the largest effect on the severity of benthic impacts and it is recommended that the minimum free water depth below cages should be 10 m. It is general practice in finfish aquaculture to use cages between 10 and 15 m depth and allow for a similar depth of water below cages to promote the dispersal of faeces and uneaten food, consequently the most suitable areas for the installation of fish cages are those with water depths of 20 m or more. Changes in stocking density only resulted in small changes in the probability distributions of most variables.

Selected literature studies were reviewed to examine the usefulness of monitoring parameters for the assessment of benthic impacts in the Firth of Thames that were not included in the Bayesian network. Video surveys and sediment trap deployments are not recommended following problems experienced during earlier work caused by unfavourable environmental conditions. The examination of opportunistic macrofauna species was generally accepted as a good indicator of benthic impact; however, it was suggested that measurements of biogeochemical parameters may reveal earlier signs of impact and allow remedial measures to be taken if necessary to prevent severe impacts.

It is recommended that pre-impact studies should be carried out in locations chosen for fish farming to gain an understanding of these processes prior to the additional organic enrichment. This would allow changes in biogeochemical processes to be identified and limits of acceptable sediment modification to be chosen based on sound data. Additional parameters considered potentially useful

for the detection of severity and spatial extent of benthic impacts once fish farms are operating are trace metals and stable isotopes.

Estimates of the spatial extent of expected benthic impacts were derived from a review of peer-reviewed literature and monitoring data from New Zealand fish farms and it was concluded that 100 m was a cautious estimate. Since the largest change of most examined parameters took place within about 50 m of the farm and the gap between farm blocks in Area A is 75 m a 50 m buffer zone between the outermost cages inside a farm block and the perimeter of the block was considered an adequate estimate of the buffer zone for initial applications before measurements are available to make realistic assessments of spatial effects. Especially if cages larger than those examined in this study (>15 m diameter) are to be installed in the Firth of Thames, it is strongly recommended that benthic impacts should be measured at high spatial and temporal resolution until sufficient information on their severity and spatial extent has been gathered to make sound recommendations on minimum buffer zones for farm blocks.

To enable a reliable detection of farm footprints, it is also recommended that the natural variability of parameters used for future monitoring is measured prior to any farming activity. This will enable the identification of changes caused by the farms and minimise the problem of separating natural from farm induced changes observed in the farm area.

Oldman, J., 2008. **Footprint estimates for Potential Finfish farms in the Wilson Bay Area of the Firth of Thames**, Environment Waikato technical report 2008/37 prepared by NIWA
http://www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/TR-200837/

(extract from abstract)

To provide some background to assist in scoping an aquaculture diversification plan change, this report presents estimates of the scale of expected benthic effects that maybe associated with an individual cage within a fish farm in the Wilson Bay Marine Farming Zone. These estimates are based on the dispersal of waste material (i.e., feed pellets or fish faeces) due to measured currents, bathymetry, a range of realistic fall velocities, best estimates of cage dimensions (cage area and depth) and a range of depths below the cage that could be achieved within Area A.

Data presented in this report show that less than 11% of the waste material from an individual cage may end up being deposited directly beneath a cage. As cages are placed in deeper water, less farm waste will be deposited directly beneath the cage. If cages are placed in an area of higher flows, less waste material will be deposited directly beneath the cage, and if farm waste material has low fall velocity, less waste material will be deposited directly beneath the cage.

Results presented in this report give the likely level of deposition ($g/m^2/day$) for a hypothetical waste load of 1000 g/day from an individual cage. Data from the modelling exercise has shown that in the lateral direction (i.e., in the cross shore direction) there is unlikely to be any cumulative effects between individual cages if cage are placed at least 100 m apart. The modelling has shown that, in the long shore direction, waste material from a cage can be dispersed up to 700 m away from the cage. However, based on a threshold of measurable effects, the longitudinal footprint of an individual cage within a farm will be much smaller than this and may range between 100 and 200 m. Once the actual cage waste loading (based on cage dimensions, stocking rate and feed conversion ratios) is known, it will be possible to determine the actual extent of the cage footprint using the results presented in this report. Once data on the baseline sediment conditions are known the extent of the measurable effect or benthic footprint can be determined.

Sagar, P., 2008. **Assessment of the potential impacts on waders and seabirds of finfish marine farming in the Firth of Thames**, Environment Waikato technical report 2008/53 prepared by NIWA http://www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/TR200850/

(executive summary)

Currently, Environment Waikato is scoping a possible plan change to allow for the diversification of aquaculture within existing aquaculture management areas in the region. This plan change would allow for the cultivation of species other than mussels, including finfish. This assessment is one of several studies commissioned as part of the information gathering and consultation phase of the aquaculture plan change. The primary objective of this study is to:

> Evaluate the impact of new types of aquaculture, such as kingfish farming, on waders and seabirds, and their habitat.

Key findings are:

1. A total of 132 species of birds have been recorded from the Firth of Thames, primarily in the vicinity of Kaiaua/Miranda, at the north-western section of the Ramsar site. Of these, about 60 species are either abundant or common, the remainder being occasional or rare visitors.

2. The Firth of Thames is of international importance for the numbers of Arctic-breeding bar-tailed godwits (Limosa lapponica) and red knot (Calidris canutus) and endemic pied oystercatchers (Haematopus finschi), pied stilts (Himantopus leucocephalus), black stilts (Himantopus novaezelandiae), NZ dotterels (Charadrius obscurus aquilonius) and wrybills (Anarhynchus frontalis) that it supports. All of these species forage on the intertidal mudflats. Of these, the species of conservation concern are black stilt (threat status B.1 Threatened - Nationally Critical); NZ dotterel and wrybill (B.3 Threatened - Nationally Vulnerable); pied stilt and pied oystercatcher (both D.1 At Risk – Declining).

3. Of the species that forage in open water, some feed on small fish either taken near the surface of the sea by plunge diving (e.g., Australasian gannet Morus serrator, Caspian tern Sterna caspia, white-fronted tern Sterna striata) or from greater depths by swimming underwater (e.g., pied shag Phalacrocorax varius, spotted shag Stictocarbo punctatus). Other species dive to feed on a range of small fish, crustaceans, and cephalopods (e.g., flesh-footed shearwater Puffinus carneipes, blue penguin Eudyptula minor) and others take mainly crustaceans from the surface of the sea (e.g., red-billed gull Larus noveahollandiae scopulinus, black-billed gull Larus bulleri). Among these, the species of conservation concern are black-billed gull (B.2 Threatened – Nationally Endangered); caspian tern, red-billed gull and pied shag (B.3 Threatened – Nationally Vulnerable); white-fronted tern, flesh-footed shearwater and blue penguin (D.1 At Risk – Declining).

4. Waders within the Ramsar site may be affected indirectly via changes to habitats and invertebrate prey species caused by nutrient release driving primary production. Such effects could be either positive or negative. Positive effects may occur if any increase in phytoplankton production causes an increase in prey productivity. Negative effects could occur if an increase in nutrient levels led to either/or an increase in mangrove expansion, blooms of intertidal macroalgae, changes in the phytoplankton community that affected invertebrate prey species, severe eutrophication that affected the functioning of the intertidal ecosystem.

5. However, these indirect effects are likely to be localised, and so not have any significant effects on the Ramsar site.

6. Seabirds may be directly affected by entanglement, habitat exclusion, disturbance associated with farm activities, and increased prey availability with wild fish attracted to farms.

7. Entanglement risk is well-managed in areas of New Zealand where marine salmon farming occurs, and so this is should be a minor risk that can be monitored effectively. Exclusion will be limited to the farm footprint. Limited anecdotal observations indicate that some seabirds become habituated to vessel movements and disturbance associated with finfish farming activities. Increased prey availability could become an additional food source of penguins, shags, gulls and terns. In addition, for some species, particularly shags, gulls and terns, marine farming structures are likely to provide roosts closer to the foraging areas of these birds resulting in them having to expend less energy commuting to the feeding areas. Overall, the potential consequences of these cumulative effects are likely to be minor.

Zeldis, J. 2005, **Magnitudes of Natural and Mussel Farm-Derived Fluxes of Carbon and Nitrogen in the Firth of Thames**, Environment Waikato technical report 2005/50 prepared by NIWA
http://www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/Magnitudes-of-natural-and-mussel-farm-derived-fluxes-of-carbon-and-nitrogen-in-the-Firth-of-Thames/

(abstract)

The eastern Firth of Thames supports the largest single block of mussel farms in New Zealand, within the Wilson Bay Marine Farming Zone. In addition to this, another Aquaculture Management Area (AMA), is under consideration by Auckland Regional Council in the western Firth. The scale of these developments has made it necessary that EW and ARC assess and predict environmental performance of Firth aquaculture at Firth-wide, as well as local AMA scales.

This study evaluates fundamental ecosystem processes at the scale of the Firth: incorporation of carbon and nitrogen into organic material through system import and primary production, and losses of nitrogen and carbon through system denitrification, respiration and export. These values are compared with carbon and nitrogen assimilation and respiration by mussel farms, at the various AMA development intensities. The intention of the work is to provide perspectives on the relative magnitudes of ecosystem and farm processes, under the various intensities of AMA development.

Information on Firth system primary production, respiration and denitrification were compared with information on mussel biomass, C and N composition, and weight-specific respiration, to draw conclusions about the importance of mussel aquaculture within the Firth ecosystem. At the present level of AMA development, mussel biomass harvest removes 0.2% of Firth C primary production y-1. At projected biomasses of maximum AMA development (= WBMFZ fully developed + Western Firth AMA) the harvest would remove 1.6% of primary production y-1. For these respective scenarios, mussel C respiration would account for 0.3 and 1.8% of present Firth system respiration. Similar to denitrification, the mussel harvest represents a net sink for nitrogen, removing nitrogen from the internal cycle supporting Firth primary production. At maximum AMA development, about 1.4% of Firth N primary production (i.e., DIN fixed) would be removed by the mussel harvest. This is about 2.8% of the size of the denitrification sink.

Zeldis, J., 2008. **Exploring the Carrying Capacity of the Firth of Thames for Finfish Farming: A Nutrient Mass-Balance Approach**, Environment Waikato tech report 2008/16 prepared by NIWA
http://www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/TR200816/

(abstract)

Environment Waikato is currently scoping a possible plan change to allow for the diversification of aquaculture within existing aquaculture management areas (AMAs) in the Region. This plan change would allow for the cultivation of species other than mussels, including finfish. The most likely site initially for this would be at the Wilson Bay Marine Farm Zone (WBMFZ) in the Firth of Thames, which is currently consented for mussel aquaculture only (total area about 1200 ha). For eco-physiological and economic reasons, the yellowtail kingfish (Seriola lalandi lalandi) is the most likely candidate for the cultivation of finfish in the Firth of Thames and is the focus for this analysis. However, effects of finfish farming are likely to be similar for most of the species that could be farmed in the Firth, assuming similar farming intensities.

To assist Environment Waikato in considering the proposed plan change, this study compares new N additions from finfish farming with aquatic ecosystem processes of the Firth, riverine and oceanic additions, and losses through hydrographic export, denitrification (the microbially-mediated loss of N to the atmosphere) and mussel harvest. It combines information from a nutrient mass-balance budget for the Firth and estimates of Firth primary production (both obtained using field surveys made in the last decade funded by the Foundation for Research Science & Technology), with estimates of N discharged to the marine environment during fish feeding calculated using feed input, composition and feed conversion ratios (FCRs) provided by NIWA aquaculture specialists. It also compares N discharges from finfish farming with potential N removal caused by existing and future farmed mussel harvests at the WBMFZ. The purpose of the report is to provide perspectives on the relative magnitudes of ecosystem and farm processes under various intensities of finfish farm development, to inform Council decision-making about sustainability of finfish culture in the region. The primary focus of the study is at the Firth-wide scale, but makes inferences about impacts at the local AMA scale.

Key findings are:

1. On average, riverine supply of inorganic and organic N to the Firth is greater than the supply arising from mixing across the boundary between the Firth and the Hauraki Gulf. During periods when ocean downwelling is dominant over the adjacent continental shelf, rivers contribute about 70% of the dissolved inorganic N (DIN) load, and when upwelling is active, 50% of the load arises from rivers.

2. The Firth is a strong net sink for inorganic N, indicating that it denitrifies large amounts of nitrogen gas to the atmosphere on a net basis (about 10,800 t N y-1). DIN inputs to the Firth accounted for only about half of this. Particulate and dissolved organic nitrogen (PON, DON) made up the shortfall, originating from riverine (mainly) and oceanic sources. The mean Firth primary production value was about 28,000 t N y-1 incorporated into organic material.

3. Nitrogen discharged to the marine environment from fish farming is estimated at 60 kg N per tonne of fish production, using a feed conversion ratio of 1.3 (FCR: defined as dry weight of feed added to harvested wet weight of fish) based on kingfish culture results from Australia and New Zealand. For FCR = 1.5, which is within the range of current practice for kingfish culture, about 75 kg N is discharged per tonne of fish produced. About 85% of this will be in dissolved forms (ammonium, urea, nitrate, the sum of which is called dissolved inorganic nitrogen DIN here), and the rest is in particulate form.

4. To place the potential N discharged by fish farming into context, scenarios ranging from 1,000 to 10,000 tonnes of fish production per year were evaluated at the two FCRs. At a production of 2,000 tonnes and FCR = 1.3, N discharged was estimated to be small relative to other Firth-wide N processes, sources and sinks: 0.4% of the Firth system N primary production, 1.1% of its denitrification rate, 1.1% of inputs of total N (inorganic plus organic) to the Firth from rivers and the ocean and 1.7% of the input of total N from rivers alone. In terms of loads of dissolved inorganic nitrogen (DIN), which is the most bio-available form of N for primary production, discharges from 2,000 tonnes per year fish production were estimated to be 2.7% of DIN inputs from rivers and the ocean, and 3.8% of the loading from rivers alone. These percentages increase by about 25% for FCR = 1.5. For the 10,000 tonnes per year (FCR = 1.3) scenario, N addition from fish farming is estimated at 5.7% of total N inputs to the Firth and 13.4% of DIN inputs, potentially significant relative to Firth-wide loading and other ecosystem processes.

5. The analyses of this report consider the sizes of fish farm discharges relative to Firth-wide ecological processes, sources and sinks involving N. It is certain that N discharged from fish farms, as proportions of areal primary production, denitrification, and loading from other sources (rivers and oceanic) will be much higher local to the WBMFZ than over the Firth-wide scale. As an example, in principle, the proportions could be 10-fold higher over an area 1/10th the Firth area, (i.e., 1100 km^2/10 = 110 km^2) surrounding the WBMFZ. The actual degree of this focussing of effects will depend on fish farming intensity and hydrodynamic dispersal of discharged N, and also on any functional effects that discharged N may have on the ecological rates themselves.

6. If, at the local AMA scale, such discharged N causes significantly increased organic supply (from new phytoplankton and from waste solids directly) sub-oxic conditions could form. This could threaten fish farming, as well as suppress nitrification, a key element of denitrification. On the other hand, if the scale of these loading effects is small relative to hydrodynamic dispersal, such feedback may not occur.

7. Mussel harvesting removes N from the ecosystem, estimated at about 6 kg N per tonne of green weight mussel harvested. Discharge of N from fish farming is estimated at about 60 kg N per tonne of fish production (FCR = 1.3), such that the harvesting of 10 tonnes of mussels will remove the same amount of nitrogen as added by the growth of 1 tonne of fish. The 2006 Coromandel region annual mussel harvest (21,000 tonnes, 95% of which is in the budgeted Firth area) would remove slightly more N than that discharged by about 2000 tonnes fish production at FCR = 1.3.

8. Because of the focussing of N discharge at the local scale (described above), only mussels growing within the perimeter of effects caused by that focussing will be relevant for remediation. If, for example, N removal by mussels harvested only at the WBMFZ are relevant in this sense (currently 14,000 tonnes) the equivalent N discharge arises from about 1300 tonnes fish production (FCR = 1.3).

9. The uncertainties introduced by the focussing of effects (which are not resolved by the mass-balance approach used here) mean that the local-scale effects of discharged N need to be examined more closely, and are a strong reason to support better-resolved dynamic bio-physical modelling of the local area, including coupling with sedimentary and oxygen dynamics and effects of mussel harvest. Remediation by other forms of co-culture (e.g., algal, deposit feeders) should be also be considered.

10. It is recommended that defensible, locally applicable 'limits of acceptable change' are designated for adaptive management of WBMFZ fish farm development. This should be informed by the modelling and by meta-analyses of known fish farm effects from other studies.

2.3 Other environmental effects

Most scientific and technical literature is focused on the ecological impacts of aquaculture. The impacts on other activities in the marine environment (such as fishing, boating, tourism), on cultural and heritage values, and on natural character, landscape and amenity are less well studied. Most assessments of this type relate to a particular proposal and are site-specific.

A few overview reports have been found. In the case of cultural impacts assessments, no general reports have been located. Two specific reports have been included as examples (one relating to a marine farm proposed in Akaroa Harbour, the second to a potential wharf development in Coromandel Harbour to service, among other users, the aquaculture industry).

Grant, A., 2011. **The siting and design of aquaculture in the landscape: visual and landscape considerations**, Prepared for Scottish Natural Heritage
http://www.snh.gov.uk/publications-data-and-research/publications/search-the-catalogue/publication-detail/?id=113

(extract from conclusion)

This guidance describes and promotes the landscape character and design issues which it is appropriate to consider when developing new fish or shellfish farm, or extending an existing one.

Further advice on landscape issues raised by this guidance is available from planning authorities and SNH local and regional offices. Local contact addresses and telephone numbers are available from the relevant web pages.

The issues raised in this guidance serve to emphasise that good detail design alone cannot limit the impact of a structure – it is very important that developments are in locations where structures and activity are appropriate in the first place. Only this, combined with well-sited, appropriately scaled and carefully laid out facilities will ensure that aquaculture integrates successfully into the Scottish landscape.

Nimmo, F., Cappell, R., Grant, A., 2009. **Literature Review of Evidence that Fish Farming Impacts on Tourism**, prepared for Scottish Aquaculture Research Forum.
http://www.sarf.org.uk/cms-assets/documents/28824-626142.sarf045-tourism-appendix-a-final.pdf

(extract from introduction)

The Scottish Aquaculture Research Forum (SARF) funded research to independently establish whether fish farming has an impact on tourism and define the scope and scale of such an impact in Scotland. This report forms the output of this research which was carried out by Royal Haskoning and Poseidon, with additional advice on landscape provided by Alison Grant, landscape architect.

...

(extract from body of report)

3 EVIDENCE OF INTERACTIONS BETWEEN FISH FARMING AND TOURISM
3.1 Introduction

There are a number of studies suggesting that aquaculture and tourism may compete for some of the same resources. Fish farming and tourism both place certain demands on the coastal environment with a range of potential interactions. This section of the report is structured as follows:

- Competition for space (land & sea);
- Navigational conflicts between fish farms and tourism;
- Visual Impact of fish farms on tourism;
- Tourist perception of the environmental impact of fish farms;
- Aquaculture as a tourist attraction;
- Tourism as a consumer of aquaculture products; and
- Conflict between fish farms and other recreational groups

The visual impact of fish farms is considered a key topic and is addressed further in Section 4.

Many coastal zone activities relating to public or national resources are regulated and may require a license. The extent of licensing required in different countries will affect how easy it is for an industry to develop and become profitable. Regulation may therefore influence the extent to which aquaculture and tourism can effectively co-exist and develop in an area in relation to the above interactions.

In some countries, user conflicts are a result of poorly defined rights over resources, where it may be unclear who owns the space and what uses they are entitled to exercise. As a result of this it can be difficult for individuals to enforce and protect their rights. To reduce the conflict between aquaculture and tourism groups in an area it is important to develop a clear policy for the rights of use across the competing users. (Holland & Brown, 1998).

Evidence shows that conflicts have arisen in many countries and that there is often no straightforward solution to resolve the matter (Deniz, 2001). However, careful planning and control strategies, such as conflict resolution management, can be implemented to prevent conflicts from arising and minimise them if they occur.

Banta, W., Gibbs, M., 2006. **Factors Controlling the Development of the Aquaculture Industry in New Zealand: Legislative Reform and Social Carrying Capacity**
http://aquaculture.org.nz/wp-content/uploads/2011/06/FINAL_MG_Wendy_report_FORMATTED.pdf

(extract from introduction)

Mussel farming, like most aquaculture activities, can lead to resource use conflicts. Mussel farming in New Zealand occurs in the coastal ocean and hence requires the occupation of a common property resource. The other primary users of this space are Maori, the recreational boating and fishing sectors, the commercial navigation and fishing sectors, and purely land-based sectors of the community who value the visual amenity of sites desirable to marine farmers. The legislation governing marine farming (detailed below) demands that adequate consideration be given to all these other sectors.

Mussel farming also requires significant land-based resources for access to farms, loading and unloading, bunkering and similar activities. Mussel farming is also a relatively labour intensive industry and hence requires local sources of labour. Since the remote Marlborough Sounds are a focal point for mussel farming in New Zealand, the growth of this industry has lead to significant

impacts on this sparsely populated region. The resulting rapid development of marine-based industries has been associated with opposition from some residents who value the region for its remoteness and lifestyle.

(extract from conclusion)

With 95 % of the refused marine farm consent applications examined at the Marlborough District Council denied at least partially on social grounds, it is clear that social carrying capacity is a major factor involved in determining the amount of water space available to marine farming. The future expansion of the aquaculture industry in New Zealand will largely depend on the degree to which marine farms are perceived to interfere with or detract from natural character, landscape and amenity values, access to public space, recreational use, and navigation. According to the MDC resource consent application records, many coastal marine area residents and visitors highly value these aspects of their environment and feel that aquaculture operations are incompatible with their aesthetic and recreational enjoyment. The majority of the refused MDC application decisions discussed these apparently contradictory uses, generally concluding that marine farm development would be considered an unacceptable visual intrusion in residential areas. The sentiment that allocation of space for private or commercial use should not occur at the expense of public benefits of access and recreational use values was also repeatedly expressed.
...

The fact that marine farm consent applications in Marlborough, Kaipara, and elsewhere are frequently refused due to social factors implies that more attention ought to be given to responsibilities for social and community sustainability when regulatory authorities perform functions required by the Act. Policy-makers may need to more carefully consider the planning and management requirements that must be met to achieve social and community stability, in part by attempting to effectively and efficiently allocate coastal marine area resources to residential and cultural users, as well as to marine farmers.

Te Aohuri (Diane) Crengle, 2000, **Akaroa Harbour Marine Farms Cultural Impact Assessment**
http://ecan.govt.nz/publications/Plans/akaroa-cia.pdf

(extract from body of report)

Summary of Concerns
Mana Whenua
There is a need for the application to more strongly reflect the Te Rünanga o Ngäi Tahu Act 1996, the mana whenua/mana moana status of Te Rünanga o Onuku and Wairewa Rünanga, and the role of Te Rünanga o Ngäi Tahu as the iwi authority.

Taiäpure
Ngä Rünanga are particularly concerned that nothing in this application should detract from the application by the iwi for a Taiäpure in the Harbour. Tapu and Taoka Values Sites K and L immediately adjacent to Onuku Marae raised the most objections amongst ngä Rünanga representatives and are likely to be vigorously opposed by ngä Rünanga should the application for consents in those two sites proceed. Täkata whenua concerns over these two sites can only be addressed by the applicant agreeing not to proceed with siting farms there.

Sites A-C lie off tapu coastline peppered with submerged ana (caves) of high wähi tapu value. Traditionally, Akaroa Ngäi Tahu did not use those areas for kaimoana gathering, and avoidance of

physical impacts on the tapu by siting offshore may not be sufficient to avoid cultural offence caused by production of food in a spiritually tapu area.

Sites H and I are sited adjacent to land and seabed areas of high tapu. Again, although physical disruption of the wähi tapu values of the area (through disturbance of the koiwi täkata for example) is not a likely result of this application, this may not be sufficient to avoid cultural offence caused by production of food in a spiritually tapu area.

Te Taiao (ecology)
Täkata whenua strongly object to any introduction into Akaora Harbour of spat, algae, or “new” species not already present within the Harbour, that may be sourced from other areas, including Te Oneroa a Tohe (Ninety Mile Beach) and Marlborough Sounds. Ecological concerns about such introductions are significant, including the threat of spread of invasive undaria. Such introductions also raise spiritual issues (mixing of the mauri of other places) and are culturally unsound, given the different tribal areas from which they are sourced and the relationship between the iwi of those areas and Ngäi Tahu.

The majority of other outstanding concerns focus on habitat quality and the predictability of effects given the lack of existing research on the effects of marine farming on the coastal environment of the Harbour, and particularly the cumulative impacts of multiple site proposals and multiple other use demands. Provided avoidance measures suggested by ngä Rünanga are adopted, and the applicant’s predictions are proven by subsequent experience in the Harbour, adverse impacts on cultural values of Ngäi Tahu from marine farm sites outside of tapu areas should be minimal.

However, the applicant’s research lacks adequate information and fails to supply research data for a number of potential effects that include:

- Cumulative effects
- Actual tidal mixing, flushing, and circulation patterns in and around each of site areas
- Sediment under and around the farm – dispersal, reef, rock, and adjacent habitat effects
- Habitat Competition effects – habitat space, food capture, and mussel reattachment
- Actual water quality baselines for the site areas – effects on water quality
- Effects on Hectors dolphins and marine birds
- Effects on existing natural character, visual and amenity values.

As the effects on cultural values from the proposal depends on the outcomes of research being proven in factual experience, ngä Rünanga representatives were keen to see more research undertaken before the proposal proceeds. In addition to the cultural and spiritual issues raised herein, ngä Rünanga focused their concerns on the establishment of Conditions that require the applicant to keep to the standards of non-effect suggested by the application, and requiring monitoring on an ongoing basis through the life of the consents.

Kennedy, N., 2012. **TCDC Aquaculture Wharf Proposal – Ngaati Whanaunga Values Assessment**, prepared by the Ngaati Whanaunga Environment Unit.
http://www.tcdc.govt.nz/Global/1_Your%20Council/2012%20Council%20Agenda%20and%20Order%20Paper/Agenda%20Item%204.7%20-%20Attachment%20C%20-%20%20Aquaculture%20Wharfing%20MVA_Ngati%20Whanaunga%20March%202012%5B1%5D.pdf

(extract from chapter 7)

The following are issues identified by Ngaati Whanaunga that might arise from the construction of new wharf facilities within Tiikapa Moana.

The alienation of ancestral lands and waters

Ngaati Whanaunga mana whenua over our ancestral lands and waters has been significantly eroded through the alienation of almost all tribal resources since colonisation. In recent decades this process has continued largely through the granting of resource consents to third parties in relation to Ngaati Whanaunga ancestral lands and waters, which effectively grant exclusive use of our resources to other parties, and through the vesting of title or long term leases for reclamations of our foreshore and seabed lands.

We have noted that we are in the late stages of Treaty settlement negotiations, in which significant areas of land will be returned to Ngaati Whanaunga and other Hauraki and Tamaki iwi. Settlement will also address Crown breaches regarding our moana. As previously stated Ngaati Whanaunga will be seeking that any reclamation be vest in the iwi with appropriate lease of other arrangement used to provide ongoing security of tenure for the wharf operation.

Reduction and contamination of the mahinga maataitai

Wharf construction, associated reclamation, dredging and ongoing operations all have the potential to displace or otherwise impact on our kaimoana, both in the immediate vicinity of the infrastructure and in its nearby environs.

As noted previously, Ngaati Whanaunga kütai beds around the Te Kouma coastline have suffered in recent decades from the activities of the aquaculture fleet, which has also acted as a physical barrier to iwi access to this important kaimoana.

The potential exists for this situation to continue if the new wharf is located at either the Sugarloaf or Puhi Rare, and action will need to be taken in that instance to investigate the extent of this valued resource and to develop an action plan to restore the beds and address the access issues arising out of intensive use of the vicinity.

We will be looking for adequate investigation into local ecology above and below mean low water springs in order to assess potential effects and determine appropriate methods for avoiding impacts prior to consent being sought. We also speak in this report about possible mitigation for existing and new impacts on our kaimoana.

Impacts on the mauri of ancestral waters

Ngaati Whanaunga remains concerned regarding impacts on local bays from wharves and associated activities. These include pollution from marine vehicles, reclamation, construction and structures within the CMA, and dredging.

We have observed ongoing and increasing effects from docked and moored mussel barges currently adjacent to Te Kouma, including the incidence of foreign invasive species within the Ngaati

Whanaunga rohe, mussels dropped overboard, and pollutants from cleaning and maintenance being washed straight into the moana.

Any wharf proposal should include the development of a contamination management plan, the construction of adequate dry dock and wash down facilities, a regime to ensure these are used, and monitoring.

Trade-offs between the interests of parties
We note that the interests and objectives of a range of parties are being balanced in the wharf selection process, and this will also be the case in the design, development, and operation of the facilities.

We note the views of the local residents at Te Kouma have been a driver to investigating other locations, and the views of both the aquaculture industry and Council have been primary considerations in the selection of preferred locations. We have often experienced Maaori interests and values being trampled in Council efforts to accommodate their own, developers, and the wider community desires. As such RMA consents processes have become a key means by which Maaori interests continue to be eroded.

The range of legislation concerned here bring with them strong recognition of the interests and rights of tangata whenua, and Ngaati Whanaunga expects to be involved in this project at all stages to ensure that our values and interests are protected.

Tikanga and Maatauranga Maaori
Similarly we repeatedly witness the treatment of tikanga Maaori (Maaori values and direction as to the correct way of doing things) and maatauranga Maaori (Maaori knowledge systems and world views) as inferior to Pakeha values and western scientific knowledge, in the planning and design of developments and in the consents process.

Ngaati Whanaunga values and views have been articulated at length in this report, but ongoing dialogue will be needed to assist Council in ensuring that the proposed development is sympathetic to tikanga Maaori, and that its location, design, and operation reflect and are consistent with Maaori values and world views.

Manawa - coastal and marine vegetation
Ngaati Whanaunga is particularly concerned with preserving the ecological, biodiversity and natural character values of the coastal marine area. An important value in this regard is the preservation of manawa (mangroves) and other indigenous vegetation. Several of the potential locations under investigation are in the vicinity of mangroves, and the iwi will be seeking that any removal of mangroves is minimised.

Furthermore we will be seeking environmental restoration in association with the development.

Waahi Tapuu and taonga
Waahi tapuu are considered at length in this report. Several of the preferred and potential wharf locations are adjacent to or nearby sites and areas that are extremely significant to Ngaati Whanaunga. These include pa sites, waahi tapuu, waahi pakanga and urupaa.

Care will need to be taken in the design, construction and operation of a wharf to ensure these are sympathetic to this significance. This will include the iwi undertaking investigations of proposed

areas prior to any works, protocols being agreed in advance, ongoing monitoring, and measures being taken to ensure the protection, and possibly restoration of significant sites.

There is similarly a high potential that köiwi (human remains) will be encountered in the CMA, and the above-mentioned approaches should also anticipate this.

Ongoing involvement formalised
The previously mentioned issues relate to the potential for Ngaati Whanaunga interests and values to be compromised. Ngaati Whanaunga should be involved at all stages of the project should the final wharf location be within the mana whenua - mana moana of the iwi. We will seek that this include the site selection process, wharf design and associated investigations, construction, management and ongoing monitoring.

Our involvement should be formalised to ensure that ourselves, Council, and the aquaculture industry understand the level of and basis for our ongoing participation in the project.

A range of other issues and potential issues are discussed in previous chapters. That any of these are not included in the above summary should not be taken as an indication that they are less important than those listed above, and the report needs to be considered in its entirety.

Brown, B., 2008. **Natural Character and Visual Impact Assessment of Potential Finfish Farming Development**, Environment Waikato Technical Report 2008/24, prepared by Bernard Brown Associates Limited.
http://www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/Natural-Character-and-Visual-Impact-Assessment-of-Potential-Finfish-Farming-Development/

5 Conclusions and key principles
The Waikawau/Wilson Bay coastal environment has a transient visual audience featuring SH25 located in close proximity to the west coast shoreline. Natural character values rate in the moderate range. Low elevation and high elevation viewpoints project due west across the CMA.

The Coromandel/Motukawao coastal environment has three sub units with varying degrees of natural character. The highest visual audience is located in the Coromandel sub unit where high natural character values exist. This sub unit has diverse viewing perspectives across the CMA.

Existing mussel farming activities in the Waikawau/Wilson Bay coastal environment have been located in a planned 1.5 km offshore zone, the Wilson Bay Marine Farming Zone. The mussel farm activities generate visual effects caused by buoys, barges and navigational lighting. The buoys are generally innocuous and their presence is signified mainly by barges working the farms.

Existing mussel farming activities in the Coromandel/Motukawao coastal environment are randomly located through the CMA often in close proximity to the mainland shoreline. The Coromandel sub unit is considered to be in a delicate balance with respect to any additional mussel farming activities being developed in this area.

Two key variables affect the ability of the marine environment to visually absorb mussel farming activities. These include:

- the scale of the coastal environment and degree of visual interest in the view
- elevation and distance viewed

The vast scale of the Waikawau/Wilson Bay coastal environment provides high visual absorption capability sufficient to accommodate full development of mussel farms in the Wilson Bay Zone, without causing adverse effects on natural character values. Low elevation viewpoints from SH25 will perceive the existing foreground mussel farms as line expressions, whilst high elevation viewpoints from SH25 will register the mussel farms as faint patterns on the water plane.

Recommendation 1: No further expansion of mussel farming activities in the Coromandel sub unit should be allowed. Some potential for additional small scale mussel farming exists in the outer Motukawao Island Group providing substantial buffers are maintained from the mainland and islands.

Fish farming activities will have greater visual effects when compared with mussel farming activities. This is primarily due to their characteristic vertical structural elements. Viewing distance (e.g. 5 km offshore) is considered a key visual instigation measure when considering the location of fish farming aquaculture in the Wilson Bay Zone. The preferred locations for potential fish farms are in Area A (western portions only with size limitation) and Area B (full development to 150 ha is possible).

Recommendation 2: A precautionary approach is recommended should fish farming activities be considered to replace existing mussel farming activities in the Coromandel/Motukawao coastal environment. Fish farming activities should avoid the Coromandel sub unit area. There is potential for small scale fish farming activities (5 ha maximum) in the Deadmans Point and Motukawao sub units.

Fish farming activities require "context" to assist visual absorption capability in the CMA and would best be assimilated with existing mussel farming activities, especially when these activities provide the foreground from any viewpoint on land.

Recommendation 3: Fish farming activities should avoid high visual audience areas where close views are gained if natural character values are to be maintained in the study area.

The visual impact of permanently moored vessels or service structures seen in association with some fish farms has not been considered in this study and would require separate assessment if they were proposed.

2.4 Fish feed

Some types of aquaculture require the addition of food, most notably the farming of carnivorous fish such as salmon, trout, kingfish and tuna. Fish feed is delivered in the form of pellets made up of fish meal and fish oil, along with a number of other ingredients such as vegetable proteins and oils.

As a result, the production of farmed of fish also requires the consumption of fish. If it is done inefficiently, it results in a net loss of fish protein. Whether it does or not, and whether it is sustainable in the long term depends on several factors, including:

- *how much fish meal and fish oil is in the pellets;*
- *the feed conversion ratio (how well the farmed fish turn feed into body mass);*
- *the levels of wastage through over-feeding on the farm;*
- *the management of the fishery from which the fish meal and fish oil is derived; and*
- *the potential for the fish used for meal and oil production to be consumed directly by people.*

These papers discuss the implications of fed aquaculture and this issue will be explored further in the second Aquaculture Round Table report.

Naylor, R., Goldburg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. & Troell, M., 2000. **Effect of aquaculture on world fish supplies**, Nature 405, 1017-1024.
http://www.nature.com/nature/journal/v405/n6790/full/4051017a0.html
Also online in an easier to read format at:
http://www.esa.org/esa/wp-content/uploads/2013/03/issue8.pdf

(abstract)

Global production of farmed fish and shellfish has more than doubled in the past 15 years. Many people believe that such growth relieves pressure on ocean fisheries, but the opposite is true for some types of aquaculture. Farming carnivorous species requires large inputs of wild fish for feed. Some aquaculture systems also reduce wild fish supplies through habitat modification, wild seedstock collection and other ecological impacts. On balance, global aquaculture production still adds to world fish supplies; however, if the growing aquaculture industry is to sustain its contribution to world fish supplies, it must reduce wild fish inputs in feed and adopt more ecologically sound management practices.

Alder, J., Campbell, B., Karpouzi, V., Kaschner, K., Pauly, D., 2008. **Forage Fish: From Ecosystems to Markets**, Annual Review of Environment and Resources, Vol. 33: 153-166.
http://www.seaaroundus.org/researcher/dpauly/PDF/2008/JournalArticles/ForageFishFromEcosystemsToMarkets.pdf

(abstract)

Fisheries targeting small-to-medium pelagic, so-called forage fish, impact on human food security and marine ecosystems. Because their operations are shrouded by the myth that forage fish are unsuitable for human consumption, the role of these fisheries in intensive food production is not well understood or appreciated. Thus, although they account for over 30% of global landings of marine fish annually, our knowledge of how these levels of removal impact on marine ecosystems is limited. Nevertheless, there is considerable scope for policy makers to change the current

management of these fisheries and to enhance their contribution to food security and economic development. Industry and consumers also have an important role in finding the balance between these fisheries contributing to human food security and poverty alleviation on the one hand, and sustaining intensive animal food production systems, especially aquaculture, on the other.

Tacon, A.G.J., Metian, M., 2008, **Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects**, Aquaculture 285: 146–158. http://www.nmfs.noaa.gov/aquaculture/docs/feeds/tacon_etal_global_fishmealoil_overview_2008.pdf

(abstract)

The finfish and crustacean aquaculture sector is still highly dependent upon marine capture fisheries for sourcing key dietary nutrient inputs, including fish meal and fish oil. This dependency is particularly strong within compound aquafeeds for farmed carnivorous finfish species and marine shrimp.

Results are presented concerning the responses received from a global survey conducted between December 2006 and October 2007 concerning the use of fish meal and fish oil within compound aquafeeds using a questionnaire sent to over 800 feed manufacturers, farmers, researchers, fishery specialists, and other stakeholders in over 50 countries. On the basis of the responses received, it is estimated that in 2006 the aquaculture sector consumed 3724 thousand tonnes of fish meal (68.2% total global fish meal production in 2006) and 835 thousand tonnes of fish oil (88.5% total reported fish oil production in 2006), or the equivalent of 16.6 million tonnes of small pelagic forage fish (using a wet fish to fish meal processing yield of 22.5% and wet fish to fish oil processing yield of 5%) with an overall fish-in fish-out ratio of 0.70. At a species-group level, calculation of small pelagic forage fish input per unit of farmed fish or crustacean output showed steadily decreasing fish-in fish-out ratios for all cultivated species from 1995 to 2006, with decreases being most dramatic for carnivorous fish species such as salmon (decreasing from 7.5 to 4.9 from 1995 to 2006), trout (decreasing from 6.0 to 3.4), eel (decreasing from 5.2 to 3.5), marine fish (decreasing from 3.0 to 2.2) and to a lesser extent shrimp (decreasing by 1.9 to 1.4 from 1995 to 2006. Net fish producing species in 2006 (with fish-in fish-out ratios below 1), included herbivorous and omnivorous finfish and crustacean species, including non-filter feeding Chinese carp (0.2), milkfish (0.2), tilapia (0.4), catfish (0.5), and freshwater crustaceans (0.6).

On the basis of increasing global fish meal and fish oil costs, it is predicted that dietary fish meal and fish oil inclusion levels within compound aquafeeds will decrease in the long term, with fish meal and fish oil usage increasingly being targeted for use as a high value specialty feed ingredient for use within higher value starter, finisher and broodstock feeds, and by so doing extending supply of these much sought after and limited feed ingredient commodities.

Naylor, R.L., et. al., 2009. **Feeding aquaculture in an era of finite resources**, Proceedings of the National Academy of Sciences of the USA, vol. 106, no. 36, 15103–15110 http://www.pnas.org/content/106/36/15103.full.pdf

(abstract)

Aquaculture's pressure on forage fisheries remains hotly contested. This article reviews trends in fishmeal and fish oil use in industrial aquafeeds, showing reduced inclusion rates but greater total

use associated with increased aquaculture production and demand for fish high in long-chain omega-3 oils. The ratio of wild fisheries inputs to farmed fish output has fallen to 0.63 for the aquaculture sector as a whole but remains as high as 5.0 for Atlantic salmon. Various plant- and animal-based alternatives are now used or available for industrial aquafeeds, depending on relative prices and consumer acceptance, and the outlook for single-cell organisms to replace fish oil is promising. With appropriate economic and regulatory incentives, the transition toward alternative feedstuffs could accelerate, paving the way for a consensus that aquaculture is aiding the ocean, not depleting it.

Tacon, A.G.J.; Hasan, M.R.; Metian, M., 2011. **Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects**. FAO Fisheries and Aquaculture Technical Paper No. 564. http://www.fao.org/docrep/015/ba0002e/ba0002e00.htm

(executive summary)

The rapid rise and growth of finfish and crustacean aquaculture has been due, in part, to the availability and on-farm provision of feed inputs within the major producing countries. If the aquaculture sector is to maintain its current average growth rate of 8 to 10 percent per year to 2025, the supply of nutrient and feed inputs will need to grow at a comparable rate. While this may have been readily attainable when the industry was still in its infancy, this may not be the case in the future as the sector matures and grows into a major consumer and competitor for feed resources.

It is estimated that about 31.5 million tonnes of farmed fish and crustaceans (46.1 percent of the total global aquaculture production in 2008) is dependent upon the supply of external nutrient inputs provided in the form of fresh feed items, farm-made feeds or commercially manufactured feeds. Total industrial compound aquafeed production increased more than threefold, from 7.6 million tonnes in 1995 to 29.2 million tonnes in 2008, with production growing at an average rate of 11.0 percent per year. Aquafeed production is expected to continue growing at a similar rate to 71.0 million tonnes by 2020. Although current estimates for industrially produced aquafeed for the period 2007–2010 vary between 24.4 and 28.9 million tonnes, aquafeed volume represents only 4 percent of the total global animal feed production of the over 708 million tonnes in 2009. In contrast to compound aquaculture feeds, there is no comprehensive information on the global production of farm-made aquafeeds (estimated at between 18.7 and 30.7 million tonnes in 2006) and/or on the use of low-value fish/trash fish as feed, with 2008 estimates for China at 6 to 8 million tonnes.

Fed aquaculture production, in particular, of higher trophic level finfish and crustaceans (includes marine shrimps, salmonids, marine finfishes, eels) are largely dependent upon capture fisheries for the supply of their major dietary source of protein and lipids. For example, on a global basis, it is estimated that the aquaculture sector consumed 3.72 million tonnes of fishmeal (60.8 percent of global fishmeal production) and 0.78 million tonnes of fish oil (73.8 percent of global fish oil production) in 2008; it was 3.84 million tonnes of fishmeal (or 68.4 percent of global production) and 0.82 million tonnes of fish oil (or 81.3 percent of global production) in 2007. Despite this continued dependence of aquaculture production on fishmeal and fish oil, there remains a wide variation in fishmeal and fish oil usage between major producing countries for individual farmed species. This variation mainly reflects differences between countries concerning the selection and use of fishmeal and fish oil replacers from plant sources or by the use of land animal proteins and fats in feeds for high trophic-level fish and crustacean species.

The total use of fishmeal by the aquaculture sector is expected to decrease in the long term. It has gone down from 4.23 million tonnes in 2005 to 3.72 million tonnes in 2008 (or 12.8 percent of total

aquafeeds by weight), and is expected to decrease to 3.49 million tonnes by 2020 (or 4.9 percent of total aquafeeds). The reasons for this are the diminishing amount of fishmeal and fish oil supplies owing to tighter quota setting and additional controls on unregulated fishing and the increased use of more cost-effective dietary fishmeal replacers. On the contrary, the use of fish oil by the aquaculture sector will probably increase in the long run albeit slowly; total usage will increase by more than 16 percent, from 782 000 tonnes (2.7 percent of total feeds by weight) in 2008 to the estimated 908 000 tonnes (1.3 percent of total aquafeeds for that year) by 2020. Increased usage will shift from salmonids to marine finfishes and crustaceans because of the current absence of cost-effective alternative lipid sources that are rich in long-chain polyunsaturated fatty acids. Increasing volumes of fishmeal and fish oil are likely to come from fisheries by-products, extracted from both wild capture and farmed fish. Estimates have been made that around 25 percent of fishmeal production in 2007 came from by-products. This will grow as it becomes increasingly viable to process this material.

It is estimated that the total usage of terrestrial animal by-product meals and oils within compound aquafeeds ranges between 0.15 and 0.30 million tonnes, or less than 1 percent of total global compound aquafeed production – clearly, there is considerable room for increased usage. In addition to meat meal, or, to a lesser extent meat and bone meal, ingredients such as blood meal, poultry by-product meal and poultry oil have all been very effective in feeds for a number of aquatic species.

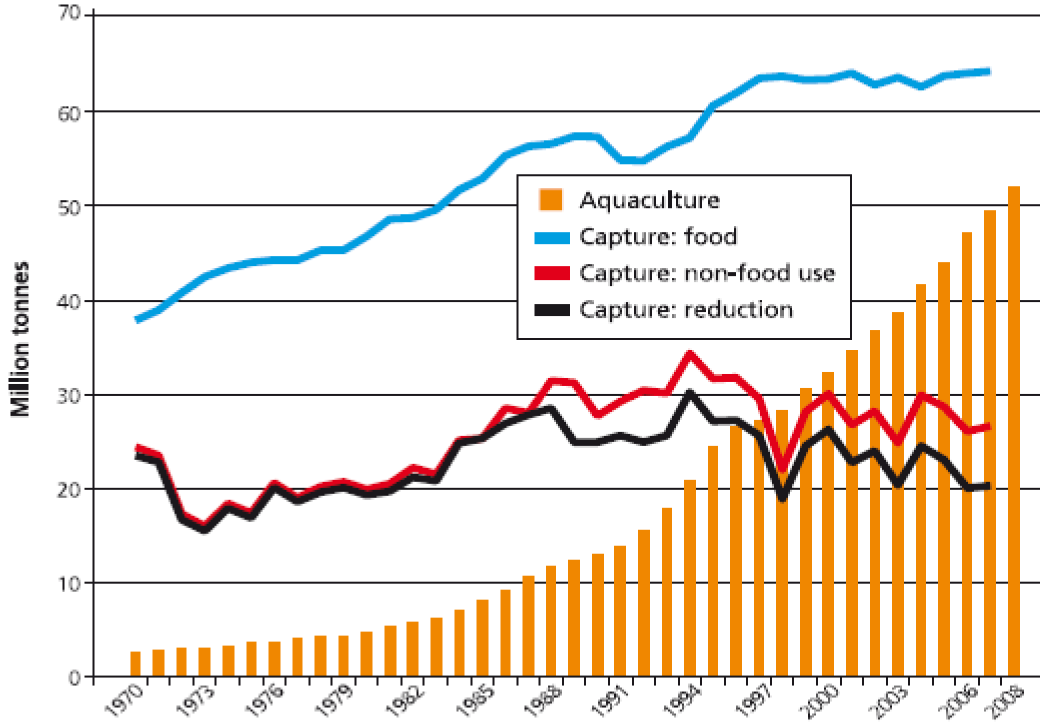
Soybean meal is the most common source of plant proteins used in compound aquafeeds, with feeds for herbivorous and omnivorous fish species and crustaceans usually containing from 15 to 30 percent soybean meal, with a mean of 25 percent in 2008. In global usage terms, and based on a total compound aquafeed production of 27.1 million tonnes in 2007, it is estimated that the aquaculture feed sector consumed about 6.8 million tonnes of soybean meal (25.1 percent of total compound aquafeeds by weight). Other plant proteins being increasingly used include corn products, pulses, oilseed meals and protein from other cereals products.

Alternative lipid sources to fish oil are being used in greater amounts. Key alternatives include vegetable oils, preferably those with high omega-3 contents, and poultry oil. The use of oil from farmed fish offal is also a potential omega-3 source for other farmed fish. The production of marine microalgae or bacteria with very high contents of highly unsaturated fatty acids is currently expensive for use in most aquaculture feeds, but more cost efficient production methods will change this.

Prices for food and feed ingredients have been rising and are likely to continue to rise owing to the increasing demands from an increasing population, the diversion of some grains for use in biofuels, the increasing costs of production and transport, and the changes in global trade owing to the demand of food and raw materials from China and other emerging economies. The focus on carbohydrate-rich fractions for production of biofuels may indeed provide an opportunity to use protein fractions for feed ingredients.

Although current discussion on the use of marine products as aquafeed ingredients focuses on fishmeal and fish oil resources, the sustainability of the aquaculture sector is more likely to be linked with the sustained supply of terrestrial animal and plant proteins, oils and carbohydrate sources for aquafeeds. This is because a significant proportion of aquaculture production is of the non-carnivorous species. Therefore, aquaculture producing countries should place more emphasis to maximize the use of locally available feed-grade ingredient sources and use nutritionally sound and safe feed ingredients that can be sustainably produced and grow with the sector.

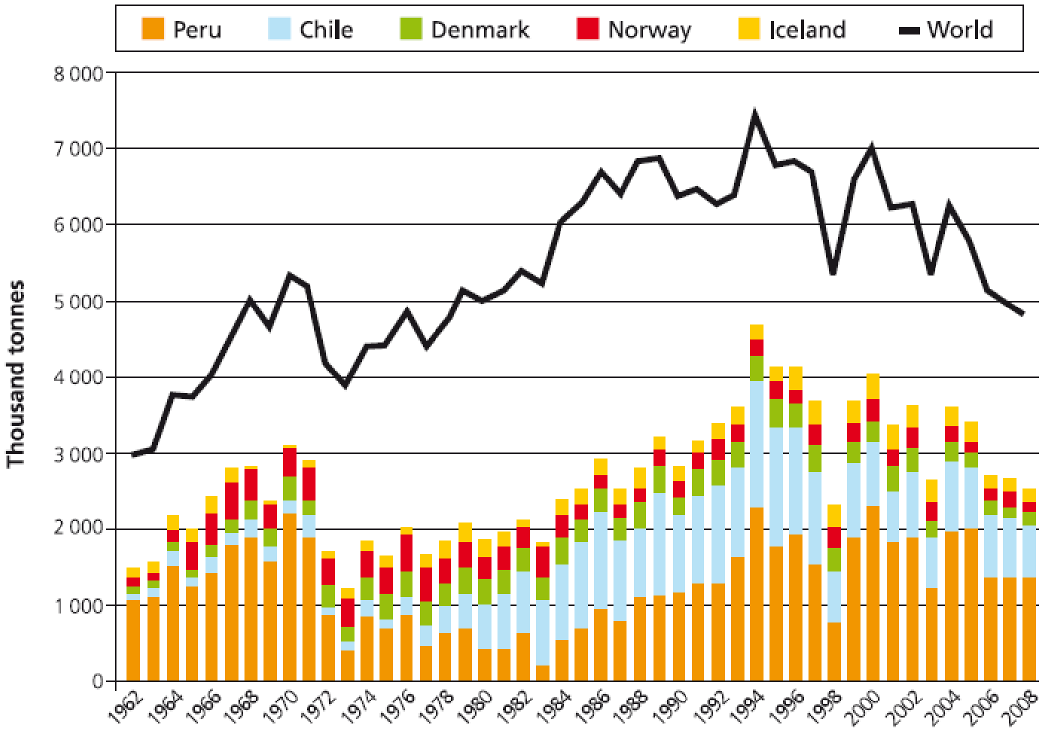
FIGURE 8
Total capture fisheries and aquaculture production and volume of the catch destined for reduction and other non-food uses, 1970–2008



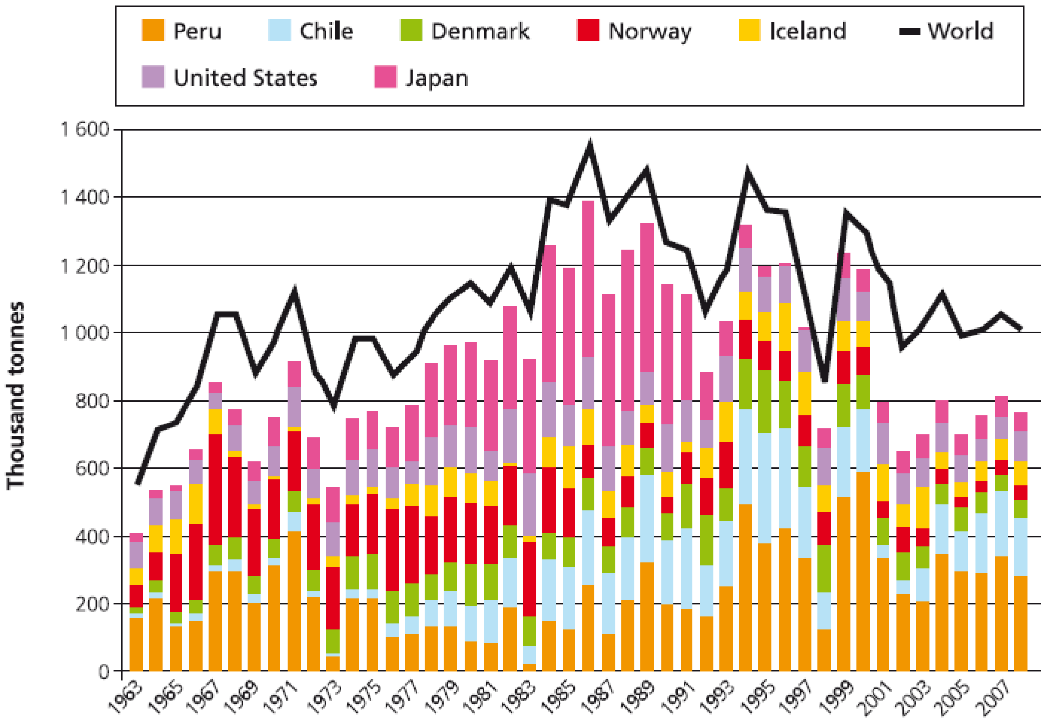
Note: Capture and aquaculture production exclude mammals, reptiles and aquatic plants.
Source: FAO (2009a and 2010a).

FIGURE 10
Historical production trend of fishmeal and fish oil, 1962–2008

Fishmeal production, 1962–2008



Fish oil production, 1963–2008



Source: Shepard (2009).

Wijkström, U.N. 2012. **Is feeding fish with fish a viable practice?** In R.P. Subasinghe, J.R. Arthur, D.M. Bartley, S.S. De Silva, M. Halwart, N. Hishamunda, C.V. Mohan & P. Sorgeloos, eds. *Farming the Waters for People and Food*. Proceedings of the Global Conference on Aquaculture 2010, Phuket, Thailand. 22–25 September 2010. pp. 33–55. FAO, Rome and NACA, Bangkok
http://www.fao.org/docrep/015/i2734e/i2734e02a.pdf

(abstract)

The use of fish as feed for aquaculture is controversial. Some say that the practice should be reduced or stopped, arguing that it is not in the interest of consumers who otherwise would have eaten the fish used. Capture fisheries produces some 90–95 million tonnes of fish per year of which between 20 and 25 million tonnes are processed into fishmeal and oil. During the last two decades, a growing portion of the world's fishmeal and oil has been converted into fish and shrimp feed. Most of the 25–30 million tonnes are obtained by industrial fisheries in the North Atlantic and in the Pacific Ocean off South America. In Asia, by-catch, particularly from trawl fisheries for shrimp, is used as fish feed. It is believed that this may be on the order of 6 million tonnes/fish/year.

The farming of carnivorous fish and shrimp uses more fish as feed than is produced as finfish or shrimp. However, if the fish used as feed would not be consumed as food, then its use as feed might in the end lead to more food fish. Industrial fishing for forage species via manufacture of fishmeal and fish/shrimp feeds brings about a net contribution of food fish supplies without causing a systematic collapse of the exploited species. However, the practice of using bycatch as feed has apparently led to a decrease in the availability of fish as food for the very poor in some regions of Asia. Also, the ever-expanding demand for fish as feed is thought to endanger the long-term sustainability of targeted fish stocks.

Much of the "forage fish" used to produce fishmeal is edible. If this fish could be made available as low-cost food to the poor, no doubt their food security would improve. Aquaculture contributes about half of the world's seafood. Doubtlessly, the price of all fish would be substantially higher today if aquaculture did not exist. Most governments see unemployment as a problem; thus, jobs in feed fisheries, fishmeal/fish oil industries, fish/shrimp feed industries and aquaculture are positive contributions. In the absence of fishmeal/fish oil, most of these employment opportunities would likely not exist.

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EXECUTIVE SUMMARY
This briefing represents the fifth edition of the SFP global sustainability overview of a subset of Pacific and Atlantic small pelagic fish stocks used for fishmeal, fish oil, and human consumption; the document covers the most recent assessment period for which comparable data is available as of March 2014. The analysis covers 28 fish stocks from 16 species around the Atlantic and central/south Pacific oceans (which account for 39% of the global wild harvest of small pelagics), rated according to the sustainability assessment presented on FishSource (www.fishsource.com).

Most of the stocks analyzed are currently used for fishmeal and fish oil, but this is not true for all. For instance, some herring stocks from the northwest Atlantic have not been processed for meal or oil in

recent times, and more recently most of the NE Atlantic sardine and horse mackerel catches have been for human consumption. The proportion of any given species/stock being utilized for meal and fish oil will be a function of market demand and can change from year to year.

The fisheries are ranked into four sustainability categories (A, B1, B2, and C) according to scores on FishSource, the SFP public database of fisheries information. The categorization is based on the quality of management (scores 1 to 3) and status of the target stock (scores 4 and 5). While information on environmental impacts of fishing activities is also captured in the narrative sections of the FishSource fishery profiles, it is not currently captured by the scoring system. The categories, defined within the context of FishSource's 10-point scoring scale, are:

> **Category A** – Very well managed fisheries that score 8 and above across all FishSource scores
>
> **Category B1** – Reasonably managed fisheries that score ≥ 6 across all FishSource scores, and score ≥ 8 in terms of biomass
>
> **Category B2** – Reasonably managed fisheries that score 6 or above across all FishSource scores
>
> **Category C** – Poorly managed fisheries where at least one FishSource score is below 6

In summary, the briefing concludes that for the 28 small pelagic fish stocks analyzed:

- Just 8% of the total catch comes from stocks in very good condition (Category A). This corresponds to two herring stocks and one blue whiting stock from the Northeast Atlantic.
- Cumulatively, 66.5% of the catch supply comes from stocks that are reasonably well managed (or better) (i.e., that score 6 or above on all five FishSource criteria).
- More than half (55.3%) of the catch comes from stocks that score 6 or above in all criteria AND the score for biomass is 8 or more, meaning biomass is at or above target levels (Category B1). These stocks are in very good shape in terms of biomass, but still need some improvements in management strategy. This level of performance is in line with the current Aquaculture Stewardship Council requirements for fisheries providing fishmeal and fish oil for feed to certified farms.
- 33.5% of the catch comes from stocks that score below 6 on at least one of the criteria (Category C). These stocks have not been effectively managed or are currently in poor condition and significant improvements are required.
- In terms of stock status and exploitation rates, specifically:
    - 73.1% of the catch supply (c. 7.95 million tonnes) comes from stocks considered to be healthy (i.e., in which the stock biomass is at or above its biological reference points), 8.5% from stocks at intermediate levels of biomass, and 17.8% from stocks currently depleted (i.e., below limit biological reference points or at historical low levels of biomass).
    - Around 70% of the catch supply comes from stocks managed within agreed targets (i.e., either with fishing mortality below FMSY or proxy levels or low fishing mortalities), 17% from

moderate fishing mortality (i.e., with fishing mortality slightly above the historical average or FMSY or proxy levels), and 13% from stocks where overfishing is occurring.

- For 3 stocks, cumulatively representing 0.5% of the total catch supply, the stock and exploitation status are unknown.

- Fifteen of the 28 stocks contain fishery improvement projects (FIPs). The majority of catch coming from stocks where FIPs exist is from fisheries that are making exceptional progress according to the SFP FIP Progress Rating scheme (34% of catch; 5 stocks); while 16% of catch comes from fisheries that made some recent progress (3 stocks). Six FIPs, which correspond to 12% of total catch, made only negligible progress.

- In terms of MSC certification, four of the stocks contain fisheries that are certified according to the Marine Stewardship Council or in full assessment. Twelve of the stocks are used as sources of fishmeal that are certified for use under the International Fishmeal and Fish Oil Organisation Responsible Supply (IFFO RS) program. Only 3% of the total volume of fish from the 28 stocks is MSC certified.

- There is an emerging scientific consensus that certain small pelagic stocks can be considered "key" to ecosystems because of their role in energy flows from primary producers to higher trophic levels. Stocks that are identified as key in the future will need to be managed with greater precaution than under current regimes in order to ensure responsible stewardship of this resource. It is a matter of urgency that those stocks subject to greatest exploitation be assessed for key status as soon as possible

Table 3. Changes in sustainability categories across the stocks evaluated.

	Stock	Change in category	Notes
	Blue whiting - Northeast Atlantic	B_1 to A	Fishers compliance improved, with catches in 2012 below the set TAC.
	Atlantic herring - Icelandic summer-spawning	B_1 to A	The management strategy in place has been proven precautionary in maintaining the stock at healthy levels.
↑	Anchoveta - Peruvian northern-central stock	B_2 to B_1	Recent surveys have been optimistic and spawning stock biomass currently estimated at twice the size of the 2012 estimate, and well above the precautionary limit. Compliance is deemed good overall. Managers seem to be following scientific advice, but disclosure of information is still a problem.
	European sprat - North Sea	C to B_1	Overall improvements in management and stock condition. In 2013, set TACs more in line with scientific advice; spawning stock biomass above its precautionary reference point and on a decreasing trend, and below provisional F_{MSY} proxy since 2005.
	Lesser sand-eel - Dogger Bank area	C to B_2	Since 2011, specific catch limits are set per management area. After the TAC overshoot in 2012, catches in 2013 (preliminary) were within set limits.
	Capelin - Icelandic	B_2 to C	Recruitment has been below average. Projections for 2014 in terms of spawning biomass are divergent, with two methods indicating SSB above below the 400,000 t threshold.
↓	European pilchard - Iberian	B_2 to C	Currently no international annual TAC is set, and this has led the most recent total catches to significantly exceed scientifically advised limits. Spawning stock biomass is well below the historical average.
	European pilchard - Northwest Africa southern stock	B_1 to C	Spawning stock biomass on a decreasing trend, probably due to environmental factors, and currently below its limit reference point (estimates from 2011).

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