Te Puni Kōkiri
REALISING MĀORI POTENTIAL

NIWA
Taihoro Nukurangi

RAWA RESOUCES

Ahumoana Ahutāngata

Aquaculture Development in New Zealand: Scientific and Technical Information to Inform Māori

Te Kāwanatanga o Aotearoa

REALISING MĀORI POTENTIAL

1	*Mātauranga – Building of knowledge and skills.*
2	*Whakamana – Strengthening of leadership and decision-making.*
3	*Rawa – Development and use of resources. This area recognises the imoprtance of ensuring Māori can access the necessary resources at the right time and place in order to meet their basic needs and take advantage of opportunities to use, develop and retain their resources in ways that will improve their quality of life.*
4	*Te Ira Tangata – The quality of life to realise potential.*

The framework above identifies three key enablers that are fundamental to Māori achieving Te Ira Tangata (improved life quality) and realising their potential. All our written information has been organised within these three key enablers or Te Ira Tangata.

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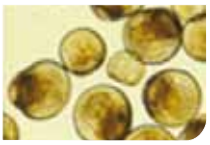

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FOREWORD:
Hon Pita Sharples: Minister of Māori Affairs, Associate Minister of Corrections, Associate Minister of Education

E ngā iwi o ngā tai e whā, e ngā uri o ngā tātai whakaheke, mai rā anō i Hawaiki, whakawhiti mai i te Moana Nui a Kiwa ki Aotearoa nei, tēnā koutou.

Ko o tātou tīpuna, he tohunga hī ika, hao ika, ruku kai; he iwi ora i ngā momo kaimoana katoa. Mo ngā iwi kāore o rātou takutai, he hokohoko huahua te mahi. Tae noa mai ki tēnei wā, e rapu tonu ana ngā iwi i te oranga mo rātou i ngā mahinga kaimoana.

Kei te mihi ki ngā rangatira i pakanga kia whai mana te Tiriti o Waitangi, kia whai wāhi te tangata whenua ki ngā mahinga ika hei hokohoko; kia whai wāhi hoki ki ngā takutai moana hei wāhi ahumoana.

Kei te takataka mai ngā painga ki a tātou ngā uri o rātou mā. Ko tēnei pukapuka, hei whakamārama i te huarahi e taea ai ngā mahinga ahumoana.

Our ancestors who came out of the Pacific were equipped with knowledge and skills to live off the riches of the sea and the coast. Inland tribes traded delicacies from the bush in order to savour the rich and salty flavours of the sea.

Seafood is still part of our identity as tangata whenua. The legend of Kahungunu and Rongomaiwahine records one way in which the bounty of the sea led to the founding of a whole new tribe!

In recent times, our elders fought for recognition of our ancestral rights, guaranteed by the Treaty of Waitangi, to control their fisheries and to participate in aquaculture. This generation has been enjoying some results of their efforts, though progress in aquaculture has been quite slow.

Recent changes to Resource Management and Aquaculture laws have reopened a pathway for tangata whenua. In this book, Te Puni Kokiri and the National Institute of Water and Atmospheric Research have gathered together scentific and technical information to inform iwi who are keen to enter this industry.

Globally, aquaculture is an industry with vast potential. The Government hopes aquaculture will be a billion-dollar industry by 2050. But the economic opportunities carry risks, and yet I am confident that iwi haveboth the acumen and the courage to excel in the field of aquaculture, as did our ancestors.

Tena, kei a koutou inaianei te whakamahi i enei korero hei oranga mo tatau!

Hon Pita Sharples
Minister of Maori Affairs

FOREWORD: National Institute of Water & Atmospheric Research Ltd John Morgan

Tēnā koutou

The aquaculture industry represents considerable economic opportunity for Māori and New Zealand as a whole.

Worldwide demand for seafood products continues to increase, and as a consequence, aquaculture is now the fastest growing global food sector. It is predicted that the industry will continue to expand to more than double its current export value by 2010, and the Government and industry have together proposed a target for New Zealand aquaculture to reach NZ$1 billion in sales by 2025.

The National Institute of Water & Atmospheric Research Ltd, Taihoro Nukurangi (NIWA) aims to work with Māori and the seafood industry to rapidly advance new aquaculture species into commercial production. Introducing new species will provide opportunity for Māori to work in advanced aquaculture technologies.

NIWA has the largest team of aquaculture specialists and dedicated facilities in New Zealand and is able to help with all aspects of aquaculture. NIWA believes that the contribution made by Māori to the overall New Zealand aquaculture strategy will be significant.

The appetite for current scientific and economic information pertaining to aquaculture by Māori has been overwhelming. It is Te Puni Kōkiri and NIWA's shared intention to meet that thirst for information with current data and considerations that will have business applications for Māori.

John Morgan
Chief Executive
NIWA

FOREWORD:
Te Puni Kōkiri Chief Executive Leith Comer

Tēnā rā koutou katoa,

Aquaculture is an industry currently worth over $300 million to our national economy. Māori are already significant participants in the aquaculture industry.

The Government has determined that aquaculture should be part of its economic transformation agenda and the industry is working to become a sustainable billion dollar business by 2025.

In order to participate in the opportunities and challenges this industry represents, it is important that Māori have access to sound advice about, and research on, forms of aquaculture. This is required so that Māori can make informed decisions about entering this challenging enterprise and maximising the potential for aquaculture assets obtained through the Government's aquaculture settlement obligations.

Te Puni Kōkiri commissioned the National Institute of Water and Atmospheric Research (NIWA) to prepare this report to provide Māori with up-to-date research information on the potential of five species for aquaculture within 10 regions of Aotearoa. The information contained in the report provides realistic evaluations on the potential of, and challenges to, Māori participation in the aquaculture industry.

Further careful research on species and the environment suitability for aquaculture will be required on a site-specific basis before the potential for aquaculture in any area can be realised.

I commend this report to you as an introduction to the complexities and opportunities aquaculture offers as a means of maximising Māori potential.

Leith Comer

Leith Comer
Chief Executive
Te Puni Kōkiri

EXECUTIVE SUMMARY

ROLE OF MĀORI IN THE NEW ZEALAND AQUACULTURE INDUSTRY

Culturally and economically, Māori have a considerable stockholding in the New Zealand aquaculture industry. Both the aquaculture industry's development plan (*New Zealand Aquaculture Strategy* (Burrell et al 2006)) and the government's National Position Statement on Aquaculture (in *Our Blue Horizon: He Pae Kikorangi: The Government's Commitment to Aquaculture* (Ministry of Economic Development 2007)) have identified that the participation of Māori in the growth of the aquaculture industry is critical to its future success.

AQUACULTURE LAW REFORMS

The aquaculture law reforms that came into force on 1 January 2005 included the enactment of the Maori Commercial Aquaculture Claims Settlement Act 2004. This Act entitled Māori to develop 20 percent of the space within new aquaculture management areas (AMAs) and 20 percent of the 'pre-commencement space', which is the marine farming space that was created by permits, leases or licences issued from 21 September 1992 to 1 January 2005. This ensures Māori will remain significant players in the aquaculture industry in the future.

ROLE OF TE PUNI KŌKIRI

Te Puni Kōkiri has taken the initiative to encourage further Māori participation in all aspects of the aquaculture industry by building Māori capacity to participate in the industry, supporting strategic planning relating to Māori, creating an environment than enables (rather than hinders) iwi participation and facilitating commercial ventures between Māori and industry.

HUI TO PROVIDE MĀORI WITH INFORMATION ABOUT AQUACULTURE

Te Puni Kōkiri's Māori Potential Fund funded the National Institute of Water and Atmospheric Research Ltd (NIWA) to undertake hui to provide Māori with technical information on aquaculture species and technologies, the economics and business of marine farming, and the regulatory environment following the introduction of the aquaculture law reforms. The aim of the hui was to provide Māori with access to scientific and technical information and resources to inform their decision-making on aquaculture-related issues.

Ten hui were held during June to August 2007. Five hui were held in 'priority regions' (Northland, Auckland, Waikato, Bay of Plenty and Nelson–Marlborough) where the potential for development and demand for aquaculture space is likely to be greatest. The other five hui were held in regions (Gisborne, Hawke's Bay, Taranaki, Greater Wellington and Canterbury) that were chosen for the level of interest generated by Māori requests for information on understanding the aquaculture reforms.

Each facilitated hui included written materials, presentations and open discussions. NIWA, Takutai Trust and Te Puni Kōkiri experts presented on the science of aquaculture, the aquaculture of five representative species (pāua, kingfish, mussels, eels and oysters), and the aquaculture legislation (including regulations) pertinent to Māori involvement. The open discussions focused on regional potential and the implications of the Māori Commercial Aquaculture Claims Settlement Act 2004.

PURPOSE OF THIS REPORT

This report, *Aquaculture Development in New Zealand: Scientific and Technical Information to Inform Māori*, was developed from the materials presented at the 10 hui and includes additional information about aquaculture practice, policy and governance worldwide. It provides Māori with a resource about why and how iwi should and can participate in the development of New Zealand's aquaculture industry. The compilation of the information into one document gives Māori a nationwide perspective to supplement the regional emphasis of the 10 hui.

CONTENT OF THIS REPORT

This report is made up of three parts.

Part 1 (sections 1–11) provides information on current aquaculture methods, species and production, from both global and New Zealand perspectives (sections 1–4). The potential for aquaculture development in New Zealand and for Māori to participate in that development are discussed in sections 5 and 6 respectively, and reference is made to relevant industry and government documents. Two key points are that the 20 percent allocation of aquaculture space to iwi, unlike commercial fishing quota, has the potential to immediately realise income and aquaculture space requires investment and expertise to enable Māori to achieve any returns from it.

Section 7 on why and how to get into aquaculture and section 8 on the regulation and control of aquaculture emphasise that Māori need to be conversant with, and involved in all aspects of the industry. The sections guide new entrants to the industry to the agencies providing facilitation, information and advice.

Section 9 on business planning for aquaculture reiterates earlier statements that aquaculture in New Zealand is high risk, typically has high capital and operating costs, generally requires the economies of large scale to achieve a good return on investment, and often the return comes only after a prolonged period of investment.

Section 10 contains the reference list for Part 1 and section 11 contains contacts for further information.

Part 2 (sections 12–21) contains the appraisals of the 10 regions in which the hui were held from Northland (Te Tai Tokerau) in the north to Canterbury in the south. Each regional appraisal starts with a brief description of its area and coastline. This is followed by details of existing aquaculture, the region's potential for development and its available infrastructure, and the regulatory environment particular to the region. Each appraisal ends with an analysis of the region's marine sites and the potential for farming each of five species within the region.

Part 3 (sections 22–26) discusses in detail the aquaculture in New Zealand of the five species, mussels (kutai, kuku), oysters (tio), abalone (pāua), yellowtail kingfish (kahu, haku) and eels (tuna), in New Zealand. The five species were chosen for their potential for development in New Zealand and to represent a range of commonly used aquaculture technologies that may be applied to other species. These sections, separately authored by NIWA experts, provide information in much greater detail than was presented at the hui. The sections describe the species and its life cycle, world and New Zealand production, farming techniques (including processing, marketing and economics), the legislation relevant to each species, and any obvious production constraints or bottlenecks.

LIMITATION OF THE REPORT

Worldwide the aquaculture industry invests millions of dollars each year to improve production techniques and develop new products and markets. While this report provides the best available information on development options in 2008, new technologies are continually being developed that may provide significant advances and opportunities for new aquaculture species and areas, enabling further widespread Māori participation in the industry in the future.

REFERENCES

Burrell M, Meehan L and Munro S. 2006. *The New Zealand Aquaculture Strategy*. Nelson: New Zealand Aquaculture Council. 26 pp. Available at http://www.seafood.co.nz/f431,15491/15491_Aquaculture_Sector_Strategy.pdf

Ministry of Economic Development. 2007. *Our Blue Horizon: He Pae Kikorangi: The Government's Commitment to Aquaculture*. Wellington: Ministry of Economic Development. 44 pp. Available at www.aquaculture.govt.nz

PART 1:

OVERVIEW

RAWA – RESOURCES: THIS PATTERN DRAWS INSPIRATION FROM THE KORU WHICH REFERENCES THE FERN FROND.

1 INTRODUCTION

1.1 BACKGROUND TO THIS REPORT

In 2006, the National Institute of Water and Atmospheric Research Ltd (NIWA) approached Te Puni Kōkiri for funding to undertake hui to provide Māori with information on potential aquaculture species, the economics and business of marine farming, and the regulatory environment for aquaculture following the aquaculture legislation reforms that came into force on 1 January 2005.

Te Puni Kōkiri used its Māori Potential Fund to contract NIWA to:

- provide 10 hui in five (later 10) regions "to inform Māori of the potential for aquaculture related activity within key identified regions"
- publish technical and scientific appraisals, so "Māori will have access to scientific and technical information and resources that inform their decision making on aquaculture related issues" (Seymour 2007).

1.2 AIM OF THE 10 REGIONAL HUI

The hui aimed to provide iwi and other interested parties with information about aquaculture through written materials, presentations by experts and open discussions. Each hui comprised a series of presentations covering the national and international aquaculture industry, the science underlying aquaculture, the business of aquaculture, and a detailed analysis of five species that are currently or potentially significant as aquaculture resources (mussels (kutai, kuku), oysters (tio), abalone (pāua), yellowtail kingfish (kahu, haku), and eels (tuna)).

Included in both the industry-wide and species-specific presentations were analyses of aquaculture legislation and its implications, which introduced further presentations and discussions on relevant legislative issues such as the Māori Commercial Aquaculture Claims Settlement Act 2004 and the process under the Resource Management Act 1991 for establishing aquaculture management areas and marine farms.

The target audience for the hui included iwi involved, or likely to be involved, in aquaculture, local government practitioners working in aquaculture, and members of the aquaculture industry. Each hui was held over one day.

The 10 hui were held between 9 June and 17 August 2007 throughout the country, with two in the South Island and eight in the North Island. Five hui were held in 'priority regions' identified as being areas "where demand for aquaculture space is most likely to be supported by the relevant regional councils, namely Northland, Auckland, Waikato, Bay of Plenty and Nelson–Marlborough" (Seymour 2007). The other five hui were held in regions chosen for the level of interest generated by Māori requests for information on understanding the aquaculture reforms, namely Gisborne, Hawke's Bay, Taranaki, Wellington and Canterbury.

1.3 PURPOSE OF THIS REPORT

This report, *Aquaculture Development in New Zealand: Scientific and Technical Information to Inform Māori*, was developed from materials presented at the 10 hui and supplemented with a broad selection of published material on aquaculture practice, policy and governance worldwide and in New Zealand. The compilation of the information into one document gives Māori a nationwide perspective to supplement the regional emphasis of the 10 hui.

1.4 CONTENT OF THIS REPORT

This report is made up of three parts.

Part 1 (sections 1–11) provides information on current aquaculture methods, species and production, from both global and New Zealand perspectives (sections 1–4). The potential for aquaculture development in New Zealand and for Māori to participate in that development are discussed in sections 5 and 6 respectively, and reference is made to relevant industry and government documents. Two key points are that the 20 percent

allocation of aquaculture space to iwi, unlike commercial fishing quota, has the potential to immediately realise income and aquaculture space requires investment and expertise to enable Māori to achieve any returns from it.

Section 7 on why and how to get into aquaculture and section 8 on the regulation and control of aquaculture emphasise that Māori need to be conversant with, and involved in, all aspects of the industry. The sections guide new entrants to the industry to the agencies providing facilitation, information and advice.

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1.5 LIMITATION OF THE REPORT

Worldwide, the aquaculture industry invests millions of dollars each year to improve production techniques and develop new products and markets. While this report provides the best available information on development options in 2008, new technologies are continually being developed that may provide significant advances and opportunities for new aquaculture species and new areas, enabling further widespread Māori participation in the industry in the future.

2 INTRODUCTION TO THE CHOSEN SPECIES

2.1 FIVE SPECIES SELECTED FOR DISCUSSION

The five species selected for discussion in this report are the:

- green-lipped mussel *Perna canaliculus* (kutai, kuku) (known in New Zealand under the trade-marked name Greenshell mussel) (section 22)
- Pacific oyster *Crassostrea gigas* (tio) (section 23).
- abalone *Haliotis iris* (pāua) (section 24)
- yellowtail kingfish *Seriola lalandi* (kahu, haku) (section 25)
- eel *Anguilla australis* (shortfin) and *A. dieffenbachii* (longfin) (tuna) (section 26).

The five species are at different stages of commercial aquaculture development in New Zealand and were each selected according to four criteria.

- The species is in, or has substantial potential for, commercial production (existing production).
- The species has been the subject of substantial research (knowledge and infrastructure).
- The species is, or has potential to be, economically viable (economics).
- The species reflects one of a range of typical growing systems for aquaculture species (system diversity).

2.2 EXISTING PRODUCTION

All the species are in full commercial production (mussels and oysters), early commercial production (pāua) pilot commercial production (kingfish) or have clear indicators of strong production potential (eels). Considerable information and/or experience in ongrowing systems exists for all five species, and, with the exception of eels, there are existing commercial suppliers of seed stock. The availability of eel seed (glass eels) is subject to regulatory constraints, but these are under review.

2.3 KNOWLEDGE AND INFRASTRUCTURE

All five species have been the subject of substantial research efforts over several years and a considerable amount of information exists relating to their aquaculture. Greenshell mussels and Pacific oysters have been farmed in New Zealand for many years and are the basis of much of the current aquaculture production. Consequently, large established industries provide goods and services to the shellfish farming sector. Shellfish aquaculture research in New Zealand has investigated issues such as the carrying capacity of bays, the environmental impacts of production, technological advances to improve productivity and spat production and quality.

Technological advances in pāua aquaculture have been rapid in recent years, and these advances have been reflected in changes in the New Zealand industry. Large-scale, land-based abalone production systems have operated in South Africa, Australia, the United States, United Kingdom and China for several years, and the development of pāua farming in New Zealand is in line with these overseas trends. A local knowledge base for such systems and supporting infrastructure (equipment suppliers and so on) are growing.

Kingfish aquaculture has been the focus of a sustained research effort in Australia and New Zealand since 2000. The research has progressed production to commercial levels in Australia and pilot commercial scale in New Zealand. Although research has focused on hatchery-related issues, necessary to ensure commercial fingerling production, issues affecting ongrowing such as disease management, feeding and transport have also been investigated. With a well-established salmon sea-cage industry, much of the infrastructure to support the establishment of a kingfish sea-cage farming industry is in place.

While there is no eel aquaculture in New Zealand, research has focused on the development of production techniques for local species of eels. Research has dealt with all stages of production, from glass eel collection and transport to harvest-size animals and has included health management, feeding and husbandry. Considerable international resources exist on eel aquaculture, many of which are directly relevant to the local species.

2.4 ECONOMICS

Mussels and oysters have been in commercial production for many years and remain economically viable operations. While pāua farms have had a chequered history, more recent operations, such as those of OceaNZ Blue Ltd, have shown that large-scale land-based farms can be viable, particularly considering the technological and biological advances in pāua aquaculture made over recent years. Similarly, kingfish sea-cage farming is in its infancy, but shows substantial economic potential and is the type of high-value marine-farming activity that is in keeping with the theme of *maximising economic benefits,* which is one of the guiding principles in the government's National Position Statement on Aquaculture (in Ministry of Economic Development 2007). Eels are farmed worldwide, and because the local species differ little in their general farming requirements, eel farming is also likely to be a viable practice in New Zealand.

2.5 SYSTEM DIVERSITY

The species selected also represent the range of typical growing systems for aquaculture species: sea-cage farming of finfish, intertidal and subtidal shellfish farming and marine and freshwater land-based production.

Sea-cage farming in New Zealand is almost exclusively of Chinook salmon. Kingfish are considered a good candidate for sea-cage production, with the opportunity to mirror the successful development of the several thousand tonne industry in South Australia.

Success in land-based abalone farming worldwide over recent years has been the result of the development of large-scale production facilities, using either flow-through or recirculation systems, and this offers the greatest potential for pāua production in New Zealand.

As filter-feeding species, mussels and oysters represent typical species for subtidal, longline or intertidal rack culture respectively.

Eels may be grown in fresh or salt water, and production systems in operation in Europe and Asia are highly intensive recirculation systems or extensive pond-based systems, and both are considered in NIWA's economic models and the discussions in Part 3.

3 OVERVIEW OF GLOBAL AQUACULTURE

The word aquaculture is derived from the Latin 'aqua' meaning water and 'cultum' meaning to cultivate or farm. In essence, therefore, aquaculture is the farming of plants or animals in water. Where aquaculture occurs in the sea, it is often referred to as marine aquaculture (or 'mariculture').

In New Zealand legislation, aquaculture activities are defined as "the breeding, hatching, cultivating, rearing, or ongrowing of fish, aquatic life, or seaweed for harvest" (section 2 of the Resource Management Act 1991).

Although most people regard aquaculture as simply fish and shellfish farming, a diverse range of aquaculture technologies and products have been developed to encompass a wide variety of market opportunities, including:

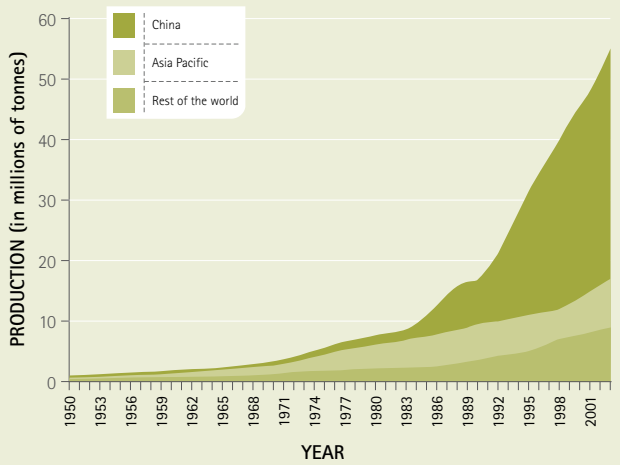
- luxury food production
- staple food production
- stock enhancement and conservation
- stock for sport fishing
- bait production
- aquarium supplies
- scientific specimens
- waste recycling
- aquaculture and aquarium feed production
- non-food production (eg, drugs and pearls).

Partly as a result of its versatility, aquaculture is said to be the fastest growing of the world's food production sectors. Total world production from aquaculture in 2004 was just under 60 million tonnes and valued at just over US$70 billion (figures are from the Food and Agriculture Organization of the United Nations[1]), and accounted for almost 50 percent of the aquatic production from capture and culture fisheries combined (FAO Fisheries Department 2006).

According to the Food and Agriculture Organization: "aquaculture is developing, expanding and intensifying in almost all regions of the world [whilst] global demand for aquatic food products is increasing, production from capture fisheries has levelled off, and most of the main fishing areas have reached their maximum potential" (FAO Fisheries Department 2006, p 113).

Growth in world aquaculture was particularly rapid from about 1990, with an average annual growth rate of 10.5 percent during 1990–2000. However, much of the increase resulted from the phenomenal growth in production in China (Figure 3.1).

FIGURE 3.1: WORLD AQUACULTURE PRODUCTION WITH CHINA AND REST OF ASIA–PACIFIC DISAGGREGATED FROM THE REST OF THE WORLD, 1950–2004



Source: FAO Fisheries Department (2006, Chapter 2, Figure 2, p 5). Courtesy of R Subasinghe, Food and Agriculture Organization, Rome.

1 The Food and Agriculture Organization of the United Nations leads international efforts to defeat hunger. The Food and Agriculture Organization serves both developed and developing countries, acts as a neutral forum where all nations meet as equals to negotiate agreements and debate policy, and is a source of knowledge and information.

3.1 PRODUCTION

Quantity and location of production

World aquaculture is centred in Asia. China is the dominant country with an annual production of over 41 million tonnes or almost 70 percent of the world's total production. China's production is valued at almost US$36 billion or 51 percent of the value of world aquaculture production. India has the world's second-largest aquaculture production of 2.5 million tonnes per year, and four other nations produce in excess of 1 million tonnes. Chile is the only non-Asian country in the top 10 of world aquaculture production (Table 3.1).

TABLE 3.1: TOP 10 AQUACULTURE PRODUCTION COUNTRIES

COUNTRY	PRODUCTION VOLUME (TONNES)	GLOBAL (%)	PRODUCTION VALUE (US$)	GLOBAL (%)
China	41,329,608	69.6	35,997,253,000	51.2
India	2,472,335	4.2	2,936,478,000	4.2
Philippines	1,717,028	2.9	794,711,000	1.1
Indonesia	1,468,612	2.5	2,162,849,000	3.1
Japan	1,260,810	2.1	4,241,820,000	6.0
Viet Nam	1,228,617	2.1	2,458,589,000	3.5
Thailand	1,172,866	2.0	1,586,625,000	2.3
Republic of Korea	952,856	1.6	1,211,741,000	1.7
Bangladesh	914,752	1.5	1,363,180,000	1.9
Chile	694,693	1.2	2,814,837,000	4.0

Source: FAO Fisheries Department (2006, Chapter 2, Box 2, p 9).

South America is the region that has shown the largest average annual growth (14.5 percent) in aquaculture production over the last decade, followed by Oceania (13.2 percent).

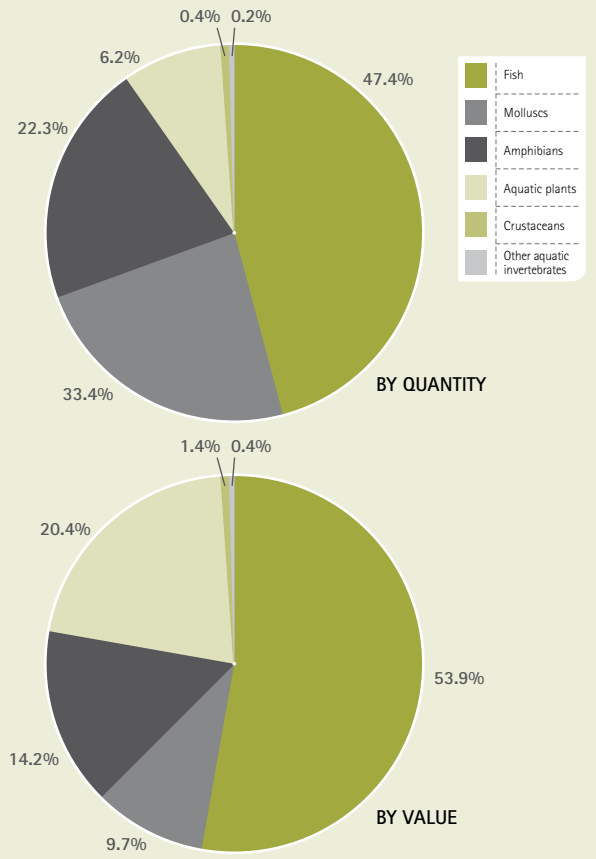
In Australia (included with New Zealand in Oceania in Food and Agriculture Organization statistics), the aquaculture sector has become the fastest-growing rural industry, with about a 13 percent annual increase in the overall value of its production in the past decade (from A$200 million in 1990 to nearly A$700 million in 2000). Oceania contributes only about 0.3 percent of global aquaculture production, with New Zealand contributing less than 0.1 percent. In terms of value, New Zealand's aquaculture production makes up less than 0.2 percent of global aquaculture sales.

Although aquaculture production in Asia accounts for just over 90 percent of world production, it represents only 75 percent of its value. This reflects the dominance in the Asian aquaculture sector of lower-value species, and particularly the lower-value finfish species.

Method of production and type of product

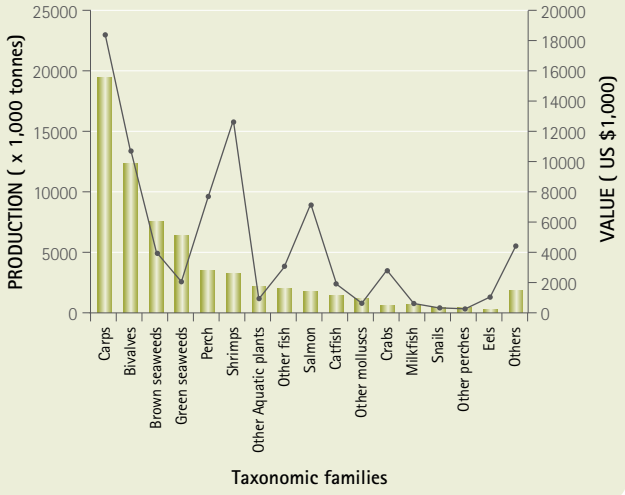
World aquaculture production covers the aquatic spectrum from marine (51 percent) to fresh water (43 percent) but with only a small production in brackish or estuarine water (6 percent or just under 3.5 million tonnes). The Food and Agriculture Organization's database of fisheries statistics (FishStat Plus) lists 442 species as having been cultured from 1950 to 2004, but only 336 recorded as being in production in 2004 (FAO Fisheries Department 2006, Chapter 2, pp 10 and 11). Fish are by far the most important aquaculture product both by quantity (47 percent) and value (54 percent), with aquatic plants (23 percent), molluscs (22 percent) and crustaceans (6 percent) ranking next in quantity of production, or crustaceans (20 percent), molluscs (14 percent), then plants (10 percent) based on their value (Figure 3.2).

FIGURE 3.2: WORLD AQUACULTURE PRODUCTION BY MAJOR TAXONOMIC GROUPING, 2004



Source: FAO Fisheries Department (2006, Chapter 2, Figure 8, p 11). Courtesy of R Subasinghe, Food and Agriculture Organization, Rome.

FIGURE 3.3: TOP TAXONOMIC FAMILIES IN WORLD AQUACULTURE (WITH PRODUCTION OF MORE THAN 250,000 TONNES) WITH THEIR CORRESPONDING VALUES, 2004



Source: FAO Fisheries Department (2006, Chapter 2, Figure 9, p 11). Courtesy of R Subasinghe, Food and Agriculture Organization, Rome.

Fish culture is predominantly of cyprinids (carps), of which over 18 million tonnes, worth US$16 billion, are produced annually, followed by over 200,000 tonnes each of tilapia (cichlids), milkfish (chanids) and catfish (clariids). Laminarian and alariacean kelps make up most of the aquatic plant production, while oysters, clams and mussels are the major molluscs that are cultured. The penaeid shrimps and grapsid crabs that comprise most of the crustacean production are more valuable than many other aquaculture products, so that shrimps rank second by value (US$10 billion) but only sixth by quantity, and crabs are eighth by value but 18th by volume. Similarly with the salmonid fish, which rank third in the world in value (at over US$6 billion) but are only seventh in quantity of production (Figure 3.3).

The species that are being cultured, together with the places in which aquaculture is being practised to its greatest extent, show that the majority of the world's aquaculture comprises local production of low-value products that are targeted at local consumption rather than export. Aquaculture of higher-value species generally aims to generate increased income and often targets export rather than local markets. Introduced species are frequently chosen for this type of aquaculture development, as shown by some of the penaeid shrimps, the Pacific oyster, the Atlantic salmon and the European eel, all of which are now produced more in regions other than their region of origin.

Worldwide, the production systems used for aquaculture reflect the variety of cultured species and the economic and social circumstances in which production is undertaken. Land-based systems range from earthen ponds to tanks and concrete raceways, and there is increasing development of high-technology, controlled-environment facilities and recirculation systems. On-water production includes sea pens and cages of varying structural complexity, fixed or moored structures such as stakes, racks and floating lines, as well as the use of the seabed for direct in situ seeding with stock. Because of increasing competition for limited coastal space all around the world, interest is growing in the development of large offshore production systems, primarily for producing high-value products.

3.2 PRODUCTION AND MARKETING TRENDS

The most evident long-term trend in aquaculture worldwide is one of decreasing unit value with increasing production. Typically with any new aquaculture species there is an initial increase in value as consumer acceptance and demand build, but this is then followed by a gradual downward progression in product value as the volume of production increases because of increased effort and improvements in farming technology. Data from the Food and Agriculture Organization shows that the downward price trend occurs both in high-value species (eg, a 20–40 percent

reduction in the value of Atlantic salmon from 1986 to 2004 and a 37 percent loss of value of giant tiger shrimp from 1997 to 2004) and also in low-value species (eg, a 20–40 percent reduction in the value of carps and tilapia over the past two decades) (FAO Fisheries Department 2006, Chapter 2, pp 12-13). Niche markets that retain value over the longer term exist for some aquaculture products and this may be at the species level such as Chinook salmon production or at the product level such as for large (over 1 kilogram) eels.

Global aquaculture production and marketing are affected by a range of factors across the whole spectrum, depending on whether production is of a commodity or niche product, whether for food or non-food use, and whether for local or export markets. However, the Food and Agriculture Organization has identified overall trends (FAO Fisheries Department 2006, pp 114–117).

- The "intensification of aquaculture production" has resulted largely from the limited availability of suitable aquaculture sites and the need to be able to sustain profitability as production costs increase.
- The "diversification of species use", particularly into higher-value species and often into non-indigenous species, has raised broodstock and seed supply availability issues, as well as concerns over the risks from introducing species and the impacts on biodiversity.
- The "diversification of production systems and practices" has been generally to improve sustainability or limit environmentally damaging practices by introducing new technology, such as multispecies culture, to improve the efficiency of resource and energy use and reduce negative environmental impacts.
- The "increasing influence of markets, trade and consumers" includes trends towards value-added product forms, more stringent demands from export markets, international requirements for high safety and quality standards, and recognition of environmentally friendly and sustainable production.
- "Enhancing regulation and improving governance of the sector" has been undertaken by developing codes of practice and monitoring, surveillance and regulation processes, so a product can be traced throughout its life and certified, as well as developing controls on aspects affecting product quality, such as food ingredients, the use of chemicals and therapeutics, disease, and toxins and contaminants in the rearing water.
- The "drive towards better management of the aquaculture sector" has been to make the sector more economic, sustainable and competitive at all levels, from the farm to the market, by engaging all the stakeholder groups in the effort to make aquaculture environmentally and socially responsible.

4 OVERVIEW OF NEW ZEALAND AQUACULTURE

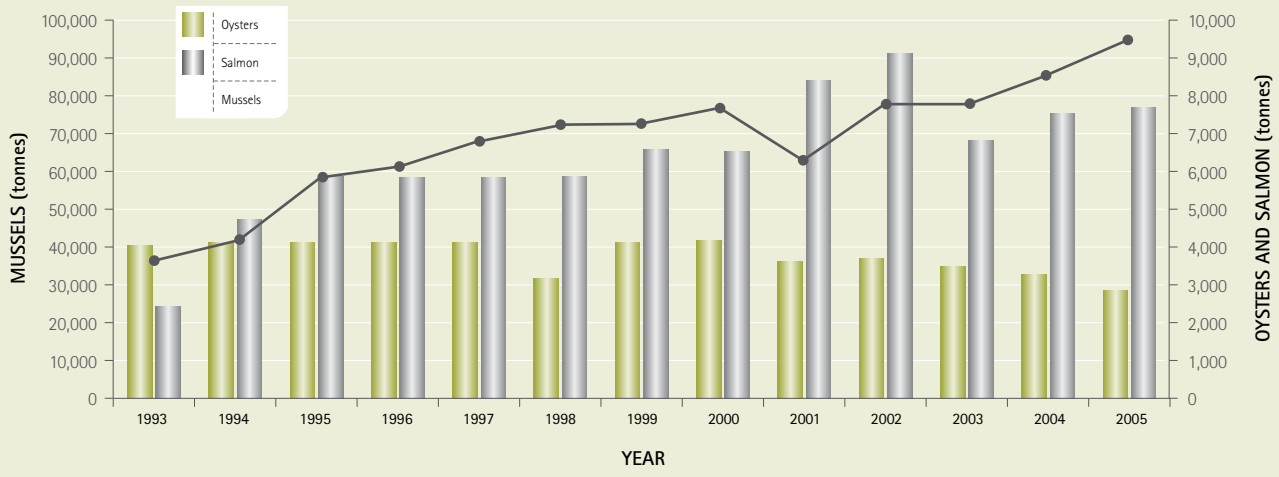
Aquaculture, as the managed production of aquatic organisms, was undertaken by Māori well before European settlement through customary gathering and enhancement of oysters, other shellfish, and eels. The recorded history of aquaculture in New Zealand goes back as far as the early 1900s, when the native rock oyster *Saccostrea glomerata* was 'enhanced' by providing additional settlement surfaces to collect its natural intertidal spatfall in northern harbours, for subsequent harvesting. Commercial aquaculture in New Zealand has a history spanning less than 50 years, because although the native rock oyster may have been commercially harvested since the 1930s, it was not until the 1960s that serious farming attempts began for that species, and, subsequently, for the introduced Pacific oyster *Crassostrea gigas*, as well as for the green-lipped mussel *Perna canaliculus* in the 1970s. It was not until the late 1970s that the first crops of farmed green-lipped mussels (trade-marked as Greenshell mussels) were harvested and this sector began its rapid rise in production, to become the dominant export earning sector of the New Zealand aquaculture industry. Commercial farming of Pacific salmon *Oncorhynchus tschawytscha* started with ocean ranching in 1976 and the first sea-cage rearing in 1983.

4.1 PRODUCTION

Quantity and location of production

New Zealand aquaculture has achieved rapid and massive growth, both in production and in the value of its exports. The industry developed at a fast rate during the 1980s, growing in volume of production at an average annual rate of 11.7 percent throughout the 20 years to 2005.

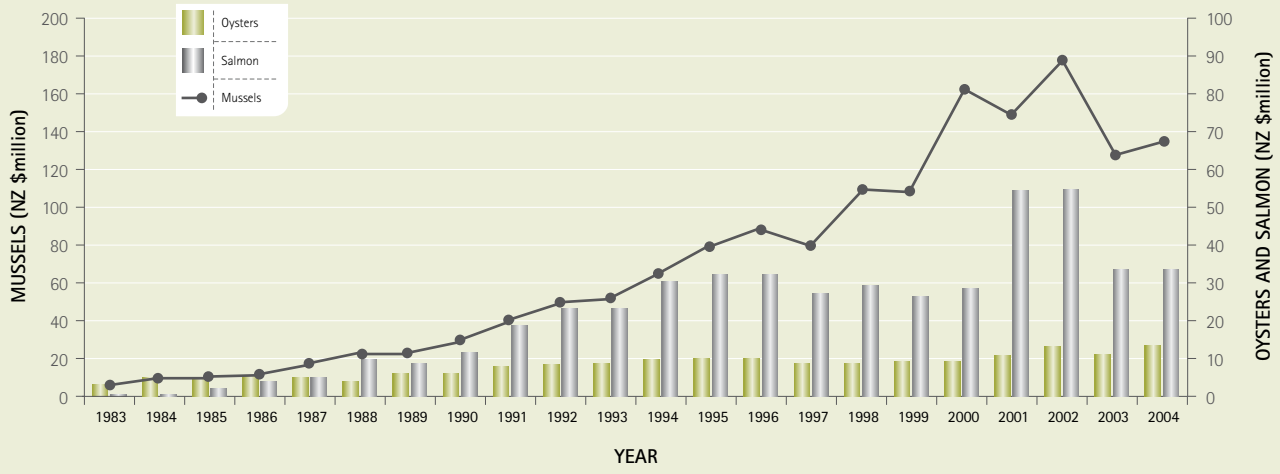
FIGURE 4.1: NEW ZEALAND AQUACULTURE PRODUCTION OF THREE MAIN SPECIES, 1993–2005



Source: Ministry of Economic Development (2007).

Export markets are the primary target for almost all of this country's aquaculture produce. Upwards of 70 percent by volume of New Zealand's aquaculture produce is exported, with the main markets being Australia, the United States and South East Asia. The value of New Zealand's aquaculture exports in 2005 was more than NZ$210 million per year, having risen from only $25 million in 1989. The domestic market adds a further $110 million to give the aquaculture industry a total annual market revenue of around NZ$325 million (which, for comparison with the global figures, equates to just over US$190 million). Revenue from aquaculture therefore comprises a significant proportion, at around 20 percent, of New Zealand's total seafood export earnings of NZ$1.2 billion dollars (or US$700 million).

FIGURE 4.2: NEW ZEALAND AQUACULTURE EXPORT EARNINGS OF THREE MAIN SPECIES, 1983–2004



Source: Ministry of Economic Development (2007).

It is predicted that the industry will continue to expand to more than double its current export value by 2010, and the government and industry have together proposed a target for New Zealand aquaculture to reach NZ$1 billion in sales by 2025.

Production of farmed mussels is around 95,000 tonnes per year. Mussel exports, at NZ$166 million, comprise almost 80 percent of New Zealand's aquaculture export revenue, with the combined domestic and export revenue from mussels (NZ$209 million) making up almost two-thirds of the total annual value of the aquaculture industry. Annual production of Pacific salmon, often called King salmon in New Zealand, is around 7,500 tonnes with a value of almost NZ$90 million (36 percent from exports). Annual production of Pacific oysters is almost 3,000 tonnes valued at almost NZ$30 million (57 percent from exports). The contribution and value of the three individual sectors to the New Zealand aquaculture industry has been estimated, by Investment New Zealand[2] in *Aquaculture in New Zealand* (2006), on the basis of the number of farms, the total hectares of marine farming space and their revenue per year per hectare (Table 4.1).

TABLE 4.1: CONTRIBUTION AND VALUE OF INDIVIDUAL SECTORS OF THE NEW ZEALAND AQUACULTURE INDUSTRY, 2004

SPECIES	NUMBER OF FARMS	HECTARES OF MARINE SPACE	REVENUE PER YEAR PER HECTARE (NZ$)	EXPORT REVENUE (NZ$ millions)	TOTAL SECTOR REVENUE (NZ$ millions)
Greenshell mussel	645	4,747	38,000	166	209
Pacific oyster	230	750	35,000	16	28
King salmon	23	50	1,350,000	32	88

Source: Investment New Zealand (2006).

Method of production for current species

The three established sectors of the aquaculture industry in New Zealand, mussel, oyster and salmon, predominantly use different methods of production. Greenshell mussel farming uses the longline system, which comprises a series of surface buoys connected by twin horizontal lines that suspend the vertical growing or culture lines that hold the crop of mussels. The backbone of buoys and ropes is anchored at either end to heavy mooring blocks. Mussel farming typically takes place in near-shore areas in relatively sheltered embayments or harbours, mainly in the Marlborough Sounds, Coromandel, Stewart Island and several northern North Island harbours. A modification of the system, which is at an early commercial development stage for use in offshore deep water mussel farms, is a subsurface longline system with all the farming equipment (apart from a few marker buoys) set out at least 10–15 metres below the water surface. The seed supply for almost the whole mussel industry is from natural spat catch, with most of it coming from Ninety Mile Beach ('Kaitaia spat') or from Tasman Bay and Golden Bay. Commercial hatchery production of Greenshell mussel seed is still in its infancy.

Some Pacific oyster farming is also done using the longline system, usually with suspended trays or baskets to hold the crop of oysters rather than ropes as in mussel farming. However, by far, most of New Zealand's oyster farming uses rack, stick, tray and basket systems, situated in sheltered intertidal foreshore areas of numerous east and west coast harbours around the upper third of the North Island, and also in a few parts of the Marlborough Sounds, Tasman Bay and Golden Bay areas. Oyster farming also relies largely on natural spatfall onto sticks, which are set out in known spat catching areas, notably the Kaipara Harbour. There is increasing interest in, and use of, hatchery-produced Pacific oyster seed, which is fuelling a change from stick culture to tray and basket culture techniques.

New Zealand salmon farming is based on the ongrowing of hatchery-produced smolts, mainly in sea-cages. Hatcheries use a mix of wild returns and retained broodstock. Eggs and sperm are stripped and fertilised externally. Fry, and later smolt, are reared in freshwater facilities until the smolt achieve seawater competence, typically at a weight of 30–50 grams about 15 months after spawning. The ongrowing sector is based in sheltered areas of coastal water in the outer Marlborough Sounds, on Banks Peninsula and at Stewart Island. There is also some production completed entirely in fresh water, with the ongrowing undertaken either in cages located in the hydro canal of a power generation scheme in the southern lakes district of Canterbury, or in raceways and tanks.

Although the species that have been successfully commercialised for aquaculture in New Zealand is limited, the range of species that has been considered, and in many cases investigated, as potential aquaculture candidates is extensive. Even in 1979, when the mussel industry was only just starting to flourish, the Minister of Fisheries was promoting "the development of a viable, multi-faceted aquacultural industry" (MacIntyre 1980, p 5). By the late 1980s, both research and commercial interests were providing lists, together with assessments and evaluations, of more than 40 fish, crustacean, mollusc and seaweed species with potential for aquaculture in New Zealand (Hayden 1988; New Zealand Trade Development Board 1989).

However, recent reports on the status of the industry, together with assessments of its potential for development (eg, Jeffs 2003a), have highlighted the lack of diversification within the industry, because virtually throughout its entire history the industry has comprised just the three species – mussels, oysters and salmon. A succinct assessment of the range of species with potential to add to the diversity of New Zealand aquaculture was published in the Investment New Zealand aquaculture report (2006). The report describes the types of technology for use in either marine or freshwater locations, encompassing intertidal, longline, cage, and land-based farming, plus enhancement, together with lists of the species suitable for culture by each technology (see Figure 4.3).

The marine and freshwater species identified in the report as having opportunities for aquaculture have been described (see Figure 4.4) as follows: "the inner core … represents species with well established technology and successful ventures" (the three currently exported species), "the inner circle represents species that are the focus of significant research and some limited commercial ventures" (comprising seven marine and four freshwater candidates), and "the outer circle of species that have yet to be explored … but which may present opportunities in the future" (with 10 marine and two freshwater candidates) (Investment New Zealand 2006, p 7).

2 Investment New Zealand is a government agency "committed to helping investors discover the opportunities that New Zealand offers aquaculturists and assisting inward investment to this growing sector" (Investment New Zealand 2006, p 1).

FIGURE 4.3: SUMMARY OF CULTURE TECHNOLOGIES WITH EXAMPLES OF SPECIES SUITED TO EACH TECHNOLOGY

Source: Redrawn from Investment New Zealand (2006).

FIGURE 4.4: AQUACULTURE SPECIES AND TECHNOLOGY OPPORTUNITIES IN NEW ZEALAND

Source: Redrawn from Investment New Zealand (2006).

Method of production for potential species

Of the 21 potential aquaculture candidates mentioned in the Investment New Zealand report (2006) only two are considered as 'emerging' aquaculture sectors that are likely to be in commercial production and achieving export returns in the next few years. These are pāua *Haliotis iris* and yellowtail kingfish *Seriola lalandi*, for which commercial farms are already in existence. They are described in detail in Part 3, as is the aquaculture potential for eels *Anguilla australis, A dieffenbachii*, which, along with pāua and kingfish, are the 'inner circle of species with limited commercial ventures' mentioned above (Figure 4.4).

Scallop *Pecten novaezelandiae* farming in New Zealand is sometimes considered to be an existing commercial practice. However, the production methods of the scallop fisheries in Tasman Bay and Golden Bay and some northern North Island harbours are more correctly categorised as enhancement, because they consist primarily of supplementing natural recruitment by spat catching and relaying of seed, together with manipulation of production through management of the stocking densities and the harvesting of populations that are growing naturally in the wild on the seabed. Actual farming of scallops, by suspended culture in pearl and lantern nets, has been the focus of research and development leading to pilot scale trials, but ongoing problems with juvenile mortality, slow growth and competition from fouling organisms have deterred commercial uptake of the technology (Hayden and Woods 1997).

Flat (Bluff) oyster *Tiostrea chilensis* farming has been extensively researched and shown to have potential for suspended culture, for enhancement of the wild fishery populations, and as a possible alternative species to the Pacific oyster in intertidal oyster-farming situations. The main constraints on commercialisation of flat oyster farming are developing reliable seed supplies and minimising the disease risk from *Bonamia* (a type of parasite) (Hickman et al 1999).

Rock lobster (or crayfish) *Jasus edwardsii* farming was investigated in the 1990s, when large quantities of puerulus stage[3] juveniles, found to be settling on mussel lines and settlement monitoring equipment, were seen as a seed source for ongrowing to market size in land-based tank or raceway facilities, or in 'habitats' in sea-cages. Puerulus settlements have subsequently proved to be unreliable, and rearing larvae from eggs, as an alternative source of seed for farming, appears economically unviable because of its complexity and long duration. There is continuing interest in the packhorse lobster Jasus verreauxi for aquaculture because it may be an easier species for rearing the larvae from eggs (Tong and Moss 2000).

Snapper *Chrysophrys auratus,* turbot *Colistium nudipinnis* and seahorse *Hippocampus abdominalis* are three finfish that have been investigated and shown to have potential for aquaculture, if economically viable production can be achieved on a commercial scale in New Zealand (Hickman and Tait 2001; Hickman et al 2002; Tait 1996; Woods 2000). Experimental rearing of seahorses, using low technology methods compatible with existing mussel farming techniques to minimise the cost of feed production, is ongoing (Woods 2000).

Various sponge and seaweed species (including *Lissodendoryx, Mycale, Gigartina, Gracilaria, Pterocladia*) have been, or are being, studied for their properties and biochemical components which may have pharmaceutical, nutriceutical or other useful or valuable attributes. This work has led to further investigation and development of aquaculture techniques suitable for mass production of those species showing biotechnological potential (Page et al 2005).

Apart from salmon farming, there are two other types of commercial freshwater aquaculture in New Zealand. Both involve small-scale enterprises focused on domestic niche markets. A small number of kōura (freshwater crayfish) farms exist in Wairarapa, Nelson–Marlborough and Central Otago. They produce either *Planifrons planifrons or P. zealandicus* in low density, low technology, pond cultures based on natural conditions, with individual owner–operators marketing their product to local restaurants (Parkyn 2001). The Wairakei prawn farm is unique in New Zealand as the only commercial aquaculture activity based on a species, the giant river prawn *Macrobrachium rosenbergii,* that was deliberately imported. The original broodstock came from Malaysia in 1987. The species was chosen to suit the particular conditions of a freshwater pond aquaculture system that uses heated waste water (at a constant 28°C) from the geothermal power station for rearing the prawns, before discharging it into the Waikato River. The self-contained enterprise, incorporating tourism, raises its own larval seed stock and markets the majority of its 32 tonne annual production through an onsite restaurant (Ingram 2005).

4.2 PRODUCTION AND MARKETING TRENDS

Although small and of limited species range by world standards, New Zealand aquaculture does exhibit most of the general production and marketing trends identified by the Food and Agriculture Organization (and discussed in the following

3 The puerulus is a transparent miniature swimming juvenile, the last stage in the complex larval development of the rock lobster.

paragraphs). This is probably as a consequence of the strong focus of the industry on exporting its produce, and through the knowledge that the quality and the value of New Zealand product on world markets are fundamental factors in the profitability of this country's aquaculture.

Intensification of aquaculture production has always been a factor in New Zealand aquaculture development because the industry has had to compete with a diverse range of alternative uses, such as navigation, fishing and recreation, and to overcome numerous legislative, commercial, social and aesthetic issues for the right to occupy marine space. New Zealand's major production species, mussels, salmon and oysters, are effectively priced as commodity species, so intensification has been necessary to maintain world competitiveness in price.

Diversification into new aquaculture species has driven the significant amount of research and development that has been undertaken with the aim of making the overall industry less vulnerable to changing market demands or to species-specific risks, such as disease or environmental change. Regulatory limitations on the development of some new species (eg, eels) and on the expansion of existing licences to accommodate them, have helped stifle the uptake of emerging new species. Instead, companies have opted to expand the production of existing species, and, coupled with strong promotion of consumer demand in both export and domestic markets, this has resulted in a slow commercial take-up of new species. New Zealand's philosophy of encouraging the use of endemic (native) species and opposing the introduction of alien species may also have limited the diversification of the aquaculture industry.

Diversification of production systems and practices has helped significantly in the expansion of the New Zealand aquaculture industry, which has taken up appropriate overseas methodology (eg, the introduction of the Japanese longline system to make mussel farming aesthetically acceptable), has been innovative in the development and improvement of its high-technology farming techniques (eg, the adoption of continuous culture rope rather than individual droppers to increase the efficiency of seeding and harvesting mussels) and is mindful of the need for ongoing research to ensure continued innovation, development and increased profitability.

The ***Increasing influence of markets, trade and consumers*** on New Zealand aquaculture has been evident throughout its development, because all three sectors (mussels, oysters and salmon) were rapidly able to satisfy local demand for farmed product. These sectors have consequently had to focus on the demands and requirements of overseas markets to ensure both the continued expansion and profitability of their aquaculture activities. Although both oysters and mussels are worldwide commodity products, the New Zealand mussel and oyster sectors have consistently targeted high-value niches within the export markets. This is shown by the development of a new product line, the frozen half-shell Greenshell mussel, specifically for the high-priced Japanese restaurant and retailing outlets. Likewise, New Zealand oyster growers target the premium end of the world market for Pacific oysters, notably the lucrative Japanese market for raw oysters, with a New Zealand company having been "the first oyster production company in the world to achieve organic certification in 2005" (Investment New Zealand 2006, p 12). Although massive global production of salmon has seen it become a commodity product, the New Zealand King Salmon Company has maintained access to a niche in the high-value end of the world salmon market by promoting product quality on the basis of the high environmental quality of New Zealand's growing waters (Investment New Zealand 2006). The overall trend has been for New Zealand aquaculture to increasingly use its natural competitive advantages, such as a clean, pathogen-free environment and sustainable farming practices, to develop, maintain or expand export markets for its increasing aquaculture production.

Enhanced regulation and governance of aquaculture has brought both benefits and constraints to aquaculture industry development in New Zealand. Significant impacts have resulted from the lengthy periods of gestation of new and revised aquaculture legislation, and the changes in responsibilities between national and regional authorities. During the 1980s, the rapid expansion of mussel farm licences in the Marlborough Sounds under local government jurisdiction led to a nationally imposed moratorium on the granting of licences. The aquaculture reforms and enactment of subsequent Acts to regulate aquaculture has resulted in little progress in the development of new aquaculture licences, primarily because the legislation is perceived as unwieldy and imposing substantial financial burdens on both industry and regional government.

The industry itself developed *The New Zealand Aquaculture Strategy,* which includes a section on strengthening its partnership with government because of the "positive impact government can have in promoting the growth of aquaculture" (Burrell et al 2006, p 10). The industry initiative has been complemented by publication of *Our Blue Horizon: He Pae Kikorangi: The Government's Commitment to Aquaculture,* which states that "good governance is required to enable the industry to develop to its full potential within a sustainable and supportive regulatory framework" (Ministry of Economic Development 2007, p 37). Increased co-operation between industry and government is seen by both as key to achieving the aim of making aquaculture a $1 billion industry by 2025.

Improving the management of aquaculture has been a trend throughout the development of the New Zealand industry from the early mussel farming co-operatives, which attempted to manage production more efficiently on a multi farm rather than individual farm basis. The establishment of Aquaculture New Zealand has amalgamated the various sector group organisations into one national organisation representing all commercial aquaculture participants and presenting one voice for New Zealand aquaculture. The aim of Aquaculture New Zealand is to progress 'better management' across the whole spectrum of aquaculture activities, through practical farming improvements that will grow production, improve efficiency and increase profitability without compromising sustainability or environmental impact. It also aims to implement measures to support aquaculture through increasing public understanding, promote investment, strengthen relationships with stakeholders and regulatory bodies, develop markets and marketing, and invest in the industry's future through training, education and workforce promotion (Burrell et al 2006).

5 POTENTIAL FOR AQUACULTURE DEVELOPMENT IN NEW ZEALAND

5.1 GOVERNMENT AND INDUSTRY AQUACULTURE STRATEGIES

Aquaculture is part of the New Zealand government's Economic Transformation Agenda that was set out in 2006 to confirm its "long term commitment to improving income per capita through innovation and raising productivity in an environmentally sustainable way" (www.med.govt.nz/templates/ ContentTopicSummary 23387.aspx).

The industry has defined, in its 10-point plan in *The New Zealand Aquaculture Strategy* how it sees aquaculture development taking place and achieving the vision of a billion dollar industry by 2025 (Burrell et al 2006).

The government, in its National Position Statement on Aquaculture in *Our Blue Horizon*, has committed to "working in partnership with the aquaculture industry, local government, Māori and communities to maximise the contribution aquaculture makes to the national economy and its potential for growth" (Ministry of Economic Development 2007, p 31).

5.2 REPORTS ON NEW ZEALAND'S AQUACULTURE POTENTIAL

Numerous reports have been prepared on New Zealand's aquaculture potential. The reports have focused on regional government areas such as Northland (Jeffs 2003a), Bay of Plenty (Jeffs et al 1999; Jeffs et al 2001) and Taranaki (Roberts et al 2002; Hickman et al 2003) or on Māori tribal areas such as Maniapoto (Heath and Hickman 2003).

Species-specific reports have also been produced on crayfish or kōura, eel, mussel, kingfish, scallop and Pacific oyster farming in Northland (Jeffs 2002; Parkyn 2001; Watene 2003; Jeffs 2003b; Poortenaar et al 2003; Morrison and Cryer 2003; Handley and Jeffs 2003a).

The most recent and comprehensive aquaculture potential assessments are in the Investment New Zealand report *Aquaculture in New Zealand* (2006) and on the government's aquaculture information website (www.aquaculture.govt.nz).

5.3 ANALYSIS OF STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS

NIWA has undertaken a SWOT (strengths, weaknesses, opportunities, threats) analysis of New Zealand's aquaculture potential.

The strengths of New Zealand's aquaculture potential are:

- economic benefits at local, regional and national levels
- regional employment opportunities
- environmental sustainability
- the abundance of marine space (if it is made available)
- New Zealand's international image as clean, green and honest.

The weaknesses of New Zealand's aquaculture potential are that:

- farming takes time
- farming takes money
- farming takes skill
- stock can die
- high-value products can become low-value commodities
- distances to markets are long.

The opportunities of New Zealand's aquaculture potential are that it could:

- use new marine space
- grow the profitability of existing cultured species
- use new higher value species
- adopt new approaches, such as multi-trophic aquaculture.

The threats to New Zealand's aquaculture potential are:

- delayed access to marine space
- variable economic factors, such as transport costs and exchange rates
- competition between New Zealand companies for offshore markets
- a deterioration of New Zealand's clean, green image.

6 POTENTIAL FOR MĀORI IN AQUACULTURE DEVELOPMENT IN NEW ZEALAND

6.1 MĀORI PARTICIPATION IN AQUACULTURE

During the period, since the early 1970s, in which the aquaculture industry has developed in New Zealand, it has become of increasing social and economic importance. The country has had to develop a structured system of aquaculture legislation to manage the competing demands for coastal marine space and to evaluate the impact of aquaculture on the values placed on the land, coastline and adjacent water. This evaluation has had to include the strong cultural, traditional and historical values placed on the environment by Māori, and take into account a more spiritual perspective of land and water than is generally attributed to New Zealanders of European descent.

Māori figure prominently in the aquaculture industry and government strategies for aquaculture development. Number 6 in the industry's 10-point plan in *The New Zealand Aquaculture Strategy* is to "promote Māori success in aquaculture" and to "ensure that iwi ... are informed and active participants" (Burrell et al 2006, p 14). Investment New Zealand writes in *Aquaculture in New Zealand* that "the future of the industry is such that the sector as a whole will not reach its full potential unless iwi prosper" (Investment New Zealand 2006).

While the promotion of Māori success is specified in the 10-point plan in *The New Zealand Aquaculture Strategy*, it should be noted that all 10 points in the strategy are important aspects for Māori, and iwi will be critical in delivering these aspects of the plan in order to achieve the vision of a $1 billion industry by 2025. The government has also stated that "the aquaculture industry provides Māori with a number of opportunities to strengthen existing involvement, encourage new initiatives and expand their economic base" and has echoed the industry view that "the participation of Māori in the growth of the aquaculture industry will be critical to its future success" (Ministry of Economic Development 2007, Māori Participation).

Māori are already extensively involved in the aquaculture industry through successful Māori-owned companies in the Marlborough Sounds and Coromandel region, to cite just two examples, and this participation will increase as Māori develop space allocated through the Māori Commercial Aquaculture Claims Settlement Act 2004. The Act requires that iwi, through Te Ohu Kai Moana as trustee for the Takutai Trust (the Māori Commercial Aquaculture Settlement Trust), be provided with 20 percent of all new aquaculture space. In additional, the government will provide iwi with the equivalent of 20 percent of the 'pre-commencement space', which is the marine farming space created by permits, leases or licences issued from 21 September 1992 to 1 January 2005.

6.2 MAIN CHALLENGES TO MĀORI PARTICIPATION IN AQUACULTURE

Māori face three main challenges in achieving further participation in aquaculture.

- ***Allocation of settlement assets between iwi within a region:*** When space (or a financial equivalent) is available for allocation, the Takutai Trust will receive assets on behalf of the relevant iwi, and hold and maintain those assets pending allocation. However, the iwi concerned must agree how the assets are to be allocated among them.
- ***Development of new space by regional councils:*** Without allocation of new marine space it will be difficult for Māori to develop aquaculture operations within their rohe. Cash equivalents may be beneficial for iwi development but may not necessarily result in new aquaculture initiatives.

- ***Commercial development of settlement space:*** To be beneficial to Māori, the space must be appropriate for aquaculture development (eg, have appropriate water quality, shelter and access) and should be large enough to establish a farming operation that is economically sustainable. Unlike commercial fishing quota that has the potential to realise income immediately, aquaculture space requires investment and expertise to enable Māori to achieve any returns from it. In many instances, iwi will have to work with commercial partners to develop settlement space.

6.3 CONSIDERATIONS AT STAGES OF DEVELOPMENT

The Ministry of Māori Development (Te Puni Kōkiri's predecessor) published the *Guide to Aquaculture Development for Māori* (1996), which outlined what needed to be considered at the various stages of development. It provided basic information about planning, commercial lending and processing and exporting. A more comprehensive review has since been published: *Māori me te Whanaketanga Ahumoana: Māori and Aquaculture Development* (Te Puni Kōkiri 2007a). The review covers the implications for Māori of the aquaculture reforms, planning issues in relation to the Resource Management Act 1991, and the relationships between tangata whenua and the aquaculture industry, and discusses issues related to the 20 percent settlement allocation.

The review is supported by six information sheets (puka pārongo) providing details about:

- the aquaculture industry (Te Puni Kōkiri 2007e)
- roles and responsibilities in aquaculture (Te Puni Kōkiri 2007c)
- business services for aquaculture (Te Puni Kōkiri 2007d)
- aquaculture science providers (Te Puni Kōkiri 2007b)
- the aquaculture settlement (Te Puni Kōkiri 2007f)
- planning for aquaculture (Te Puni Kōkiri 2007h).

The review also has a cover sheet entitled *Te Whakauru atu ki te Ahumahi Ahumoana: Getting into the Aquaculture Industry* (Te Puni Kōkiri 2007g).

These documents make the point that the recent legislative changes affecting aquaculture have special relevance for Māori because of the potential for impacts on customary harvest of kai moana, and on the existing involvement of many iwi in the fishing industry. The 20 percent allocation of aquaculture space to iwi, which will complement current allocation of fishing assets to, in many cases, the same iwi (under the 1992 Fisheries Deed of Settlement), will require iwi to manage these assets positively and consistently with kaitiakitanga, and in partnership with industry if appropriate, to ensure that inappropriate development does not compromise values and resources important to coastal whānau, hapū and iwi.

Māori me te Whanaketanga Ahumoana concludes that aquaculture development presents many challenges for Māori, not the least being to ensure that aquaculture development gives effect to kaitiakitanga (Te Puni Kōkiri 2007a). Advantages are seen in whānau, hapū and iwi working together to develop aquaculture ventures. There will also be benefits from iwi working collectively to manage the relationships between tangata whenua, industry and the agencies involved in establishing regional coastal plans and aquaculture management areas.

7 WHY AND HOW TO GET INTO AQUACULTURE IN NEW ZEALAND

7.1 WHY GET INTO AQUACULTURE IN NEW ZEALAND?

The demand for seafood is increasing both internationally and locally but supply from the fishing industry is stagnant. Aquaculture has the potential to meet this increasing demand and, therefore, good market opportunities exist for those with the capacity to get into aquaculture in New Zealand, to either expand production in the existing sectors or to develop new aquaculture activities.

A range of reasons can be given for why Māori might get involved in aquaculture. These include investment opportunities, providing kai for customary purposes, creating employment, doing research or even making money, but, whatever the reason, it is essential for those involved to have a realistic vision of how to move from an aquaculture concept to a commercial aquaculture enterprise.

7.2 BUSINESS PLANNING

To make progress along a development pathway from concept to commercial reality requires that the potential aquaculture venture chooses the right species, technology and people. Once an objective has been identified and practical visualisation of the concept undertaken, the logical steps along the development pathway will lead from a feasibility study, through the design and construction stages, whether on land or in the water, to full-scale operation of the aquaculture facility or farm.

The essential prerequisite to determining the feasibility of the venture is a business plan. This plan needs to incorporate as much information as possible on all aspects of the proposed development, from the species, technology and location chosen for the venture, to the regulatory consents, infrastructure requirements and funding that are necessary for the venture to be approved, sustainably operable and economically viable.

Some of the questions regarding species, technology and location that need to be answered in the business plan include the following.

- Is there a market for this product?
- What is the product's market value?
- What, and how much, competition is there in the market place for this product?
- How accessible is the market?
- Is there established farming technology and husbandry?
- Are you sufficiently experienced with the level of technology and husbandry required?
- Are the production costs known?
- Will it work and be economically viable in New Zealand?
- Are supplies of seed and feed available, reliable and cost effective?

Some of the questions regarding regulation, infrastructure and funding issues that need to be answered in the business plan include the following.

- Is the required land-based or sea-based aquaculture space available?
- Can the regulatory requirements be met?
- Can the necessary consents be obtained in an acceptable time frame?
- How accessible are the required resources such as power, water and site access?
- Is there sufficient and appropriately skilled labour available?
- Is there adequate provision for both the capital investment in technology and the ongoing labour and operating costs?
- Is there assured funding for full commercial-scale development of the venture, with due consideration given to time to full production and market price expectation?

In answering these questions the business plan will have analysed and assessed the economics of the venture, covering

both the farming and marketing of the product, to show that it can be a profitable enterprise. It is important that the business plan also includes an assessment of the risks associated with all aspects and stages of the aquaculture venture, and provides a comprehensive risk-management strategy.

Production of the business plan will require input from the intending aquaculturist and any associated investors, and will benefit from independent consultancy advice. Te Puni Kōkiri provides a free business facilitation service for Māori interested in starting up a commercial business or wanting to improve an existing one (see *Ratonga Pakihi mō te Ahumoana: Business Services for Aquaculture* (Te Puni Kōkiri 2007d)). The service includes mentoring, facilitation, guidance, information and advice. The Ministry of Foreign Affairs and Trade (www.mfat.govt.nz) and New Zealand Trade and Enterprise (www.nzte.govt.nz) are two other government agencies that can provide advice, particularly on marketing and export–import trading issues. Science agencies that can also provide consultancy advice include NIWA, the Cawthron Institute and Crop and Food Research. There are also organisations within the aquaculture industry itself, notably the New Zealand Marine Farming Association (www.nzmfa.co.nz) and Aquaculture New Zealand Ltd (www.aquaculture.org.nz) that have promotion and advice as part of their stated objectives.

Ratonga Pakihi mō te Ahumoana also lists and gives website addresses for a range of government and non-government funding opportunities and training opportunities, some of which are specifically focused on Māori development initiatives (eg, the Poutama Trust (www.poutama.co.nz) and Federation of Māori Authorities (www.foma.co.nz)) (Te Puni Kōkiri 2007d).

Once the business plan is accepted and funding confirmed, the aquaculture development can proceed to the design and construction stages, which will be specific to the species, technology, location and scale of the venture. This phase of the development typically involves considerable input from a wide range of specialists, such as scientists for the husbandry aspects, architects and engineers for the planning and building of facilities and equipment, consultants for obtaining consents and approvals, and probably a project manager for overseeing all activities.

Staff training, commissioning and troubleshooting will be necessary before the establishment of the operating procedures, quality control protocols and marketing strategies that will enable the venture to move from pilot scale to a full commercial-scale aquaculture enterprise.

7.3 KEY MAXIMS FOR INVOLVEMENT IN AQUACULTURE

Although aquaculture offers sound business opportunities for Māori, several maxims apply:

- Aquaculture is high risk, so do not invest more than you can afford to lose.
- Aquaculture research and development is high risk, so opting for established technology is safer.
- Aquaculture will always cost more and take longer than expected.
- Costs always go up and market prices come down.
- Good independent advice is worth paying for.

8 BUSINESS PLANNING FOR AQUACULTURE IN NEW ZEALAND

8.1 IMPORTANCE OF HAVING A BUSINESS PLAN

Aquaculture, like most primary production industries, requires a large outlay of funds for start up, and a ready access to additional funds to cover operating costs that arise before any income is generated from the sale of the produce. In all businesses 'cash is king', and understanding the in-flow and out-flow of cash is essential for a business to be viable. Therefore, it is important that a thorough business plan is developed before any business is started.

8.2 ROLE OF A BUSINESS PLAN

A thorough business plan should support your decision to proceed with an investment in any business. For higher-risk ventures such as aquaculture, it is important the core activities of the business are broken down and understood, and a financial analysis is done for all key parts.

A simple plan drafted 'on the back of an envelope' is likely to end up with money being wasted. Understanding the key drivers to making a venture successful and the risks associated with the venture is one aim of the business plan development process. If a person goes into a venture well informed about the potential ups and downs of the business, is it more likely that they will make decisions on an informed basis rather than always reacting to crises.

A thorough business plan shows a viable business and helps to secure investors or support from banks.

8.3 CONTENT OF A BUSINESS PLAN

A business plan for aquaculture should cover the seven areas of:

- concept and visualisations (define the business)
- feasibility, including:
  - market research
  - location and resource consents
  - technology and knowledge
  - production costs
  - capital requirements
  - contingency provisions
- design and build, including:
  - the design of the facility
  - husbandry requirements
- production, including:
  - seed product requirements
  - staffing and feed requirements
  - working capital
- harvesting and processing
- transport to market
- marketing.

See Figure 9.1 for a detailed checklist and Table 9.1 for questions to ask when developing the business plan. However, these are not exhaustive lists and need to be tailored to the specific venture being developed. Get professional advice and expertise to help with the business plan.

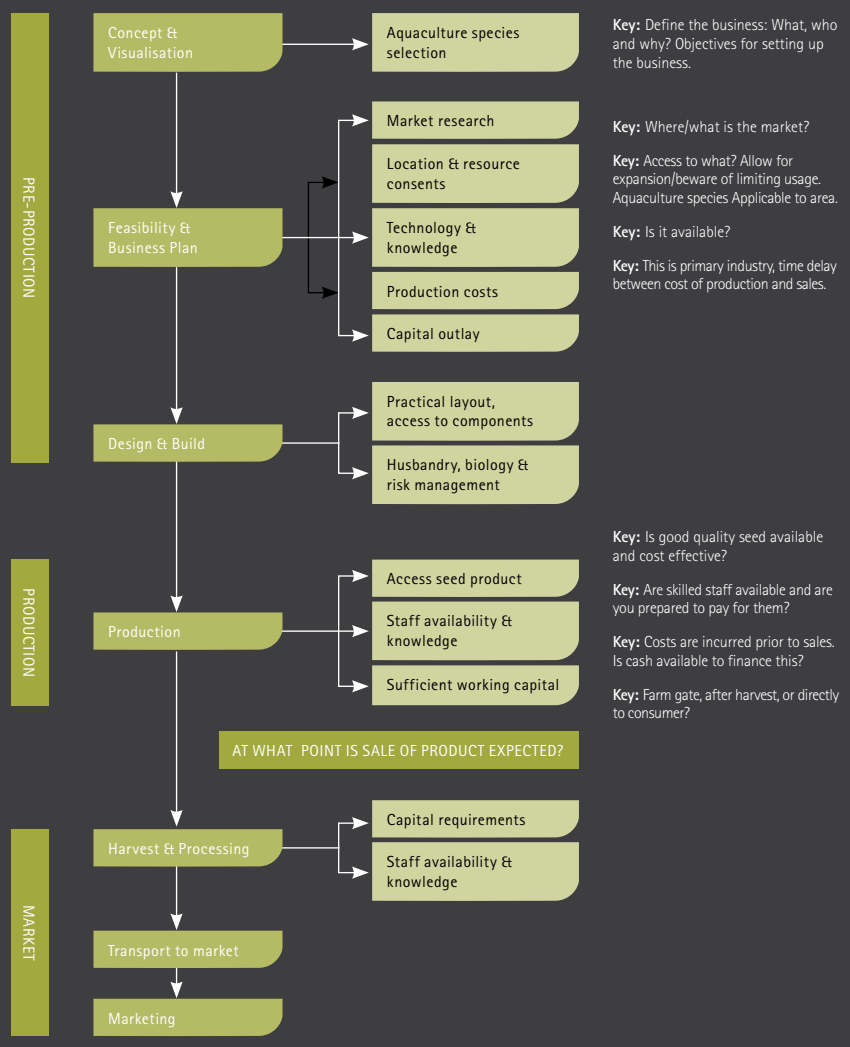
8.4 KEY BUSINESS COSTS

Capital cost

In general, capital cost refers to the cost of fixed assets. These are items such as plant and equipment that require a large outlay at the beginning of the venture. For aquaculture, fixed assets include buildings, tanks, filtration systems, sea-cages, and boats. Funds for these items, whether borrowed from a bank or investors, are needed well in advance of any income coming from the venture, in fact, even before production starts.

Capital costs also include the cost of setting up the business and business structure (eg, lawyers' costs and resource consent costs). These too need to be funded before the venture is generates any income.

FIGURE 8.1: BUSINESS PLAN CHECKLIST FOR A GENERIC AQUACULTURE VENTURE



Source: R Haydon, NIWA

Capital spending is essential for any business, but is also the point at which the risk starts to increase. This money, once spent, is, in general, sunk. If the venture does not produce the required return, then the probability of recovering these funds is low. This is particularly true in aquaculture, where the technology is specialised and is unlikely to be able to be sold for use in another industry.

Operating costs

Operating costs are the running costs of a business. They are generally split between fixed and variable costs.

Fixed costs are costs that are incurred whether or not the business is producing a product (eg, rental or lease costs and staffing costs, such as for managers and office staff). However, these costs do not generally increase as production increases.

Variable costs are costs directly related to production (eg, electricity, feed costs and production staff). These costs are generally not incurred if the business is not in production, but they increase directly in proportion to the quantity of stock produced.

The funds used to meet the operating costs are usually referred to as 'working capital'.

In all industries, costs are incurred before products are sold. Primary producers, however, can generally expect a much larger delay between incurring the production cost and receiving the sales income than in the manufacturing or retail industries. For example, kingfish can have a production cycle of 18 months and operating costs must be covered over this period because income from sales is not received until the 19th month. Therefore, access to adequate working capital over this period is essential.

Cost of production

The cost of producing a unit of product is referred to as the cost of production. The cost of production refers to the operating costs (fixed and variable) and the depreciation allocated to each unit produced.

Depreciation is an allocation of the money spent on fixed assets (capital cost) over the life of the asset. For example, if a fixed asset is expected to last 10 years then one-tenth of the capital cost is allocated to each year's production.

As a business grows and production increases, the fixed costs (including depreciation) are spread over a larger number of production units, so the cost of production per unit reduces. This is the concept of economies of scale. An increase of 50 percent in production will not normally result in a 50 percent increase in costs because fixed costs tend to remain the same. Capital outlay will also not increase as long as the production capacity is sufficient. Therefore, increasing production usually reduces the cost of production and increases the profitability of, or return from, the venture. It is important when developing the business plan that this concept is explored to determine the best level of production for the level of profit or return required.

8.5 RISKS

In general, when it comes to investing in a business venture the risk factor impacts on the return required, the more risky the venture the higher the return that should be sought by the investor. This assumes that the business is in existence to generate returns or profit. If a venture's purpose is, say, to provide kai to the whānau rather than product for sale, then the return or profit required will generally be of low priority, although risk still needs to be considered.

A low-risk investment, such as a bank term deposit or government bonds, generally provides the minimum return an investor requires for investing their funds. By placing money in a bank, an investor reasonably expects the money to be safe and to receive some return (interest) on that money. Investment into a business has an inherent risk because the business might fail and the investment is then lost. Business investors, therefore, expect a premium to be added to the return that they could achieve from putting the money into a bank, and the premium should be proportional to the additional risk of them losing the money on that venture. The greater the risk, the higher the return expected.

The aquaculture industry in New Zealand is an emerging industry, which means the likely success of a new aquaculture venture is not easy to determine. The technology and science are fairly new, markets are untested and a large cash outlay is usually required for a considerable period before any sales are generated. This means that aquaculture investments are often considered to be high risk, particularly when new species or technologies are being used.

It is important that all risks are considered and actions are taken to mitigate or contain them as an aquaculture venture is developed.

TABLE 8.1: BUSINESS PLANNING CHECKLIST FOR AN AQUACULTURE VENTURE

AREA	QUESTIONS
CONCEPT AND VISUALISATION	
	Is aquaculture the right venture?
	What species do you want to produce?
	Is knowledge about the species and its production available?
	Is there any indication of demand for this species?
	What size business do you want (eg, a small family business or a large multi-million dollar business)?
FEASIBILITY	
Market research	Have you done a detailed market analysis?
	Is there an established market?
	Where is demand coming from?
	What is the size of the market?
	What percentage of the market are you aiming to supply?
	What competition is there?
	What is the expected growth of market?
	What is the value of the market (eg, in dollars per kilo)?
	What is the export potential of this species?
	Are there any export issues (eg, quotas or tariffs)?
	What is the access to market?
	At what point will you sell (eg, from the farm gate or after processing)?
	How do fluctuations in exchange rates affect prices for export markets?
Aquaculture management area and/or resource consent	What regulatory process do you need to follow?
	What are the application requirements and cost?
	What objections might there be? How might you mitigate these?
Technology and knowledge	Are experienced people available to set up a viable farm?
	Are experienced people available who understand stock and health issues?
	Is technology available for viable production runs?
	Is technology available to minimise the risk of a system failure?
	What expansion requirements might there be?
Production	What is the level of production going to be?
	Are you going to plan for expansion?
	What production processes are involved?
	What equipment is needed?
	What facilities are needed?
	Where will you source seed or fingerlings from?
	Is the supply of seed or fingerlings guaranteed?
	Are there alternative suppliers of seed or fingerlings?
	What are the suppliers' payment terms?
	What are the quality control and grading requirements?
	How will production be managed?
	What is the budget and timing of expenditures?
	What is the timing of production? When will you harvest? At what size product will you harvest? Have you sufficient cash to cover costs until product is sold?
Capital outlay	Note: The capital outlay is driven by production.
	What is the cost of the equipment needed?
	What is the cost of the facilities needed?
	What land area is needed and what will it cost?
	How is the access to water and what will it cost?
	Is there room for expansion?
	What are the funding requirements? Will you have sufficient cash to cover capital expenditure?
	Have you allowed for an overrun?

9 REFERENCES

Burrell M, Meehan L, and Munro S. 2006. *The New Zealand Aquaculture Strategy*. Nelson: New Zealand Aquaculture Council. 26 pp.

FAO Fisheries Department. 2006. *State of World Aquaculture 2006*. Fisheries Technical Paper 500. Rome: Food and Agriculture Organization of the United Nations. 134 pp. Available at www.fao.org/docrep/009/a0874e/a0874e00.htm

Handley S and Jeffs A. 2003. *Assessment of Future Expansion of Pacific Oyster* (Crassostrea gigas) *Farming in Northland*. NIWA Client Report AKL2003-027. Auckland: National Institute of Water and Atmospheric Research. 36 pp. Available at www.niwa.co.nz/ncfa/news_pubs

Hayden B. 1988. Evaluation of species with potential for aquaculture in New Zealand. Draft report held in Fisheries Research Centre library, Wellington. 48 pp.

Hayden BJ and Woods C. 1997. Scallops are particular about their culture conditions. *Aquaculture Update* 19: 4–5.

Heath P and Hickman R. 2003. *Assessment of the Potential for Aquaculture Development within the Maniapoto*. NIWA Client Report: WLG2003-75. Wellington: National Institute of Water and Atmospheric Research. 96 pp.

Hickman R, Heath P and MacDiarmid A. 2003. *Assessment of Aquaculture Potential in the Motunui Area, Taranaki*. NIWA Client Report: WLG2003-08. Wellington: National Institute of Water and Atmospheric Research. 25 pp.

Hickman R, Illingworth J, Forman J and Kendrick T. 1999. A pump pot nursery system for rearing juvenile New Zealand dredge oysters *Tiostrea lutaria*. *Aquaculture Research* 30: 673–680.

Hickman R, Redfearn P and Tait M. 2002. Novel effects of salinity and water re-use on growth of juvenile New Zealand turbot, *Colistium nudipinnis* (Waite 1910); a potential aquaculture species. *Aquaculture Research* 33: 1,009–1,018.

Hickman R and Tait M. 2001. Experimental rearing of juvenile New Zealand turbot *Colistium nudipinnis* (Waite 1910): A potential new aquaculture species. *Aquaculture Research* 32: 727–738.

Ingram K. 2005. Kiwi prawns a tourism success. *New Zealand Aquaculture* 5: 6–8.

Investment New Zealand (a division of New Zealand Trade and Enterprise). 2006. *Aquaculture in New Zealand*. Wellington: New Zealand Trade and Enterprise. 17 pp. Available at www.investmentnz.govt.nz/common/files/Aquaculture%20Brochure%20-%20high%20res.pdf 17 pp.

Jeffs A. 2003a. *Assessment of the Potential for Aquaculture Development in Northland*. NIWA Client Report AKL2003-012. 258 pp. Auckland: National Institute of Water and Atmospheric Research. Available at www.niwa.co.nz/ ncfa/news_pubs

Jeffs A. 2003b. *Assessment of the Potential for Mussel Aquaculture in Northland*. NIWA Client Report: AKL2003-057. Auckland: National Institute of Water and Atmospheric Research. 15 pp. Available at www.niwa.co.nz/ncfa/news_pubs

Jeffs A. 2002. *The Potential for Crayfish Aquaculture in Northland*. NIWA Client Report AKL2002-053. Auckland: National Institute of Water and Atmospheric Research. 19 pp. Available at www.niwa.co.nz/ncfa/news_pubs

Jeffs A, Holland R and Tait M. 1999. *Strategic Assessment of the Development of Aquaculture in the Western Bay of Plenty*. NIWA Client Report: AK99107. Auckland: National Institute of Water and Atmospheric Research. 133 pp.

Jeffs A, Perry L, Kelly S, Tait M and Woods C. 2001. *The Development of Aquaculture in the Opotiki District of the Bay*

of Plenty. NIWA Client Report: AK01137. Auckland: National Institute of Water and Atmospheric Research. 233 pp.

MacIntyre D. 1980. Opening address. In: P Dinamani and R W Hickman (eds) *Proceedings of the Aquaculture Conferenc*e, pp 5–6. Fisheries Research Division Occasional Publication 27. 104 pp.

Ministry of Economic Development. 2007. *Our Blue Horizon: He Pae Kikorangi: The Government's Commitment to Aquaculture*. Wellington: Ministry of Economic Development. 44 pp. Available at www.aquaculture.govt.nz_

Ministry of Fisheries. 2006. *Details of the Māori Commercial Aquaculture Claims Settlement*. Wellington: Ministry of Fisheries. 20 pp.

Ministry of Māori Development. 1996. *A Guide to Aquaculture Development for Māori*. Wellington: Ministry of Māori Development. 22 pp.

Morrison M and Cryer C. 2003. *Potential for Artificial Enhancement of Scallops in Northland*. NIWA Client Report AKL2003-038. Auckland: National Institute of Water and Atmospheric Research. 33 pp. Available at www.niwa.co.nz/ ncfa/news_pubs

New Zealand Trade Development Board. 1989. *Directions in: Foreign Exchange Earnings. The New Zealand Aquaculture Industry*. Wellington: Government Printer. 55 pp.

Page M, Webb V, Northcote P, Mackey S and Handley S. 2005. Aquaculture trials for the production of biologically active metabolites in the New Zealand sponge *Mycale hentscheli* (Demospongiae: Poecilosclerida). *Aquaculture* 250: 256–269.

Parkyn S. 2001. *Koura: Biology, Aquaculture and Potential for Hatchery/Release and Habitat Enhancement*. NIWA Client Report: TBG02201. Hamilton: National Institute of Water and Atmospheric Research. 25 pp.

Poortenaar C, Jeffs A and Heath P. 2003. *Commercial Opportunities for Kingfish Aquaculture in Northland*. NIWA Client Report AKL2003-026. Auckland: National Institute of Water and Atmospheric Research. 51 pp._Available at www.niwa.co.nz/ncfa/news_pubs

Roberts R, Heasman K, Thompson S and Dodgshun T. 2002. *Preliminary Information on Aquaculture Options for the Taranaki Region*. Cawthron Report 734. Nelson: Cawthron Institute. 47 pp.

Seymour T. 2007. Report on key findings of the aquaculture roadshow hui conducted by NIWA-Te Puni Kōkiri. TPK Briefing Paper NR 5040, 29 October 2007. 21 pp.

Tait M. 1996. Rearing snapper: From egg collection to egg production in 25 months. *Seafood New Zealand* 4(4): 54–55.

Te Puni Kōkiri. 2007a. *Māori me te Whanaketanga Ahumoana: Māori and Aquaculture Development*. Wellington: Te Puni Kōkiri. 28 pp. Available at www.tpk.govt.nz/mi/in-print/our-publications/publications/maori-and-aquaculture-development

Te Puni Kōkiri. 2007b. *Kaiwhakawhiwhi Pūtaiao Ahumoana: Aquaculture Science Providers*. Information sheet 4. Wellington: Te Puni Kōkiri. 2 pp. Available at www.tpk.govt.nz/mi/in-print/our-publications/fact-sheets_

Te Puni Kōkiri. 2007c. *Ngā Tūranga Mahi me ngā Mana Whakahaere Ahumoana: Roles and Responsibilities in Aquaculture*. Information sheet 2. Wellington: Te Puni Kōkiri. 4 pp. Available at www.tpk.govt.nz/mi/in-print/our-publications/fact-sheets

Te Puni Kōkiri. 2007d. *Ratonga Pakihi mō te Ahumoana: Business Services for Aquaculture*. Information sheet 3. Wellington: Te Puni Kōkiri. 4 pp. Available at www.tpk.govt.nz/mi/in-print/our-publications/fact-sheets

Te Puni Kōkiri. 2007e. *Te Ahumahi Ahumoana: The Aquaculture Industry*. Information sheet 1. Wellington: Te Puni Kōkiri. 2 pp. Available at www.tpk.govt.nz/mi/in-print/our-publications/fact-sheets

Te Puni Kōkiri. 2007f. *Te Whakataunga Ahumoana: The Aquaculture Settlement*. Information sheet 5. Wellington: Te Puni Kōkiri. 4 pp. Available at www.tpk.govt.nz/mi/in-print/our-publications/fact-sheets

Te Puni Kōkiri. 2007g. *Te Whakauru atu ki te Ahumahi Ahumoana: Getting into the Aquaculture Industry*. Cover sheet. Wellington: Te Puni Kōkiri. 1 p. Available at *www.tpk.govt.nz/mi/in-print/our-publications/fact-sheets/getting-into-the-aquaculture-industry*

Te Puni Kōkiri. 2007h. *Whakamahere mō te Ahumoana: Planning for Aquaculture*. Information sheet 6. Wellington: Te Puni Kōkiri. 4 pp. Available at www.tpk.govt.nz/mi/in-print/our-publications/fact-sheets

Tong L and Moss G. 2000. Summary of the work done in New Zealand at NIWA Mahanga Bay, on rock lobster (*Jasus edwardsii* and *J. verreauxi*) propagation. In: PR Hart and R van Barnveld (eds) *Technical Potential for Rock Lobster Propagation in Aquaculture Systems*, pp 21–29. Rock Lobster Enhancement and Aquaculture Subprogram Publication 3. Hobart: University of Tasmania.

Watene E. 2003. *Potential for Commercial Eel Aquaculture in Northland*. NIWA Client Report AKL2003-032. 36 pp. Auckland: National Institute of Water and Atmospheric Research. Available at www.niwa.co.nz/ncfa/news_pubs

Woods C. 2000. NIWA's seahorse project: Past, present and future. *Aquaculture Update* 27: 3–4.

10 CONTACTS FOR FURTHER INFORMATION

The following tables show the websites of the central and local government agencies with responsibilities for aquaculture in the regions covered in this report.

TABLE 10.1: CENTRAL GOVERNMENT WEBSITES AND RESPONSIBILITIES

MINISTRY/DEPARTMENT	WEBSITE
Ministry of Fisheries	www.fish.govt.nz
Department of Conservation	www.doc.govt.nz
Ministry for the Environment	www.mfe.govt.nz
Ministry of Economic Development	www.med.govt.nz
New Zealand Trade and Enterprise	www.nzte.govt.nz
Te Puni Kōkiri	www.tpk.govt.nz

TABLE 10.2: REGIONAL AUTHORITY WEBSITES

REGIONAL AUTHORITY	WEBSITE
Auckland Regional Council	www.arc.govt.nz
Environment Bay of Plenty	www.envbop.govt.nz
Environment Canterbury	www.ecan.govt.nz
Environment Waikato	www.ew.govt.nz
Gisborne District Council	www.gdc.govt.nz
Greater Wellington Regional Council	www.gw.govt.nz
Hawke's Bay Regional Council	www.hbrc.govt.nz
Marlborough District Council	www.marlborough.govt.nz
Northland Regional Council	www.nrc.govt.nz
Taranaki Regional Council	www.trc.govt.nz
Tasman District Council	www.tasman.govt.nz

TABLE 10.3: TERRITORIAL AUTHORITIES WITHIN THE 10 REGIONS COVERED IN THIS REPORT

REGIONAL COUNCIL	TERRITORIAL AUTHORITY
Northland Regional Council	Far North District Council
	Whangarei District Council
	Kaipara District Council
Auckland Regional Council	Rodney District Council
	Auckland City Council
	North Shore City Council
	Waitakere City Council
	Manukau City Council
	Papakura District Council
	Franklin District Council (part)
Waikato Regional Council (Environment Waikato)	Thames-Coromandel District Council
	Franklin District Council (part)
	Hauraki District Council
	Waikato District Council
	Matamata-Piako District Council
	Hamilton City Council
	Waipa District Council
	South Waikato District Council
	Otorohanga District Council
	Rotorua District Council (part)
	Waitomo District Council
	Taupo District Council (part)
Bay of Plenty Regional Council (Environment Bay of Plenty)	Western Bay of Plenty District Council
	Tauranga City Council
	Opotiki District Council
	Whakatane District Council
	Rotorua District Council (part)
	Kawerau District Council
Gisborne District Council (unitary authority)	
Hawke's Bay Regional Council	Wairoa District Council
	Taupo District Council (part)
	Hastings District Council

TABLE 10.3: TERRITORIAL AUTHORITIES WITHIN THE 10 REGIONS COVERED IN THIS REPORT CONT.

REGIONAL COUNCIL	TERRITORIAL AUTHORITY
Hawke's Bay Regional Council	Hastings District Council
	Napier City Council
	Central Hawke's Bay District Council
	Rangitikei District Council (part)
Taranaki Regional Council	New Plymouth District Council
	Stratford District Council (part)
	South Taranaki District Council
Greater Wellington Regional Council	Masterton District Council
	Kapiti Coast District Council
	Carterton District Council
	South Wairarapa District Council
	Upper Hutt City Council
	Porirua City Council
	Hutt City Council
	Wellington City Council
Tasman District Council (unitary authority), Nelson City Council (unitary authority), and Marlborough District Council (unitary authority)	
Canterbury Regional Council (Environment Canterbury)	Kaikoura District Council
	Hurunui District Council
	Selwyn District Council
	Waimakariri District Council
	Christchurch City Council
	Ashburton District Council
	Mackenzie District Council
	Timaru District Council
	Waimate District Council

Note: Territorial authorities with areas that encompass more than one region are denoted as (part) in the table. Some territorial authorities perform the functions of a region council and are designated as unitary authorities.

Source: Territorial authorities of New Zealand. 2006. In Wikipedia: The free encyclopedia. en.wikipedia.org/wiki/Territorial_authorities_of_New_Zealand (retrieved 29 November 2007). See also: www.localcouncils.govt.nz

PART 2:

REGIONAL APPRAISALS FOR AQUACULTURE DEVELOPMENT

11 NORTHLAND (TE TAI TOKERAU)

At each of the hui held in the 10 regions there were presentations, followed by discussion, of the existing and potential aquaculture resources specific to the region. The following sections of this report elaborate on the material presented and discussed at the hui, to provide regional appraisals of the potential for aquaculture development and the ways for Māori to realise the opportunities in aquaculture.

11.1 DESCRIPTION OF THE REGION

Northland (Te Tai Tokerau) covers about 1.25 million hectares and has about 3,200 kilometres of coastline. The west coast of Northland has four harbours (Kaipara (part of which is also in the Auckland region), Hokianga, Whangapē and Herekino) and the east coast has nine harbours (Parengarenga, Houhora, Rangaunu, Mangōnui, Whangaroa, Bay of Islands, Whangaruru, Whangārei and Mangawhai). Three districts make up Northland (the Far North, Kaipara and Whangarei).

Much of the Northland coastline, including the east coast islands, is influenced by a warm subtropical current. This has allowed many species that are not found elsewhere in New Zealand to establish here.

The area has a long Māori heritage, with Northland home to some of the country's first human inhabitants. Today it is one of the fastest growing regions in New Zealand and home to nearly 150,000 people.

Visit the Northland Regional Council's website (www.nrc.govt.nz/Living-in-Northland/ About-our-region) for further information about the Northland district, its environment and people.

11.2 EXISTING AQUACULTURE

Northland is the most significant oyster-farming region in New Zealand. The farms cover around 670 hectares, have production worth around $20 million and employ over 400 people, of whom a significant proportion are Māori. The major areas for oyster farming are the Bay of Islands, Whangaroa Harbour and Kaipara Harbour.

Mussel farming is not well established in Northland, with the relatively small production mainly coming from farms in Houhora Harbour (Figure 12.1). However, Northland plays a

crucial role in the New Zealand mussel industry because the spat or seed supply for much of the industry is collected on Ninety Mile Beach (and called 'Kaitaia spat') and subsequently transported to farms throughout the country. A commercial spat-catching project that supplies seed to the industry also operates in Whangapē Harbour.

FIGURE 11.1: MUSSEL FARM IN HOUHORA HARBOUR

Onshore, a land-based kingfish farm at Parengarenga was closed in 2006, after two years in operation, because of technical problems, but it is reported to be re-opening sometime in 2007–08.

A commercial pāua farm (OceaNZ Blue Ltd) has established itself at NIWA's Bream Bay Aquaculture Park in Ruakākā (Figure 12.2). The farm is in its first year of commercial sales and aims to be producing over 100 tonnes of pāua annually by 2009. (See OceaNZ Blue Ltd's website at www.oceanzblue.co.nz.)

FIGURE 11.2: NIWA'S BREAM BAY AQUACULTURE PARK, RUAKĀKĀ

Freshwater aquaculture licences exist for a small grass carp production pond near Mangawhai and an experimental eel farm at Ruawai.

11.3 POTENTIAL FOR DEVELOPMENT

NIWA and Enterprise Northland reviewed aquaculture development potential in the region in 2003 (Jeffs 2003a)). This report identified considerable potential within the region for marine aquaculture. The warm waters of the region and abundant sheltered harbours and bays provide suitable rearing environments for a wide range of marine species. Low-lying coastal land could support more onshore aquaculture developments such those at Bream Bay. Limited freshwater resources probably preclude development of large-scale freshwater farms.

Aquaculture in the region is seen by some as offering significant potential for providing regional employment and regeneration opportunities for Māori.

11.4 INFRASTRUCTURE

The existing oyster and mussel seed supply industries have well-established infrastructure and marketing links. However, much of Northland is remote from air transport and, despite good quality roads, is several hours from Auckland by truck or train. Boat-building and fishing fleet servicing facilities in Whangārei would provide valuable infrastructure support for the development of fish farming in Northland.

Aquaculture research and development in the area is supported by NIWA's Bream Bay Aquaculture Park. This multimillion dollar facility provides access to sea water, research staff and infrastructure to help establish new aquaculture industries. Projects at the park include pāua farming, kingfish fingerling production, hatcheries for groper, and the development of eel production systems.

11.5 REGULATORY ENVIRONMENT

The Northland Regional Council controls marine aquaculture in Northland under its regional coastal plan. The regional council has proposed a change to its regional plan to provide for aquaculture. Plan Change 4 sets out the way the regional council intends to manage aquaculture in Northland. The regional council is also developing threshold evaluation criteria, use and value maps, and aquaculture evaluation maps, which can be used to evaluate plan changes. The regional council will use the invited private plan change process to establish aquaculture management areas (AMAs) and develop marine farms.

For further information, see the Northland Regional Council's website (www.nrc.govt.nz).

11.6 MARINE SITES

The region has numerous sheltered sites with high-quality water suited to farming a range of marine species. Considerable tourist activity and associated pressures for access to coastal space for recreational activities are likely to preclude aquaculture development in some areas.

Two marine reserves are within the Northland region. These reserves are protected areas of coastal environment where all marine life is protected and fishing is not allowed. The Poor Knights Islands Reserve was established in 1981 and the Whangārei Harbour Marine Reserve was established in 2006.

The area also has numerous harbours, lakes and swamps that are valuable feeding grounds for migratory waders such as plovers, godwits, turnstones and tattlers, and are areas where aquaculture development may be restricted.

11.7 PĀUA

The development in 2002 of a pāua farm at the Bream Bay site has highlighted the potential for this type of shore-based aquaculture in Northland. High water quality and warm temperatures favour pāua production, although ambient summer water temperatures may be too high (over 22oC) in many areas to support flow-through pāua farms. Recirculation system farms fitted with water-cooling facilities should be able to produce good growth rates year round.

11.8 KINGFISH

Northland, with its warm seawater temperatures and numerous sheltered bays, is well positioned to become the major area for kingfish production in New Zealand. NIWA and Enterprise Northland have identified potential sites, and several companies have expressed interest in establishing kingfish farms in the area.

The small footprint of kingfish farms (and finfish farms in general) relative to their potential production capacity, suggests that such operations offer the greatest potential value for aquaculture per hectare of marine space used.

11.9 MUSSELS

Opportunities exist for developing mussel aquaculture activities in Northland. There is potential to expand the existing mussel farms, and there are several sheltered locations where new farms could be established. The spat-catching activities could be increased to supply additional seed to the industry in other parts of the country. Given the high level of tourism in the area, there may also be potential to develop aqua-tourism ventures, providing visitors with the opportunity to see mussel farms in action and sample the final product.

11.10 EELS

There is little history of eel fishing or aquaculture in Northland. A small seawater system eel farm operated at Ruawai with reasonable results, and NIWA has operated a pilot recirculation system for eels at Bream Bay since 2003.

Opportunities for eel farming in Northland are restricted by the absence of good glass eel supplies and limited freshwater resources.

11.11 OYSTERS

Further development of Pacific oyster farming, the largest aquaculture sector in Northland, is constrained more by competition for coastal space and by potential pollution from residential and commercial developments, than by a shortage of environmentally suitable sites or any limitation in the carrying

capacity of the numerous bays. Development of offshore oyster farms may alleviate some of these limitations to development.

Diversification into farming the Bluff oyster on existing oyster farms, either intertidally or subtidally, could improve the economics of oyster farming because it is a more valuable species, although it would require hatchery production of spat to stock the farms.

11.12 REGIONAL AQUACULTURE REPORTS

Handley S and Jeffs A. 2003. *Assessment of Future Expansion of Pacific Oyster (*Crassostrea gigas) *Farming in Northland*. NIWA Client Report AKL2003-027. Auckland: National Institute of Water and Atmospheric Research. 36 pp. Available at www.niwa.co.nz/ncfa/news_pubs_

Jeffs A. 2002. *The Potential for Crayfish Aquaculture in Northland*. NIWA Client Report AKL2002-053. Auckland: National Institute of Water and Atmospheric Research. 19 pp. Available at www.niwa.co.nz/ncfa/news_pubs_

Jeffs A. 2003a. *Assessment of the Potential for Aquaculture Development in Northland*. NIWA Client Report AKL2003-012. Auckland: National Institute of Water and Atmospheric Research. 258 pp. Available at www.niwa.co.nz/ncfa/news_pubs

Jeffs A. 2003b. *Assessment of the Potential for Mussel Aquaculture in Northland*. NIWA Client Report AKL2003-057. Auckland: National Institute of Water and Atmospheric Research. 15 pp. Available at www.niwa.co.nz/ncfa/news_pubs

Morrison M and Cryer C. 2003. *Potential for Artificial Enhancement of Scallops in Northland*. NIWA Client Report AKL2003-038. Auckland: National Institute of Water and Atmospheric Research. 33 pp. Available at www.niwa.co.nz/ncfa/news_pubs

Poortenaar C, Jeffs A and Heath P. 2003. *Commercial Opportunities for Kingfish Aquaculture in Northland*. NIWA Client Report AKL2003-026. Auckland: National Institute of Water and Atmospheric Research. 51 pp. Available at www.niwa.co.nz/ncfa/news_pubs_

Watene E. 2003. Potential for *Commercial Eel Aquaculture in Northland*. NIWA Client Report AKL2003-032. Auckland: National Institute of Water and Atmospheric Research. 36 pp. Available at www.niwa.co.nz/ncfa/news_pubs

12 AUCKLAND (TĀMAKI MAKAU RAU)

12.1 DESCRIPTION OF THE REGION

The Auckland region stretches from the west coast beaches on the Tasman Sea to the Pacific Ocean in the east. It has four cities (Auckland, Manukau, North Shore and Waitakere) and three districts (Franklin, Papakura and Rodney). The region represents about 2 percent of New Zealand's land area and covers 16,104 square kilometres. The mainland coastline is 1,613 kilometres long, much of it comprising tidal inlets and estuaries, together with the large semi-enclosed Waitemata, Manukau and Kaipara Harbours (which is also in the Northland region). The region includes dozens of offshore islands ranging in size from Great Barrier Island (biggest) to Pollen Island (smallest).

Nearly one-third of New Zealand's population, about 1.3 million people, live in the Auckland region, which continues to be the fastest growing area in the country.

Visit the Auckland Regional Council's website (www.arc.govt.nz/auckland/population-and-statistics/population-and-statistics_home.cfm) for further population and statistics data about the Auckland region.

12.2 EXISTING AQUACULTURE

The 68 marine farms in the Auckland region occupy 247 hectares of farm space, 17 farms are mussel farms and 51 are oyster farms (Figure 13.1). All except two farms were approved under the Marine Farming Act 1971. The A uckland Regional Council is reviewing the consent conditions of all the deemed coastal permits to ensure they are consistent with the Resource Management Act 1991. This review is taking place under the aquaculture reform legislation, which gives consent holders objection and appeal rights.

FIGURE 12.1: KAIPARA HARBOUR – A SHELLFISH-FARMING AREA AND MAJOR OYSTER SPAT-COLLECTION SITE

For further information, see the Auckland Regional Council's website (www.arc.govt.nz).

12.3 POTENTIAL FOR DEVELOPMENT

The Auckland Regional Council had 18 applications for marine farms, covering 6,888 hectares, lodged in 2000–01, which included 6,313 hectares in the Firth of Thames (which is also in the Waikato, see section 14.3). The regional council notified three applications before the commencement of the licensing moratorium[4] in November 2001. Applications that were not notified before the moratorium remain on hold until an aquaculture management area (AMA) over the area applied for becomes operative.

4 A moratorium on the issuing of new marine farming licences existed during 2002-2004 in an attempt to counter the 'gold rush' of licence applications that occurred during the 1990s.

As in other areas, the population of the Auckland region places significant demands on its coastal resources and spaces for recreation. Several marine parks and reserves have been established in the region, including Hauraki Gulf Marine Park and Goat Island Marine Reserve. Considerable commercial boating traffic and fishing activity also occurs within the Hauraki Gulf.

Up to 1,200 hectares in the Auckland region is likely to be made available to Māori for development under the terms of the Maori Commercial Aquaculture Claims Settlement Act 2004.

12.4 INFRASTRUCTURE

The area, given its existing aquaculture activity and high population density, is naturally well catered for in terms of infrastructure to support aquaculture. There is also both manufacturing and equipment supply capability locally. There is a significant fishing industry in the area with associated seafood-processing plants. A large domestic seafood market is available in Auckland city, along with air and sea freight facilities to export aquaculture products.

12.5 REGULATORY ENVIRONMENT

The Auckland Regional Council is responsible for aquaculture within the coastal marine area, and the region's district councils are responsible for managing and administering aquaculture on land. The regional council has resolved, in principle, to use the invited private plan change process to establish AMAs within the Auckland region. This process involves the regional council inviting parties to make private plan change requests to establish AMAs.

The Auckland Regional Council is committed to developing a regional aquaculture policy framework and the associated rules to guide assessment of invited private plan change applications and management of any resulting AMAs. The regional council is working co-operatively with Environment Waikato (the regional council for the Waikato) on aquaculture issues relating to the Hauraki Gulf Marine Park because Environment Waikato has control responsibilities for the western sector of the park. (The Hauraki Gulf (Tikapa Moana) is split, through the Firth of Thames, into two regions.)

For further information on aquaculture development in the Auckland region, see the Auckland Regional Council's website (www.arc.govt.nz).

Three district councils and four city councils have responsibilities for land-based aquaculture facilities and activities in the region.

12.6 MARINE SITES

The marine environment in the Auckland region is well suited to aquaculture, with favourable water temperatures and generally high water quality. Demand for marine space for recreational activities and other commercial use is likely to severely reduce opportunities for establishing marine farms in the area.

12.7 PĀUA

No active pāua farms are in the Auckland region, despite the potential for such ventures to meet a growing local market for pāua. Demand for residential land close to the coast will probably provide a disincentive for such developments within the region.

12.8 KINGFISH

The water temperature and water quality within the area are highly suitable for kingfish culture, and indeed some of the early kingfish farming development work was completed at Pah Farm in the Hauraki Gulf. Fingerling supply capacity exists at NIWA's Bream Bay Aquaculture Park in Northland, which is within easy reach of potential kingfish farming sites in the region by road or helicopter and using equipment developed overseas for transporting salmon smolt.

No licensed marine finfish cultivation sites are in the area, and new developments are unlikely in the short term.

FIGURE 12.2: OYSTER (LEFT) AND MUSSEL (RIGHT) FARMING IN THE AUCKLAND REGION

12.9 MUSSELS

Mussel farming is the largest aquaculture activity in the Auckland region (Figure 13.2A). Areas within the Hauraki Gulf and Firth of Thames are under consideration for the development of new mussel farms. Several potential sites have been identified, but their development will depend on the Auckland Regional Council's aquaculture planning process.

12.10 EELS

Given the limited freshwater resources that exist in this region and the high land costs, it is unlikely that significant eel farming ventures will establish in this area. Mahurangi Technical Institute is undertaking research into breeding glass eels in captivity and runs a hatchery for other freshwater species such as grass carp. Regulatory restrictions prevent the commercial harvest of eels under 220 grams, so any eel aquaculture venture based on ongrowing glass eels will require either a change in the regulations or an exemption from them.

12.11 OYSTERS

The Auckland region is extremely well suited to oyster production, and has been described by the industry as being one of the best areas in the world to grow oysters (Figure 13.2B) (www.clevedonoysters.com). Several areas have potential for the development of both intertidal and subtidal oyster farms, and there is potential for farming both Pacific oysters and Bluff oysters because both species occur within the region.

12.12 REGIONAL AQUACULTURE REPORTS

Auckland Regional Council. 1999–2007. Aquaculture in the Auckland region. www.arc.govt.nz/environment/coastal-and-marine/aquaculture/aquaculture--marine-farming-in-auckland.cfm

13 WAIKATO

13.1 DESCRIPTION OF THE REGION

Waikato is the fourth largest region in New Zealand. It covers most of the central North Island, being about 25,000 square kilometres in area. Waikato has 1,138 kilometres of coastline, including sections on both the east and west coasts of the North Island.

The population of the Waikato is around 360,000, making it the fourth-largest region on a population basis after Auckland, Canterbury and Greater Wellington.

This information is available from Environment Waikato's web pages about the people, economy and natural environment of the Waikato region (www.waikato.govt.nz/ Environmental-information/About-the-Waikato-region).

13.2 EXISTING AQUACULTURE

There are 160 marine farms in the Waikato region, covering about 1,000 hectares of coastal water space, and some marine farms in the Hauraki area that fall within the Auckland region (Hauraki is split between the Auckland and Waikato regions).

Māori are significantly involved in aquaculture in the region, with marine farms owned and/or operated by organisations such as the Hauraki Māori Trust Board.

The existing marine farms mainly focus on mussel and oyster production. They are mostly in the Hauraki–Coromandel area, including the Firth of Thames (which is also in the Auckland region, see section 13.3) (Figure 14.1), and in Coromandel Harbour, Port Charles, Kennedy Bay, Whangapoua Harbour and Whitianga Harbour on the Coromandel Peninsula. On the west coast a mussel spat-catching operation is in Aotea Harbour and an oyster farm is in Kāwhia Harbour (Figure 14.2).

Waikato also has New Zealand's only prawn farm (located near Taupo), a whitebait ranching project in Raglan and a goldfish farm near Te Awamutu.

FIGURE 13.1: WILSON'S BAY, FIRTH OF THAMES – MUSSEL FARM

FIGURE 13.2: KĀWHIA HARBOUR, WEST COAST – INTERTIDAL OYSTER FARM

13.3 POTENTIAL FOR DEVELOPMENT

The Waikato, particularly the Coromandel–Firth of Thames area, has a history of marine farming going back at least as far as the earliest mussel farming activities in the late 1960's. Space exists for further marine farms, and there is scope for changes in the species that are farmed in the area.

Applications are with Environment Waikato (the regional council for the Waikato) for around 500 hectares of marine space in the western Firth of Thames, and with the Auckland Regional Council for more than 6,000 hectares in the eastern Firth of Thames.

About 200 hectares of marine space within the Waikato is likely to be made available to Māori for development under the terms of the Maori Commercial Aquaculture Claims Settlement Act 2004.

The Maniapoto Māori Trust Board and NIWA have also identified several potential aquaculture opportunities on the west coast.

There is some resistance to new aquaculture development within the region. Space within the Firth of Thames may be limited by commercial shipping routes, the requirements of large groups of recreational water users, and by significant environmental reserves. Well-organised action groups are strongly opposing any new aquaculture development.

Inland, the Waikato also has considerable water and geothermal resources that can be tapped into to provide facilities for freshwater aquaculture developments.

13.4 INFRASTRUCTURE

The area is well catered for in terms of infrastructure to support aquaculture because of its existing aquaculture activities. In addition, it has a long history of fishing, and therefore has numerous ports and harbours. Significant seafood-processing plants exist nearby in Auckland and Whitianga. Auckland also provides a large domestic seafood market and has air and sea freight facilities available to export aquaculture products.

13.5 REGULATORY ENVIRONMENT

Environment Waikato is responsible for regulating aquaculture development in the Waikato. Environment Waikato's regional coastal plan identifies marine farming as an important industry that provides for the social and economic well-being of people and communities, primarily by creating jobs and contributing directly and indirectly to the local, regional and national economies. The plan's objective for marine farming is that it be developed in an efficient and sustainable manner that avoids adverse effects on the coastal environment as far as is practicable. The plan provides for spat catching, oyster farming, mussel farming and shellfish research. All other forms of aquaculture are prohibited. For further information about aquaculture development information in the region, see Environment Waikato's website (www.ew.govt.nz).

The Hauraki Gulf (Tikapa Moana) is an area of great importance to the region's people, and its environmental significance has been recognised through the establishment of the Hauraki Gulf Marine Park (under the Hauraki Gulf Marine Park Act 2000). The park is split, through the Firth of Thames, into regions controlled by the Auckland Regional Council (to the west) and Environment Waikato (to the east). These two organisations recognise the need for co-operative management of the area as a whole and are working closely together to plan marine farming in the Hauraki Gulf, including research to assess the sustainability of aquaculture in the Firth of Thames.

13.6 MARINE SITES

The marine environment within the Waikato region is suited to the cultivation of a wide range of species. The Firth of Thames and several bays and estuaries on both the east and west coasts offer sheltered sites suited to the development of marine farms, using established technologies. The sustainability of developments in the Firth of Thames is being monitored and Environment Waikato has identified potential 'trigger points' (or performance criteria) for the environmental variables being monitored around the marine farms in the Wilson's Bay marine farming zone in the Firth of Thames. These include nutrients and phytoplankton[5] in the water, animals found in the sediment below the farm and the accumulation of shell-hash on the seafloor. The high levels of tourism that occur in the region also offer opportunities for developing aqua-tourism ventures.

13.7 PĀUA

Waikato has only one small onshore pāua farm, although a second, larger facility is under construction. The generally high water quality within the region, coupled with available low-lying coastal land and ready access to domestic and export markets, makes the area suitable for further pāua farm developments.

13.8 KINGFISH

At present, there are No marine fish farming permits are held within the region. Under the regional coastal plan, marine

5 Phytoplankton are single-celled plants or seaweeds that form the basis of the food chain in the sea.

space can be used only for shellfish farming. Environment Waikato is considering a plan change to allow other types of aquaculture, including fish farming, in the existing marine farms. The conversion of mussel leases to fish farms may, therefore, be possible, but the mechanism for achieving this has yet to be established or tested. Temperature and water quality profiles suit kingfish aquaculture and good growth would be expected for this species, should farms be established.

13.9 MUSSELS

Mussel farming is the predominant form of aquaculture in the Waikato and new large developments are planned. Environment Waikato is considering an application for a 500 hectare site in Wilson's Bay (and the Auckland Regional Council is also considering applications for large mussel farms in the Firth of Thames).

Environment Waikato is endeavouring to understand the capacity for mussel farming in the region, and the potential for developments will depend on the outcome of its studies.

Mussel spat-catching activities occur in Aotea Harbour on the west coast. The activity appears to be environmentally benign, and good potential exists to expand spat catching within Aotea Harbour and probably other west coast harbours.

13.10 EELS

The Waikato has a long history of eel fishing, and Waikato's eel fishery comprises 15 percent of the national commercial harvest. Considerable amounts of research have gone into understanding the sustainability of the fishery. The Waikato River is a major site of glass eel recruitment, and the role of Tainui, under the terms of the Tainui Waikato River Claim, will significantly affect access to the glass eel stocks within the region, which would be the basis of eel aquaculture projects.

The availability of geothermal resources in the region to provide warm water for intensive eel farming further increases the potential for eel culture in the region.

13.11 OYSTERS

Aquaculture began in the Waikato region in the late 1960s with the establishment of intertidal oyster farms. The region has several oyster farms, and both the east and west coasts are environmentally suited to this activity. Natural oyster spatfalls occur on both coasts, but may not be sufficiently high to support seed collection in all areas. The Maniapoto Māori Trust Board and NIWA have identified several potential oyster farming sites on the west coast.

13.12 REGIONAL AQUACULTURE REPORTS

Heath P and Hickman R W. 2003. *Assessment of the Potential for Aquaculture Development within the Maniapoto*. NIWA Client Report: WLG2003-75. Wellington: National Institute of Water and Atmospheric Research. 96 pp.

Irvine R, Robinson M and Carboni A. 2007. *Economic Impact of Aquaculture in the Waikato Region*. Technical Report 2007/33. Hamilton East: Environment Waikato. 25 pp. Available at www.ew.govt.nz/publications/technicalreports/tr0733.htm

Maniapoto H. 1997. *Kaupapa a Tuna: The Maniapoto Tuna Report*. Kihikihi: Tainui Tuna Working Party. 39 pp.

14 BAY OF PLENTY (TE MOANA Ā TOI TE HUATAHI)

14.1 DESCRIPTION OF REGION

The Bay of Plenty is on the east coast of the North Island. The region takes in the full sweep of the coastline from Lottin Point in the east to Waihi Beach in the west. The total area of the region is 21,740 square kilometres, comprising 12,231 square kilometres of land and 9,509 square kilometres of coastal marine area.

The region also has two major harbours: Tauranga Moana or Tauranga Harbour in the western Bay of Plenty and Ohiwa Harbour in the central Bay of Plenty.

The population of the Bay of Plenty is around 257,000, just over 100,000 of whom live in Tauranga (www.en.wikipedia.org/wiki/Bay_of_Plenty#Demographics).

14.2 EXISTING AQUACULTURE

Three oyster farms are in the Bay of Plenty. They are all in the Ohiwa Harbour and are about 2 hectares each. There is also one small-scale permit for a mussel farm at Factory Bay, Te Kaha that has not yet been developed.

Environment Bay of Plenty (the regional council for the Bay of Plenty) administers aquaculture within the region. It is processing applications for two large mussel farms, namely, a 4,750 hectare farm off Opotiki and a 4,009 hectare farm off Otamarakau (Figure 15.1).

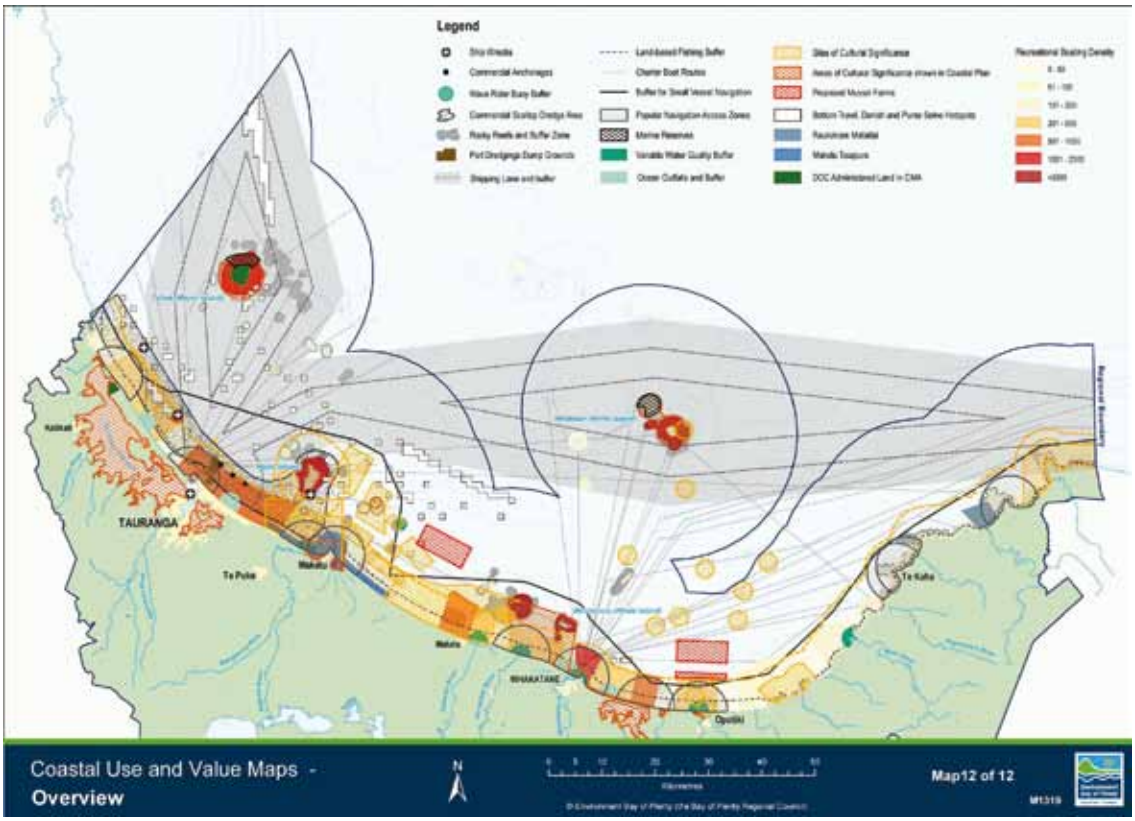
FIGURE 14.1: AQUACULTURE MANAGEMENT AREAS IN THE BAY OF PLENTY

14.3 POTENTIAL FOR DEVELOPMENT

There have been several reports into the aquaculture development potential in the Bay of Plenty, including two extensive reports produced by NIWA in 1999 and 2001 (Jeffs et al 1999, Jeffs et al 2001), and in 2006 Ngāti Ranginui commissioned research into land-based aquaculture opportunities around Tauranga. The area has been deemed to have good and varied aquaculture development potential. However, work done by Environment Bay of Plenty indicates several activities within the area may conflict with aquaculture development (Figure 15.2). These activities include:

- commercial shipping
- large groups of recreational water users
- significant environmental reserves at Mataitai and Taiapure
- limited sheltered water space
- river run-off that may negatively affect water quality inshore.

FIGURE 14.2: BAY OF PLENTY COASTAL USE AND VALUE MAP



Source: Environment Bay of Plenty.

14.4 INFRASTRUCTURE

The region has good infrastructure to support the existing successful aquaculture operations and potential new large developments.

14.5 REGULATORY ENVIRONMENT

Environment Bay of Plenty has an aquaculture management area (AMA) project to identify opportunities for AMAs in the Bay of Plenty. For further information about planning and aquaculture development in the region, see Environment Bay of Plenty's website (www.ebop.govt.nz).

Five district councils and one city council have responsibilities for land-based aquaculture facilities and activities in the region.

14.6 MARINE SITES

Bay of Plenty has a favourable environment (temperature, water quality) for the key species in some areas. However, few sheltered sites are suitable for traditional marine farming, so future large developments are likely to be sited offshore.

14.7 PĀUA

One small onshore pāua farm exists within the Bay of Plenty. Water temperatures and water quality profiles appear to be well suited to pāua farming. The area suffered from one known disease outbreak in farmed pāua in the 1990s but this has not reoccurred.

14.8 KINGFISH

Although temperature and water quality profiles in the Bay of Plenty would suit kingfish farming, the limited availability of sheltered marine space makes the development of significant kingfish, or other finfish farms, unlikely.

Offshore finfish farming has been trialled in other parts of the world, but this technology is not yet proven and it would probably be unwise for new entrants to kingfish farming to look at using such technically challenging systems on an unproven species.

14.9 MUSSELS

Environment Bay of Plenty is processing applications for two large offshore mussel farms, and one small inshore mussel farm is in production. Water quality and temperature regimes appear to be well suited to mussel culture.

If offshore mussel farming is shown to be productive and economically sustainable, there may be opportunities to develop this type of activity further.

14.10 EELS

Lake Aniwhenua in the Bay of Plenty is an important eel fishery and is therefore of particular significance to Māori. An ongoing programme transfers migrating eels both upstream and downstream from Lake Aniwhenua and is successfully maintaining eel stocks.

One of the original New Zealand eel farms was sited in the eastern Bay of Plenty, but it ceased to operate in the 1970s. Modern high-technology European eel farming systems could be sited throughout the Bay of Plenty, but may be better suited to areas around Tauranga, where transport infrastructure would support eel processing and exporting.

14.11 OYSTERS

Productive Pacific oyster farms are operating within the Bay of Plenty. There may be opportunities to expand these farms, but the limited availability of suitable sheltered space severely restricts aquaculture development for this species.

14.12 REGIONAL AQUACULTURE REPORTS

Jeffs A, Holland R and Tait M. 1999. *Strategic Assessment of the Development of Aquaculture in the Western Bay of Plenty.* NIWA Client Report: AK99107. Auckland: National Institute of Water and Atmospheric Research. 133 pp.

Jeffs A, Perry L, Kelly S, Tait M and Woods C. 2001. *The Development of Aquaculture in the Opotiki District of the Bay of Plenty.* NIWA Client Report: AK01137. Auckland: National Institute of Water and Atmospheric Research. 233 pp.

Longdill P, Black K and Healy T. 2005. *Locating Aquaculture Management Areas: An integrated approach.* Report for Environment Bay of Plenty, ASR Ltd and the University of Waikato. Hamilton: Environment Bay of Plenty.

15 GISBORNE (TE TAIRĀWHITI)

15.1 DESCRIPTION OF REGION

The Gisborne region covers a land area of 8,265 square kilometres. It has about 250 kilometres of high-energy coastline and around 530,000 hectares of coastal marine area.

According to Gisborne District Council's website (www.gdc.govt.nz/District/) the region's population is about 44,500; 41,900 of whom live in the city of Gisborne and its peripheral environs.

15.2 EXISTING AQUACULTURE

No aquaculture management areas (AMAs) or coastal permits for aquaculture are in the Gisborne District. Until 2005, one pāua farm operated to the north of Gisborne city. A pāua hatchery is being developed at the Tūranga Ararau training facility in Gisborne.

15.3 POTENTIAL FOR DEVELOPMENT

Despite much of the Gisborne coastline being a high-energy wave exposed environment, several sheltered bays exist that would provide opportunities for aquaculture development.

The lack of existing marine farms means Māori in the region will not receive an allocation of marine space under the Maori Commercial Aquaculture Claims Settlement Act 2004 based on historical development, but are eligible for 20 percent of any new AMA space. Future development in the region will, therefore, be industry driven.

15.4 INFRASTRUCTURE

The region has an active fishing industry, and fish-processing facilities exist in Gisborne that could support the processing of other aquaculture products. Good road freight and air freight links exist that would facilitate the transport of aquaculture products to markets in Auckland or for export. Tūranga Ararau has an aquaculture training facility in Gisborne.

15.5 REGULATORY ENVIRONMENT

The Gisborne District Council regulates aquaculture development in Gisborne. It is the only territorial authority for the region, so has full responsibility for both marine and land-based aquaculture facilities and activities. For further information on aquaculture planning and development in the region, see the Gisborne District Council's website (www.gdc.govt.nz).

15.6 MARINE SITES

The Gisborne region coastline has several relatively sheltered bays with potential for development. Water quality is generally high, with few large rivers discharging into the coastal zone.

15.7 PĀUA

Water quality throughout the region is high, and preliminary investigations into the potential to establish land-based pāua farms (Figure 16.1) around the East Cape identified potential sites, typically on low-lying land next to sheltered bays.

FIGURE 15.1: LAND-BASED PĀUA FARMING IN THE GISBORNE REGION

Source: Environment Bay of Plenty.

15.8 KINGFISH

Water quality and temperature profiles in the region suit the development of kingfish farms. A few sheltered bay sites may provide development opportunities.

15.9 MUSSELS

Mussel development in the area may be possible in sheltered bays or by developing offshore farms, should these prove to be economically feasible in other areas.

15.10 EELS

The region has a long history of eel fishing and Māori-led eel research and enhancement projects have been undertaken in recent years. Access to glass eels stocks may be possible within the region, along with geothermal resources to help to offset heating costs for intensive eel aquaculture.

15.11 OYSTERS

The sheltered bays within the region offer opportunities to develop oyster culture projects. Such developments may present a low-cost route into aquaculture for coastal communities.

15.12 REGIONAL AQUACULTURE REPORTS

No relevant reports were located for this region.

16 HAWKE'S BAY (TĀKITIMU)

16.1 DESCRIPTION OF THE REGION

The Hawke's Bay covers a land area of about 1.42 million hectares, with 350 kilometres of coastline on the Pacific Ocean. The region stretches from Te Māhia (Māhia Peninsula) in the north to the sweeping beaches of Pōrangahau in the south, and inland to the dramatic Ruataniwha and Kaweka mountain ranges. The region has seven major rivers (Wairoa, Mōhaka, Esk, Tūtaekurī, Ngaruroro, Tukituki and Waipawa). Waikaremoana is the major inland lake within Te Urewera National Park. Significant wetland areas include Pekapeka Swamp and Whakakī.

The population of Hawke's Bay is about 148,330. The Hawke's Bay Regional Council says Māori are a higher proportion of the population than other regions in the country (www.hbrc.govt.nz/WhoWeAre/AboutourRegion/tabid/54/Default.aspx).

16.2 EXISTING AQUACULTURE

The exposed coast of Hawke's Bay does not make it ideal for traditional marine aquaculture activities. However, two aquaculture management areas (AMAs) are designated within the region. Napier Mussels Ltd has been granted consent to develop a 2,806 hectare Greenshell mussel farm about 5.5 kilometres offshore of Waipātiki Beach. Preliminary trials have commenced at the site, but it is not yet in commercial production (Figure 17.1). A smaller AMA has been created over 4 hectares on the western coast of Te Māhia (near Long Point), but it is not yet in commercial production. Two marine farming permits were issued in this area more than 10 years ago but they have expired.

Onshore, the region has supported aquaculture developments for pāua, seahorses and lobsters. Two small pāua farms operate in Napier and Nūhaka. A seahorse farm in Napier closed around 2005.

FIGURE 16.1: NAPIER MUSSELS LTD OFFSHORE MUSSEL FARM, WITH THE NAME AND LOGO ON A MARKER BUOY SHOWING NGĀTI KAHUNGUNU INVOLVEMENT IN THE VENTURE

Source: Ngāti Kahungunu Iwi Inc's website, www.kahungunu.iwi.nz.

16.3 POTENTIAL FOR DEVELOPMENT

Hawke's Bay has a predominantly open, exposed coastline, with sheltered areas being restricted to shallow tidal estuaries. Deepwater marine farming is being trialled in the Hawke's Bay, but it is unlikely there will be further applications to establish this type of farm until the technology and economic viability of open-coast marine farming have been tested. Onshore aquaculture opportunities may exist within the region.

16.4 INFRASTRUCTURE

The Hawke's Bay has reasonable supporting infrastructure for aquaculture. A small fishing fleet works out of Napier, where there are good port facilities that handle refrigerated containers. Small-scale fish-processing facilities are in Hastings and Napier. The small regional airport at Napier has regular flights to Auckland with limited capacity for cargo.

16.5 REGULATORY ENVIRONMENT

The Hawke's Bay Regional Council considers aquaculture in its 2007 proposed coastal plan and provides a potential pathway for development. The plan states that "Hawke's Bay has a predominantly open exposed coastline with sheltered areas restricted to shallow tidal estuaries. Though deep water marine farming does occur elsewhere in the country, it is not common, and it is therefore likely that there will be few future applications for marine farming in this region, at least until the technology and economic viability of open coast marine farming are tested." (www.hbrc.govt.nz/WhatWeDo/Coast/MarineFarms/tabid/146/Default.aspx).

The Hawke's Bay Regional Council has indicated that it will allocate new AMA space on a 'first in, first served' basis. However, applicants of successful plan changes will get preferential access to space within their AMA less any space used for Treaty of Waitangi settlement purposes, so it will be any 'surplus' space that is allocated on a 'first in, first served' basis. For further information, see the Hawke's Bay Regional Council's website (www.hbrc.govt.nz).

Five district councils and one city council have responsibilities for land-based aquaculture facilities and activities in the Hawke's Bay.

16.6 MARINE SITES

Water temperatures and water quality in the Hawke's Bay are generally favourable for a wide range of aquaculture activities, and initial reports from the trial lines at Napier Mussels Ltd's offshore mussel farm indicate that growth rates are good at that site. Many large rivers enter Hawke Bay and these can cause localised salinity issues. Overall, the exposed nature of the coastline is likely to restrict marine developments. The Te Angiangi Marine Reserve, several ecologically significant estuaries, lagoons and headlands, and commercial and recreational boating and fishing interests may also restrict aquaculture development in some areas. The existing marine farm site at Te Māhia is licensed for mussels but is not developed. Re-establishing the other two expired marine farming licences at Te Māhia would probably require a full AMA planning process, but the Hawke's Bay Regional Council could be consulted to clarify this.

16.7 PĀUA

Onshore pāua farms exist in the Hawke's Bay, and low-lying coastal land is available that could be used for more pāua farming development. Periodic low salinity flushes into Hawke Bay have caused mortalities in the existing pāua farms, but new recirculation technologies can be used to overcome issues associated with short-term low salinity.

16.8 KINGFISH

Cage farming of kingfish may have potential for development at the small and sheltered marine farm sites at Te Māhia, provided that the AMA (or AMAs) could be redefined to allow finfish aquaculture. Water temperatures suit kingfish growth for most of the year.

Offshore finfish farming has been trialled in other parts of the world, but this technology is not yet proven and it would probably be unwise for new entrants to kingfish farming to look at using such technically challenging systems on an unproven species.

16.9 MUSSELS

Preliminary studies suggest that the Hawke's Bay's environmental conditions are suitable for mussel production. However, the shortage of sheltered coastal water space means most future development will have to use offshore technologies in offshore sites. Development of the Te Māhia site probably offers the most immediate opportunity for establishing new mussel farming in the region.

16.10 EELS

Eels are a cultural icon to Ngāti Kahungunu, who hold about 20 tonnes of eel quota under the quota management system. An experimental eel farm was established as a joint venture between Ngāti Kahungunu and Wiptec Aquaculture Ltd, using overseas recirculation technology at a disused freezing works in Hastings. The venture proved unworkable and the system has since been moved to the NIWA Bream Bay Aquaculture Park, Northland.

The Ministry of Fisheries is considering allowing eel quota to be traded for access to glass eels. If this occurs, Ngāti Kahungunu may be in a good position to supply glass eels for eel aquaculture projects in the region.

16.11 OYSTERS

The limited number of sheltered estuaries and bays, coupled with the ecological and cultural significance attributed to estuaries and lagoons within the region, suggest very limited potential exists to establish oyster farms in the region. Temperature regimes would support oyster growth, but might not support the natural spawning of Pacific oysters. Farms would, therefore, have to rely on hatchery-produced spat to replenish the stock on the farm or bring in wild caught spat from other areas (eg, Kaipara Harbour). In either case, there would be issues about introducing a species into areas in which it does not already occur.

16.12 REGIONAL AQUACULTURE REPORTS

No relevant reports were located for this region.

17 GREATER WELLINGTON (TE ŪPOKO O TE IKA Ā MAUI)

17.1 DESCRIPTION OF THE REGION

Greater Wellington covers a land area of 813,005 hectares and a coastal marine area of 786,700 hectares, with 497 kilometres of coastline extending from the Ōtaki River in the west to the Matikona River north of Castlepoint in the east.

Greater Wellington's population is around 445,400 (www.gw.govt.nz/section682.cfm).

17.2 EXISTING AQUACULTURE

The generally exposed nature of the Wellington coastline has severely limited the development of marine farms in this area. Only two marine farming sites exist and both are in Mahanga Bay in Wellington Harbour. These two sites are a mussel, seaweed and pāua farm belonging to Sea-Right Investments Ltd and NIWA's site for experimental aquaculture (Figure 18.1).

FIGURE 17.1: MAHANGA BAY, WELLINGTON HARBOUR, SHOWING SEA-RIGHT INVESTMENTS LTD'S LONGLINE (LEFT OF PICTURE) AND NIWA'S EXPERIMENTAL AQUACULTURE RAFTS (RIGHT OF PICTURE)

Onshore, the region has small aquaculture ventures. Several pāua farms have been established on the Wairarapa coast, including New Zealand's first pāua farm sited near Blairlogie.

NIWA's Mahanga Bay facility undertakes research to develop aquaculture technologies for a range of marine species (Figure 18.2). The facility has been in operation for over 30 years. It was initially developed as a mussel hatchery, but was subsequently developed to undertake hatchery studies on a range of shellfish (including oysters, scallops, cockles and clams) and fish (snapper, turbot and kingfish) and has latterly been undertaking research on pāua cultivation, seaweed farming, kina roe enhancement and lobster diet development. The facility also houses a commercial pāua seed production unit that supplies pāua seed to farms around New Zealand.

Another pāua hatchery in the region is located in Porirua city. It relies on sea water transported to the site by tanker.

At Hongoeka, near Plimmerton, Hongoeka Development Ltd has constructed a small pāua and seaweed farm. The facility opened in 2007 and forms part of Hongoeka Development Ltd's plans to regenerate the site to create local employment (Figure 18.2).

FIGURE 17.2: NIWA'S MAHANGA BAY AQUACULTURE FACILITY, WELLINGTON (LEFT), AND HONGOEKA DEVELOPMENT LTD'S PĀUA PRODUCTION UNIT AT PLIMMERTON (RIGHT)

17.3 POTENTIAL FOR DEVELOPMENT

The limited amount of existing marine farming space (about 3 hectares) indicates that the region is probably not well suited to the development of sea-based farms. Under the terms of the Maori Commercial Aquaculture Claims Settlement Act 2004, an area (or equivalent) of less than 1 hectare of marine space is likely to be made available for Māori development of aquaculture in the region. However, there are opportunities for land-based aquaculture developments within the region.

17.4 INFRASTRUCTURE

The region is well serviced to support aquaculture. Sites with commercial development potential and good access to sea water occur around Wellington and on the east and west coasts of the region. Lobster-holding facilities and fish-processing facilities exist throughout the region, and these have developed good live transport, marketing and exporting pathways that new aquaculture ventures could use. Local markets and high-end restaurants provide further marketing opportunities for small ventures. Well-established air and sea freight pathways exist to supply aquaculture products to export markets.

17.5 REGULATORY ENVIRONMENT

The Greater Wellington Regional Council appears to support aquaculture development, but has yet to state its position on how the development of aquaculture management areas (AMAs) will progress within the region. The regional council received little response to its consultation document on aquaculture development in the region (Greater Wellington Council 2003). For information on aquaculture development in the region, see the Greater Wellington Regional Council's website (www.gw.govt.nz).

The Greater Wellington Regional Council provides free advice in the early planning stage of aquaculture development to help identify which resource consents are required.

Four district councils and four city councils have responsibilities for land-based aquaculture facilities and activities in Greater Wellington.

17.6 MARINE SITES

Despite having a considerable length of coastline, in only a limited number of sheltered harbours or bays where the development of traditional marine farms possible.

Wellington Harbour provides a large area of relatively sheltered water but is subject to heavy commercial shipping and recreational boating use, as well as much recreational fishing and diving. The northern shores of the harbour are subject to freshwater influences from the Hutt River.

Porirua Harbour (21 kilometres north of Wellington) provides the only other large area of sheltered water. The harbour was originally named Parirua, which translates as 'twin flowings of the tide'. This refers to the two arms of the harbour: the Onepoto Inlet and Pāuatahanui Inlet.

The Onepoto Inlet flows from the Paremata bridges south to the shoreline of Porirua City. It is a shallow inlet and popular with rowers and users of powerboats, small dinghies and personal water craft.

The Pāuatahanui Inlet stretches eastwards from the Paremata bridges past Whitby. It is shallow and a popular spot for yachting, water skiing and general boating. The inlet has a wetland reserve area at its head.

17.7 PĀUA

Land-based pāua farming technology was initially developed within Greater Wellington, and several farms have been established on the east and west coasts as well as inland from the coast. Ambient water temperatures are largely conducive to pāua production and few large rivers cause the low salinity flushes that preclude production of this species.

17.8 KINGFISH

Cage farming of marine fish has some potential within Greater Wellington, due to the relatively small footprint of these farms, but it is likely that significant opposition to such development would come from a range of sources, including recreational boating interests and conservation groups.

NIWA trials at its Mahanga Bay site have determined that water temperatures are generally too low to produce kingfish efficiently.

17.9 MUSSELS

Although temperature and water quality profiles in Greater Wellington suit mussel farming, the limited number of sheltered sites with sufficient depth of water, restricts the potential for this aquaculture activity to develop to a significant level. If offshore mussel farming is shown to be productive and economically sustainable, there may be opportunities to develop this type of activity off both the east and west coasts.

17.10 EELS

The west coast has established eel fisheries and processing facilities, and trials on eel fattening have been undertaken in Levin. Given access to freshwater resources and glass eels, considerable potential exists to develop intensive eel farming within Greater Wellington.

17.11 OYSTERS

Oyster farming technology is one of the more straightforward aquaculture activities, so it lends itself to aquaculture start-up projects.

In Greater Wellington, Porirua Harbour and some of the estuarine harbours on the west coast may be sufficiently shallow and sheltered to support oyster farms. Concerns may exist in some areas about sewage pollution making sites unsuitable for shellfish farming. Temperature regimes in the area are probably too cold to achieve a natural spat fall of Pacific oysters, so operations would have to rely on hatchery-reared seed. Low water temperatures may also lead to extended grow-out time for the oysters, but could lead to oysters being in saleable condition when other New Zealand stocks are not suitable for market, providing niche marketing opportunities.

The Bluff oyster, which is present in the region, has been experimentally reared under farming conditions in Mahanga Bay and shown to be a potentially viable commercial aquaculture species.

17.12 REGIONAL AQUACULTURE REPORTS

Greater Wellington Council. 2003. *Aquaculture in the Greater Wellington Region: A Discussion Document*. Attachment 1 to report 03.452. Wellington: Greater Wellington Council. 15 pp. www.gw.govt.nz/council-publications/pdfs/Environment%20Management_20030903_160127.pdf_

NIWA. 2007. *Environmental Impact Assessment for the Mahanga Bay Experimental Marine Farm Site*. NIWA Client Report NEL2007-005 Nelson: National Institute of Water and Atmospheric Research. 48 pp.

18 NEW PLYMOUTH (TARANAKI)

18.1 DESCRIPTION OF THE REGION

The New Plymouth region (commonly referred to as Taranaki) covers 232,400 hectares, stretching from the Mōhakatino River in the north to the Hangatahua (Stony) River in the south, and inland as far as Tāriki. The district has a relatively short coastline of only 150 kilometres.

The New Plymouth District has a population of about 68,900. The Taranaki region itself has a total population of 104,124 people. See Taranaki Regional Council's website (www.trc.govt.nz/about+taranaki/taranaki.htm) for further information.

18.2 EXISTING AQUACULTURE

No active aquaculture operations are in Taranaki. An onshore pāua farm operating near the Port of Taranaki closed in 2005.

18.3 POTENTIAL FOR DEVELOPMENT

The exposed nature of the Taranaki coastline makes it largely unsuitable for coastal aquaculture development. However, abundant freshwater resources may make onshore aquaculture activities feasible.

18.4 INFRASTRUCTURE

A regional airport, good road links and an active port mean that the supporting infrastructure for aquaculture could easily be further developed. A small fishing fleet operates out of New Plymouth, and local fish-processing facilities could be adapted for use by aquaculture ventures.

The development of large-scale onshore seawater facilities associated with the oil and gas industry have been seen as having potential to spin off aquaculture enterprises (Figure 19.1). The development of new gas and oil resources may support such developments in the future.

18.5 REGULATORY ENVIRONMENT

The Taranaki Regional Council regulates aquaculture development in Taranaki, and the New Plymouth District Council has responsibilities for land-based aquaculture within its territorial region.

The New Plymouth District Council has developed a coastal strategy but it makes scant mention of marine aquaculture, perhaps reflecting the limited opportunities for development in this area. See the websites of the appropriate authority For further information about marine or land-based aquaculture development, see the Taranaki Regional Council's website (www.trc.govt.nz) and New Plymouth District Council's website (www.newplymouthnz.com).

18.6 MARINE SITES

The exposed nature of Taranaki's coast and large river inputs make much of the coast unsuitable for the aquaculture development for species such as kingfish, mussels or oysters.

18.7 PĀUA

The pāua farm that operated in New Plymouth experienced problems with water quality, particularly from high silt loads due to river inputs into the coastal waters of the region. The application of recirculation technologies could overcome this issue and offer opportunities for further onshore developments in Taranaki.

18.8 EELS

The eel fishery has traditionally been important in Taranaki and has provided local employment for Māori. In recent years, several groups have investigated the options for eel farming in the region. Initial investigations suggest that glass eel supplies and ongrowing sites are available, and it may be possible to develop joint projects with some of the larger oil and gas companies in the region. It appears that the development of eel farming offers the best aquaculture opportunity for this region. However, legislation preventing the capture of glass eels hampers development in the area.

18.9 KINGFISH, MUSSELS AND OYSTERS

The development of aquaculture of kingfish, mussels and oysters in the coastal marine areas of Taranaki requires innovative offshore technology, such as is being developed overseas but which is unlikely to be feasible or economic for use here in the near future.

18.10 REGIONAL AQUACULTURE REPORTS

Roberts R, Heasman K, Thompson S and Dodgshun T. 2002. *Preliminary Information on Aquaculture Options for the Taranaki Region*. Cawthron Report 734. Nelson: Cawthron Institute. 47 pp.

Heath P and Hickman R W. 2003. *Aquaculture Potential for the Wanganui Breakwater*. NIWA Client Report: WLG2003-92. Wellington: National Institute of Water and Atmospheric Research. 13 pp.

Hickman R W, Heath P and MacDiarmid AB. 2003. *Assessment of Aquaculture Potential in the Motunui Area, Taranak*i. NIWA Client Report: WLG2003-08. Wellington: National Institute of Water and Atmospheric Research. 25 pp.

19 NELSON–MARLBOROUGH (TE TAU IHU)

19.1 DESCRIPTION OF THE REGION

Nelson–Marlborough covers around 25,000 square kilometres and stretches from Karamea and Farewell Spit in the west, through Golden Bay, Tasman Bay and the Marlborough Sounds, to Cape Campbell in the east.

The many bays and islands of the Marlborough Sounds give the area an extensive coastline and numerous areas of sheltered water for aquaculture development.

The combined population for Nelson–Marlborough is around 85,000. Marlborough's population is around 40,000 people (www.marlborough.govt.nz/home/location.cfm); Tasman district's population is around 44,625 (www.tasman.govt.nz/index.php?Demographic Information); and Nelson City's population is about 42,890 (www.ncc.govt.nz/aboutnelson/ nelsoninfocus/bynumbers.htm).

19.2 EXISTING AQUACULTURE

Over 70 percent of New Zealand's marine farming occurs in the Nelson, Marlborough Sounds and Tasman Bay area, with 4,700 hectares of coastal marine space farmed for mussels in the region, producing around 72,000 tonnes of mussels each year. Around 6,000 tonnes of farmed salmon are also produced in Nelson–Marlborough from sea farms with surface structures (sea-cages) occupying less than 10 hectares water space. There are a few intertidal leases for oyster farming in Nelson–Marlborough. The farms use rack culture technology, with some deeper sites using subtidal longline farming techniques.

Pāua production for pearls and meat occurs at two sea-based sites and two onshore facilities. Trials on the culture of seahorses, seaweed, kina and kingfish have been undertaken in the Marlborough Sounds.

Onshore, a salmon hatchery is located near Tākaka. It supplies smolt to the salmon farms in the Marlborough Sounds. The Cawthron Institute has a mussel and oyster hatchery and research facility at its Glenhaven Aquaculture Centre near Nelson. The Cawthron aquaculture park has facilities for developing commercial shellfish hatchery technology and selectively breeding shellfish. For further information about this facility see the Cawthron Institute's website (www.cawthron.org.nz).

19.3 POTENTIAL FOR DEVELOPMENT

Despite the existing high level of aquaculture within Nelson–Marlborough, it is widely believed that there is room for expansion by developing new inshore farming sites, developing offshore farming sites, converting mussel farm sites to other species, and identifying new species and technologies that will increase productivity at existing sites (co-culture and polyculture).

The large amount of existing aquaculture in this region requires that several hundred hectares of new or existing aquaculture space be allocated to local iwi under the Maori Commercial Aquaculture Claims Settlement Act 2004.

19.4 INFRASTRUCTURE

Given the existing high level of aquaculture activity in the region, it is not surprising to find the area well serviced in terms of infrastructure to support aquaculture. Species-specific processing plants, engineering companies and transport infrastructure for domestic and international markets are all well established in Nelson–Marlborough. NIWA and the Cawthron Institute have offices in Nelson and provide research support to the aquaculture industry.

19.5 REGULATORY ENVIRONMENT

Nelson–Marlborough is controlled by the Tasman District Council, covering the coast from Whangamoa to Farewell spit, and the Marlborough District Council, covering Wharanui to Whangamoa and including the Marlborough Sounds.

These two district councils together with the Nelson City Council have responsibilities for marine and land-based aquaculture planning and development in the region.

The Marlborough District Council's provisions for marine farms are set out in the coastal marine sections of its resource management plans. Two coastal marine zones, CM1 and CM2, are in the Marlborough Sounds resource management plan. New marine farms or extensions to existing farms are prohibited in CM1. For further information on this issue, see the appropriate pages of the Marlborough District Council's website (www.marlborough.govt.nz/regulatory/marinefarms.cfm).

For further information about marine or land-based aquaculture development see the Tasman District Council's website (www.tdc.govt.nz) and the Marlborough District Council's website (www.marlborough.govt.nz).

19.6 MARINE SITES

The area has favourable conditions for the culture of several marine species, although the water may be too warm for salmon culture in the summer and too cool for the most efficient production of Pacific oysters. There are considerable areas of sheltered marine space and offshore marine space that could be developed for aquaculture (Figure 20.1), although there is increasing resistance to further development in the region as tourism and recreational water use increases.

Only shellfish farming is permitted in the Tasman district plan, so the development of farms for other species in the Tasman district will not be possible until the plan is changed.

FIGURE 19.1: EXISTING (LEFT) AND POTENTIAL (RIGHT) MARINE-FARMING SPACE IN THE NELSON–MARLBOROUGH REGION

19.7 PĀUA

Nelson–Marlborough has two onshore and two marine-based pāua farms. These farms are used for both pearl and meat production. The Marlborough Sounds environment appears well suited to pāua culture, with even temperatures and good water quality. Low-lying land adjacent to the sea in several areas offers the possibility of further onshore aquaculture activities, although the increasing demand for residential development in the area is pushing up land prices.

19.8 KINGFISH

Initial trials with kingfish in the Marlborough Sounds had mixed results, with particular concern being expressed about poor winter growth due to low water temperatures during winter months. If this problem can be addressed, it may be possible to convert either salmon or mussel farms to kingfish production.

19.9 MUSSELS

Substantial increases in mussel production in Nelson–Marlborough are most likely to occur through the development of large offshore farms. There are proposals for 11 offshore farms in the region and proposals to extend existing farm sites within the Marlborough Sounds. The Tasman District Council considers there is potential for increasing mussel production in its region to over 50,000 tonnes and opportunities for increasing mussel spat-catching activities.

19.10 EELS

Commercial eel fishing in Nelson–Marlborough accounts for around 20 tonnes of eels per year. The area has abundant freshwater supplies and there is potential to catch glass eels in local rivers. However, access to geothermal resources that could be used to offset the heating requirements and costs for eel farms is limited. These factors suggest that the area has reasonable potential for eel farming, but developments need to carefully consider their scale and energy requirements.

19.11 OYSTERS

The potential for oyster farming in Nelson–Marlborough is limited by both the cool water environment and competition for intertidal space for recreation and tourism. While space is limited for the traditional intertidal rack culture of oysters, at least two companies are successfully growing Pacific oysters in Pelorus Sound and Croisilles Harbour. These farms show that there are opportunities for growing Pacific oysters subtidally for oyster meat or finishing the oysters off intertidally to harden the oysters and improve their shelf-life and marketability for the most lucrative half-shell trade. Problems with predator

(flatworm) and parasite (mudworm) infestations have been managed at sites where they have been a problem, with advice from NIWA. Therefore, potential exists for an increase in oyster-farming activity in Nelson–Marlborough.

Experimental farming of Bluff oysters has also been undertaken in the region over the past 15 years with some success. Further development has been hampered by the lack of reliability of spat supply and mortalities related to disease. If these problems can be overcome, this oyster species could prove to be a more suitable aquaculture candidate than the Pacific oyster for the environmental conditions in this region.

19.12 REGIONAL AQUACULTURE REPORTS

Marlborough Regional Development Trust. 2005. *Discover Marlborough's Aquaculture*. www.mrdt.co.nz/marlborough-info/water-based/aquaculture_

Marlborough District Council. No date. *Marine Farms*. www.marlborough.govt.nz/regulatory/marinefarms.cfm

20 CANTERBURY (WAITAHA)

20.1 DESCRIPTION OF THE REGION

Canterbury has a land area of 44,638 square kilometres with around 800 kilometres of coastline and neighbouring marine area extending from the Waitaki River mouth in the south to Kekerengu in the north.

Canterbury's population is around 503,000 (www.ecan.govt.nz/NR/rdonlyres/9109AE5A-20B1-403E-9B10-95C3DD0DBADE/0/Part_C_Demographics.pdf).

20.2 EXISTING AQUACULTURE

Canterbury has four existing commercial mussel farms on Banks Peninsula: with two at Pigeon Bay, one at Squally Bay and one at Menzies Bay. In addition, an offshore farm of 2,600 hectares has been approved for Pegasus Bay but is not yet in production.

Two pāua farms are in the region: a sea-based pearl farm in Akaroa Harbour (Figure 21.1) and an onshore farm at Amberley that is ongrowing for meat production.

Marine and freshwater salmon farms (Figure 21.1) are also in the region: a marine farm is located in Akaroa Harbour and freshwater farms are in the Ōhau and Tekapō hydro-canals.

There is also a salmon hatchery in Silverstream.

FIGURE 20.1: FRESHWATER SALMON FARM (WITH STOCK TRANSPORT TRUCK) AT OHAU (LEFT) AND PĀUA PEARL FARMING AT AKAROA HARBOUR (RIGHT)

20.3 POTENTIAL FOR DEVELOPMENT

Despite a limited amount of sheltered marine space, Canterbury has considerable potential for developing aquaculture both onshore and offshore. The existing amount of aquaculture development requires that a significant quantity of marine space is made available for aquaculture development by Māori under the Maori Commercial Aquaculture Claims Settlement Act 2004.

20.4 INFRASTRUCTURE

Canterbury has excellent infrastructure to support existing and new aquaculture developments. The fishing industry has a long history in the region, with major seafood-processing facilities in Lyttleton. Sea freight facilities are also available from Lyttleton, and direct international flights to Asia and the United States operate out of Christchurch.

20.5 REGULATORY ENVIRONMENT

Environment Canterbury is responsible for regulating aquaculture in the region. Environment Canterbury's responsibility extends out to the 12 nautical mile limit and covers 11,620 square kilometres of open water and coastal marine area.

Environment Canterbury has mapped some constraints with regard to AMAs, and the maps, together with current information on the state of aquaculture development in the region, are available on the council's website (www.ecan.govt.nz).

Eight district councils and one city council have responsibilities for land-based aquaculture facilities and activities in Canterbury.

20.6 MARINE SITES

The Canterbury coastline is generally exposed, with few sheltered areas other than around Banks Peninsula. Offshore farming is being trialled in the coastal marine area. If it is successful, a considerable amount of offshore space may become available for aquaculture development. Water temperatures and water quality in the region are suitable for most species, but may be too cold for optimum growth of kingfish and oysters.

20.7 PĀUA

Existing onshore and offshore pāua farms show there is potential for further development of pāua farms in Canterbury. Considerable areas of low-lying coastal land make onshore development particularly favourable.

20.8 KINGFISH

Water temperatures within Canterbury are probably too low to produce kingfish efficiently. This, coupled with the limited availability of sheltered marine space, suggests that kingfish production is unlikely to develop significantly in this region.

20.9 MUSSELS

Mussel farming in Canterbury is well established, and existing farms are reasonably productive. Recent offshore developments need further growth trials to establish whether the technology offers potential for the expansion of mussel farming in the region.

20.10 EELS

Canterbury has a long-established tradition of eel fishing, with considerable catches being taken from Lake Ellesmere and Canterbury rivers. The wild catch in 2003 was worth in excess of $2 million. The existing wild resource indicates that there is potential for the region's rivers to supply glass eels for aquaculture development. Some limitations on freshwater supplies in the Canterbury region may restrict the development of extensive eel culture projects but eel farming using recirculation systems, which have low water requirements, should be possible.

20.11 OYSTERS

Pacific oysters are not found in Canterbury, so there may be opposition to introducing this species to the region. Low water temperatures make it unlikely that Pacific oysters would spawn successfully, thereby preventing natural seed production, and would also reduce oyster growth rates. Any farms that were established would have to rely on hatchery-produced seed. It is, therefore, unlikely that oyster farms will be established in the region.

The Bluff oyster is found in the region and has potential as an aquaculture species for suspended farming, but would require a source of hatchery-produced seed to provide ongoing stock for farming, because the collection of natural spatfall in sufficient quantities is unlikely for this species.

20.12 REGIONAL AQUACULTURE REPORTS

Environment Canterbury. 2008. *Identification of Excluded Areas for Aquaculture in Canterbury*. www.ecan.govt.nz/Plans+and+Reports/Coast/Identification+of+Excluded+Areas+For+Aquaculture+In+Canterbury.htm

PART 3:

A CLOSER LOOK AT FIVE POTENTIAL AQUACULTURE SPECIES

RAWA – RESOURCES: THIS PATTERN DRAWS INSPIRATION FROM THE KORU WHICH REFERENCES THE FERN FROND.

21 MUSSEL (KUTAI, KUKU)

In this section each of the five species selected as having the most immediate potential and relevance for Māori aquaculture development is examined in depth. The five species were chosen for their potential for development in New Zealand and to represent a range of commonly used aquaculture technologies that may be applied to other species.

These sections, separately authored by NIWA experts, provide information in much greater detail than was presented at the hui. The sections describe the species and its life cycle, world and New Zealand production, farming techniques (including processing, marketing and economics), the legislation relevant to each species, and any obvious production constraints or bottlenecks.

21.1 INTRODUCTION

The green-lipped mussel is one of the few endemic (native) species of mussel that are farmed in New Zealand. There are 16 species of mussel in New Zealand, but the two most common and abundant are the green-lipped mussel (*Perna canaliculus*) and the blue mussel (*Mytilus galloprovincialis*). Both of these species are suitable for aquaculture.

Worldwide, production of mussels focuses on the *Mytilus* species, but in New Zealand the green-lipped mussel is regarded as a more attractive species to culture because it can be readily differentiated from other mussel commodity products on the world market.

Green-lipped mussel

The green-lipped mussel (*Perna canaliculus*) is marketed under the trade name Greenshell mussel to distinguish it from green mussels found elsewhere in the world, and this is the name that is used throughout the New Zealand mussel industry. It is also known by Māori as kutai or kuku.

This mussel species is unique to New Zealand. It is found in the waters around New Zealand, including the Chatham and Kermadec Islands, but is more common in warmer northern waters than in colder southern waters.

Green-lipped mussels occur in low intertidal areas and subtidally to over 50 metres depth. They attach to a wide range of substrate, including rock faces and artificial structures, such as wharf piles, but are sometimes found in muddy or sandy areas in deeper waters.

Green-lipped mussels grow up to 240 millimetres in length. Sexes are differentiated by gonad colour, with males having a characteristically creamy white gonad and mature females a reddish apricot colour. Juvenile mussels normally have a bright green shell, but as the mussels age the shell colour varies and can range from

black to yellow to green. Shell colour depends on water depth and ultraviolet exposure, age and the location of the mussels.

These mussels are readily distinguished from other mussels by the distinct green lip on the inside of the shell margin, from which they derive their common name (Figure 22.1).

The green-lipped mussel grows to 90–100 millimetres (normal harvest size) in 18–24 months when farmed.

FIGURE 21.1: GREEN-LIPPED MUSSELS (*PERNA CANALICULUS*)

Blue mussel

The blue mussel (*Mytilus galloprovincialis*) is also known as the Mediterranean or black mussel. Blue mussels occur worldwide and, along with a closely related species *M. edulis*, form the basis of much of the world's mussel aquaculture. This species is most common in southern New Zealand, and is abundant in Cook Strait.

Blue mussels attach to hard surfaces from high intertidal to shallow subtidal areas. They do not commonly occur in areas of muddy or sandy substrate.

Blue mussels grow to 100 millimetres in length.

The sexes are differentiated by gonad colour in the same way as green-lipped mussels.

The species has a characteristic blue to black shell, often with a chalky white appearance near the hinge area (Figure 22.2). When cultured, the shell appears glossy blue/black and is thin and fragile.

FIGURE 21.2: BLUE MUSSELS (*MYTILUS GALLOPROVINCIALIS*)

21.2 MUSSEL LIFE CYCLE

All mussel species are broadcast spawners, meaning they simply release sperm and eggs into the water. The eggs of female green-lipped mussels are about 0.05 millimetres in size and are fertilised in the open water by sperm that the males have released. The environmental cue that triggers mussels to spawn in the wild remains a mystery, but it can be triggered in a controlled environment using temperature and salinity shocks.

Mussel larvae are free swimming and have a planktonic phase that can last up to six weeks before they are ready to settle. This planktonic stage allows the larvae to disperse to new areas with the assistance of water currents. During this phase, the larvae go through two changes, from trochophore to D-stage and from D-stage to veliger, before metamorphosing into miniature adult mussels, which are called spat.

Within two days of fertilisation the eggs have developed into D-stage larvae, so called because of their shape (Figure 22.3). These larvae have some ability to move vertically in the water column using an organ called the velum, which is covered in small cilia (microscopic hair-like vibrating structures) and is also used for feeding. However, they are mostly at the mercy of ocean currents during the early stages of life.

The larva continues to grow and changes shape to become the veliger larva, with an umbo (pointed end of the shell) and fully developed velum. Once the veliger develops two pigmented eyespots and a functional foot, it is called a pediveliger or late veliger, and is ready to settle.

The pediveliger uses its foot to search for settlement surfaces and its velum to move between potential settlement sites. The larvae seek out a suitable filamentous substrate. They then attach themselves to the surface of the substrate by secreting byssal threads (silky filaments). Immediately after settlement, the larvae metamorphose into the adult form, loosing the velum and becoming bottom dwellers. At this stage they are known as spat.

Even after settlement spat can still move if the site they have chosen does not suit them. They can release the byssal threads and produce mucous threads that act like parachutes, enabling them to drift in the water currents. They lose this ability to drift when they are around 6 millimetres in length, but retain the ability to release and secrete more byssal threads throughout their life.

21.3 WORLDWIDE MUSSEL PRODUCTION

Worldwide aquaculture production of mussels is in excess of 1.8 million tonnes per year, including production of both *Mytilus* and *Perna* species. The largest mussel-producing country is China, with production in excess of 600,000 tonnes, almost all of which is consumed domestically.

Thailand is the second-largest mussel producer (Figure 22.4). It farms the green mussel (*Perna viridis*) using intertidal pole culture techniques that have been practised in Thailand for more than 60 years.

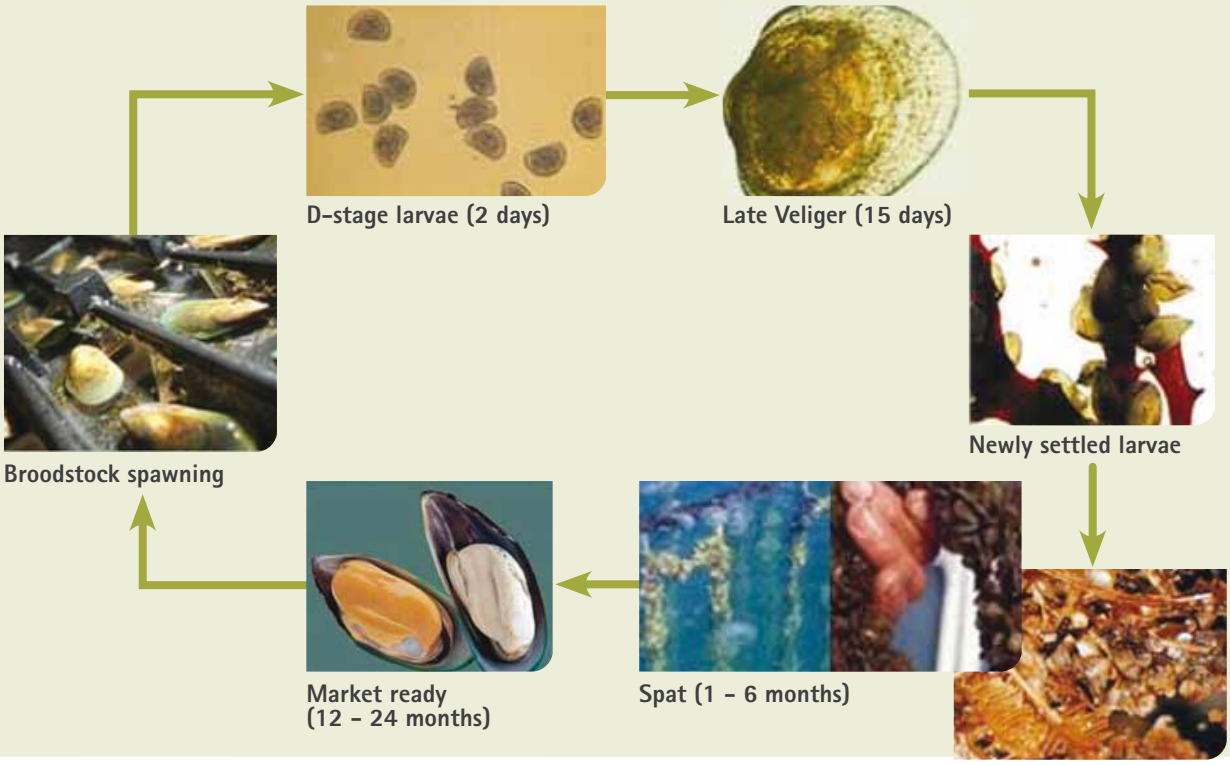
New Zealand is the only other major mussel-producing country that farms significant quantities of a green mussel (Figure 22.4).

In Spain, Chile, Italy and Ireland, blue mussels (*Mytilus edulis* and *M. galloprovincialis*) are cultured, mainly using suspension technologies, where ropes of mussels are suspended below floating longlines or rafts.

In France, mussel farming occurs on poles in the intertidal zone.

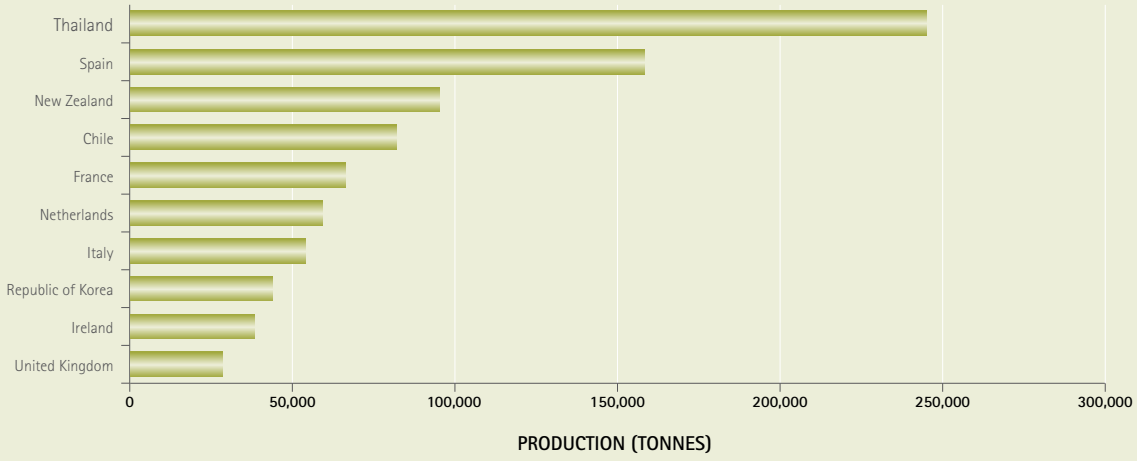
In The Netherlands, Ireland and the United Kingdom, seed mussels harvested from the open sea are relaid onto the seabed in the inland sea, loughs or estuaries for ongrowing.

FIGURE 21.3: GENERALISED LIFE CYCLE OF THE GREEN-LIPPED MUSSEL (APPROXIMATE TIME SPENT IN EACH STAGE)



Source: NIWA

FIGURE 21.4: TEN OF THE ELEVEN TOP MUSSEL-PRODUCING COUNTRIES (EXCLUDING THE TOP PRODUCER, CHINA, WHICH AT OVER 600,000 TONNES HAS PRODUCTION THAT ALMOST OUTWEIGHS THE COMBINED PRODUCTION OF THE NEXT 10 PRODUCER COUNTRIES)



Source: Food and Agriculture Organization

21.4 NEW ZEALAND MUSSEL INDUSTRY

Green-lipped mussels have been harvested since the beginning of human habitation in New Zealand. The first commercial activity was the dredging of wild mussel populations from soft sediments, which mainly occurred in the waters of the Hauraki Gulf and Tasman Bay.

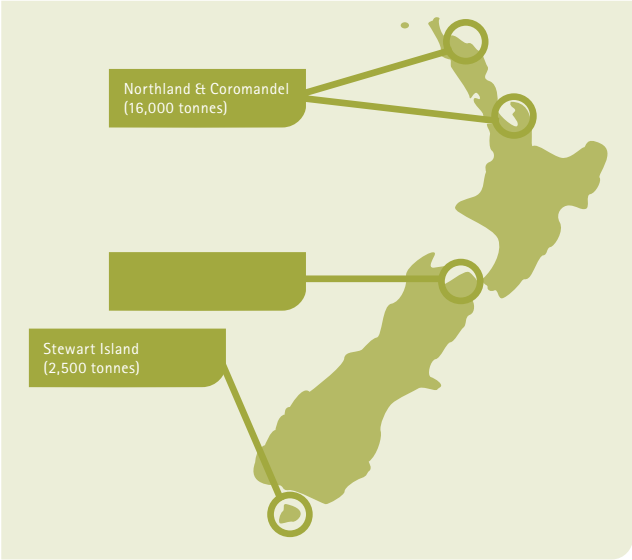
The first mussel rafts were installed in the Hauraki Gulf in the mid-1960s and in the Marlborough Sounds in the late 1960s, using rafts similar to those used for mussel farming in Spain. However, it became apparent that this method would be unsuitable in New Zealand, primarily because the rafts were considered aesthetically unacceptable. Also, the mussels in the middle of these rafts were not exposed to sufficient water flow and feed, so grew more slowly and were in poor condition at time of harvest.

The labour-intensive raft production method was phased out during the early 1970s as the industry turned to longline cultivation. This method of mussel farming was modified from the Japanese oyster farming longline system. Spat-catching techniques for collecting natural wild seed were also developed during the early 1970s, and the methodology for this is still used today.

The first commercial harvest of 7 tonnes was made in 1971. Since then, the longline technology has been refined and adapted to achieve today's cost-effective, highly automated and mechanised mussel farm management system for use in sheltered near-shore areas. In the last 3-5 years, research and commercial development projects have started to adapt the technology for use in subsurface longline systems in exposed off-shore waters.

The current annual production of around 90,000 tonnes comes mainly from the Marlborough Sounds (Figure 22.5).

FIGURE 21.5: NEW ZEALAND GREEN-LIPPED MUSSEL PRODUCTION AREAS, 2006



Source: S Handley, NIWA

21.5 PRODUCTION CYCLE

Spat supply

The spat (seed) supply for the New Zealand mussel industry is obtained from two sources: beach stranding and spat catching.

Beach stranding of 'Kaitaia spat' is a natural phenomenon that occurs on the north-west coast of the North Island. It provides the major supply of mussel seed for the industry. At irregular times throughout the year, considerable quantities of newly settled spat attached to seaweed are washed up on along Ninety Mile Beach, near Kaitaia. Local people licensed by the Ministry of Fisheries collect the seaweed, which is then carefully and quickly transported to growers in other parts of the country.

Spat catching is undertaken by suspending lengths of special rope (Figure 22.6), commonly known as 'Christmas tree rope' or 'hairy rope', in areas that are known to produce high numbers of planktonic larvae ready to settle. This method is practised in several areas, including Whangapē Harbour, Aotea Harbour, the Hauraki Gulf, Tasman Bay and Golden Bay. Spat catching on ropes is costly (requiring more effort and having higher transport costs than are associated with beach stranded spat), and provides only a small portion of the total spat required. However, this spat tends to be of high quality.

FIGURE 21.6: MUSSEL SEED COLLECTING ROPE WITH SEED ATTACHED

Transferring seed from either capture method has been successful with mussels less than 1 millimetre in size (ie, about four to eight weeks after spatfall). Transfers with larger mussels (3–20 millimetres) are more difficult because these mussels have an increased tendency to become detached from ropes.

Hairy ropes or beachcast seaweed can be safely removed from, and transported out of, water. Moistened sacks or similar material can be used to cover the mussel spat to prevent dehydration during transport. Ideally, transit time should not exceed 12 hours, although mussels are held in cool and moist conditions they can survive out of the water for 48 hours.

The gathering of beachcast seaweed for mussel spat collection has, since October 2004, been included within New Zealand's quota management system.

The technology for small-scale hatchery seed production has been developed in New Zealand, and commercial-scale hatchery production is expected in the near future.

Nursery

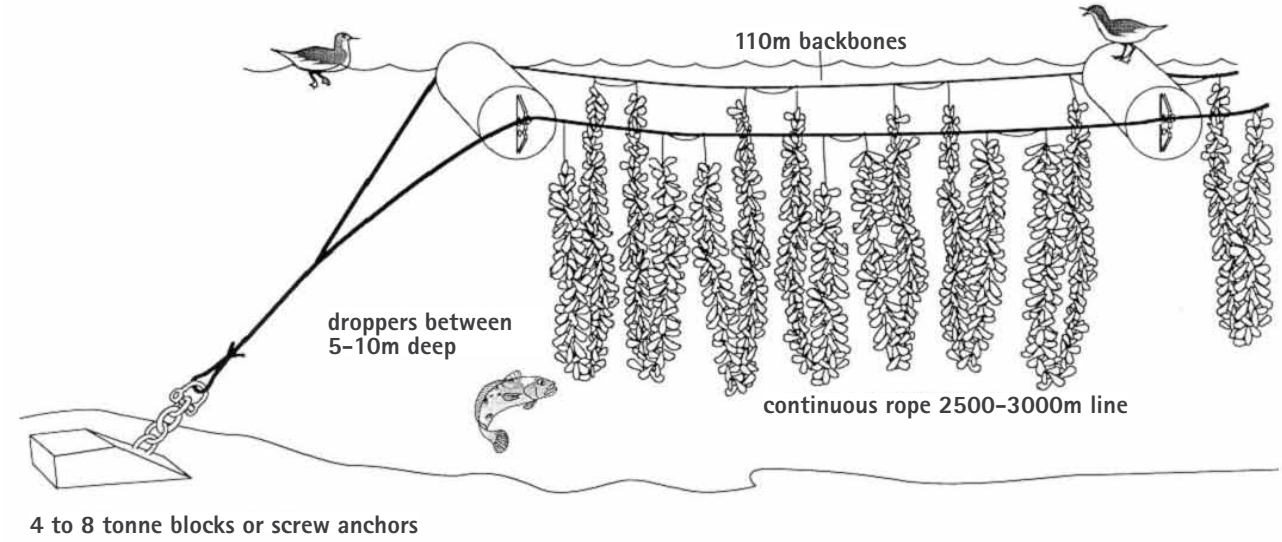
On the spat's arrival at the farm, it is resettled (reseeded) onto nursery lines. This is done by feeding the seaweed and the rope together into a narrow cotton stocking, which forms a light continuous small-mesh tube that holds the seaweed against the nursery rope. The seed mussels attach to the rope within hours, and the stocking and seaweed biodegrade within two to three weeks. A seeding density of 1,000–5,000 spat per metre is optimal. It is important to minimise stresses such as heat and dehydration on the spat throughout harvesting, transport and reseeding.

Small mussels are vulnerable to predation by various fish species such as snapper, spotty and leather jacket. Nursery lines are kept in areas with low fish abundance, and growers usually encourage recreational fishers to tie up to the farm and fish from it.

Mussel ongrowing

Several factors must be considered when siting mussel farms. Clean, unpolluted water is the most essential consideration, followed by the need to site farms in areas of relatively calm sea conditions and out of the effect of ocean swells. These factors make the protected waters of the Marlborough Sounds and Hauraki Gulf ideal for

FIGURE 21.7: REPRESENTATION OF A SECTION OF A MUSSEL LONGLINE



Source: Jeffs (2003).

mussel farming. Water depth is also important, with most farms being established in depths of 15–30 metres.

Mussel farming in New Zealand uses the longline technique (Figure 22.7). A longline is typically 110 metres long and consists of a backbone of two parallel ropes attached to and separated by up to 50 plastic floats that are each about 0.6 metres in diameter and 1.2 metres long. The longline is anchored at both ends to the seafloor with concrete blocks or screw anchors.

The culture rope holding the mussels hangs in loops of 5–10 metres depth from the longline backbone. The typical continuous length of culture rope that is suspended from the backbone is 3,500 metres long, which can carry 40 tonnes of mussels at harvest. As the weight of the crop increases as the mussels grow, more floats are tied along the backbone of the longline.

The average farm area is 3–5 hectares, although farms can vary from 1 hectare to 20 hectares or more. The shape of the boundary is often determined by the geography of the area and the water depth. Much bigger offshore farms of up to 10,000 hectares are planned.

After three to six months' growth on the nursery rope, the juveniles (10–30 millimetres) are stripped from the ropes and reseeded at 150–200 per metre onto a thicker rope. This rope uses a larger diameter cotton stocking to secure the juveniles until they attach to the rope by secreting new byssal threads, before the cotton stocking biodegrades. This reseeded rope, hung in loops on the longline, will hold the mussels until they are ready for harvest (Figure 22.8).

FIGURE 21.8: NEWLY RESEEDED MUSSELS SUSPENDED ON A LONGLINE WITHIN COTTON SOCKING

It normally takes 12–18 months from reseeding for the juvenile mussels to achieve the harvest size of 90–120 millimetres. However, the duration of the grow-out period varies from site to site and depends on stock density, food availability, temperature and water movement. Farmed mussels reach market size about twice as fast as wild mussels growing in the same area.

The crop needs little attention during the grow-out period, except for ensuring adequate buoyancy on the longline. The rapid increase in production since the mid 1970s, from 1,000 tonnes to 90,000 tonnes, has, however, required all the processes relating to farming to become highly mechanised. This has led most noticeably to the development of a fleet of purpose-built vessels to service the mussel industry, which are capable of highly automated spat seeding and reseeding; harvesting, washing and declumping; and transporting as much as 100 tonnes of crop to the wharf for processing.

Harvesting techniques

Harvesting was originally carried out by hand, but is now done by specially designed, large harvesting vessels. Harvesting vessels are equipped with machinery to lift whole sections of a fully laden longline, strip the mussels from the droppers, then de-clump, clean and bag them.

The cleaned mussels are packed into specially designed 1 tonne transporting bags or 25 kilogram wholesale sacks for the local market.

These self-contained harvesting vessels employ a crew of three to six people depending on the size of the vessel. The larger vessels can harvest up to 100 tonnes of mussels in a day.

The time of harvest is largely determined by the size and condition of the mussels. Different markets demand specific sizes and/or product forms, and size is often the most important consideration in deciding when to harvest any particular crop.

Mussels are in peak condition just before spawning. However, spawning times vary from site to site, so care must be taken to select and harvest mussels at their peak. Before harvesting a longline, experienced assessors inspect samples to ensure the mussels are ready for harvest.

Harvesting is often linked to factory production schedules to ensure mussels are held out of water for the shortest time possible, with preferably only a few hours between harvesting and processing.

Handling and processing

New Zealand mussels are processed in state-of-the-art, high-technology factories that operate under strict hygiene and quality-control regimes that are determined by New Zealand regulations and international food-processing standards. Government inspectors regularly inspect each factory, and each factory runs a quality assurance programme.

Mussels are processed into many product forms, but, regardless of the final form, the passage through the processing chain is rapid. Processing takes little more than 30 minutes from the beginning of the cycle until final packaging. All plants use quick-freezing spiral freezers, and most plants use automatic weighing and packaging equipment.

21.6 ECONOMICS OF MUSSEL FARMING

The cost of establishing longline farming structures is around $40,000 per hectare. This infrastructure would yield an average crop worth around $38,000 over 12–24 months, depending on the growing site.

The economics of production depend greatly on both the scale of the operation and the way in which it is managed. Small mussel farming operations often opt for contract growing rather than investing in specialised seeding and harvesting vessels and processing infrastructure. Contract growers are supplied with seed by larger producers or processors that also undertake stocking, grading and harvesting. The farm owner is paid a percentage of the final value of the mussels harvested from the farm.

The larger farms are generally part of a vertically integrated operation that encompasses the range of mussel aquaculture activities, from growing and farm management to harvesting, processing and marketing.

21.7 PROCESSING AND MARKETING

The domestic market takes about 20 percent of the product from the mussel industry. The other 80 percent is exported to about 60 countries, with the major importers being Japan, Australia, the United States, Hong Kong and Europe.

Production first rose above 70,000 tonnes per year in 1998, and has remained above that level to date. In 1988, exports had a total value of NZ$24 million, and by 2000 that figure had risen to NZ$170 million. This represents growth of over 600 percent for the 12-year period. In 2000, 605 farms had a total farming area for mussel longlines of 2,850 hectares. Based on the total processed weight of exports in 2000, the export return on processed product was NZ$59,649 for each hectare used for mussel production[6].

New Zealand mussels are sold in several forms. All overseas markets are supplied with processed products, while both live and processed mussels are sent to New Zealand supermarkets. Live mussels are often held at supermarkets in specially designed spray tanks to keep them alive and fresh for sale.

Mussels frozen in the half-shell make up over 70 percent of total export sales, making New Zealand the world's leading exporter of half-shell mussels. Several factories also specialise in a variety of other lines, including individually quick frozen meats, smoked mussels, mussel chowder and marinated mussels. Mussel extracts and powders are also supplied to specialist healthcare markets.

21.8 WATER QUALITY

The New Zealand mussel industry carefully monitors water quality to ensure that harvested product is free of bacterial or viral contaminants and toxins.

Rainfall monitoring

Rainfall affects the bacterial loads in coastal sea water by carrying microbes (mainly animal faecal bacteria) from the land into the growing waters. Mussels may ingest these bacteria and concentrate them in their digestive system. A shellfish quality programme monitors rainfall events. The programme uses remote monitoring stations and a data set built up over many years, so can predict when bacterial contamination risks are likely to occur. The programme then alerts farmers to close the affected areas to prevent the harvest of mussels that may pose a health risk to consumers. Independent authorities carry out regular monitoring to specifications and standards set by the United States Food and Drug Administration.

Biotoxin monitoring

Microalgae form the main food for mussels. On occasions blooms of microalgae occur that produce chemicals that are toxic to humans and can accumulate in mussels and other shellfish. All New Zealand shellfish-producing waters are regularly monitored for the presence of microalgal blooms. When toxic blooms or contaminated shellfish are detected, the harvesting of all shellfish, both farmed and wild, is suspended until tests show that the toxins are no longer present. New Zealand has led the world in developing shellfish monitoring programmes, and the tests used are approved by all of New Zealand's export destinations.

6 To produce 50,000 tonnes of sheep meat (live weight) for export more than 500,000 hectares of suitable pastureland are needed. The mussel aquaculture industry requires less than 0.5 percent of that area to produce 50,000 tonnes of mussels (live weight).

21.9 SUSTAINABLE AQUACULTURE PRACTICES

The mussel industry depends on a high-quality marine environment and takes great care to maintain environmental standards and, where possible, to seek improvements.

Evidence suggests that the mussel industry is environmentally benign. The mussel-farming process does not have feed or chemical inputs, and there is little evidence to suggest that feed uptake (ie, the consumption of phytoplankton[7]) by the mussels in mussel farms affects other marine species. Many studies indicate that the structures created by marine farms may in fact benefit a range of sedentary and pelagic species.

The main impact of mussel farms on the environment is the visual impact of the floats that support the longlines. This can be minimised by using dark floats and maintaining the lines in good and tidy order. The industry code of practice calls for growers to avoid untidy lines, upended buoys and shoreline debris and detritus.

To ensure that coastal water quality is maintained, the shellfish industry works closely with land users to avoid adverse effects on the marine environment from land use. The industry's vessel operators are bound by the anti-pollution regulations that apply to all marine users in New Zealand.

In all of its land-based operations, the New Zealand mussel industry is conscious of its obligation to eliminate or minimise pollution. The industry funds and promotes research to provide environmentally sustainable waste management practices and has developed a comprehensive environmental code of conduct that stresses the '5R' principles of waste management – reduction, reuse, recycling, recovery and residual management.

21.10 PRODUCTION CONSTRAINTS AND BOTTLENECKS

Increasing competition for inshore marine space has led several farms and consortiums to apply for substantial offshore farms. To date, offshore farms have not progressed beyond the experimental phase. This may be because in recent years the strengthening New Zealand dollar has reduced the export returns for mussels significantly. In addition, increasing regulation and compliance costs, coupled with rising labour and fuel costs have severely affected the industry's profitability. The current economic climate for mussel farming does not, therefore, lend itself to significant investment in developing offshore farms. Recent government initiatives to improve mussel marketing, together with an expected weakening of the New Zealand dollar, may change this situation.

21.11 REFERENCES

Jeffs A. 2003. *Assessment of the Potential for Mussel Aquaculture in Northland.* NIWA Client Report AKL2003-057. Auckland: National Institute of Water and Atmospheric Research. 15 pp. Available at www.niwa.co.nz/ncfa/news_pubs

Jeffs A, Holland R, Hooker S and Hayden B. 1999. Overview and bibliography of research on the Greenshell mussel, *Perna canaliculus*, from New Zealand waters. *Journal of Shellfish Research* 18(2): 347–360.

Jenkins R. 1985. *Mussel Cultivation in the Marlborough Sounds (New Zealand)* (2nd ed). Wellington: New Zealand Fishing Industry Board. 77 pp.

Seagar V. 2003. *Biology of the New Zealand Greenshell Mussel.* Wellington: Seafood Industry Training Organisation. 40 pp.

7 Phytoplankton are single-celled plants or seaweeds that form the basis of the food chain in the sea.

22 OYSTER (TIO)

22.1 INTRODUCTION

The name 'oyster' is used for several different groups of molluscs that grow in marine or brackish water. The 'true oysters' are members of the family *Ostreidae*, which includes the flat oysters, which mainly belong to the genera *Ostrea*, *Tiostrea* and *Ostreola*, and the cupped oysters in the genera *Crassostrea* and *Saccostrea*.

The three oyster species commonly found in New Zealand are the: Bluff or dredge oyster (*Tiostrea chilensis*); rock oyster (*Saccostrea glomerata*) and Pacific oyster (*Crassostrea gigas*).

Bluff or dredge oyster

The Bluff or dredge oyster (*Tiostrea chilensis*) occurs in New Zealand and South America, and is similar in appearance (Figure 23.1) and habitat to the northern hemisphere flat oyster (*Ostrea edulis*).

This species occurs subtidally on mud, sand and shell substrates and is occasionally found in the low intertidal zone.

The Bluff oyster's maximum length is around 105 millimetres and it can reach a weight of 300–400 grams.

Despite being New Zealand's most highly valued oyster, the Bluff oyster is not farmed to any great extent in New Zealand.

FIGURE 22.1: DREDGE OYSTER (*TIOSTREA CHILENSIS*)

Rock oyster

The rock oyster (*Saccostrea glomerata*) is New Zealand's native cupped oyster (Figure 23.2). Its maximum length is around 80 millimetres and it reaches a weight of 200–300 grams.

Rock oysters tolerate a wide range of salinities. They are usually found in the intertidal zone to 3 metres below the low water mark.

The species is less common in New Zealand than it used to be, having been displaced by the Pacific oyster.

Some scientists think the Sydney rock oyster *Saccostrea commercialis*, which is found (and farmed) in New South Wales, is synonymous with the rock oyster *S. glomerata*.

FIGURE 22.2: ROCK OYSTER (*SACCOSTREA GLOMERATA*)

Pacific oyster

The Pacific oyster (*Crassostrea gigas*) is an important aquaculture species throughout the world. It was introduced into New Zealand, probably inadvertently, from Japan. It was first reported among native rock oysters on oyster farms in Mahurangi Harbour in 1971. By the late 1970s it had spread to harbours on the east and west coasts of the North Island and to the northern coasts of the South Island. The Pacific oyster now occurs predominantly to the north of a line from New Plymouth to East Cape, but with small populations extending down the west coast of the North Island and across to the Marlborough Sounds and Tasman Bay and Golden Bay areas.

The Pacific oyster has a white-ish elongated shell, an average size of 150–200 millimetres and a maximum length of over 250 millimetres, and reaches 1 kilogram in weight. The two halves (valves) of the shell are solid, but unequal in size and shape. The left valve is slightly convex and the right valve is quite deep and cup shaped. The right valve is usually cemented to the substrate along most of its length. The shells are sculpted with large, irregular, rounded, radial folds (Figure 23.3).

The Pacific oyster will attach to almost any hard surface in sheltered waters. While they usually attach to rocks, the oysters can also be found in muddy or sandy areas. Pacific oysters will also settle on adult oysters of the same or other species. They prefer sheltered waters in estuaries, where they are found in the intertidal and shallow subtidal zones to a depth of about 3 metres.

FIGURE 22.3: PACIFIC OYSTER (*CRASSOSTREA GIGAS*)

22.2 PACIFIC OYSTER LIFE CYCLE

The Pacific oyster has a prolonged breeding season with several spawnings throughout the warmer months, but with spring and autumn spawning peaks. The eggs and sperm are released into the water for fertilisation and larval development. (This is in contrast to *Ostrea*-type oysters in which fertilisation occurs within the female and partial incubation of the developing larvae continues in the mantle cavity of the female.)

Larval development requires a water temperature in excess of 18°C. At 20°C development through to settlement takes 21–24 days. The late stage larva (veliger) develops a foot, which it uses to test surfaces for settlement. Once the oyster larvae settle and cement themselves to a surface they are not capable of moving to another site.

Settlement onto a clean hard substrate can take place over a wide vertical range, but survival is generally better in the intertidal zone, where there is less predation from crabs, starfish and polychaete worms; less competition and fouling from mussels, barnacles, sponges and tunicates; and fewer problems with parasites and associated organisms such as mudworm, flatworms, copepods and pea crabs.

Once settled, the oysters feed and grow. Males reach sexual maturity within one year and females within two years. The oysters become marketable from 12 to 24 months. (See Figure 23.4.)

FIGURE 22.4: GENERALISED LIFE CYCLE OF THE PACIFIC OYSTER (APPROXIMATE TIME SPENT IN EACH STAGE)

Source: NIWA

22.3 WORLDWIDE OYSTER PRODUCTION

Worldwide, oysters are both harvested from the wild and farmed for their meat and pearls. Statistics from the Food and Agriculture Organization show that, in 2005, 41 countries produced around 4.7 million tonnes of oysters with a first sale value of US$120 million. The Pacific oyster accounted for around 4.5 million tonnes of the world oyster production, and 3.8 million tonnes of that production came from China. Other significant oyster-producing countries include the Republic of Korea, Japan and France (Figure 23.5).

Oysters are known to be relatively easy to culture, both low on the shore (intertidally) or in open water (subtidally), and a wide range of culture techniques are used worldwide. The choice of farming technique depends on labour costs and the sea space available for culture. Farming techniques include sowing oysters onto mats in the intertidal zone; attaching oysters to poles, shells and sticks in the intertidal and subtidal zones; caging oysters in trays, bags or baskets in the intertidal zone; and suspending oysters in various mesh containers attached to buoyed lines in open water.

22.4 NEW ZEALAND PACIFIC OYSTER INDUSTRY

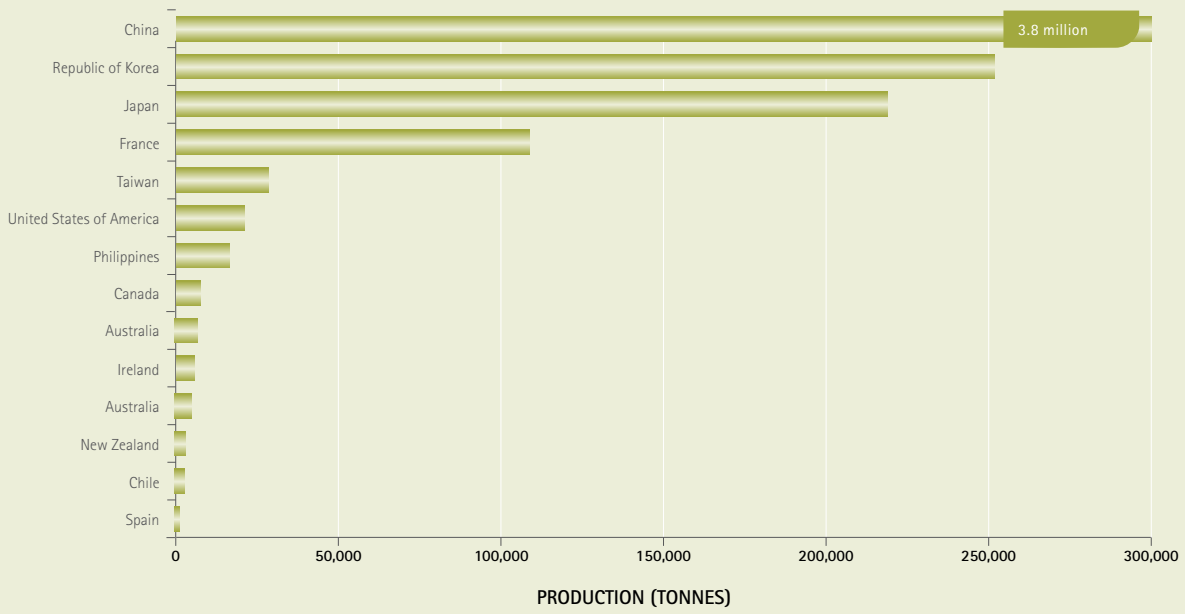
One of New Zealand's leading oyster farming exponents claims New Zealand is "the best country in the world for farming oysters" (Ingram 2005, p 6). The claim is based on New Zealand's position in the sub-Antarctic convergence zone where the cold, nutrient-rich southern ocean waters mix with warm tropical waters to produce high concentrations of phytoplankton[8] and the optimum conditions for growing filter feeding shellfish. These growing conditions, combined with the existence of numerous harbours and inlets and pollution-free coastal waters provide the "ideal environment for oyster farming" (Ingram 2005, p 6).

The native rock oyster had been exploited by licensed picking from natural beds in northern parts of the North Island since the late 1870s, and by licensed marine farming on leased areas of foreshore, following the passing of the Rock Oyster Farming Act 1964. By 1975, 121 oyster leases covered around 650 hectares with an annual rock oyster production of over 500 tonnes.

During the 1970s oyster farmers increasingly farmed Pacific oysters in preference to the native rock oyster because they grow faster, reach a larger size and have several spawnings each year (Figure 23.6). Pacific oysters can be grown to market size within 12–24 months in New Zealand. Discerning markets in Europe, the

8 Phytoplankton are single-celled plants or eaweeds that form the basis of the food chain in the sea.

FIGURE 22.5: TOP 14 OYSTER-PRODUCING COUNTRIES, 2005



Source: Food and Agriculture Organization

United States and Japan offer premiums for half-shell oysters that are uniform in shape, are deeply cupped and have consistently good condition (ie, a good meat volume).

By 1978 the Pacific oyster had invaded all of the oyster farming areas and become the sole commercially exploited oyster species in northern New Zealand, so that by 1984 some 50 oyster farms occupied around 350 hectares of intertidal foreshore and produced about 2000 tonnes annually.

About 236 Pacific oyster farms occupy around 928 hectares, with an annual production of just under 3,000 tonnes. This generates export revenue of NZ$14 million and a further $12 million on the domestic market (www.fish.govt.nz/en-nz/Commercial/Aquaculture/Marine.htm).

FIGURE 22.6: ROCK OYSTER *SACCOSTREA GLOMERATA* (LEFT) AND PACIFIC OYSTER *CRASSOSTREA GIGAS* (RIGHT) OYSTERS

Pacific oysters are farmed in most of the larger embayments on the east coast of the North Island, from Parengarenga Harbour in Northland to Ohiwa Harbour in the Bay of Plenty, and in west coast inlets as far south as Kawhia Harbour. Major concentrations of farms occur in the Parengarenga, Houhora, Raungaunu, Whangaroa and Mahurangi Harbours, in the Bay of Islands, and around the Coromandel Peninsula. The Kaipara Harbour on the west coast is a major spat-catching area. There are also some Pacific oyster farms in the Marlborough Sounds.

There are essentially two situations in which Pacific oysters are farmed in New Zealand. They are grown intertidally or subtidally, but intertidal cultivation is the most common practice.

22.5 INTERTIDAL FARMING

The typical intertidal Pacific oyster farm comprises a series of horizontal racks spread across the gently sloping intertidal zone in a shallow embayment of a harbour or estuary (Figure 23.7).

FIGURE 22.7: INTERTIDAL OYSTER FARM AT LOW TIDE

The substrate is generally a mudflat or muddy sand. Each rack is constructed with two parallel lines of wooden posts driven vertically into the mud, and the tops of the posts are joined in each line horizontally by wooden rails.

Each rack is about 1 metre across and is separated from adjacent racks by several metres, to allow flat-bottomed work barges to move between the racks and to access both sides of each rack.

The oysters are grown either on sticks, which are nailed to the rails across each rack, or in mesh trays or baskets, which are laid across the rack and fixed in position. The arrangement and layout of the racks within the licensed area of the marine farm is designed to achieve maximum use of the space for growing oysters, having regard to the rise and fall of the tide. It should also provide optimum opportunity for efficiently working on the farm when the oysters and the farming structures are out of water during low tide. The ideal positioning of the rack is such that the oysters are just out of the water for a short period at low tide, so only a minimum amount of time is available for inspecting, handling and harvesting the crop and for maintaining the farming structures. Growing oysters at the optimum intertidal level is critical to achieving good growth, managing pests and ensuring favourable farm economics.

Stick culture is the traditional method of growing Pacific oysters in New Zealand (Figure 23.8). The seed, called oyster spat, that are required to stock the farms are caught from the wild, mostly from spat-catching areas in Kaipara Harbour. Bundles of wooden sticks are set out in known spat-catching areas during the summer months. Oyster larvae that are drifting in the water settle onto the sticks within the bundles. The bundles, with their attached oyster spat, are then transferred to oyster farms in other areas. Here, the bundles are 'broken down' and the individual sticks are spaced out at about 150 millimetre intervals along the intertidal racks and nailed into position for ongrowing the oysters.

FIGURE 22.8: BUNDLES OF SPAT STICKS (LEFT) AND STICKS SPREAD OUT ON RACKS (RIGHT)

The bundles of sticks for spat catching are carefully constructed to allow a sufficient flow of water through the bundle to sustain the spat during their early growth. This means that the sticks can be left in bundles and the bundles placed on the racks, if the farmer wishes to slow down the growth of the young oysters by limiting their space and food supply. By controlling the growth rate of the seed, the farmer can have new sticks to put out at intervals throughout the year and can maintain a continuous supply of crop that is reaching the harvest size. Because the oysters on any one stick do not all grow at the same rate, often as a consequence of the marked variation in the number of spat per stick, mesh trays, baskets and bags (or purses) are increasingly used in intertidal Pacific oyster farming. These containers are used to ongrow the oysters that are found to be undersized when first harvested (Figure 23.9).

FIGURE 22.9: OYSTER RACKS (LEFT) AND OYSTER BASKETS (RIGHT)

At harvest, the sticks are removed from the racks and all the oysters are knocked off into bins on the work barge. Either on the barge or ashore, the harvested oysters are sorted and any undersized individuals are put into the mesh containers to be returned for a further period of growth on the racks. The use of ongrowing trays and baskets is estimated to have reduced the overall wastage from up to 50 percent of the crop that was undersized at first harvest to 5 percent.

A recent innovation in intertidal oyster farming in New Zealand has been the use of adjustable longline farming systems, such as the BST system (Figure 23.10) and the SEAPA system (Figure 23.11) (see the two company websites at http://www.bstoysters.com and www.seapa.com.au).

FIGURE 22.10: INTERTIDAL OYSTER FARM USING THE BST LONGLINE SYSTEM

In this alternative to the traditional rack system, baskets or purses are suspended from a single horizontal wire that is attached to a row of vertical wooden posts driven into the substrate. The system is reminiscent of one side of a rack system without the rails. A clip system, which holds the wire onto the posts, allows the wire to be raised or lowered to increase or decrease the period during which the baskets are out of the water, thereby affecting the growth of both the oysters and any fouling organisms growing on the baskets.

A further variation, which is essentially the same as the traditional stick and rack system, sees the horizontal rails joining the tops of the posts replaced by wires, with the baskets or purses slung across between the two wires.

FIGURE 22.11: INTERTIDAL OYSTER FARMS USING DIFFERENT SEAPA LONGLINE SYSTEMS

22.6 SUBTIDAL FARMING

Some Pacific oysters are cultivated subtidally, generally in areas where there is a depth of at least 3 metres of water at low tide. Subtidal culture systems use the longline technology and equipment originally developed in New Zealand for mussel farming. The longline comprises a pair of horizontal ropes supported at intervals by large floats and fixed to the seabed at either end by large mooring blocks or anchors. The oysters are grown on vertical ropes attached at intervals along the length of the backbone of the longline (ie, the horizontal ropes and floats).

Spat catching directly onto growing ropes is uncommon, but with the increasing use of hatcheries for producing Pacific oyster spat, spatted cultch materials (eg, plastic discs, shells or hollow tubes) that can be threaded onto or attached to ropes and then suspended as vertical droppers are more available than in the past. Rope itself may also be used as the settlement substrate for the spat in an oyster hatchery and then hung directly on a longline. However, it is more common for the oysters grown on longlines to be held in stacks of trays or in lantern nets. The attachment mechanisms for some of the basket systems (eg, the SEAPA system) enable them to be also held in stacks for suspension on a longline.

The single oysters used to stock longline trays, nets or baskets may have come from the thinning or harvesting of spat sticks, or may be hatchery-produced cultchless spat. Longline farming tends to be a more mechanised method of farming, because it requires the use of a barge with a winch to enable the farming equipment (eg, the stacks of trays) to be lifted out of the water for inspection, cleaning or harvesting of the crop (Figure 23.12, Figure 23.13).

FIGURE 22.12: OYSTER BARGES SERVICING SUBTIDAL LONGLINE FARMING SYSTEMS

Oysters grown by subtidal farming typically have faster growth, because they are continually submerged, but this results in a thinner shell and a weaker adductor muscle than in intertidally grown oysters. Site-specific problems with mudworm and shell quality can also affect the marketing of subtidally grown oysters, because the most lucrative product form of Pacific oysters for both the export and domestic markets is in the shell, either whole or half-shell.

FIGURE 22.13: OYSTER TRAYS USED ON A SUBTIDAL LONGLINE SYSTEM

Terminology differences between New Zealand and Australia

In New Zealand the word 'longline' is used to describe subtidal oyster farming equipment, based on the typical mussel farming arrangement of a backbone comprising two horizontal lines attached to and suspended from a series of large floats or buoys and anchored at either end.

In Australia the word 'longline' more commonly describes the single horizontal wire or rope attached to a line of vertical posts, as used in intertidal farming, with baskets or aquapurses attached to and suspended from the wire or rope.

22.7 HATCHERY SEED PRODUCTION

In the last 5-10 years, interest in using hatchery-produced seed for oyster farming in New Zealand has increased. Hatchery seed offers the possibility of developing selected market traits, but primarily is favoured because stocking rates and productivity on farms can be controlled more tightly than is possible with the variable seed settlements that occur from wild collection.

Oysters are relatively easy to produce in a hatchery. Broodstock can be conditioned with phytoplankton and elevated water temperature (26oC) over a period of weeks. Spawning is then induced with a temperature and/or salinity shock or, less often, by using chemicals. An individual Pacific oyster can produce millions of eggs. Males and females are spawned separately and the eggs and sperm mixed in carefully measured amounts to ensure optimum fertilisation rates.

The fertilised eggs hatch after 24 hours, and larval rearing runs for 20–25 days. Large larval tanks (up to 25 cubic metres) are used for rearing larvae, which are held at 26°C and fed a mixture of cultured phytoplankton.

When the larvae are ready to settle (Figure 23.14), several options are available. Larvae can be settled onto sticks as used for wild collected larvae or onto various other hard surfaces, generally referred to as cultch, such as fibre cement slats or plastic strips or even rope that can be placed in the larval-rearing tanks. Alternatively, the larvae can be settled onto small less than 1 millimetre) shell fragments, with the aim of producing seed with one spat attached to each shell fragment. Such seed, often called single seed, are generally referred to as 'cultchless' or 'cultchfree' (Figure 23.14). Truly 'cultchless' Pacific oyster seed can also be produced by chemically inducing the spat to undergo the settlement process (metamorphosis) without forming any attachment to the substrate. Cultchless settling techniques produce individual oyster seed that are suited to ongrowing in mesh tray or bag culture.

FIGURE 22.14: LARVAL OYSTER (PEDIVELIGER) WITH FOOT, READY TO SETTLE (LEFT) AND CULTCHLESS SPAT (RIGHT)

22.8 PROCESSING AND MARKETING

The New Zealand Fishing Industry has agreed implementation standards that cover the growing, harvesting, transporting, processing, packaging and storing of farmed oysters (see the New Zealand Food Safety Authority's website at www.nzfsa.govt.nz/ animalproducts/seafood/iais/index.htm).

22.9 WATER QUALITY

Oyster farming is governed by two water quality monitoring programmes. The National Shellfish Sanitation Programme involves microbiological and biochemical testing for possible harmful organisms or products in the growing waters. The New Zealand Shellfish Quality Assurance Programme involves the sampling of sea water for the presence of toxic phytoplankton species and the sampling of mussel flesh for shellfish toxins. These programmes enable the New Zealand oyster farming industry to meet shellfish-growing water quality requirements and the shellfish import quality standards of the world's two major food quality control agencies (the United States Food and Drug Administration and European Commission of the European Union). They also meet the import regulator requirements in New Zealand's major Pacific oyster export markets, such as those of the Japanese Ministry of Health and Welfare and the Australian Quarantine and Inspection Service.

22.10 HARVESTING AND PROCESSING

Pacific oysters are predominantly harvested from June to December when they are in peak condition. After being harvested at the farm, Pacific oysters are washed, sorted (dead ones are removed) and machine graded in a processing facility that is usually situated next to the farm. Major oyster-production companies have their own processing facilities with sophisticated machinery for handling the oysters. Such processing factories are registered and approved with the Ministry of Agriculture and Forestry, and operate under Hazard Analysis Critical Control Point programme conditions. Computerised graders, with size and weight measuring capacity, sort the oysters into up to five grades and reject undersized specimens.

Pacific oysters are marketed live, chilled or frozen and typically are available in four sizes or grades (ie, standard (60–75 millimetres), premium (75–90 millimetres), large (90–105 millimetres) and jumbo (over 105 millimetres)).

The two main product lines are whole and half-shell oysters but other product forms include chilled and frozen meat, smoked product, and prepared meals, oyster pies and soups (Figure 23.15).

For half-shell or meat product, a skilled staff of oyster openers use pneumatic oyster knives to open up to 500 dozen oysters

a day. The half-shell oysters are washed and packed and either chilled for the domestic market or blast-frozen to –40°C for both domestic and export markets.

Frozen half-shell Pacific oysters can be stored at –20°C for at least 18 months, which allows them to be exported to the main markets in South East Asia, Australia, Europe and the United States in freezer containers.

The marketing of Pacific oysters focuses strongly on the clean, green image of aquaculture in New Zealand, and emphasises the natural spat collection, the high-quality continuously monitored growing waters, and the harvesting and processing of naturally safe, fresh shellfish that are free from chemical, microbiological and toxic algal contamination or genetic modification.

FIGURE 22.15: PROCESSED (LEFT) AND UNPROCESSED (RIGHT) PACIFIC OYSTERS

During the late 1990s, five individual companies formed a joint venture oyster marketing company called JEMCO Ltd. The five companies include four of New Zealand's largest and longest-established oyster grower processors, all with extensive farming operations and 90 years' combined experience. JEMCO Ltd represents more than 70 percent of New Zealand's annual oyster production.

22.11 PRODUCTION CONSTRAINTS AND BOTTLENECKS

The principal bottleneck to the expansion of Pacific oyster farming in New Zealand is the availability of suitable intertidal or subtidal sites for establishing new farms. Under the legislative framework, new aquaculture activities can be established only within aquaculture management areas. Around most of the country, these have yet to be defined.

At present, Pacific oysters occur only in the waters in the upper half of the country, and there has been resistance from the Department of Conservation and the Ministry of Fisheries to actively spreading the species further south. However, suitable conditions for Pacific oyster farming do occur widely throughout the South Island. The major constraint on expanding Pacific oyster farming into these areas would be the need for hatchery production to supply adequate quantities of high-quality seed to stock these farms. The economics of farming Pacific oysters, with an expected slower growth rate in cooler southern waters, might be a further constraint.

22.12 SEED SUPPLY

By far, most of the spat supply for New Zealand's oyster farms comes from natural settlement onto artificial collectors (ie, bundles of spatsticks) that have been specifically sited in known oyster settlement areas. The stocking of farms is, therefore, vulnerable to changes in the environmental and seasonal factors that determine the reproduction, larval development and settlement of the Pacific oyster. Limited availability of further reliable spat-catching sites could constrain the supply of spat for a major expansion of the industry.

The alternative source of spat, from hatchery production, has only recently started to develop in New Zealand. Hatchery production is still at a small scale and its expansion is constrained by the need for changes in two factors: the industry's limited use of single-seed production techniques and the industry's predominant philosophy and aim to farm a "completely natural product" grown from "naturally occurring spat selected over many years by nature to grow well and be healthy in our natural environment" (see JEMCO's website at www.oystersnz.com/oysters.html).

22.13 BIOLOGICAL CONSTRAINTS

Biological constraints on the expansion of Pacific oyster farming include problems with mudworms and flatworms (Handley 1997, 2002; Handley and Jeffs 2003) and fouling. Mudworms cause the inside of the oyster shell to blister, which can render the oysters unsuitable for sale in the shell (or, if sold, give the purchasing customer an unpleasant surprise) and can contaminate the meat with anaerobic mud during processing.

Flatworms are oyster predators and parasites that, like mudworms, are more of a problem in subtidal than intertidal oyster farming, because drying out is one of the most effective ways of combating infestations (Handley 2002). Farm management techniques, such as removing old wild oysters from intertidal racks and avoiding overstocking intertidal and subtidal baskets and trays, can minimise the potential for infestations of these unwanted organisms.

The prevention and/or removal the fouling organisms that settle on oyster farming equipment are major factors in farm management and in the economics of oyster farming. The positioning of the racks or lines at the optimal intertidal height is critical for obtaining optimum growth, as well as for

minimising the settlement of competitive fauna, such as mussels, tubeworms, barnacles and feral oysters. Fouling is more of a problem in subtidal farming where the permanently submerged equipment is prone to the settlement of a wide range of organisms, including bivalves, tubeworms and barnacles, as well as sponges, tunicates and seaweed. Subtidal fouling needs to be regularly removed to prevent equipment failure and reduced growth of the oyster crop.

In recent years the increased development of coastal land for housing has raised ecological issues relating to sustainability and water quality. These issues are likely to be major concerns for the potential expansion of Pacific oyster farming in New Zealand. Of particular concern is the risk of sewage pollution, which can render stock unsaleable.

22.14 ECONOMICS OF OYSTER FARMING

The level of income from most New Zealand oyster-farming operations is dictated by the quantity of oysters that can be held at the farm site and the growth rate of those oysters. Producers using stick culture methods find that annual production varies with settlement success. For example, farmers who achieve settlement of around six dozen oysters per stick will make twice as much per hectare of production as farmers who achieve settlement of three dozen oysters per stick.

Based on 2004 figures the annual revenue on a per hectare basis for Pacific oysters is estimated at NZ$35,000, which is similar to green-lipped mussels (trade-marked as Greenshell mussels) at $38,000, but much less than King salmon at $1.35 million (Investment New Zealand 2006, p 16).

22.15 REFERENCES

Handley S. 1997. Optimizing subtidal oyster production, Marlborough Sounds, New Zealand: Spionid polychaete infestations, water depth and spat stunting. *Journal of Shellfish Research* 16(1): 143–150.

Handley S. 2002. Optimizing intertidal Pacific oyster (Thunberg) culture, Houhora Harbour, northern New Zealand. *Aquaculture Research* 33: 1,019–1,030.

Handley S and Jeffs A. 2003. *Assessment of Future Expansion of Pacific Oyster* (Crassostrea gigas) *Farming in Northland.* NIWA Client Report AKL2003-027. Auckland: National Institute of Water and Atmospheric Research. 36 pp. Available at www.niwa.co.nz/ncfa/news_pubs

Ingram K. 2005. Clevedon Coast Oysters are a growing success. *New Zealand Aquaculture* 6: 6–9.

Investment New Zealand (a division of New Zealand Trade and Enterprise). 2006. *Aquaculture in New Zealand.* Wellington: New Zealand Trade and Enterprise. 17 pp. Available at http://www.investmentnz.govt.nz/common/files/ Aquaculture%20 Brochure%20-%20high%20res.pdf

23 ABALONE (PĀUA)

23.1 INTRODUCTION

Abalone, known in New Zealand as pāua, belong to the molluscan genus *Haliotis*. The name *Haliotis* derives from Latin and means sea ear, reflecting the ear-like shape of the abalone shell. Abalone are also known as ear-shells, Venus's ears, muttonfish or muttonshells in Australia, ormer in Jersey and Guernsey and perlemoen in South Africa.

Three species of abalone occur naturally in New Zealand: blackfoot pāua (*Haliotis iris*); yellowfoot pāua (*H. australis*) and whitefoot pāua (H. virginea).

Blackfoot pāua

Blackfoot pāua (*Haliotis iris*) is the largest abalone species found in New Zealand (Figure 24.1). It is most commonly found in shallow waters (less than 6 metres) around mainland New Zealand and the Chatham Islands. These pāua often form large clusters in the sublittoral zone on open, exposed coasts where drift seaweed accumulates and there is good water movement.

Black foot pāua grow to about 180 millimetres in shell length. The legal size for harvesting blackfoot pāua from the wild is 125 millimetres at the widest part of the shell.

FIGURE 23.1: BLACKFOOT PĀUA (*HALIOTIS IRIS*), SHELL (LEFT) AND FOOT (RIGHT)

Yellowfoot pāua

The yellowfoot pāua (*Haliotis australis*) occurs all around the mainland coast. Yellowfoot pāua have a more rounded and less brightly coloured shell than blackfoot pāua, and have a characteristic yellow sole to their foot with a black skirt (Figure 24.2).

Yellowfoot pāua grow to about 110 millimetres in shell length. The legal size for harvesting yellowfoot pāua from the wild is 80 millimetres. These pāua live in similar areas to the blackfoot pāua, but do not form dense clusters, rarely forming groups of more than six. They are more mobile than blackfoot pāua and actively forage for food. They have a greater depth range, with many being found in waters deeper than 20 metres.

Yellowfoot pāua have similar growth rates to the blackfoot pāua but have not been extensively farmed because they are difficult to handle through the hatchery and nursery stages.

FIGURE 23.2: YELLOWFOOT PĀUA (*HALIOTIS AUSTRALIS*)

Whitefoot pāua

The whitefoot pāua (*Haliotis virginea*) has a longitudinally ridged shell surface and a less colourful shell than the blackfoot pāua has. It is characterised by its white foot with a greyish epipodium (Figure 24.3).

Whitefoot pāua grow to about 80 millimetres (although this depends on the subspecies).

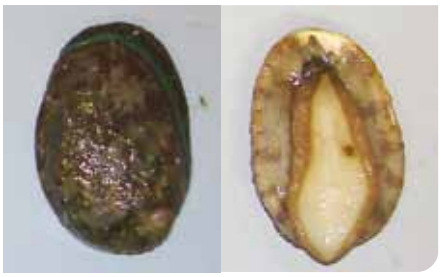
The whitefoot pāua has been subdivided into four subspecies.

- *H. virginea crispata* are up to 40 millimetres long and found in the northern North Island.
- *H. virginea virginea* are 50–75 millimetres long and found in the southern North Island, the South Island and Stewart Island.
- *H. virginea moriora* are up to 70 millimetres long and found in the Chatham Islands.
- *H. virginea huttoni* are up to 80 millimetres long and found in the sub-Antarctic Islands.

Some subspecies are always found living under rocks and boulders (*H. v. crispata* and *H. v. virginea*) and others live on exposed rock surfaces in deep rock pools (*H. v. huttoni*).

The relatively small size of the whitefoot pāua makes them unattractive for farming.

FIGURE 23.3: WHITEFOOT PĀUA (*HALIOTIS VIRGINEA*), SHELL (LEFT) AND FOOT (RIGHT)



23.2 PĀUA LIFE CYCLE

In the wild, pāua are broadcast spawners and fertilisation takes place in the water around the pāua. Fertilised eggs sink to the sea bottom and rapidly develop into free-swimming trochophore larvae. These larvae are planktonic (free swimming) for 7–10 days, which enables them to disperse to areas some distance away from the parent populations.

The trochophore larva rapidly develops into a shelled veliger larva, which develops a foot, an operculum (the covering of the shell opening), eye spots, a mouth and a radula (rasping tongue). The veliger larva is the stage that settles onto the seabed. Veliger larvae settle onto pink encrusting coralline (or Lithothamnion) algae, shed their velum (swimming organ), start to feed and grow the juvenile shell.

FIGURE 23.4: GENERALISED LIFE CYCLE OF PĀUA (APPROXIMATE TIME SPENT IN EACH STAGE)

Source: NIWA

FIGURE 23.5: WORLDWIDE ABALONE PRODUCTION BY COUNTRY, 2004 AND 2005

Source: Food and Agriculture Organization

The small juveniles (less than 5 millimetres in length) live below low tide in 1–2 metres depth. At 5–10 millimetres long the juveniles begin to appear in the intertidal zone under rocks and boulders. The juvenile stage lasts three to five years.

At maturity (about 70–90 millimetres shell length), pāua emerge from under rocks and boulders in the intertidal zone and move into deeper water to begin life on reef surfaces in adult aggregations. (See Figure 24.4.)

23.3 WORLDWIDE ABALONE PRODUCTION

Statistics from the Food and Agriculture Organization show that worldwide farmed abalone production reached around 22,000 tonnes in 2005, with China and Taiwan producing around 19,500 tonnes of this. Korea, South Africa, Australia, the United States and Chile account for most of the remaining production (Figure 24.5).

China and Taiwan rely on low technology, highly labour-intensive pond systems where abalone are fed on wild harvested or farmed seaweed.

South Africa uses land-based, pump-ashore systems that are also highly labour intensive and the abalone are fed on seaweed diets. The South African abalone *Haliotis midae* is one of the most valuable of the farmed species and is in the highest demand.

Australia uses pump-ashore systems that are less labour intensive than the South African systems, and abalone are fed on artificial diets.

Abalone farming in Chile has developed rapidly in the last 10 years. It uses sea-based systems, with production likely to continue to increase.

23.4 NEW ZEALAND PĀUA INDUSTRY

The New Zealand pāua industry has existed since the Fisheries Research Division (NIWA's predecessor) developed hatchery techniques for pāua in the mid-1980s. However, the industry has been slow to establish at scale. Chen (2002) reviewed the industry in 2001 and found 20–22 active farms. Most were still in the growth stage and were aiming to be small (1–2 tonnes) to medium (8–10 tonnes) production enterprises.

Since the 2001 review, most of these farms have ceased to operate. The cause of the demise of these farms varied, but the root causes were probably a mix of under-capitalisation and poor understanding of the ongrowing requirements for this species.

New farms have established since 2001, and industry participation remains at around 12 farms. Most notable of these farms is the OceaNZ Blue venture at NIWA's Bream Bay Aquaculture Park, which is on track to become a 100 tonne production facility by 2010.

Farm production is split between meat, pearl and seed production. Traditionally, farms focusing on meat and seed production were land based and used flow-through technology, but recirculation systems are increasingly being used. Two farms are sea-based and use barrel technology.

Several farms have opted for vertical integration (ie, to incorporate all aspects of production within their business), so are attempting to produce their own seed. The driver behind vertical integration is the perceived high cost of seed obtained from specialist hatcheries.

23.5 HATCHERY PRODUCTION

Broodstock

The breeding biology of pāua is well understood. Pāua spawn in late summer and early autumn when seawater temperatures are falling. Wild broodstock are often used for seed production. Ripe animals are collected from the wild (eg, *Haliotis iris* of at least 125 millimetres shell length) and held in the hatchery until required for spawning. Alternatively, farm-produced broodstock (eg, *H. iris* at over 75 millimetres shell length) can be selected from the farm or purchased from another farm and conditioned in the hatchery.

NIWA has embarked on a breeding program to develop elite broodstock for the New Zealand pāua farming industry.

It is essential that pāua are not cut during collection because they lack a mechanism to clot blood.

Broodstock are maintained on a diet that should be as varied as possible and include seaweed and/or a mixture of manufactured diets.

Spawning

Spawning pāua release their sperm and eggs directly into the surrounding sea water. Legal-sized females can spawn up to 11 million eggs in a season.

In the hatchery, ripe animals can be induced to spawn using chemical stimulation (a mixture of hydrogen peroxide and sodium hydroxide). The eggs are easily collected and fertilised using 70–80 micron mesh screens.

A manual on pāua hatchery techniques is available from NIWA (Tong et al 1992).

Larval culture

The fertilised eggs are placed in a hatch tank where they develop through trochophore larvae into veliger larvae within about 20 hours at 15°C.

The veliger larvae are reared in 500 litre tanks at a density of about six larvae per millilitre of sea water. Pāua larvae have a large amount of yolk, which is sufficient for their development to the settlement stage. This technique for larval rearing can produce a consistent supply of competent post-larvae but depends on the skill and meticulous attention to detail of the hatchery staff, and the hatchery seawater supply must deliver good quality water. High levels of bacteria, rapid changes in salinity and rapid fluctuations in water temperature can be lethal to the larvae.

Settlement

Larval settlement and early post-settlement is the most critical period in the hatchery production of pāua. Mortalities of 90–95 percent are commonplace, but with experience these can be reduced to 40–60 percent.

Settled pāua are grazing animals and the post-larvae need a supply of appropriate food. The first food consists of the extra-cellular (mucous) secretions produced by benthic diatoms (which grow in sheets on a surface rather than floating in the water column) and the bacteria associated with the mucus. As the post-larvae grow they eat the small diatoms. Some species of diatoms produce better post-larval growth and survival.

Settlement tanks require a large surface area to grow the food if large numbers of post-larvae are to survive. For successful settlement, the larvae must be sufficiently well developed and exposed to the appropriate settlement cues. These cues are usually derived from the biofilm, an assemblage of bacteria and diatoms that has been allowed to develop in the settlement tank. Biofilm formation can be enhanced by adding cultured diatoms. The key difficulty after settlement is to control the biofilm to maintain a range of appropriate diatoms in sufficient density to supply the feeding pāua. The biofilm species mix will change naturally with time and the conditions in the tank. It can be manipulated by supplying extra cultured diatoms, controlling the incident light and controlling the grazing pressure.

At three to four weeks, the 1 millimetre long post-larvae change their feeding behaviour and dietary requirements. This is often the period when hatcheries experience the highest mortalities if appropriate species of diatoms are not available. Once the juveniles reach 3–5 millimetres they can be weaned on to seaweeds or manufactured foods for ongrowing.

A variety of specialised tanks have been developed for settlement and early grow-out. Several farmers, both in New Zealand and overseas, use the V-tank NIWA developed. This tank has a triangular cross-section and can be fitted with vertical plates to increase the surface area. The sea water flowing through the tanks maintains the water quality, brings nutrients for diatom growth and, with appropriate filtration, can provide a source of natural diatoms.

Purchasing seed pāua

Purchasing seed pāua is a viable alternative to onsite production. Seed pāua at 10–20 millimetres long (about six months old) have usually been weaned onto a manufactured diet and their future mortality can be expected to be no more than 10 percent. Purchasing seed removes the costs and learning time associated with installing plant, managing broodstock, spawning, and larval rearing and settlement, but it makes the ongrowing farmer

dependent on a hatchery's ability to supply seed. Also, seed pāua are not cheap at around 40 cents each.

Studies by NIWA have shown that around 15 percent of a typical batch of seed are runts that should be culled. This should be allowed for in calculations of seed requirements for stocking a farm. On average, a farmer should allow for 20 percent loss of seed through mortality and the culling of slow growers. When a farmer is purchasing seed, they need to beware of hatcheries that grade seed before sale, because they may end up with runts.

Selective breeding

Selective breeding offers an opportunity to improve population growth rates and enhance desirable characteristics within the stock. The industry has long talked about a selective breeding programme to improve growth rates, but has lacked the cohesion to achieve a meaningful programme. The long lead in time (five to six years between generations) has meant many of the farmers who attempted such a programme went out of business before they could spawn a second generation. OceaNZ Blue and NIWA have secured funding to establish a selective breeding programme based on the use of genetic markers to identify individuals. This allows generation times to be reduced because offspring are selected from the most productive parents at an early stage.

23.6 ONGROWING PĀUA

Tank design

Pāua grow-out systems largely depend on the type of food used and the space available to the farmer. Tank designs must allow for sufficient water flow to meet the metabolic requirements of the animals as well as being accessible for feeding and cleaning. Pāua to be grown on a seaweed diet need a tank that is relatively deep (over 300 millimetres). Ideally, seaweeds are collected fresh and they generally float in the tank, thus acting as both cover and food supply for the grazing pāua. In New Zealand, seaweeds are generally not available in sufficient quantity for a large farm, so most farmers use manufactured diets. Manufactured diets sink, so shallow tanks (100 millimetres or less) are more appropriate.

Space requirements

The area required for a pāua farm is directly related to the density at which the pāua can be stocked within the rearing tanks. Pāua increase in weight exponentially with length, so the stock density (in terms of biomass) increases rapidly as the pāua grow (Table 24.1).

Stock density within a rearing system is normally described as a two-dimensional area measurement (ie, as percentage cover or as biomass per square metre). These two measurements provide the best measures of stock density because they change as the animals grow. Stock density measured as individuals per square metre has a different biomass per square metre, depending on the size of the animals. A guide to stocking densities is in Table 24.1.

On average, farms with a three-year production cycle (selling pāua at 75 millimetres) that are harvesting regularly require around 150 square metres of tank surface area per tonne of pāua produced.

TABLE 23.1: STOCKING DENSITIES FOR PĀUA OF A GIVEN WEIGHT AND LENGTH

LENGTH (MILLIMETRES)	WEIGHT (GRAMS)	INDIVIDUAL AREA (SQUARE MILLIMETRES)	MAXIMUM NUMBER OF PĀUA PER SQUARE METRE	RECOMMENDED STOCKING DENSITY (80% COVERAGE)	BIOMASS AT RECOMMENDED STOCKING DENSITY (GRAMS)
10	0.1	79	12,731	10,185	1,018
15	0.4	177	5,658	4,526	1,811
20	1.0	314	3,183	2,546	2,546
25	1.9	491	2,037	1,630	3,096
35	5.1	962	1,039	831	4,240
40	7.6	1,257	796	637	4,838
50	14.6	1,964	509	407	5,948
55	19.4	2,376	421	337	6,532
60	25.1	2,828	354	283	7,101
65	31.7	3,319	301	241	7,641
70	39.5	3,849	260	208	8,210
75	50.0	4,418	226	181	9,053

Nutrition and feeding

The natural food of juvenile and adult pāua consists of a wide range of seaweeds. Ten tonnes of farmed pāua will consume 100–250 tonnes of seaweed per year. Fresh seaweed to supply a pāua farm is not readily available in New Zealand.

Manufactured pāua foods have been developed and are commercially available. Although relatively expensive, these feeds are convenient to use and store and their nutrient content is more consistent than that of seaweed. The food conversion ratio for manufactured food is around two to one (2 kilograms of food are required to produce 1 kilogram of stock). The stability of the food in sea water appears to be important and may influence the growth rate and food conversion rate. There is some evidence that mixed diets of two or more feeds will sustain greater growth than a single-food diet.

Manufactured diets are not produced in New Zealand. Supplies are obtained from Australia and South Africa. Anecdotal evidence suggests that pāua raised on pellet diets exhibit a lighter foot colour than those reared on seaweed (Figure 24.6). This lighter colour is likely to be preferred on international markets, as evidenced by the routine bleaching of wild caught pāua.

FIGURE 23.6: WILD PĀUA (ON THE LEFT) SHOWING A BLACK FOOT AND FARMED PĀUA (CENTRE AND RIGHT) WITH A LIGHTER FOOT COLOUR

Growth rate

Growth rates from feeding trials are highly variable and are often influenced by the systems used for trial. Differences in the tank design, stocking density, size of pāua, seawater flow, water quality, light, temperature and feeding regimes all influence growth rates. Productive farms aim to achieve an average growth rate of 2 millimetres shell length per month throughout the production cycle.

Water quality

Pāua have evolved to survive in open sea areas, where wave action provides a constant supply of high-quality, well-oxygenated water to the animals. It is important that any system designed to grow pāua delivers high-quality water to the specifications shown in Table 24.2.

Pāua growth rates are sensitive to rearing temperature. At ambient temperatures pāua grow considerably slower in winter than in summer. The optimum rearing temperature is thought to be around 18°C, with the growth rate falling by as much as 10 percent for every degree each side of this optimum.

Pāua are not adept at passing water over their gills, so do not perform well when the water surrounding them is short of oxygen. Pāua-rearing systems, therefore, need to maintain high oxygen levels and move water continuously so it is forced over the gills of the pāua. It has been estimated that each tonne of pāua requires up to 90 cubic metres of water flowing past it each hour to meet its oxygen requirements.

Pāua shell is formed from two forms of calcium carbonate, aragonite and calcite. Aragonite is highly soluble in sea water that has a pH under 7.6. At a low pH the shell erodes, becoming shiny, and the respiratory pores begin to elongate (Figure 24.7). Therefore, it is critical to maintain high pH levels within the system. The level of pH is primarily affected by the level of carbon dioxide dissolved in the sea water.

FIGURE 23.7: EROSION OF PĀUA SHELL RESULTING FROM LOW PH

TABLE 23.2: FACTORS INFLUENCING PĀUA GROWTH

FACTORS	REQUIREMENTS AND IMPACT
Water temperature	Temperature should preferably be stable with minimal daily and annual fluctuations. The preferred temperature range for growth is 13–20°C, with the optimum temperature around 17–19°C. Growth slows appreciably at temperatures below 13°C. Mortalities can occur at temperatures above 24°C.
Water quality	Oxygen levels should be maintained above 85 percent saturation. Salinity should be that of normal sea water (33 parts per thousand). Waste products are ammonia (Total Available Nitrogen less than 1 milligram per litre), nitrite (less than 1 milligram per litre) and nitrate (less than 55 milligram per litre). The pH should be maintained in the range of 7.8–8.2 (if the pH drops below pH 7.7 the pāua shell begins dissolving, particularly in the apex of the spire). Alkalinity should be maintained above 100 mg/l.
Water flow rate	Water flow rates past pāua must be sufficient to maintain the water quality around them. (Pāua live on exposed coasts with good water movement, so this needs to be simulated in tanks.)
Stocking density	Pāua grow faster at lower (rather than higher) densities, but densities must be economic (30–50 percent initial cover and 70–80 percent final cover).
Husbandry techniques	Disturbances caused by activities such as handling and cleaning should be minimised as they can affect growth and survival. Pāua prefer low light levels and can be grown in the dark.
Sediments	Appropriate filtration is required for the site and the life-cycle stages being reared. Larvae and post-larvae are susceptible to fine silts, so 1 micron filtration is recommended. Juveniles are less susceptible to fine silts than are larvae and post-larvae, but are troubled by larger particles.
Biological contamination	Bacterial infections can be controlled by filtration and ultraviolet sterilisation of the sea water. Toxic algae can affect the survival of pāua, but can be controlled by treating incoming water with ozone.
Food types	Pāua eat a range of seaweeds but juveniles generally prefer red seaweeds and adults the larger brown seaweeds. Commercially produced pelleted diets are available that produce good growth rates.
Feeding rates	Feeding rates depend on water temperature and other factors. For manufactured diets, feeding rates are generally around 2 percent body weight per day. For seaweeds, feeding rates are around 10–15 percent body weight per day.
Food accessibility	Food must be easily accessible to the pāua. (The tank design is important, so the pāua and the food are close to each other.)
Stress	Pāua are good indicators of water quality, so it is important to observe their behaviour. Signs that a water parameter is causing pāua stress include the pāua crawling out of tanks, being lethargic, hanging out of their shell, having poor adhesion to surfaces, losing their righting reflex and their appetite.

Ongrowing systems

Traditionally, pāua have been cultured in flow-through systems where sea water is pumped ashore, filtered, then passed over the stock and allowed to return to the sea. These systems offer little opportunity to control the temperature or the quality of the water for rearing the stock.

Over the past decade, the industry has started to use recirculation for pāua farming. Recirculating aquaculture systems are often described as closed systems because the same water is used many times, with the water being treated by mechanical and biological means between each use. However, most recirculation systems are semi-closed systems that require regular additions of new water (10–15 percent per day) to prevent the build-up of toxins and significant changes in the chemistry of the water within the system.

The two great advantages of recirculation systems are that they:

- enable the water quality within the system to be controlled and the water in the system to be efficiently heated or cooled
- can be sited on almost any piece of coastal land, and have relatively low water requirements, so the quality of the incoming water can be controlled by water treatment, which effectively isolates the stock from ambient water conditions.

Recirculation systems are generally cheaper to operate than flow-through systems, but they are considerably more expensive to construct.

The greatest disadvantage of recirculation systems relates to the difficulty in treating disease outbreaks. Most bacterial and parasitic infections require chemical treatment, which affects the functioning of the biofilter, and the biofilter itself may act as a reservoir for disease entering the system. Risk management and biosecurity strategies are, therefore, critical in recirculation systems.

23.7 LEGISLATION

Recent changes in legislation, as a consequence of the Aquaculture Reform Act 2004, require all marine farms to be within designated aquaculture management areas (AMAs). Onshore aquaculture facilities, whether freshwater or marine, are covered by the Freshwater Fish Farming Regulations 1983, which require the facility to have resource consent from the regional council and a freshwater fish farming permit from the Ministry of Fisheries.

Obtaining consent can be a relatively long and costly exercise. The Resource Management Act 1991 requires a written application to the local regional council. This application must include detailed information on the location of the proposed site, the type of activity to be carried out, the types of consent required, an assessment of the effect that the activity may have on the environment and any other information specified by the local regional plan. The regional plan generally entails an assessment of the effect of the activity on the wider community in social, economic and cultural senses. The council must notify the public and all other parties that may be affected by the proposed activity. This generally involves other government departments (eg, the Department of Conservation and Ministry of Health), other national groups (eg, the Royal Forest and Bird Protection Society of New Zealand), and the local Acclimatisation Society, the local iwi, and any neighbours who might be affected by the aquaculture development.

Written application is made to the Ministry of Fisheries for the freshwater farming permit for the species to be farmed. Securing this permit depends on a successful application for consent under the Resource Management Act 1991.

The regional councils and the Ministry of Fisheries have set fees for the various consents. The applicant is also responsible for all other legal costs that may result from objections to the proposed activity.

23.8 PRODUCTION CONSTRAINTS AND BOTTLENECKS

Probably the greatest issue facing the pāua industry at present is the continued low level of production. Total production from the New Zealand industry stands at around 1–2 tonnes per year, produced from about three of the smaller farms, but this is set to increase significantly as production from the OceaNZ Blue facility comes onstream.

It is hard to envisage that the industry will make any significant move forward or will attract any significant level of new investment until some of the existing farms produce a reasonable quantity of pāua for sale. Until production levels increase the industry is forced to rely on the small domestic market and to sell sporadically into export markets. It is a challenge to the industry to achieve a realistic price and to maintain product quality during this period. If all the farms in operation at the moment meet their production estimates, the industry could expect to be producing 200 tonnes by 2010. However, the history of the industry suggests caution is required in making this estimate.

Information from the pāua farming industry indicates that the market price for whole, farmed, 75 millimetre (50 gram) abalone is around NZ$60 per kilogram (or $3 per animal), but the export market will pay more for animals of around 95 millimetres

shell length (100 grams). Higher prices have been obtained by individual farmers accessing the local restaurant market, but this is unlikely to be sustainable at the predicted production levels.

Another challenge facing the industry is to agree on a production technology that works. There are nearly as many system designs as there are farms. NIWA has made advances in identifying the water quality requirements and how to control them, but ongrowing technologies, in terms of tray design and husbandry best practice, have yet to be defined.

23.9 SEED

The total seed production capacity in New Zealand in 2008 is around 4 million seeds per year. About half of this comes from the OceaNZ Blue hatchery and is used to supply the company's own needs.

Several new entrants to the industry are hatchery facilities rather than grow-out units for meat production. This is probably due to the more rapid return envisaged from seed sales (six to eight months) compared with meat sales (three to four years). However, seed production is a difficult process and it remains to be seen how many of these farms will be viable.

Estimates of production indicate that 6–7 million seeds are required for the industry to reach 200 tonnes of annual production. The existing seed-production facilities can probably raise production to meet this demand, but there may also be additional demand for seed to enhance wild pāua stocks.

23.10 PEARLS

A recent up-turn in the demand for pāua pearls, based on a sustained marketing strategy by the largest producer, Eyris Blue Pearls, has seen renewed interest in production from this sector (Figure 24.8).

Pearl production is usually based on implanting pearls in wild harvested stock or in large (more than 75 millimetre) farmed individuals. The production of good quality pearls relies on pāua feeding on seaweed, so access to ample, reliable, high-quality seaweed is essential for pearl ventures.

FIGURE 23.8: PĀUA PEARL IN SHELL (LEFT) AND MADE INTO JEWELLERY (RIGHT)

23.11 ECONOMICS OF PĀUA FARMING

Pāua are one of New Zealand's most commercially valuable shellfish species. Despite this high value it is not easy to make money farming pāua. Slow growth rates and high water quality requirements translate to high production costs, so a considerable amount of money is tied up in infrastructure and working capital before any income is realised. A failure to appreciate the true costs associated with pāua farming has been the downfall of many pāua farms in New Zealand.

NIWA has produced a cost model that provides an indication of the costs and returns associated with pāua production.

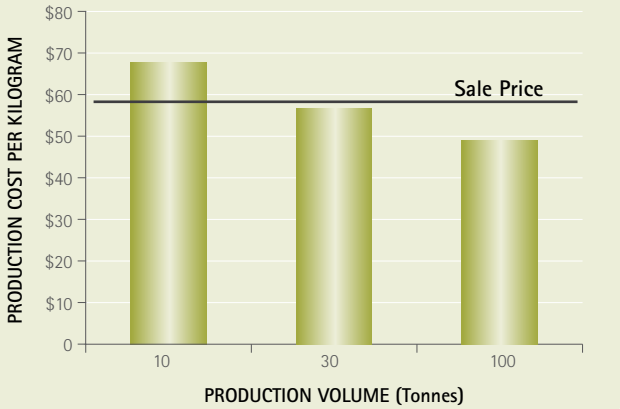
Limitations of NIWA's cost model

The figures from NIWA's model are intended as a guide only and are likely to vary with the individual circumstances of each farm. They indicate the level of investment required to establish a viable farm under current best estimates of production costs.

Cost of production

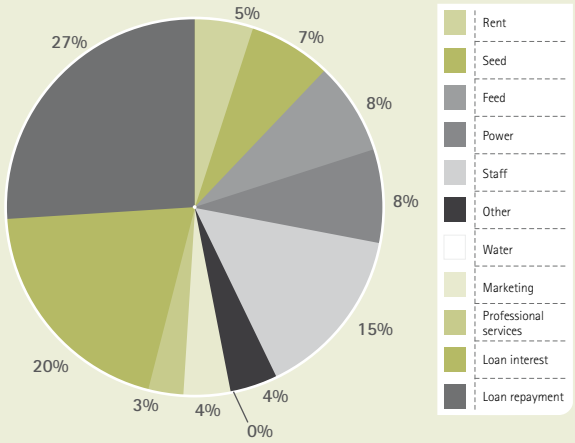
The cost of production is largely related to the size of the farm. Generally, in aquaculture, the larger the farm, the lower the unit cost of production. Figure 24.9 shows that for a 10 tonne farm, the cost of production is above the potential sales price, so the farm is unlikely to be sustainable, whereas for a 30 tonne farm, and even more so for a 100 tonne farm, the cost of production is below the sales price, which allows a margin for profit.

FIGURE 23.9: COST OF PRODUCTION AND ESTIMATED SALES PRICE (RED LINE) FOR PĀUA FARMS AT DIFFERENT LEVELS OF PRODUCTION



When the cost of production is considered in more detail (Figure 24.10), it can be seen that a large proportion (47 percent) of the cost is tied up in repaying the loans on infrastructure and working capital expenditure required to sustain the farm until first sale. The remaining costs are the annual operating expenditure, of which labour, electricity, feed and seed account for 38 percent of the production cost.

23.10: PRODUCTION COST COMPONENTS FOR A 30 TONNES PER YEAR PĀUA PRODUCTION UNIT IN FULL PRODUCTION



The model of production costs can also estimate the overall investment required to develop a farm to the point where sales income more than meets production costs. NIWA believes that a 30 tonne farm is the smallest scale at which this can be achieved. This size farm is likely to cost around $5 million to establish ($2 million for infrastructure and $3 million in operating costs). After four years of production, a farm at this level should have annual sales of around $1.8 million.

23.12 REFERENCES

Chen G. 2002. A survey on water and system performance of abalone aquaculture in New Zealand. In P Redfearn (ed) *Proceedings of the New Zealand Abalone Farmers Association Conference and Annual General Meeting, 26–27 October 2001*, pp 19–33. Wellington: New Zealand Abalone Farmers Association.

Tong L, Moss G, Redfearn P and Illingworth J. 1992. *A Manual of Techniques for Culturing Pāua*, Haliotis iris, *through to the Early Juvenile Stage*. New Zealand Fisheries Technical Report 31. Wellington: Ministry of Fisheries. 21 pp.

24 YELLOWTAIL KINGFISH (KAHU, HAKU)

24.1 INTRODUCTION

Fish of the genus *Seriola* are important recreational and commercial fish and are the basis of important aquaculture industries internationally. One of the most valuable species, *S. lalandi* or yellowtail kingfish (kahu and haku) is found all round the world in subtropical waters over reefs, and around islands and offshore shallow seamounts in depths of up to 200 metres. Kingfish are divided into three subspecies that are geographically separated: the California yellowtail (*S. lalandi dorsalis*); Asian yellowtail (*S. lalandi aureovittata*) and southern yellowtail (*S. lalandi lalandi*). In New Zealand, kingfish are common in the waters around the northern half of the North Island but also occur further south from the Kermadec Islands to Foveaux Strait (from 29°S to 46°S).

Yellowtail kingfish can reach 2.5 metres in length and weigh as much as 70 kilograms (see the example in Figure 25.1). Kingfish are carnivorous. They prey on other fish species and chase down prey singly or, more commonly, in large shoals of up to several thousand kingfish.

FIGURE 24.1: BROODSTOCK YELLOWTAIL KINGFISH

24.2 KINGFISH LIFE CYCLE

Tank-based video footage reveals that two to three hours before spawning the female kingfish is followed closely by at least one male. Minutes before she releases the eggs and the spawning event occurs, additional males may pursue the female. The spawning event culminates in rapid circular swimming, with the female and males releasing eggs and sperm simultaneously. Kingfish produce up to 1 million eggs at each spawning and may spawn 15–20 times in a season. Fertilised eggs float, while those that are unfertilised, damaged or over-ripe sink. The eggs float in the upper layers of the water column, but are difficult to see because they are transparent. Cell divisions begin two hours after fertilisation, and development rapidly progresses to produce a visible embryo that is ready to hatch in four days.

The embryo hatches at a relatively undeveloped state as a yolk-sac larva, which is characterised by a large unpigmented eye and a sizable yolk-sac attached to the bottom of the larva. The yolk-sac contains nutrients supplied by the female and sustains the larva in a non-feeding state while it develops.

After nine days, the larva's eye has pigmented and the jaw has developed enough to open. At this point, larvae are called 'first-feeding larvae' and they begin to actively chase and consume plankton. Under controlled aquaculture conditions, live feed is produced artificially and supplied to the first-feeding larvae. The natural diet of kingfish larvae is almost exclusively planktonic crustaceans, particularly copepods.

By 42 days after hatching, the kingfish are no longer considered to be larvae and have developed cryptic colouration in the form of vertical stripes along the sides of their body. This colouration pattern is thought to provide the fish with camouflage, because young fish are often found around floating weed mats.

By 74 days after hatching, the cryptic colouration has gone and the animal, although small at around 5 grams, is nevertheless

recognisable as a kingfish. It is now called a juvenile or fingerling (Figure 25.2).

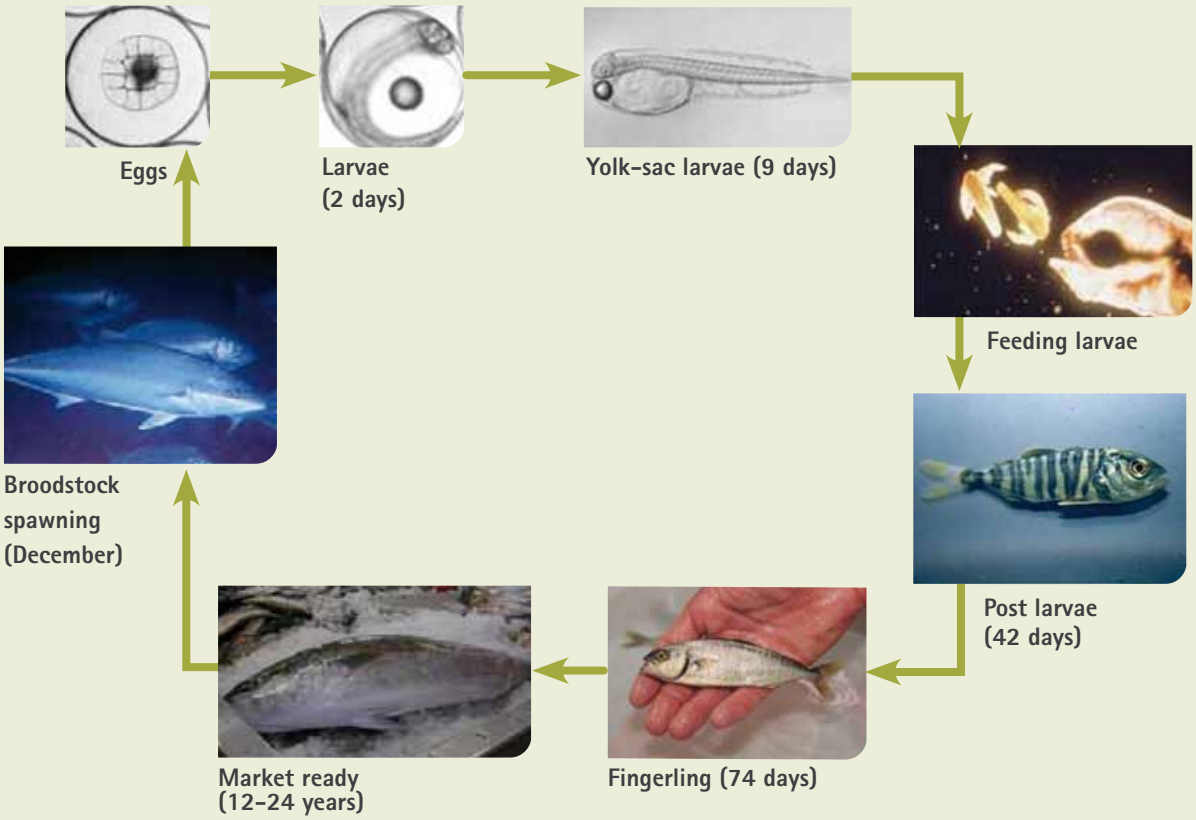
In the wild, juvenile kingfish are strictly pelagic (ie, they inhabit the upper layers of open sea) and travel in schools. Small juveniles are often found near clumps of floating seaweed, while sub-adults tend to school with other small pelagic fish species. Intermediate and adult kingfish primarily feed on other schooling fish (eg, pilchard, koheru and kahawai), squid and crustaceans, and they generally hunt in packs, which shows that there is a high degree of co-operation between the hunters.

Some of the *Seriola* species are migratory, with migration patterns being influenced by water temperature and the sexual maturity of the fish. No consistent migration patterns have been shown for the southern yellowtail *S. lalandi lalandi*. Tag–recapture[9] studies frequently report identical positions of release and recapture, even after the fish has had a long period at liberty, suggesting that New Zealand kingfish may be susceptible to localised depletion by target fishing. However, a small number of kingfish move large distances (more than 2,000 kilometres) from the site of release.

Kingfish show rapid growth, especially in the first few years. However, no estimates of New Zealand kingfish growth rates based on an analysis of skeletal structures such as otoliths or vertebrae have been published. However, estimates from length-increment data from a gamefish tagging programme, together with data generated by NIWA, suggest kingfish can grow from a 5 gram fingerling to over 3 kilograms during a 12-month period.

Kingfish, once mature, spawn between October and January. NIWA studies have reported that the smallest size at which females are sexually mature is 780 millimetres length, with 50 percent reaching sexual maturity at 940 millimetres and 100 percent at 1.28 metres. The smallest size at which males are sexually mature is 750 millimetres, with 50 percent reaching sexual maturity at 810 millimetres and 100 percent at 930 millimetres length. An earlier study on New Zealand populations of kingfish, reported sexual maturity at between 580 and 670 millimetres, with all fish mature by 700 millimetres (Poortenaar et al 2001)

FIGURE 24.2: GENERALISED LIFE CYCLE OF KINGFISH (APPROXIMATE TIME SPENT IN EACH STAGE)



Source: NIWA

9 Tag release studies aim to estimate fish stocks or detect movement patterns by tracking individual fish with tags. Tags vary in sophistication depending on the objectives of the study, however in its simplest form tags are simply labels which are attached to fish and provide information for the capturer to contribute details of the fish and where it was caught to the research provider.

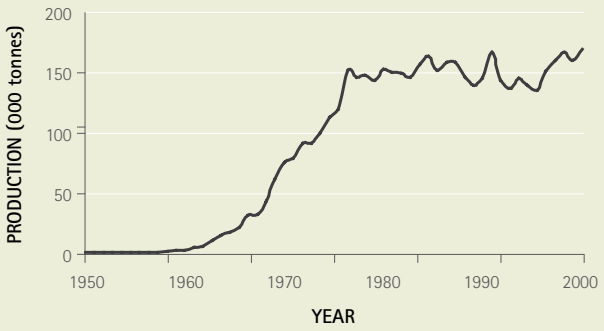
24.3 WORLDWIDE KINGFISH PRODUCTION

Most of the estimated 173,000 tonnes (Figure 25.3) of farmed kingfish produced globally is produced in Japan. Historically, Japanese farmers relied on wild-caught juveniles to stock their farms, but they are now switching to hatchery production.

Australia produces about 3,000 tonnes of kingfish annually, predominantly for its domestic market, although export sales have increased markedly in recent years.

New Zealand has no commercial quota for kingfish, with annual landings over the past 10 years being 250–400 tonnes.

FIGURE 24.3: WORLD PRODUCTION OF FARMED KINGFISH, 1950–2005



Source: FAO 2007

24.4 NEW ZEALAND KINGFISH INDUSTRY

Research on kingfish was initiated in New Zealand because internationally wild harvests of fish were, and continue to be, characterised by a decline in high-value species and increased landings of low-value species. An international shortage of high-quality pelagic fish species remains.

Since the advent of New Zealand's quota management system, harvest levels for some species have been halved and commercial fishing companies cannot satisfy demand from overseas markets (of about 2 million tonnes per year) for premium quality pelagic fish. Kingfish aquaculture would provide an opportunity for New Zealand to meet some of the international demand, especially given the value-added benefits of a cultured product over wild products (eg, guaranteed quality, supply and specifications such as to meet cultural and presentation preferences).

The specific aquaculture attributes of kingfish include its:

- high quality and high value (ie, it is a sashimi-grade fish in Japan)
- diverse range of end-products (eg, whole, fillets, steaks, sushi and sashimi)
- significant and diverse market opportunities internationally
- being a high-quality pelagic finfish species that is in short supply internationally
- limited supply internationally
- amenability to culture conditions
- fast growth rate
- being a traditional food source for Māori
- ability to provide opportunities for coastal iwi to get involved in commercial kingfish aquaculture to enhance economic wealth and employment opportunities for Māori in rural areas
- having no commercial quota, so commercial catches are small, seasonal and unpredictable (300 tonnes per year) (which means aquaculture could guarantee supply of this premium quality product)
- potentially being a lucrative industry (on the basis of preliminary economic models), with bright prospects as the culture technology improves.

NIWA, along with its commercial partner at the time, Moana Pacific Ltd, embraced these attributes and began a project to evaluate the aquaculture potential of *S. lalandi*. Research to develop hatchery production technology for kingfish was initiated in 1999 at Moana Pacific's experimental hatchery at Pah Farm, Kawau Island. Important breakthroughs were made at this site, but it was soon realised that the location and water quality were not going to be suitable for establishing a commercial hatchery operation. In response to this, NIWA searched for a suitable location and identified and committed to the construction of a warm-water aquaculture research facility in Bream Bay, the Bream Bay Aquaculture Park. Broodstock were transported to the park in 2003, and by 2005 the project had succeeded in closing the kingfish production cycle and produced the first batches of kingfish fingerlings to supply to commercial clients.

24.5 PRODUCTION TECHNIQUES FOR KINGFISH

The principles of kingfish production are much like those of any commercial finfish production operation and can be split into two discrete production sections: hatchery and ongrowing.

Commonly, one marine hatchery is used to service several ongrowing operations. The systems required are always land based and complex to cover the broad range of life stages and the varied husbandry requirements of kingfish. The hatchery stage of production encompasses broodstock conditioning and the generation of seed (eggs and sperm) through the early life stages to the production of fish of suitable size (fingerlings) to be transferred for ongrowing.

Ongrowing operations are large and usually marine based, with fish held in groups of sea-cages where the animals are fed and maintained until they reach a marketable size and can be harvested.

24.6 HATCHERY PRODUCTION

Hatchery production is usually divided into five stages associated with:

- broodstock
- egg and yolk-sac larvae
- larvae to fingerling
- algal culture
- live-feed culture.

Broodstock

Broodstock are the cornerstone of any hatchery because they provide the seedstock, so determine the success of the operation. Any broodstock quality issues will radically affect the success and viability of the entire operation. Hence, emphasis is placed on the careful selection of broodstock and the husbandry thereafter to maximise egg yields and egg quality. Kingfish are encouraged to spawn naturally (unlike salmon).

NIWA has embarked on a breeding program to develop elite broodstock for the New Zealand kingfish farming industry.

NIWA's Bream Bay Aquaculture Park can produce up to 600,000 kingfish fingerlings per year and can spread this production throughout much of the year. The facility holds two kingfish broodstocks, with a third to be established during 2007–08.

Kingfish spawn naturally from early December to late January in the waters around the North Island. However, kingfish ongrowing facilities, like every other established marine finfish enterprise, need to be able to stock and harvest fish all year, so need fingerlings to be produced outside the natural spawning season. A controlled seed supply enables the farmer to supply product for market throughout much of the year, without being restricted to the natural breeding cycle of kingfish.

NIWA can facilitate year-round production of kingfish fingerlings by manipulating the holding environment of its three broodstocks by changing the light and temperature regime experienced by each group of broodstock. One group of broodstock is maintained on a light and temperature regime that mimics ambient light and temperature, so spawns at the same time as do wild populations at the same latitude as Bream Bay. The control of this 'natural broodstock' is required so that the vagaries of short-term weather change do not influence the spawning of this stock. The two other broodstocks are held under light and temperature regimes that fool the stock into thinking that they are in different seasons, so induce the adults in one group to begin spawning in August and in the other group in March.

The holding system for each kingfish broodstock consists of one 70 tonne cylindrical tank housed in a light- and temperature-controlled room. The tank contains an approximate ratio of two males to one female. Lights are computer controlled to accurately mimic a chosen season. Broodstock are fed a diet of human-grade squid and pilchards enriched with beneficial oils, vitamins and minerals to further encourage good spawning (Figure 25.4).

FIGURE 24.4: FRESH SQUID BEING INJECTED WITH A BROODSTOCK OIL, VITAMIN AND MINERAL MIX

NIWA research on broodstock is ongoing and focuses on optimising broodstock feed and selective breeding to identify traits that will benefit and support the development of the industry (such as fast growth, disease resistance and slow maturation).

Egg and yolk-sac larvae

Once the eggs have been naturally spawned and fertilised in the broodstock tanks they must be removed for controlled incubation. This allows the eggs to be disinfected, the batch quality to be assessed and the incubation environment to be optimised to engender successful development and hatching.

Egg collection

Egg-collection apparatus is installed within the broodstock tank before the expected onset of spawning. The system comprises a section of 100 millimetre PVC pipe, spanning half the diameter of the tank. The pipe is slotted on one side and skims the top 30 millimetres depth of water in the tank, facilitating the removal of floating eggs.

The surface-skimming pipe is connected to a partially submerged 70 litre cylindro-conical tank, which is the egg collector. Water is airlifted from the collector, which creates a current that draws eggs through the surface-skimming pipe to be retained within the collector. Once the air supply is turned off and the pipe is capped, the eggs can be harvested from the collector.

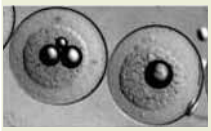
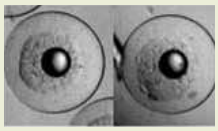
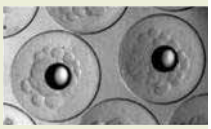
Viable eggs are buoyant and float at the water's surface where a jug can be used to skim them off the water. They are then

gently transferred to a bucket containing a few litres of sea water. Before being transferred to the egg-incubation room, the eggs are disinfected. Gentle aeration using an air stone is maintained during the disinfection procedure.

Egg-quality assessment

The method of egg collection explained above, roughly separates the viable and non-viable eggs. However, a more rigorous assessment of egg quality is required so effort and incubation system capacity are not wasted on eggs of suboptimal quality. This is achieved by characterising the early cell divisions of the floating eggs, using criteria developed for Atlantic halibut eggs and adapted for kingfish. This assessment technique involves sampling eggs during the early stages of cell cleavage (two to ten hours after fertilisation) and observing them under a microscope. Eggs are scored against a predetermined scale of 1–4 for five types of cell division abnormality, thus providing a cumulative score of out of 20 for egg quality. Only those egg batches with a cumulative score greater than 15 are deemed of sufficiently good quality to incubate (Figure 25.5).

FIGURE 24.5: GOOD, MODERATE AND POOR CELL DIVISION IN KINGFISH EGGS AT THE EARLY BLASTULAR STAGE (NINE HOURS AFTER FERTILISATION)

GOOD CELL DIVISION	MODERATE CELL DIVISION	POOR CELL DIVISION
		
• Evenly shaped cell mass • Evenly shaped and sized cells • Often more advanced than poorer eggs	• Unevenly shaped cell mass • Some unevenly shaped and sized cells • Some indistinct cell margins	• Unevenly shaped cell mass • Unevenly shaped and sized cells • Indistinct cell margins • Slower developmental rate

Source: NIWA

Egg incubation

Eggs are incubated in 200 litre cylindrical, fibreglass tanks with conical bases. Water supplied to the incubators is 1 micron filtered, ultraviolet (UV) treated and maintained at 17oC. Water inlets are configured to create an upwelling current from the base of the tank. Aeration is provided through an open-ended airline positioned below the outlet screen that delivers sufficient air to clear the screen and maintain suitable circulation in the tank. During the incubation period, the tanks are regularly checked to ensure they have optimum water flow and aeration. Dead eggs, which become negatively buoyant and sink to the bottom, are removed daily, either by siphoning or by opening the base valve to allow the dead eggs to be collected.

Hatching is complete three days after the yolk-sac larvae have discarded the egg shell.

Yolk-sac larvae are maintained in the same system for a further two days (and remain non-feeding, existing solely on the maternally derived yolk), then they are stocked into the larval-rearing system to complete development (until the mouth-opening stage) into larvae capable of feeding externally on live prey, which occurs one day later.

Larvae to fingerling

The larvae to fingerling stage of the hatchery production cycle is the most complicated stage. Pre-feeding yolk-sac larvae are stocked into the larval system so that feeding can be initiated immediately. The larvae initially feed on live feeds then progress through a transition process (known as weaning) where the larvae are trained to take artificial manufactured feeds. The weaned larvae are then reared to a suitable size for sale or transfer to ongrowing facilities as fingerlings.

The newly hatched larvae are stocked into larval-rearing tanks at 50 larvae per litre and maintained under static culture conditions for two days in filtered water to which the green alga *Nannochlorus* has been added. After two days, a gentle flow of filtered and UV-sterilised sea water is introduced to the tank.

From this point, all development stages are characterised as 'days post-hatching (dph)'. At 2 dph, yolk-sac larvae are introduced to the tanks. At 3 dph, the larvae's mouth opens and they begin to feed on the available rotifers (minute multicellular aquatic animals). At 9 dph, enriched *Artemia salina* (brine shrimp) are added to the tank and rotifers are phased out. By 17 dph, the larvae are feeding on their greatest amount of *Artemia*, which coincides with the introduction of artificially manufactured feeds to begin the transition from live to inert feeds. Rotifers are phased out at 19 dph and the larvae are fully weaned onto inert feeds by 35 dph.

During the larval-rearing process the fish are graded twice: once at 27 dph to reduce the incidence of cannibalism, which is known to be a significant problem at this stage; and once at 45 dph, so that size disparity can be reduced and feeding protocols optimised for the two cohorts produced by the grading process.

By 74 dph the fish have reached the fingerling stage (5 grams) and are ready for transport to sea-cages for the ongrowing stage of the production cycle (Figure 25.6).

FIGURE 24.6: KINGFISH FINGERLINGS READY FOR TRANSFER TO ONGROWING FACILITY.

Algal culture

Microalgae are an essential component of kingfish larval culture. They are the 'green' in the 'static green water larval culture technique' that has been successfully adopted at NIWA's Bream Bay Aquaculture Park.

The function of the algae is not entirely known, but it is thought to be a combination of maintaining rotifer live-feed quality, providing contrast to enhance prey capture, supplying trace elements and minerals, stimulating or initiating gut activity and maintaining the water quality and rearing environment.

Live-feed culture

All commercial species of marine finfish, including kingfish, require a live-feed stage during their early larval development. The live feeds of choice for most hatcheries are rotifers (*Branchionus plicatilis*) of around 80 microns in size and the brackish water crustacean *Artemia salina* or brine shrimp of about 240 microns in size. Initially, kingfish feed on the smaller rotifers but they soon grow to be able to feed on the early instars[10] of *Artemia*.

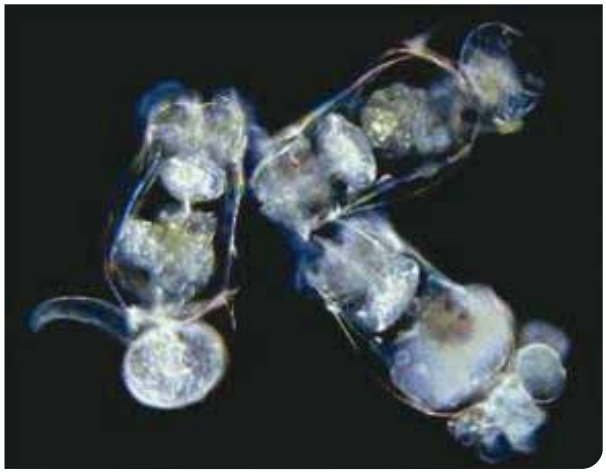
Both live feeds retain nutrients and can be enriched with mixtures containing large amounts of polyunsaturated fatty acids, such as DHA, which larval fish in particular require in large amounts to grow and develop normally.

Rotifers

Rotifers are small bell-shaped animals (Figure 25.7) that can be grown under a four-day batch culture technique from stock cultures of rotifers maintained at NIWA's Bream Bay facility.

The main feed for rotifers is a proprietary product called Culture Selco High Density (from the aquaculture supplies company INVE in Belgium), which supplies complete nutrition for the rotifers. On the last day of the four-day production cycle, half of the rotifers are enriched (with a proprietary product from INVE, Rotiselco-Alg, which is high in DHA) and the other half is transferred to be the stock culture for the next four-day production cycle.

FIGURE 24.7: ROTIFERS (LENGTH 80 MICRONS)



Artemia

Artemia possess the unusual trait of being able to produce over-wintering cysts that are a dormant life stage. These cysts can be collected from the wild and are predominantly sourced from the Great Salt Lakes in Utah, United States. The cysts are dried, packed into tins in 500 gram lots and sold predominantly for use in aquaculture.

When *Artemia* are required for larval rearing, the cysts are placed into 1 micron filtered, UV-sterilised sea water at 28–30°C in a purpose-built, temperature-controlled room held at 30°C. Because of the temperature of the culture media and the xenic[11] nature of the *Artemia* (and the variable success of hatching and occurrence of crashes[12]), Hatch Controller, a proprietary product of INVE, is used to control the microbial environment and increase the reliability of hatching. Around 20 hours later, the *Artemia*, hatched, washed and separated from their cyst shell, are separated into four to six batches (depending on the feeding regime). These batches are transferred to 1,300 litre cylindro-conical tanks to be enriched with nutrients, using a proprietary product Super HUFA (Salt Creek, United States). The following morning, after an overnight enrichment period, one batch of *Artemia* is fed to the fish larvae immediately, with the remainder

10 The instar is one stage between moults in the larval development cycle of the brine shrimp.

11 Xenic denotes the presence of contaminating bacteria.

12 Crashes are catastrophic failures of the culture system.

paced in a chiller unit and held at 40°C to be fed out at intervals during the day to provide the larvae with regular food freshly enriched with nutrients. The total culture time from cyst to enriched *Artemia* nauplii is around 36 hours (Figure 25.8).

FIGURE 24.8: *ARTEMIA SALINA* NAUPLIUS (250 MICRONS) FOR FEEDING TO KINGFISH LARVAE

24.7 ONGROWING

In Australia and Japan, kingfish are cultured in large numbers using only sea-based techniques to raise the fish to a marketable size. Indeed, sea-based culture is the predominant technique for most marine finfish culture operations.

The reason for the prevalence of sea-based ongrowing has been primarily economic: land-based systems have been considered too expensive compared with sea-based systems. Of course there are notable exceptions, for example, turbot culture. Land-based culture was chosen for turbot because turbot have a bottom-dwelling habit that makes them intolerant of the instability inherent in the sea-cage environment. Turbot held in tanks will, most of the time, remain on the bottom of the tank, stacked several deep at densities providing up to 250 percent coverage of the tank bottom, and only showing significant movement when food is introduced. Turbot held in sea-cages consistently underperform because of the constant movement of the base of the cage, which disturbs the turbot and physically damages them.

The development of land-based systems for many different types of finfish is gaining in popularity. For example, a lot of producers of red seabream, sea bass and bream in the Red Sea are being forced to consider land-based systems, at least in part, because of the risk to sea operations caused by higher levels of pollution, due to the proliferation of tourism, and the changing global environment.

Also, high capital costs, limited production capacity, energy requirements and the associated greenhouse gas footprint which accompanies these energy requirements are likely to limit land based development to juvenile production or the production of species with specific rearing requirements.

In New Zealand, the major risk to sea-cage fish farming comes not from pollution or the environment but from legislation and the ongoing uncertainty over the allocation of marine space for sea-cage culture.

NIWA has no direct experience of the sea-based cage culture of kingfish. However, the technology and techniques required to culture finfish in sea-based operations are well-developed globally. Systems have been developed and are used by industry that can be deployed in even the most exposed areas of the ocean.

Although technology for the sea-cage culture of a wide range of species abounds and will be applicable to kingfish, how kingfish will be farmed at sea in New Zealand waters is yet to be determined.

The eight key areas needing research before a sustainable kingfish cage culture can be developed in New Zealand are as follows.

- *Environmental impact*: An initial and ongoing assessment of sites to minimise the impacts on benthic (bottom dwelling) flora and fauna.
- *Growth performance*: Of paramount importance to the economic feasibility of any farm operation is the growth per unit of feed given to the fish. Significant work needs to be carried out to determine the optimum feeding levels for obtaining the best growth rates and product quality for the investment in feed. It is important to optimise feed rates because feed costs are around 35–40 percent of the total cost of producing a kingfish.
- *Density*: The density at which the fish can be cultured is of direct relevance to the economics of running a cage-farming site. Too high a density and crowding may mean some fish do not get enough to eat and/or the interactions between fish may physically affect the stock, either or both of which can cause the overall stock performance to be compromised.
- *Health (preventing and treating disease)*: Traditionally, disease remediation has been achieved by good stock management (ie, maintaining feeding and density at optimal levels) and good site management (ie, regularly moving cages to allow areas of seabed to lie fallow, so that benthic vectors of known diseases or pests do not have the chance to build to critical levels). However, managing the health of stock will

inevitably involve some active intervention and treatment. Usually in sea-cage operations, this takes the form of crowding the stock and immersing it in a chemical treatment (such as formalin) dispersed in the water (a technique known as bath treatment[13]). NIWA is researching and developing new techniques for disease control.

- *Predation*: Predation is a common issue for any open sea-based operation. Anti-predation measures, although well researched and developed globally, need to be tailored to the New Zealand physical and regulatory environments.
- *Harvesting*: If the slaughter of fish before sale is carried out without due care and attention, the quality and value of the flesh can be significantly affected. For instance, in salmon, aggressive harvesting can cause bruising, gaping[14], blood clots, poor colour retention and the rapid onset of rigour mortis, which makes the fillets less firm. The salmon industry uses a technique known as a 'rested harvest' to harvest fish in a stress-free state, which significantly improves the flesh characteristics. To develop a fully mechanised 'rested harvest' technique for kingfish requires significant research into grading, harvesting and sorting techniques. Much of the equipment could be purchased off-the-shelf, but would need to be combined, and possibly adapted, to achieve an efficient process that would allow significant value to be added to the kingfish product.
- *Diet*: NIWA is well advanced in developing diets and diet ingredients to promote sustainable kingfish aquaculture in New Zealand.

24.8 ECONOMICS OF KINGFISH FARMING

Kingfish have the potential to become New Zealand's newest finfish aquaculture species and join Chinook salmon as a valuable earner of export dollars. The species is highly prized in Asia, particularly in Japan where it is considered (next to tuna) to be one of the best species for sashimi.

Limitations of NIWA's cost model

NIWA has produced a cost model for kingfish production based on production in sea-cage operations of 100, 500 and 2,500 tonnes. The model provides an indication of the costs and returns associated with this activity but it is not a comprehensive assessment of costs or likely returns for any specific venture. The figures are intended as only a guide and are likely to vary with the individual circumstances of each farm. The figures are presented only to provide guidance as to the level of investment required to establish a viable farm under NIWA's best estimates of production costs.

Cost of production

The cost of production is largely related to the size of the farm. Generally, in aquaculture, the larger the farm, the lower the unit cost of production. Figure 25.9 shows that for a 100 tonne farm, the cost of production is above the potential sales price, so the farm is unlikely to be sustainable, whereas for a 500 tonne farm, and even more so for a 2,500 tonne farm, the cost of production is below the sales price, which allows a margin for profit.

FIGURE 24.9: COST OF PRODUCTION AND ESTIMATED SALES PRICE (BLACK LINE) FOR KINGFISH FARMS AT DIFFERENT LEVELS OF PRODUCTION

The model of production costs can also estimate the overall investment required to develop a farm to the point where sales income more than meets production costs. NIWA believes that a 500 tonne farm is the smallest scale at which this can be achieved. A farm of this size is likely to cost around NZ$3.3 million to establish ($700,000 for infrastructure and $2.6 million in operating costs). After 18 months of production, a farm at this level should have annual sales of around $4 million.

For bio-security and operational reasons, farms are generally operated on an 'all in - all out' basis with intervals between classes where the site is fallowed. In production, juvenile stocking may be spread over three months. Harvesting begins when the largest group in the farm reaches harvest size. The time spread on stocking combined with the normal variability in growth of the fish results in a harvest period which may span six months. Based on a 24 month production cycle and a six month harvest window, hour sites would be required to maintain a constant market presence.

Given 500 T as the minimum effective farm size, four farm sites would be the minimum effective cluster for business development.

13 A bath treatment is a process whereby the fish are crowded in the cage, a net is drawn up to envelop the whole cage in a bag. This separates the interior of the net from the wider environment. The treatment is then administered to the encased water body that contains the fish.

14 Gaping is the separation of the muscle blocks to produce gaps in the fillet.

24.9 REGULATORY ISSUES

To farm kingfish in marine cages the first requirement is to ensure that the site selected for the farm is designated as an aquaculture marine area (AMA). Once this is ascertained, an application has to be submitted to the Ministry of Fisheries for resource consent to use the marine space for the purpose of farming kingfish.

To farm kingfish in a land-based facility, a freshwater fish farming licence from the Ministry of Fisheries is required, together with the appropriate water intake and discharge consents from the regional territorial authority.

24.10 FURTHER READING

Poortenaar C and Hooker S. 1999. Yellowtail kingfish: An exciting new aquaculture species for New Zealand. *Aquaculture Update* 22: 1, 3–4.

Poortenaar C, Hooker S and Sharp N. 1999. Where are we with kingfish aquaculture? *Aquaculture Update* 23: 9–10.

Poortenaar C W, Hooker S H and Sharp N. 2001. Assessment of yellowtail kingfish (Seriola lalandi lalandi) reproductive physiology as a basis for aquaculture development. *Aquaculture* 201: 271–286.

Poortenaar C, Jeffs A and Heath P. 2003. *Commercial Opportunities for Kingfish Aquaculture in Northland*. NIWA Client Report AKL2003-026. Auckland: National Institute of Water and Atmospheric Research. 51 pp. Available at www.niwa.co.nz/ncfa/news_pubs

25 EEL (TUNA)

25.1 INTRODUCTION

Worldwide there are 16 species of freshwater eels (family Anguillidae), occurring on all continents, in temperate, subtropical and tropical areas. Eels are catadromous fishes (ie, they migrate down rivers to spawn), with spawning and larval stages occurring in sea water, but most of the life cycle, juvenile and adult phases, is undertaken in fresh water.

In many regions, eel species represent a major food and fisheries resource that is highly valued by societies. Eels are a taonga to Māori. They are the subject of legends of people from many regions, including Europe, Asia, North America and the Pacific.

Eels are a major fishery and aquaculture product, with an annual worldwide production (or capture) of 250,000 tonnes that is valued at more than NZ$1.3 billion (FAO 2005).

New Zealand is home to three species of eel: the longfin eel *Anguilla dieffenbachii* that is endemic (native) to New Zealand; the shortfin eel *A. australis*; and the Australian (or speckled) longfin eel *A. reinhardtii*. Shortfin and Australian longfin eels are found and farmed in Australia, but the latter is only an occasional visitor to New Zealand.

Shortfin eel

Shortfin eels (*Anguilla australis*) are found in waterways throughout New Zealand, including Stewart Island and the Chatham Islands. They are also found on the east coast of Australia from Queensland to Tasmania, and on some western Pacific islands, including New Caledonia, Norfolk Island, and Lord Howe Island, and "perhaps Fiji" (NIWA 2007).

These eels are generally found in the lower reaches of waterways, but can be found in the range of fully marine to freshwater habitats.

Females can reach 3 kilograms, while males are generally less than 300 grams.

Shortfin eels can be distinguished from longfin eels by the length of their dorsal fin. In shortfin eels, when viewed side-on, the dorsal and anal fins are almost the same length (Figure 26.1), whereas in longfin eels, the dorsal fin extends further forward (Figure 26.2).

FIGURE 25.1: SHORTFIN EEL (*ANGUILLA AUSTRALIS*)

Note the position of the end of the dorsal fin above the anal fin (arrows).
Source: Image copyright R M McDowall.

Longfin eel

Longfin eels (*Anguilla dieffenbachii*) are native to New Zealand. They are found throughout the country, generally in the higher reaches of rivers. Longfin eels are New Zealand's largest freshwater fish, and are capable of navigating past large barriers such as waterfalls (NIWA 2007).

Females may be heavier than 10 kilograms, while males are generally less than 1 kilogram.

Longfin eels can be distinguished from shortfin eels by the length of their dorsal fin. In longfin eels, when viewed side-on, the dorsal fin is longer than the anal fin and extends well forward past the end of the anal fin (Figure 26.2).

FIGURE 25.2: LONGFIN EEL (*ANGUILLA DIEFFENBACHII*)

Note the position of the dorsal fin extending forward of the anal fin (arrows).
Source: Image copyright R M McDowall.

Australian (speckled) longfin eel

The Australian longfin eel (*Anguilla reinhardtii*) is native to the Australian east coast, from Queensland to Tasmania. It has occasionally been reported in the Waikato River (Jellyman et al 1996), with unconfirmed reports from Northland to Taranaki and the Coromandel Peninsula in New Zealand (NIWA 2007).

The Australian longfin eel can be distinguished from the New Zealand native longfin eel by the presence of irregular black blotches or speckles on its back and sides (Figure 26.3).

FIGURE 25.3: AUSTRALIAN LONGFIN EEL (*ANGUILLA REINHARDTII*)

Note the blotches or speckles on the body.
Source: Image from www.fishbase.com.

25.2 EEL LIFE CYCLE

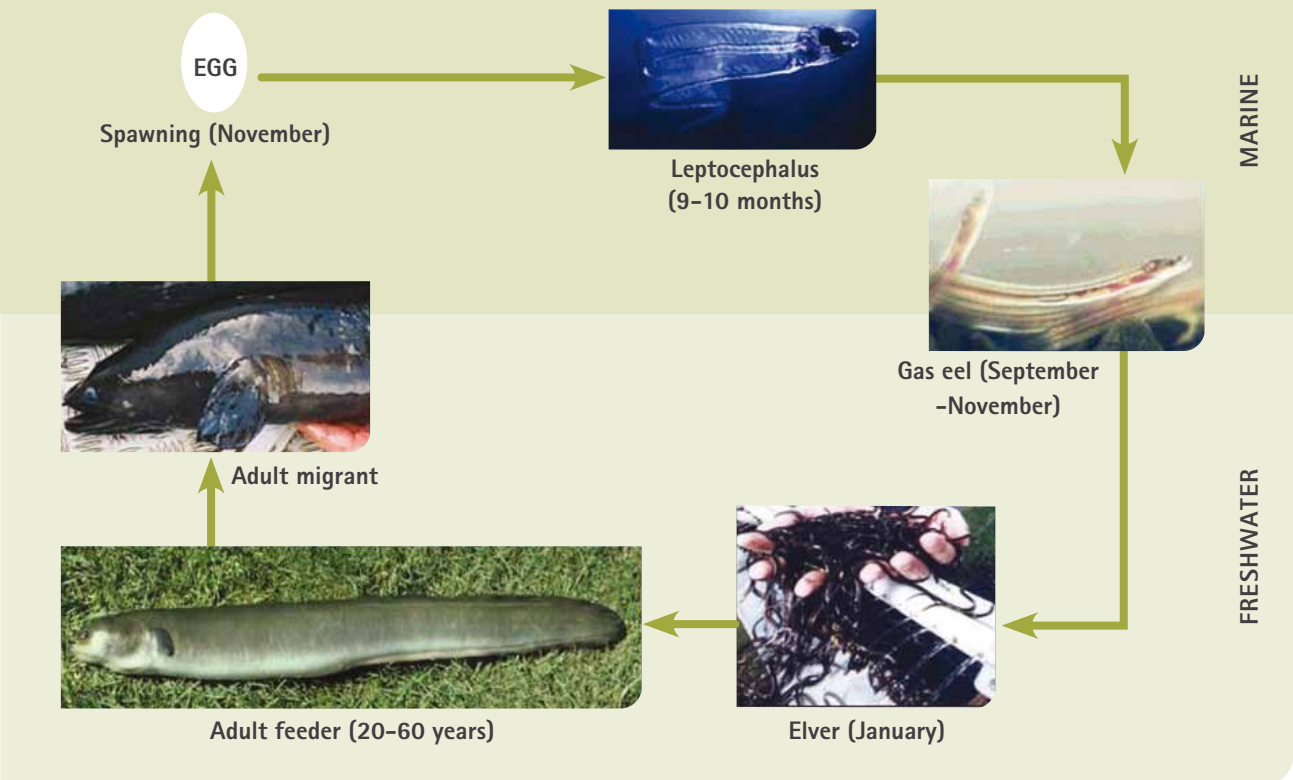
Eels have a long and complex life cycle, which includes migration down and up rivers and across many thousands of kilometres of ocean. Spawning occurs in oceanic waters, with New Zealand species believed to spawn in deep water trenches in the Coral Sea, near Tonga (longfin) and Samoa (shortfin).

The egg hatches into a fragile, transparent, leaf-shaped larva, known as a leptocephalus (Figure 26.4) that spends 9–12 months in the plankton, eventually migrating to New Zealand. Near the end of this time, the larvae undergo a change (metamorphosis) to become cylindrical, transparent, glass eels (Figure 26.4). Glass eels aggregate in large numbers in estuaries, generally arriving from August to December, and can be seen as a large, dark mass. Glass eels migrate upriver, gradually acquiring colour and becoming elvers. The elvers continue to migrate, and eventually grow to become yellow and, later, silver eels.

The time taken to reach adult size varies substantially between species and sexes and is affected by the environment, particularly water temperature and food availability. Growth rates in warmer waters with abundant food exceed those in cold waters that are low in nutrients (such as in many of New Zealand's lakes).

Female longfins may be more than 60 years old at maturity, while female shortfins may be more than 20 years old. Mature eels undergo further changes before migration, with their eyes becoming larger and fins darkening (Figure 26.4). Migratory (heke) eels move downstream in autumn, with the smaller eels (males and/or shortfins) usually commencing their migration before the larger eels (females and/or longfins). The adults migrate downstream and onward to the spawning grounds, where they spawn and die.

FIGURE 25.4: GENERALISED LIFE CYCLE OF EEL (APPROXIMATE TIME SPENT IN EACH STAGE)



Source: NIWA

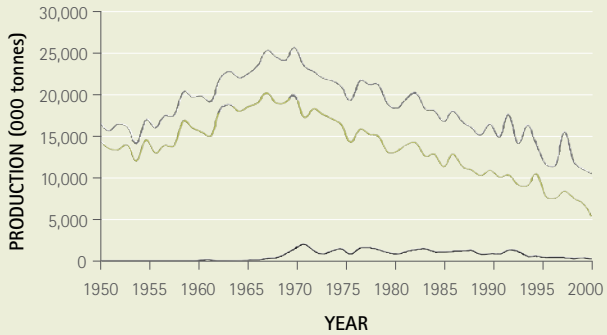
25.3 WORLDWIDE EEL PRODUCTION

In the early 2000s the capture fishery accounted for only 5 percent of the world eel market (10,000–12,000 tonnes per year). The contribution of the capture fishery to the world eel market has been declining since the late 1960s when catches peaked at more than 25,000 tonnes per year (Figure 26.5). This decline has been mainly due to the decline in European eel stocks from 20,000 tonnes in the late 1960s to less than 5,000 tonnes in 2005 (Figure 26.5).

The majority of wild caught eels are sourced from Indonesia (1,000–4,000 tonnes per year), Egypt (500–1,500 tonnes per year) and New Zealand (700–1,000 tonnes per year) (FAO 2007).

The New Zealand eel fishery has been managed through the quota management system since 2001 (South Island) and 2004 (North Island). To be caught legally, eels of both species must be no less than 220 grams, which includes immature female shortfin eels and immature male and female longfin eels. Since 1970 the total catch of eels in New Zealand has been about 1,000–1,500 tonnes per year. However, in both the 2002/03 and 2003/04 seasons, this declined to 840 tonnes and 725 tonnes respectively.

FIGURE 25.5: WORLD EEL FISHERY SHOWING TOTAL, EUROPEAN AND NEW ZEALAND CATCHES OF SHORTFIN AND LONGFIN EEL COMBINED, 1950–2005



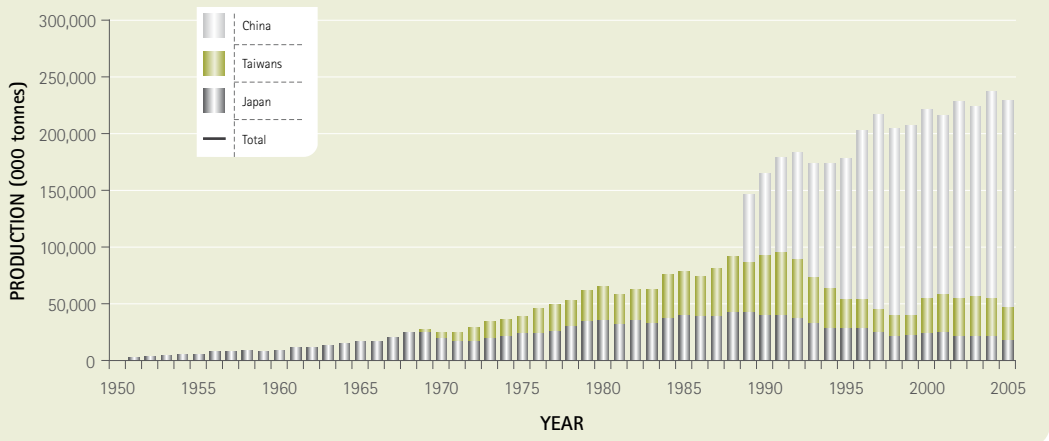
Source: NIWA

Aquaculture

The eel culture industry is based in Asia, with initially Japan, and later Taiwan, leading world eel aquaculture. Since 1990, however, production from China has accounted for more than 50 percent of world production (Figure 26.6). This largely reflects a change in China's reporting of production figures to the Food and Agriculture Organization, rather than an actual increase in production.

In 2005, China (179,000 tonnes), Taiwan (28,000 tonnes) and Japan (20,000 tonnes) dominated the world farmed eel production of 242,000 tonnes (Figure 22.6), which was valued at NZ$1.35 billion (FAO 2007). Nineteen other countries, led by South Korea (5,700 tonnes), Denmark (4,000 tonnes) and the Netherlands (1,700 tonnes), account for the balance of production.

FIGURE 25.6: WORLD PRODUCTION OF FARMED EEL, 1950–2005



Source: Food and Agriculture Organization.

Asia

China accounts for over 70 percent of world eel aquaculture. While the industry was traditionally based on the Japanese eel *Anguilla japonicus*, in recent years it has become based on the European glass eel *A. anguilla*, which is cheaper and more readily available than is the Japanese species. European glass eels now account for more than 70 percent of farmed eel production in China.

Production in China is pond based, with more than 10,000 hectares under pond culture in 2001. As a result of low-cost farming systems, substantial economies of scale, and low labour costs, production costs in China are low. Based on data from the Food and Agriculture Organization, the farm-gate value (ie, not the production cost) has been estimated at less than US$2 per kilogram live weight. However, export earnings have been enhanced by high levels of value adding, such as the preparation of 'kitchen-ready' products for the Japanese market. As a result, export prices of up to US$6.20 per kilogram live weight have been attained.

Most processing facilities in China have now adopted Hazard Analysis and Critical Control Point systems and attained ISO 9000 certification, which ensures that processors can demonstrate that their facilities and processes conform to internationally accepted standards. However, the presence of drug residues has substantially damaged the reputation of the Chinese eel farming industry in recent years. Actions such as the United States Food and Drug Administration's imposition of an import alert on Chinese eel products show the seriousness of these issues for the industry (USFDA 2007).

Taiwan produces more than 30,000 tonnes per year of eels, which are the most important farmed fish in the country. Increasing overhead costs and a declining farm-gate value (from US$10.50 per kilogram live weight in 1997 to US$7.80 per kilogram in 2002) have resulted in some farms moving to turtle and shrimp production.

Japan produces about 20,000 tonnes of eels per year for its domestic market. Production in Japan relies on the use of heated water for production efficiency. The market advantage of supplying the local species *Anguilla japonicus* to the market has declined since the late 1990s, so Japanese glass eel stocks have plummeted and Japanese farmers now compete in the marketplace with large volumes of European eels from China. The farm-gate value of eels in Japan is about US$13 per kilogram live weight.

Europe

Farmed eels account for about 60 percent of European eel production, with the remainder derived from fisheries. The Netherlands, Denmark and Italy are the main producers, and their combined production was 6,600 tonnes in 2005 (FAO, 2007). European production declined substantially in 2002, due to a falling market and oversupply.

Most European production uses recirculating aquaculture systems, which allow year-round production. Firms from The Netherlands and Denmark produce 'off-the-shelf' recirculating aquaculture systems specifically for eel production (eg, the Dutch company Hesy (www.hesy.com)).

The farm-gate value of eels in European countries declined from US$8.50–US$11 per kilogram live weight in 1997 to less than US$6 per kilogram in 2002.

Australia

Australia is a small producer of farmed eels, with production in 2003 of about 120 tonnes. Both shortfin *Anguilla australis* and Australian longfin *A. reinhardtii* are farmed.

Australian Aquaculture Products Ltd, based in Victoria (see www.aaq.com.au/aust_aqua_products.htm), and Eels Australis, based in Tasmania, Victoria and Queensland, are significant producers of eels. Both companies primarily use recirculating aquaculture systems, but also have some pond production.

Product is sold through farm-based tourism ventures on the domestic market and exported to Asia.

The farm-gate value has declined from US$7.80 per kilogram live weight in 1997 to US$5.70 per kilogram in 2002.

New Zealand

Evidence exists that Māori used to relocate migrating elvers to landlocked lakes to enhance the eel (tuna) fishery (Maniapoto 1997).

In 1969, the New Zealand Fishing Industry Board initiated interest in eel aquaculture through a seminar and by sponsoring a visit to New Zealand by Dr Matsui, a prominent Japanese eel researcher (Jellyman and Coates 1976). Government supported the development of freshwater aquaculture by instigating freshwater fish farming regulations in 1972 and providing tax concessions to freshwater fish farmers. By 1974, six farms had been established, five in the North Island and one near Dunedin. Four farms were based on static water pond culture, traditionally used in Japan, one farm used heated effluent from the Meremere Power Station and the other farm used a recirculating heated water system (Jellyman and Coates 1976).

Farms experienced substantial mortality rates in the early years. The tank-based farms sustained substantial losses of small eels due to a range of bacterial and protozoan pathogens and bird predation. Losses were also experienced when eels did not resume feeding after being transferred into the tanks and equipment failed (Jellyman and Coates 1976). Poor glass eel recruitment in some years also resulted in farms failing to meet commercial levels of stocking. Five farms had closed by 1975. One operation, near Leeton in Canterbury, continued to operate throughout the 1980s.

Eel aquaculture activity was resurrected in 2000, when Ngāti Kahungunu commissioned a Hesy recirculation system that was purpose designed and built in The Netherlands for eel aquaculture and investigated the feasibility of the system for the production of the local eel species.

NIWA was also involved in eel aquaculture in 2000, with a programme evaluating the feasibility of 'fattening' wild-caught eels to increase fishery yields (Chisnall and Martin 2002). NIWA continues to research the culture of eels through a research programme funded by the Foundation for Research, Science and Technology. The programme uses a Hesy recirculating aquaculture system for developing and refining production methods for New Zealand eel species. (The system was transferred from Whakatu to the NIWA Bream Bay Aquaculture Park near Ruakākā in 2003.)

25.4 NEW ZEALAND EEL INDUSTRY

Cultured eel production depends on the ongrowing of glass eels. Glass eels are caught in estuaries and transported to farms for ongrowing. In some regions, glass eel fishing pressure is so intense that it is estimated that 80 percent of returning glass eels are caught. Worldwide, the glass eel fishery is in decline, which is reflected in smaller catches and higher prices each year. In 2003, prices were up to NZ$15,000 per kilogram for glass eels. Given these environmental and economic factors, researchers and aquaculturists have been tying to achieve the hatchery production of eels throughout the whole eel life cycle.

Broodstock and hatchery

Techniques for inducing the maturation and spawning of adult eels were developed in the 1970s. These have since been applied by several research groups working on the major commercial eel species, including European eels (Nilsson et al 1981), American eels (Sorensen and Win 1984) and Japanese eels (Todo et al 1995; Ohta et al 1996). Some research has also focused on the artificial maturation and spawning of New Zealand eel species (Todd 1976; Lokman and Young 2000). In 2005, a research team at the Mahurangi Technical Institute in Warkworth successfully spawned and hatched shortfin eel eggs, although it was unsuccessful at rearing the larvae.

Despite success in spawning having been relatively easy to achieve, rearing larvae through their full life has been vastly more difficult. However, in 2002, after a research effort that dated back to the 1980s, researchers in Japan successfully spawned eggs of the Japanese eel *Anguilla japonica* and reared them through the leptocephalus stages and metamorphosis to glass eels. The larval-rearing phase took about 250 days, and used a specially developed diet that was based on shark-egg products (Tanaka et al 2003). This was groundbreaking research, but it does not mean that the commercial production of glass eels at a commercially acceptable price is imminent. The hatchery production of commercial quantities of glass eels anywhere in the world is likely to be 10–15 years away, and the cost of hatchery-produced eels is still unknown.

Nursery

Commercial eel production starts with the capture, transport and weaning of glass eels. In New Zealand, glass eels aggregate in river

mouths from late winter to early summer, at which time they are about 55–60 millimetres long and transparent (Jellyman 1979). Typically, glass eels are present in New Zealand rivers from August to December, although the timing and size of the peak of migration varies substantially between locations and years (Jellyman et al 1999). Both shortfin and longfin glass eels may enter waterways, and the ratio between species also varies between locations and years (Jellyman et al 1999). Following a transition period of about two weeks, glass eels start their upstream migration. This migration is strongly influenced by factors such as the season, lunar cycle and tidal cycle (Jellyman 1979).

Glass eels can be collected by a variety of means, including hand nets, whitebait nets (Jellyman 1979) or Japanese glass eel nets ('hell nets', McKinnon et al 2001). Once caught, glass eels must be transported to a nursery or ongrowing facility. Although small, glass eels are hardy and tolerant of a range of environmental conditions (Ingram et al 2001; McKinnon et al 2001).

As part of NIWA's research, glass eels caught in the Waikato River have been routinely transported to the Bream Bay Aquaculture Park over several years with negligible losses. Transport methods similar to those described by McKinnon and colleagues (2001) were used. The eels are transported in sealed plastic bags containing a small amount of river water. Bags are emptied of air then reinflated with industrial grade oxygen and sealed. The bags are placed in insulated boxes for transport by road. On arrival at the park, the bags are acclimated to temperature by being immersed in a receiving tank for an hour. Glass eels are routinely put directly into brackish water (salinity around 17 parts per thousand or half the salinity of full seawater), with high rates of survival (ie, more than 95 percent). Glass eels may also be quarantined and exposed to a full change in salinity, from fresh to full sea water (33 parts per thousand) over 24 hours to eliminate many pests or pathogens.

Once acclimated to the rearing system, the glass eels need to be weaned on to artificial feeds if they are being ongrown in tanks. There are many approaches to weaning glass eels, using a variety of live, fresh or moist feeds (McKinnon et al 2001; De Silva et al 2001). NIWA's standard weaning practices involve supplying the eels with brine shrimp (*Artemia*) as a live feed for up to 10 days, adding moistened artificial feed during the latter half of this period. After that time, the glass eels receive only artificial feed, with more than 90 percent of animals usually being weaned successfully.

Ongrowing

The commercial ongrowing of weaned of eels uses a variety of systems and strategies, each with different establishment costs, inputs and controls. Systems can be broadly described as intensive, typically tank based, and requiring large levels of inputs (eg, feed, heating and oxygen), but allowing significant control over production parameters; or extensive, typically pond based, and requiring few inputs, but with little control over production parameters.

In intensive recirculating aquaculture systems, eels are maintained in tanks at a high density (ie, to more than 100 kilograms per cubic metre). Recirculation technology allows a high level of control over the growing environment (water temperature, water quality, day length and so on), as well as control over feeding.

In intensive flow-through tank systems, water quality and feeding can be closely monitored, and some aspects of water quality, such as dissolved oxygen levels, can be manipulated. Stocking density is limited by water temperature and flow rates, but a likely maximum is 50 kilograms per cubic metre.

Extensive pond culture of eels requires fewer feed inputs because the ponds can support some aquatic life, which provides food for the eels. However, the amount and quality of this food cannot be controlled easily. Similarly, pond water quality and temperature are not easily or efficiently manipulated, so maximum stocking densities are lower (10–20 kilograms per cubic metre).

Production at Bream Bay Aquaculture Park is in a recirculating aquaculture system, using brackish water (17 parts per thousand). Shortfin eels have grown from glass eels to 200 grams in 10 months using this system. However, three major issues have been highlighted by the research at the park:

- Water temperature is a major determinant of eel feeding activity and growth rate. Occasional drops in water temperature rapidly result in lower feeding and growth rates. Recirculation is the most efficient way to maintain the high water temperatures (ie, more than 24°C) needed for the fast growth of shortfin eels. Unless heated water is available, it is difficult to control water temperature in flow-through tanks, and ponds will always be subject to ambient environmental conditions.
- Size variability has been an issue in farmed eel production for many years (Jellyman 1976). Only a small proportion (about 5 percent) of the eels reached 200 grams in 10 months, although more than 50 percent reached that size in 24 months. NIWA is continuing to investigate issues such as feed formulation and stocking density in order to reduce variability in growth rates.
- Cultured eels, including shortfins, typically show a high proportion of males, often more than 80 percent (Tzchori

et al 2002), which may be due to factors such as density, temperature or salinity (Davey and Jellyman 2005). Male shortfin eels rarely exceed 300 grams, which directly affects a farm's capacity to supply large eels. NIWA is continuing to investigate techniques to increase the proportion of females in populations of farmed eels.

25.5 EEL PROCESSING AND MARKETING

The optimal size for ongrown eels depends on the target market. The kabayaki market in Japan requires eels of 150–200 grams, but other markets prefer larger eels, particularly for smoking. Large eels (ie, those over 1 kilogram) are also suitable for the Asian banquet market.

Asia

Japan is the world's largest consumer and importer of eels, accounting for about 70 percent of the world market. Of the estimated 190,000 tonnes of eels consumed in Japan annually, about 130,000 tonnes are imported from China, and about 25,000 tonnes are imported collectively from Taiwan, Malaysia and North America. The main eel product consumed in Japan is kabayaki, which accounts for about 90 percent of eel consumption in Japan. Kabayaki is prepared by splitting (butterflying) an eel, then steaming and basting it with a sweet soy-based sauce, then grilling the eel. Small eels (about 150–200 grams) are favoured for this dish, and the peak demand period is in July and August (summer), because the dish is considered to improve a person's health in the heat. In March 2005, eels imported into Japan attracted an average price of US$14 per kilogram.

South Korea consumes 10,000–13,000 tonnes of eels annually, primarily for medicinal purposes as eel is not a traditional foodstuff. Eels for the Korean market are mainly imported from China and Taiwan. Hong Kong consumes up to 4,000 tonnes per year, including large (over 2 kilograms) cultured Australian longfin eels *Anguilla reinhardtii*. Traditionally, eels were not eaten in China or Taiwan, but the market is growing as dietary habits change. Eel products are now regularly available in markets in these countries.

Europe

Collectively, about 20,000 tonnes of eels are consumed in Europe. These are mostly locally caught and/or farmed product. Markets vary between countries, but, in general, smoked products and eels of more than 250 grams are preferred. There are smaller markets for small eels (50–65 grams) and large eels (more than 1 kilogram). Spain is Europe's largest consumer of eels, including for traditional dishes consumed at Christmas and New Year. The Netherlands, Germany and Scandinavia are also significant eel consumers.

North America

The United States and Canada consume about 2,000–4,000 tonnes per year of smoked or roasted eels.

25.6 ECONOMICS OF EEL FARMING

NIWA has developed preliminary economic models for eel production based on the use of a recirculation system. The models show clearly the economies of scale achieved with higher levels of production: production costs for a 10 tonne recirculation system are estimated at NZ$52 per kilogram, declining to $18 per kilogram for a 50 tonne system and $14 per kilogram for a 100 tonne system. This reflects the high base costs associated with developing a recirculating aquaculture system, regardless of its size. For a 100 tonne system, the capital costs are estimated at $750,000, while the operating costs are estimated at $1.5 million per year, primarily for the costs of power, feed and labour.

25.7 REGULATORY ISSUES

Fishery regulations prevent eels under 220 grams from being harvested for commercial purposes. This prevents glass eels being captured for aquaculture.

The deeds of settlement between the Crown and some iwi, for example Ngāti Tama and Ngāti Ruanui, contain a "Provision for the taking of undersized tuna (eel) as part of stocking or re-stocking ... waterways and aquaculture projects" (Office of Treaty Settlements 2001a, 2001b). However, the status of this provision in relation to the fishery regulations is unclear.

Part of the Ministry of Fisheries' regular review processes is to review the eel fishery, including consideration of adding glass eels to the fishery and evaluation of potential models for doing this.

25.8 CONCLUSIONS

Eel (tuna) aquaculture offers considerable potential to provide revenue and a food source for Māori. The major constraints to establishing an industry are regulatory. However, it is hoped that the regulatory constraints will be addressed before 2012. The economic viability of any eel aquaculture venture will be enhanced by the venture's access to heated water. However, production in regions lacking a source of heated water may also be viable provided good market prices can be achieved.

25.9 REFERENCES

Chisnall B and Martin M. 2002. Short-term fattening of wild caught shortfinned eels. *Fisheries and Aquaculture Update* 1: 4.

Davey A and Jellyman D. 2005. Sex determination in freshwater eels and management options for manipulation of sex. *Reviews in Fish Biology and Fisheries* 15: 37–52.

De Silva S, Gunasekera R, Ingram B and Dobson J. 2001. Weaning of Australian shortfin glass eels (*Anguilla australis*): A comparison on the effectiveness of four types of fish roe. *Aquaculture* 195: 133–148.

FAO, 2007 Fishstat: Fisheries and Aquaculture database, Food and Agriculture Ograniastion of the United Nations. Available at: http://www.fao.org/corp/statistics/en/

Ingram B, Gooley G, De Silva S, Larkin B. and Collins R. 2001. Preliminary observations on the tank and pond culture of the glass eels of the Australian shortfin eel, *Anguilla australis* Richardson. *Aquaculture Research* 32: 833–848.

Jellyman D. 1979. Upstream migration of glass-eels (Anguilla spp.) in the Waikato River. *New Zealand Journal of Marine and Freshwater Research* 13: 13–22.

Jellyman D, Chisnall B, Bonnett M and Sykes J. 1999. Seasonal arrival patterns of juvenile freshwater eels (*Anguilla* spp.) in New Zealand. *New Zealand Journal of Marine and Freshwater Research* 33: 249–261.

Jellyman D, Chisnall B, Dijkstra L, and Boubee J. 1996. First record of the Australian longfinned eel, *Anguilla reinhardtii*, in New Zealand. *Marine and Freshwater Research* 47: 1,037–1,040.

Jellyman D and Coates G. 1976. The farming of freshwater eels in New Zealand. FAO Indo-Pacific Fisheries Council, 17th Session, Symposium on the Development and Utilization of Inland Fishery Resources, Colombo, Sri Lanka, 27–29 October 1976. 6 pp.

Lokman P and Young G. 2000. Induced spawning and early ontogeny of New Zealand freshwater eels (*Anguilla dieffenbachii* and *A. australis*). *New Zealand Journal of Marine and Freshwater Research* 34: 135–145.

McKinnon L, Ingram B, Larkin B and Gasior R. 2001. *Best Practice Guidelines for Australian Glass Eel Fishing and Aquaculture*. Technical Report 48. Queenscliff, Victoria: Marine and Freshwater Resources Institute. 21 pp.

Maniapoto H. 1997. *Kaupapa a Tuna: The Maniapoto Tuna Report*. Kihikihi: Tainui Tuna Working Party. 39 pp.

Nilsson L, Nyman L, Westin L and Ornhagen H. 1981. Simulation of the reproductive migration of European eels (*Anguilla anguilla* (L.)) through manipulation of some environmental factors under hydrostatic compression Speculations in Science and Technology 4: 475–484.

NIWA. 2007. NIWA Atlas of New Zealand Freshwater Fishes. www.niwa.science.co.nz/rc/freshwater/fishatlas

Office of Treaty Settlements. 2001a. *Deed of Settlement between the Crown and Ngati Ruanui*. http://www.executive.govt.nz/minister/wilson/ngati_tama/index.html

Office of Treaty Settlements. 2001b. D*eed of Settlement between the Crown and Ngati Tama*. http://www.executive.govt.nz/minister/wilson/ngati_tama/index.html

Ohta H, Kagawa H, Tanaka H, Okuzawa K and Hirose K. 1996. Changes in fertilisation and hatching rates with time after ovulation induced by 17, 20_-dihydroxy-4-pregnen-3-one in the Japanese eel, *Anguilla japonica*. *Aquaculture* 139: 291–301

Sorensen P and Winn H. 1984. The induction of maturation and ovulation in American eels, *Anguilla rostrata* (LeSueur), and the relevance of chemical and visual cues to male spawning behaviour. *Journal of Fish Biology* 25: 261–268.

Todd P. 1976. Ultrastructure of the spermatozoa and spermiogenesis in New Zealand freshwater eels (Anguillidae). *Cell and Tissue Research* 171: 221–232.

Todo T, Adachi S, Saeki F and Yamauchi K. 1995. Hepatic estrogen receptors in the Japanese eel, *Anguilla japonica*: Characterization and changes in binding capacity during artificially-induced sexual maturation. *Zoological Science* 12: 789–794.

Tzchori I, Degani G, Elisha R, Eliyahu R, Hurvitz A, Vaya J and Moav B. 2002. The influence of phytoestrogens and estradiol-17_ on growth rates and sex determination in the European eel (*Anguilla anguilla*). *Israeli Journal of Aquaculture/Bamidgeh* 54: 53–54.

USFDA. 2007. Detention Without Physical Examination of Aquacultured Catfish, Basa (Pangasius sp), Shrimp, Dace, and Eel Products from the People's Republic of China due to the Presence of New Animal Drugs and/or Unsafe Food Additives. Import Alert 16-131. United States Food and Drug Administration. http://www.fda.gov/ora/fiars/ora_import_ia16131.html