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**Assessing the potential of increased commercial scale Koura farming in
the Canterbury region**

A thesis
submitted in partial fulfillment
of the requirements for the Degree of
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by

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Abstract of a thesis submitted in partial fulfillment of the
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Prospects of Blue Horizons: Potential of koura (freshwater crayfish) farming
in the Canterbury region

By M.J. Mckenna

Aquaculture is the world's fastest growing primary industry. It is expected that by 2030 aquaculture will match the wild fisheries catch (SOFIA Report 2004). Aquaculture has been growing rapidly in New Zealand mostly through the commercial production of three species; greenshell mussels, king or chinook salmon and Pacific oysters.

Within the New Zealand aquaculture industry the majority, around 70% of our production value is within the marine environment. Worldwide trends differ with only around 33% of the production value resulting from the marine environment. These ratios suggest that our freshwater/ land-based aquaculture industry has yet to be fully utilized. There are two freshwater crayfish species endemic to New Zealand; these species are known as koura and have significant potential as a species for land-based aquaculture ventures. Currently, there is only one commercially viable koura farming operation in New Zealand. The demand for koura far exceeds the supply; farmers are struggling to meet domestic demand let alone any export potential. The growth of commercially viable crayfish industries in Louisiana, USA, Australia and elsewhere has provided a stimulus for this research into the factors affecting the growth of our own industry.

Historically koura have been abundant in our streams and rivers and still are in several regions. However, given the increasing development of rural land for agriculture in particular dairy farming and the demand for water resources it is difficult to determine with any certainty whether these wild populations will remain stable without conservation and further research.

This research aims to address the potential of koura farming within the Canterbury region, by the use of case studies to assess the factors affecting the growth of the industry at large. In particular; investigating the planning/legislative provisions for koura farming and by using two established koura farms as case studies to help identify issues for a S.W.O.T. (Strengths, Weaknesses, Opportunities and Threats) Analysis for the potential of further growth of the industry. The influence of the relevant stakeholders is also considered; the role of the Department of Conservation, Ministry of Fisheries, Local Iwi (Ngai Tahu), Local Authorities and their stance on koura farming is investigated.

With little or no government assistance koura farming has developed from a backyard hobby into an enterprise with serious commercial potential. This research aims to highlight the potential of the koura industry and provides a basis for further discussion and research.

Keywords: koura; paranephros planifrons, paranephros zealandicus, freshwater Aquaculture, land-based aquaculture, sustainable farming

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1 Introduction

1.1 Motivation for Research

In Canterbury, a region dominated by agriculture, we have recently witnessed unprecedented demands on water resources. The total allocation of water in New Zealand increased by 50 per cent between 1999 and 2006. The Canterbury and Otago regions account for almost three-quarters of the total allocation, with 55 per cent and 18 per cent, respectively (Ministry for the Environment, 2006). This is mainly a result of an increase in the area of irrigated land; irrigation now uses almost 80 per cent of all water allocated of all water allocated (Ministry for the Environment, 2006). On a per capita basis, it is estimated that the demand for water is two to three times higher in New Zealand than in most other OECD countries (Organisation for Economic Co-operation and Development, 2007). The recent 'Dairy Boom' has fuelled much of this increasing demand, with irrigation schemes such as the Central Plains Water (CPW) scheme threatening to further reduce river flows and dramatically alter the landscape.

At present, water is a public resource and readily available to all. The Local Authorities have a responsibility to ensure water resources are not over allocated to large organisations compromising the rights of smaller businesses and individuals. Environment Canterbury (Ecan) is considering different methods of allocating water resources including privatization of water resources (A. Willis, pers.comm April 2008). Problems with the privatisation of the New Zealand fish stocks through the Quota Management System (QMS) could mean that the privatisation of freshwater may suffer similar consequences. Future

allocation of water should ideally take into account the environmental effects of the activity and promote the sustainable use of water.

It is claimed that freshwater or land-based aquaculture of koura (freshwater crayfish) works in harmony with the natural environment, with minimal effects on the water quality, lower demands on water resources and requires less land than most other conventional agricultural activities or even more intensive aquacultural systems. Therefore koura farming appears as an environmentally friendly alternative, however, it has met many hurdles and is far from being a fully established industry in New Zealand. It therefore makes sense to investigate the potential for koura farming as an alternative land-use/water-use in the Canterbury region.

1.2 Aim of Research

To assess the potential of koura farming in the Canterbury region and address reasons why it is not more advanced in New Zealand inline with other worldwide trends.

1.3 Main Objectives

- Review relevant scientific literature relating to freshwater crayfish farming and their applications for koura farming.
- Analyse freshwater aquaculture feasibility with competing demands for water resources in the Canterbury region.
- Assess the feasibility of koura for farming in the Canterbury region.
- Review the relevant legislative/regulatory provisions for freshwater/ land-based aquaculture in the Canterbury region.

1.4 Topic introduction

Freshwater crayfish have been considered a gourmet food for many years in Europe, especially in Sweden and France (Aquaculture, 1980). The growth of commercially viable crayfish industries in Louisiana; USA, Australia and elsewhere has provided a stimulus for research investigations on growth rate and biomass production for several species of crayfish under a variety of experimental conditions (Morrissy et al. 1990; Huner 1994). Other researchers have assessed the importance of shelter provision as a means to increase yields in red claw crayfish (Jones 2001) and the role of habitat complexity in reducing aggression between freshwater crayfish (Baird 2006). These research themes are critical to the growth and success of the industry worldwide and can be applied to the farming of koura in New Zealand.

New Zealand has two recognized species of freshwater crayfish, *Paranephrops zealandicus* and *Paranephrops planifrons* (Parastacidae), both of which are endemic and with considerable aquaculture potential. These species are allopatric: *P.zealandicus* is restricted to Stewart Island and the south-eastern side of the South Island, while *P. planifrons* inhabits the North Island, Marlborough and the northern half of the west coast of the South Island (Hopkins et al. 1970). These crayfish are collectively known as koura.

Within New Zealand the potential of koura for farming purposes has been investigated since the mid 1960's (Hopkins 1966; Hopkins et al. 1970) with research into the breeding and growth rates of *P.planifrons*. Both locally and worldwide there appears to be sufficient research into the ecological requirements of freshwater crayfish for them to be farmed successfully. Freshwater crayfish farms in the USA and Australia are proof that freshwater crayfish aquaculture industries exist and are viable.

New Zealand koura farming has not experienced the same growth as other freshwater crayfish industries have worldwide. Therefore this research aims to address the

factors that may be contributing to the lack of growth within the industry. Primarily by reviewing the scientific literature relating to freshwater crayfish farming in well established industries abroad and establishing how the research translates to koura farming in New Zealand. This research also considers the current legislative framework for land-based fish farming and the relevant planning provisions in the Canterbury region. The relevant stakeholders are defined and their roles with regard to koura farming are investigated. A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis for the potential of koura farming in the Canterbury region is also undertaken using issues identified through interviews with two South Island koura farm operators, personal communications and relevant stakeholders.

1.5 Structure of Dissertation

1.5.1.1 Chapter 1: Introduction

Addresses the motivations for research into the potential of koura farming in the Canterbury region. This chapter also lays out the overall aim and main objectives of the research. The topic is introduced with reference to any relevant background material.

1.5.1.2 Chapter 2: Literature Review

The history and origins of aquaculture are considered along with the current state and trends in worldwide aquaculture which are discussed. This provides a general overview of the aquaculture industry. Commercially viable freshwater crayfish farming industries worldwide are reviewed with regard to their relevant applications to koura farming. The various techniques and methods of crayfish farming are also considered, including

innovative research and a summary table of current worldwide freshwater crayfish farming practices.

1.5.1.3 Chapter 3: Aquaculture in New Zealand

This chapter focuses primarily on the current state of the New Zealand aquaculture industry and how koura farming fits into the wider industry. The relevant industry stakeholders and agencies are discussed along with the current planning and legislative provisions.

1.5.1.4 Chapter 4: Methods

This chapter sets out the whole methodology of this research addressing the case study approach, the communication with stakeholders and the legislative and planning review. Each approach is justified and reasons are given for each particular method of research.

1.5.1.5 Chapter 5: Results and Analysis

In this chapter the research findings are collated and analysed. Profiles of two South Island koura farms are included along with a SWOT analysis, a flow diagram illustrating the Planning/ Legislative process for establishing a koura farm and the relevant stakeholder responses.

1.5.1.6 Chapter 6: Discussion and Recommendations

This chapter takes into account the findings of this research and major themes one should consider in the future of koura farming in Canterbury. Some recommendations for further growth of the industry are also included in this section.

2 Literature Review

2.1 History of aquaculture and the current situation

It is generally well-known that fish have been a staple in the diet of people of Asian descent for many centuries. It is also well established that there has been a long-history of fish culture in Asia. The 'Classic of fish culture', believed to have been written around 500BC by Fan Lei, a Chinese politician-turned fish culturalist is considered proof that commercial fish culture existed in China in his time, as he cited his fish ponds as the sources of his wealth (Ling 1977).

The first species believed to be cultured appears to be the common carp (*Cypinus Carpo*), a native of China. It was introduced into several countries of Asia and the far east by Chinese immigrants and to Europe during the middle ages for culture in monastic ponds. The exact date aquaculture was first practiced is debatable, with some claiming 'the earliest evidence of aquaculture dates back to 900BC (Bardach et al. 1972). Although this date makes aquaculture appear an ancient technology, it is still quite young when compared to terrestrial agriculture. Diamond (1999) shows that domesticated species of both crops and animals were being cultivated as early as 8500BC.

Southwest Asia and China served as the birthplace of many agricultural and aquacultural practices. Still, in modern times China remains by far the largest producer, with reported fisheries production of 47.5 million tonnes in 2004 (16.9 million and 30.6 million tones from capture fisheries and aquaculture respectively) providing an estimated domestic food supply of 28.4kg per capita as well as production for export of non-food purposes (FAO 2006).

Aquaculture continues to grow more rapidly than all other animal food producing sectors. Worldwide, the sector has grown at an average rate of 8.8 per cent per year since 1970, compared with only 1.2 per cent for capture fisheries and 2.8 per cent for terrestrial farmed meat production systems over the same period (FAO 2006).

The freshwater environment is responsible for over half of the worldwide aquaculture production; with 56.6 per cent of the total quantity and 50.1 per cent of the total value coming from the freshwater environment (FAO 2006). In observing worldwide trends amongst the major aquaculture species groups, it is important to note which species are producing the most while comparing the value of each of the major species produced. With regard to Crustaceans, they contribute a relatively low proportion of the total production but are a high-value species; second to only 'freshwater fishes' when it comes to value (FAO 2006).

2.2 Crayfish farming worldwide

Freshwater crayfish are cultured in many parts of the world. The largest crayfish producing countries are the USA and China, which produce 55,000 and 40,000 tonnes/annum, respectively; and there are developing industries in southern Europe, South America and Australia (Huner 1994).

The most significant freshwater crayfish industry exists within the southern states of America, particularly Louisiana. Crayfish are known throughout the southern United States by several names: crawfish, crawdads, mudbugs and spiny lobsters; there are more than 300 species in existence worldwide with more than 100 known to occur in the United States and 29 species are found in Louisiana State (Lawson and Wheaton 1982). Although

captive fisheries for red swamp crayfish (*Procambarus clarkii*) exist in several other countries (such as China, Spain and Portugal) there is no place where crayfish are more highly regarded socially and have had as much impact to the economy of a region than in the southern United States. Crayfish are cultivated and consumed in several states but Louisiana dominates the crayfish industry of North America in both aquaculture and wild capture fisheries, where the industry contributes well in excess of US\$ 150, million to the State's economy annually (FAO, 2006).

Commercial sales of crayfish from natural waters began in Louisiana in the late 1800's and with the development of improved transportation and cold storage, crayfish markets shifted from local consumption in rural areas to higher volume markets in cities such as Baton Rouge, New Orleans and beyond. Annual supplies of wild harvest were extremely variable from year to year and the season often short-lived. Therefore, entrepreneurs began experimenting with the farming of Red swamp crayfish by the mid 20th century as a more dependable source of supplies. Pond culture of crayfish soon became integrated with other farming operations and today, pond-reared crayfish constitutes the majority of the annual harvest. Over the last decade, farm reared crayfish have accounted for well over 75 per cent of the total harvest. Approximately 48,000 ha are devoted to the culture of crayfish in Louisiana and the State accounts for about 90-95 per cent of the total production in the USA (source: Main producer countries of *Procambarus Clarkii*- FAO Fishery Statistics, 2005).

China along with the USA has been cited by the FAO (Food and Agriculture Organisation) as a major producer of freshwater crayfish (*Procambarus clarkii*). However, there is limited information or documentation available that indicates that China is intentionally culturing *P.clarkii* on a commercial scale. It is possible that there are some ponds where *P.clarkii* is raised but there are no details available on their numbers or size. It is believed

that red swamp crawfish exports from China are a result of both captured stocks (from rivers, streams, canals etc.) and incidental catches from seining of finfish ponds (source: Main producer countries of *Procambarus Clarkii*- FAO Fishery Statistics, 2005).

In the South Pacific region; there is continued interest in the culture of Australian crayfish of the genus *Cherax*. Three species in particular, the marron *C.tenuimanus*, the yabbie, *C. destructor/C. albidus* and the red claw, *C.quadricarinatus* are in commercial production in Australia (O'Sullivan 1991, Geddes and Smallridge. 1993).

Yabbies (*Cherax albidus*) are indigenous to central and eastern Australia and have received considerable aquaculture interest (Lawerence et al. 2000; Lawerence et.al. 1998). Consequently, Yabbies and marron have been cultured commercially in the southern regions of Western Australia (WA) for over two decades. The majority of marron (*C.tenuimanus*) farming occurs in purpose-built earthen ponds. These correctly designed, well constructed ponds and professionally managed farms are responsible for the majority of marron production, with over 50 per cent of WA Marron production coming from the most productive 10 per cent of marron farmers (Lawerence and How 2006). Yabbies are an introduced species and so for translocation reasons, the licenced commercial yabbie farming industry is restricted to the drier inland agricultural areas of South West Australia.

Yabbies (*Cherax albidus*) are farmed in stock watering dams; in these yabbies require minimal management other than supplementary feeding and harvesting by baited traps. Although yields per dam are relatively low, the combined production from a large number of farmers results in a significant form of farm diversification (Lawerence and How 2006). This approach has potential applications for koura farming in New Zealand given the high allocation of water for agricultural irrigation.

Europeans, particularly in the United Kingdom, have experimented and attempted to establish a freshwater crayfish industry, however, they have had limited success. Since the mid 19th century several species have been introduced into Europe from North America and more recently Australia. These introductions have been mainly for the purpose of cultivation or to replace native species affected by disease. Crayfish farming in England and Wales has developed around the signal crayfish (*Pacifastacus Leniusculus*), which is native to western North America and was introduced into Europe as a crayfish plague-resistant species to replace noble crayfish (*Astacus astacus*) populations and for farming purposes (Alderman and Wickens 1990).

The white-clawed crayfish (*Austropotamobius pallipes* Lereboullet) is Britain's only native crayfish. The white-clawed crayfish is susceptible to predation and competition by larger, faster-growing and more aggressive introduced species, particularly the North American signal crayfish (*Pacifastacus leniusculus*) (Holdich and Domaniewski 1995; Holdich et al. 1995b). As a result wild populations of white claw often co-exist with introduced crayfish species and are being eliminated from their natural habitat through competitive exclusion. The introduction of signal crayfish from North America initially for farming purposes has threatened native populations. Signal crayfish have also been found to be vectors for the crayfish plague, although not all harbour the fungus. Containing signal crayfish within farms is a difficult task, many escaping and colonizing natural lakes and river systems. Some signal crayfish populations are expanding at a rate of 1 km per annum (Holdich 2000). In Europe the extermination of populations of native crayfish species as a result of the introduction of North American freshwater crayfish species infected with the 'crayfish plague' disease has resulted in a heightened awareness of the problems associated with translocations of freshwater organisms (Horwitz 1990). New Zealand's freshwater

crayfish are relatively disease free and at present there are no introduced species that may pose a threat to native populations, which is a positive aspect of the koura farming industry. It is important to note Marron (*Cherax tenuimanus*) were once introduced to New Zealand from Australia in 1986 for aquaculture purposes. However, in 1990 a change in government policy lead to all commercial marron farms being disbanded, and animals destroyed. At present, Marron is an unwanted organism under the Biosecurity Act 1993. It is an offence to knowingly propagate or spread an unwanted organism with penalties of up to 5 years imprisonment, and/or a fine of up to \$100,000 (source: MAF Biosecurity NZ).

Table 1: Summary of main freshwater crayfish producing countries including species, production output (weight and value) and method.

Country	Common name/ Species	Native	Primary method of production	Total Production (weight)	Total Production (value)
USA	Redswamp crawfish (<i>Procambarus clarkii</i>)	Yes	Extensive culture systems	33,498 tonnes (FAO (2005)	US\$ 48.6 million (FAO (2005)
Australia	marron (<i>Cherax tenuimanus</i>)	Yes- Sth. W.A.	Semi-intensive systems and some extensive systems	54 tonnes (2005-06) (SoF2007)	1.4million (2005-06) (SoF2007)
	yabby (<i>Cherax destructor</i>)	Yes- Central/ Sth Aus		66 tonnes (2005-06) (SoF2007)	1.0 million (2005-06) (SoF2007)
	redclaw (<i>Cherax quadricarinatus</i>)	Yes- Nth. Aus		120 tonnes (estimated)	N/A

Country	Common name/ Species	Native	Primary method of production	Total Production (weight)	Total Production (value)
Europe	noble crayfish (<i>Astacus astacus</i>)	Yes	Semi-intensive systems/ re- stocking of lakes and rivers	Unknown	Unknown
	signal crayfish (<i>Pacifasticus leniusculus</i>)	No			
China	Redswamp crawfish (<i>Procambarus clarkii</i>)	Yes	Unknown/ Extensive culture systems	88,000 tonnes (FAO) (2005)	US\$ 303 million (FAO) (2005)

2.3 Techniques and Methods

In spite of the large number of species and diverse range of aquatic animals and plants currently under production modern aquaculture, like agriculture, can be categorized into three basic systems based on the intensity of production;

The three fundamental systems of aquaculture production

1. *Extensive aquaculture*, for organisms cultured in low densities, dependent on natural productivity for food but possibly assisted by fertilization of substrate;
2. *Semi-intensive production*, for cultured organisms at higher densities (than in extensive systems) and dependent on both increased productivity, using fertilizers and waste organic resources, and kitchen refuse and receiving supplementary artificial feed; and
3. *Intensive production*, for cultured organisms in high densities and dependent on artificial feed for their nutritional requirements.

*adopted from Nash, 1995, pg 22.

These three approaches can be applied throughout the farming cycle of freshwater crayfish. Essentially, each of the three strategies relates to the stocking densities of the species being cultured. Presently, most freshwater crayfish are cultured in extensive systems with a low dependence on formulated feed (Huner 1994). However, with growing interest in the farming of large, high value freshwater crayfish of the genus *Cherax*, there is increasing interest in the application of semi-intensive methods. These use smaller ponds along with intensive hatchery production of juveniles and a nursery culture of advanced juveniles for pond stocking (Henryson & Purvus. 2000; Verhoef and Austin. 1999; Parnes & Amir 2002 and Manor et al. 2002). Although more costly and labour intensive, semi-intensive methods have several advantages which include higher yields, greater predictability of production and development of genetic improvement programmes (Verhoef et al. 2002).

Aggressive behaviour is common in many crustaceans, including crayfish. This is problematic when it physically damages stock and reduces quality (Baird et al. 2006). In the short term, the nursery phase is the most suitable for intensification, as juvenile crayfish can be maintained at high densities with minimal demands on space and at juvenile stages damage from aggression is minimalised (Verhoef et al. 2002).

A steady supply of good quality fry (young offspring) is a basic requirement for an intensive crustacean culture system, allowing it to operate more effectively, at a higher capacity and with greater profitability. The development of a closed recirculatory water hatchery and nursery system is thus a prerequisite for the controlled production of young disease free crayfish (Parnes & Amir 2002) (refer to fig.1 Hatchery production flow chart).

Koura farming could benefit from an intensive hatchery /nursery programme given that brood stock for koura farms are often obtained from the wild or other farms. This more

intensive approach could result in improved genetics through selective breeding and would reduce dependence on wild populations.

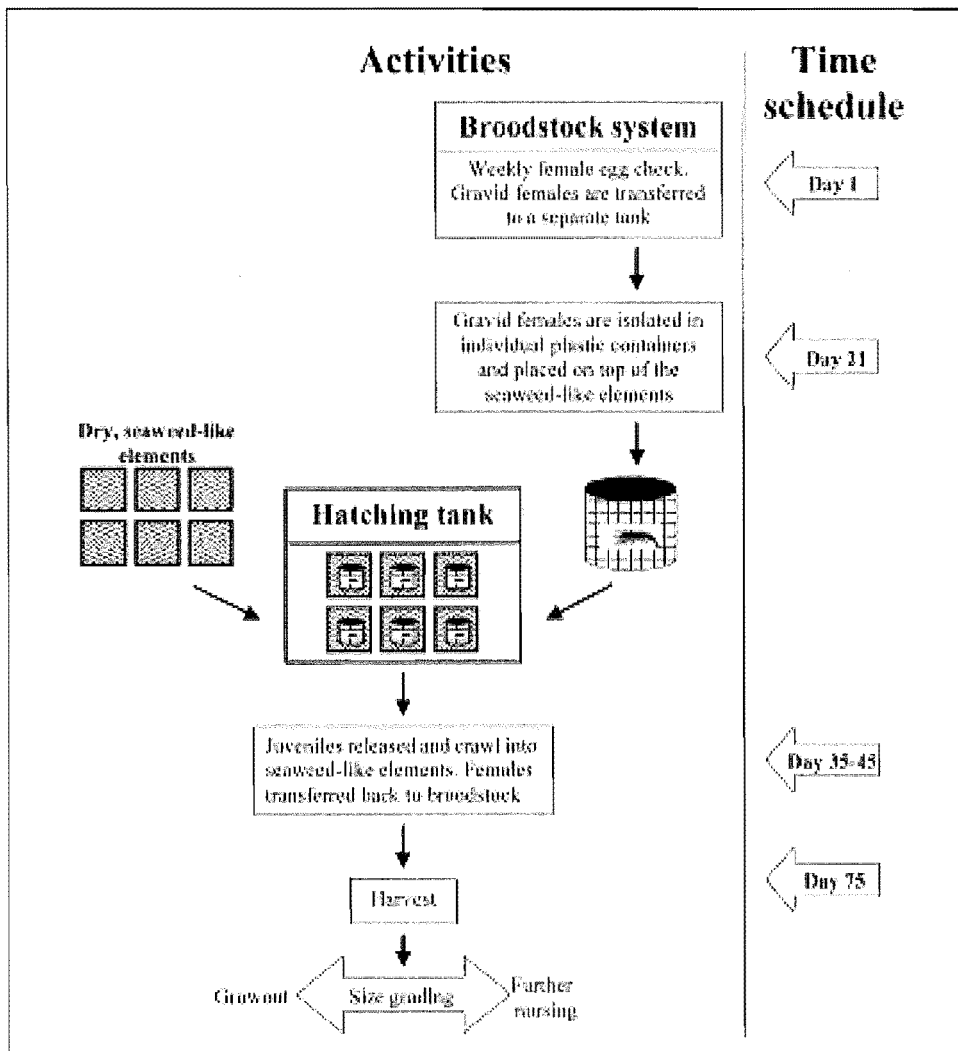


Figure 1 Flow chart of the sequence of events in the intensive hatchery system. Days are counted from the day the females were found to be gravid. The number of the females represented in the chart was chosen arbitrarily.

(* adopted from Parnes & Amir 2002, pg254)

Parnes and Amir (2002) demonstrated that Australian Redclaw crayfish (*Cherax quadricarinatus*) can be artificially hatched and reared under intensive conditions. They overcame crowding issues by including six artificial seaweed-like elements in the hatching (refer to figure 1) tank providing the crayfish juveniles with a habitat of about 50 m², a

value >80 times bigger than the area of the tank bottom (i.e. 0.6 m²). This approach allows mass production of young crayfish which can then be grown out in extensive systems, such as earthen ponds or irrigation raceways.

Parnes & Amir (2002) highlighted two major factors that complicate the mass production of Redclaw crayfish juveniles. The first is the fact that *C. quadricarinatus* is a benthic animal normally living on the bottom and leaving the water column virtually empty of animals, even though the behaviour of juvenile crayfish suggest that they may be less benthic (Jones and Ruscoe 2001). The second factor is the inability of growers to control and monitor the age of juvenile crayfish in earthen ponds. This situation results in major losses due to predation by larger animals both on smaller crayfish and on other going through the vulnerable molt stage (Parnes & Amir 2002). As a result hatching ponds must be continuously harvested.

Unlike redclaw (*C. quadricarinatus*), marron (*C. tenuimanus*) has proven to be a relatively unproblematic species for artificial incubation. Henryson & Purvus (2000) established that marron eggs and hatchlings can be incubated artificially, with high levels of survival. In fact, they found eighty-nine per cent of eggs collected from gravid females and incubated artificially, hatched and developed into independent juveniles. Previous attempts to artificially incubate crayfish eggs and hatchlings were carried out on *Astacidea* species, and resulted in lower survival rates than those observed in this study on marron. New Zealand koura species (*Paranephrops zealandicus*) is relatively slow growing, as previously described by Whitmore and Huryn (1999). Hammond et al. (2006) found growth rates of *P. zealandicus* are closest to those of Australian marron (*Cherax tenuimanus*) therefore it is likely that koura may produce similar survival rates under artificial incubation as marron. However, this is yet to be proven scientifically. A key aspect of more intensive systems of crayfish culture is the management of higher stocking

densities, separating crayfish at different grow-out phases reduces predation and helps prevent disease. Recent studies have investigated these techniques (Manor et al. 2002; Henryson & Purvus. 2000; Parnes & Amir 2002).

Extensive systems also seek methods of reducing aggressive crayfish interactions and subsequent predation during moult events. Extensive systems seek to recreate the natural habitat of the culture species while managing any potential risks and promoting growth. One factor in particular that appears to be of fundamental importance in maximizing yields of crayfish is provision of shelter. In their natural habitat freshwater crayfish species satisfy their shelter requirements by burrowing into soil substrate where they live, sometimes forming intricate burrows (Jones & Ruscoe 2001). It has been suggested that these habitat preferences provide shelter for crayfish during periods of vulnerability when moulting; reducing the likelihood of predation and aggressive interactions. (Baird et al. 2006; Jones & Ruscoe 2001).

Strategies for reducing injuries during periods of aroused aggression are limited and none have been proven to be completely effective. Techniques such as immobilizing the claws and administering drugs have been found to increase the risk of disease, in addition to being labour intensive (Wickens & Lee 2002). The most common method for reducing aggressive interactions is to provide shelters. Although shelter provision reduces the frequency of interactions, there is evidence that fights for the ownership of shelters are more aggressive-indeed, fighting is still observed in several freshwater crayfish species (Wickens & Lee 2002; Holdich 1993). Taking into account these findings Baird et al. (2006) investigated the effect of habitat complexity on the agonistic interactions of Australian freshwater crayfish ('yabbie' or *Cherax destructor*). This study found that habitat complexity reduced both the number of agonistic interactions and the total time spent interacting. It is suggested that the structure in the environment distracts crayfish

from the presence of others or physically blocks contact between them. Focusing on habitat complexity as opposed to shelter provision is a more practical means of reducing aggressive interactions and could have applications to koura farming.

Extensive systems for crayfish culture employ different strategies towards production, compared with a more intensive approach. Extensive systems are often designed around the natural life cycle of the particular crayfish species rather than manipulation through other means. Crayfish farmers from the southern States of America have long known the importance of understanding the habitat and biological requirements of the culture species. Louisiana State accounts for about 90-95 per cent of the total Red swamp crayfish (*Procambarus clarkii*) (Main producer countries of *Procambarus clarkii*-FAO Fishery Statistics, 2005). Louisiana crayfish farmers have developed a production cycle that coincides with the natural phenology of the *P. clarkii* habitat.

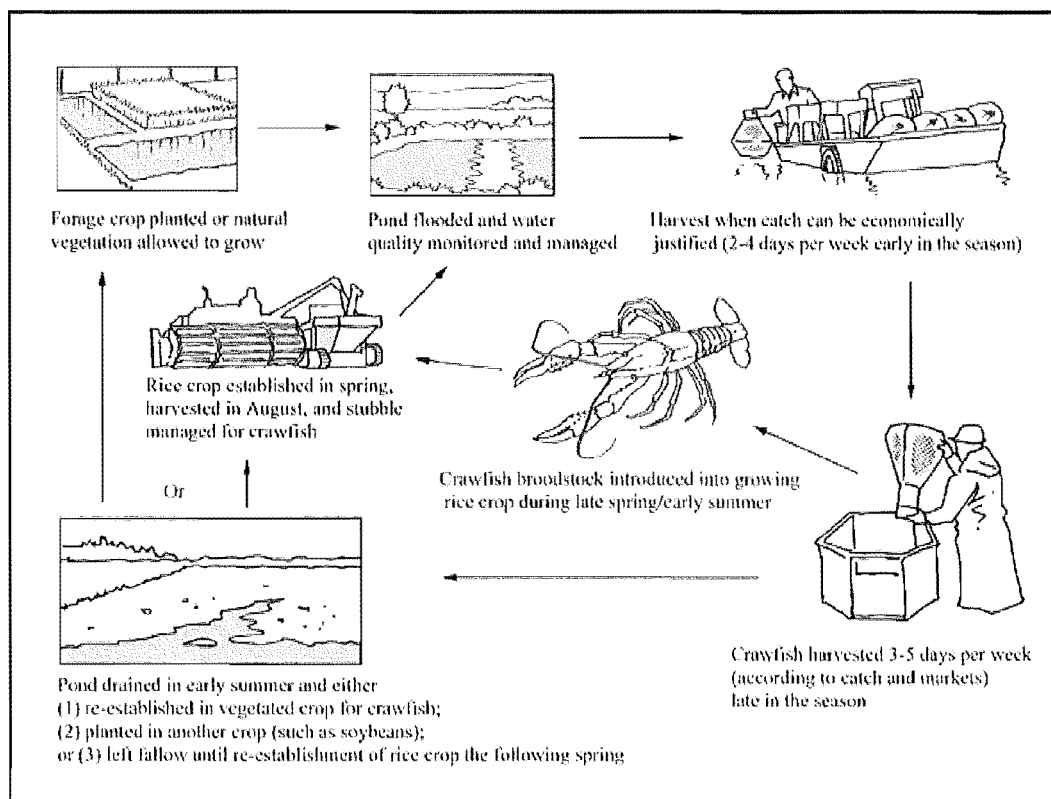


Figure 2 Illustrates the typical extensive production cycle of Red swamp crayfish in Louisiana, USA. (Retrieved from FAO website: <http://www.fao.org/culturedspecies>)

Commercial crawfish production simulates the natural hydrological cycle of the southern USA, but with precise control over when ponds are flooded and when they are drained to optimize recruitment and subsequent crawfish harvests (refer to *fig.2*: production cycle). This approach relies on earthen ponds as substrate and extensive methods of production. These methods are little more than limited control of the environmental conditions, under which these animals evolved. Crawfish survive the dry intervals by digging or retreating to burrows where they can avoid predators, acquire the moisture necessary for survival and reproduce in safety.

Louisiana commercial crawfish production methods are based on providing aquatic vegetation as forage for the crawfish. The animals feed upon decaying vegetation and other organic matter as well as micro-organisms growing on the vegetation. The most common agricultural crop integrated with crawfish culture is rice (Garces & Avault 1985). Rice is planted during the summer months when crawfish ponds have been drained and the bottoms allowed to dry (*refer to fig.2: production cycle*). Numerous studies have evaluated the use of different forage crops for the extensive culture of American red swamp crawfish (*Procambarus clarkii*) assessing the performance of animals cultured under different forage types (e.g. Avault et al. 1983; Avault & Brunson 1990; Huner et al. 1994). Although there is often a great variability in crayfish yields under different methods of cultivation, lower yields are generally obtained in systems where volunteer vegetation (whether terrestrial, semi-aquatic or aquatic) is used as forage, compared with more nutritious crops (Garces & Avault 1985; Avault & Brunson 1990). Once crops planted in the summer months are well established (around autumn) the forage crops are flooded, the rice (or chosen crop) biomass begins to slowly decay until all of the vegetation is either decomposed or consumed by the crawfish by mid-spring. Water quality problems develop as soon as the ponds are flooded. The decomposing vegetation consumes available oxygen

and can greatly reduce crawfish production if supplementary aeration is not provided (MaClain 1999). Lawson et al. (1995) demonstrated that paddlewheel aerators (see **appendix photos**) can be used effectively to aerate and circulate the water in shallow crawfish production ponds. Furthermore, recent research (Pfeiffer et al. 2007) has investigated the engineering considerations for paddlewheel aeration and found paddle wheel aerators are an inefficient option for circulating pond water especially when rice foliage dominates the total vegetative biomass of the pond. Pfeiffer et al. (2007) does conclude that aeration is a necessary component of crawfish farming and that more thought should be given to the placement and depth of the paddle-wheel aerator in relation to the pond design. Although rice is a popular forage crop amongst most red swamp crawfish farmers other crops have been used such as soybean and other fallow.

In Australia, forage crops have been used in the cultivation of freshwater crayfish for more than a decade. Green crops such as clover, rye grass, barley and oats are used depending on the season and locality. They may be either grown in the base of the ponds prior to flooding or cultivated elsewhere and sequentially added when required. Inexpensive agricultural plant products (eg.wheat, straw, lucerne, lupins) and manufactured pelleted diets are also used as feed supplements (Geddes & Smallridge 1993; Jones et al. 2002).

Harvesting freshwater crayfish of marketable size can be problematic as many freshwater crayfish species are elusive and avoid harvest by burrowing. Different techniques have been trialed and researchers have assessed the catch efficiency and retentiveness of various harvesting methods (Pfister & Romaine 1983). Given the extensive nature and heavy vegetative cover of many crawfish ponds common aquaculture harvesting techniques (e.g. seine netting) are ineffective. Most farmers use baited traps are which distributed throughout the pond area and are set out into rows for easy harvest. There are various trap

designs; however, none are 100 per cent effective as Australian studies have found that up to 30 per cent of yabbies (*Cherax destructor*) evaded harvest through burrowing (Geddes & Smallridge 1993). Utilising forage crops (like rice) as an extensive method of producing koura is unlikely to occur in New Zealand on a large scale due to the current demand for land and water resources for other more productive and profitable agriculture such as dairy farming.

2.4 Innovative Research

There are many environmental and biophysical variables one must consider in the cultivation of freshwater crayfish. Researchers from high yield crayfish producing countries and regions are often searching for new more efficient and effective methods of culture. Research themes are broad encompassing everything from the effects of eyestalk ablation (removal) on moulting intervals of red swamp crawfish (*Procambarus clarkii*) (Chen et al. 1995) to comparisons between grow rates of mixed-sex vs. mono-sex growout of yabbies (*Cherax Albidicus*) (Lawrence 2000).

More recently the importance of genetics is being considered with regard to the aquaculture of freshwater crayfish. Genetic improvements have been made through selective breeding in agriculture and horticulture for many years and as a consequence are increasingly being applied to aquaculture. Gjedrem (1997) found that in most aquacultural species where formal selective breeding programmes have been established, genetic response for desired traits such as growth rate, range between 10-20 per cent per generation. This means theoretically at least, that the growth rate of many species could be doubled after only 5-10 generations of selection. Unlike the situation with finfish, there is a lack of peer-reviewed literature reporting on the progress of selective breeding programs in

commercially important crustaceans. In general, it appears breeding programs in crustaceans are rare. As a result a selective breeding programme for yabby (*Cherax Albidicus*) was established in 1998 aimed at increasing the productivity of yabby aquaculture through genetic improvement. Researchers discovered that after two generations of selection, males and females from selected families of crayfish were 29.5 per cent and 32.7 per cent heavier than controls respectively; this represents an average genetic gain per generation of approximately 15.5 per cent (Jerry et al. 2005). As a result stocking densities at commercial crayfish farms have increased inline with advances in technology.

3 Aquaculture in New Zealand

3.1 Current state of the industry

New Zealand’s aquaculture sector has grown at a rapid rate since the late 1980s but remains in the early stages of its development. The industry has achieved an average annual growth rate of 13 per cent by sales over the past 20 years to 2005 (source: New Zealand Aquaculture Council Annual Report 2005-06). The sector is focused on a small number of species, responsible for the majority of production. The greatest contributor to the growth of aquaculture production in New Zealand has been Green Shell™ Mussels, with King Salmon and Pacific oysters the other significant species (see below *Table 2*: Industry Farm Statistics (2006)).

Table 2 :Industry Farm Statistics (2006) showing main producer species and output.

2006 Industry Farm Statistics			
Species	Number of farms	Total ha of marine space	Tonnes harvested
Greenshell™ mussels	645	4,747	97,000
Pacific oysters	230	750	2,800
King salmon	23	60	7,721
Paua (abalone)	18	20	n/a

Source: New Zealand Aquaculture Council Annual Report 2006-2007 (www.aquaculture.org.nz)
 *Note:
 1. The number of farms includes both marine and freshwater farms for the above species.
 2. Many paua farms are also land-based.

aquaculture makes up about 20 per cent of the total fisheries production values and 15 per cent of New Zealand's seafood exports by revenue. New Zealand's contribution to global aquaculture is about 0.02 per cent of sales by weight, the three main export markets are the USA, Japan and Australia (FAO).

Table 3: Industry Farm Statistics showing changes in species production from 1986 and 2006

2006 Industry Farm Statistics						
	1986			2006		
All figures in NZ \$ million	Export	Domestic	Total	Export	Domestic	Total
Greenshell TM mussels	12	16	28	181	43	224
Salmon	3	6	9	42	59	101
Oysters	5	6	11	18	14	32
Abalone (farmed)	-	x	x	x	1	1
Abalone Pearls	-	-	-	2	2	4
King Fish	-	-	-	x	1	1
All figures in NZ \$ million	Export	Domestic	Total	Export	Domestic	Total
Other Marine Finfish	-	-	-	x	x	x
Grass Carp	-	-	-	-	x	x
Kina	-	-	-	-	x	x
Eels	-	-	-	-	x	x
Koura	-	-	-	-	1	1
Ornamentals	-	7	7	1	25	25
Other	-	-	-		x	x
Total	20	35	55	244	146	390

Source: New Zealand Aquaculture Council Annual Report 2006-07 (www.aquaculture.org.nz)

Note:

1. Domestic sales are industry estimates, ex-factory gate. Export sales are FOB, ex-Dept. of Statistics.
2. "x" represents sales that are less than \$1 million.
3. "Other Marine Finfish" include snapper, turbot, tuna, groper and flounder.
4. "Other" includes other shellfish, seahorses, seaweeds, sponges, artemia cysts and marine bio-actives.
5. The above figures exclude sales of enhanced products like scallops and reseeded products such as cockles

and paua (conservatively estimated to have been some ten million dollars in 2006), earning from aqua-tourism activities and some marine bio-actives.

The New Zealand aquaculture sector is reliant upon the three major production species of Greenshell mussels, King Salmon and Pacific oysters (Tables 2 & 3). Sole reliance on these major production species for future growth of the industry is a risky strategy, innovation into different production species is essential for further growth of the industry. In addition to these major production species a number of other species are at various stages of commercial development. Foremost of these would be paua (abalone), rock lobster, sea horse and kingfish aquaculture. A great variety of other species are being examined including eels, turbot, geoducks and of course koura (freshwater crayfish). Note that *table 3* also includes ‘ornamental species’ which have received growing attention, and koura have proven potential as an ornamental species. Over the time period examined koura have grown from a virtually non-existent production species to a domestic industry valued around NZ \$1 million. Although the growth of the koura farming industry does not match that of the more productive species, the figures still indicate a positive trend-reflecting the fact that there are at least a few koura farmers operating commercially viable enterprises.

3.2 Koura Farming

3.2.1 History and Research

New Zealand has two recognized species of freshwater crayfish *Paranephrops zealandicus* and *P.planifrons* (Parastacidae) both of which are endemic (Hopkins 1970). These species are allopatric: *P.zealandicus* is restricted to Stewart Island and the south eastern side of the South Island, while *P.planifrons* inhabits the North Island, Marlborough and the northern

half of the west coast of the South Island (Hopkins 1970). These freshwater crayfish are collectively known in New Zealand by their Maori name 'koura'.

*Refer to appendix Figures 4 and 13 for photos of each species.

Early research into New Zealand freshwater crayfish sought to understand the biology of koura. Prior to the 1960's there was very little information available at all for the New Zealand freshwater crayfish species. During the mid 1960's, research undertaken by Hopkins (1967a) investigated the breeding and lifecycle of the New Zealand freshwater crayfish (*P.planifrons*) White or the northern variety of koura. Hopkins (1967b) described in detail the breeding process of *P.planifrons* and illustrated the lifecycle of koura through field collections and experimental observations. Hopkins (1967) in later study then investigated growth rates of koura (*P.planifrons*) in natural populations by establishing data on moult frequency and growth increment per moult for different sized crayfish; the results were related to the age of the crayfish and size composition of the population found at different times of the year. These early biological studies provided the basis of further research into the potential of koura aquaculture.

During the 1970's around the same time Salmon farming was becoming established in New Zealand, there was renewed interest in the potential of koura for aquaculture purposes. Demand for biological information on both species of freshwater crayfish (*P.zealandicus* & *P.planifrons*) was high as there had been no published studies on the biology or growth of *P.zealandicus*; only those mentioned previously on *P.planifrons* (Hopkins 1967a;1976b).

In response to an increased number of requests for biological data on both species, particularly people interested in the aquaculture potential of the *Paranephrops* species, a study of growth rates of aquarium populations of both species was initiated in late 1976 (Jones 1981). The author demonstrated that both *Paranephrops.zealandicus* & *P.planifrons*

were able to be grown in aquaria, establishing that when reared in unheated aquaria (10-21°C) *P.planifrons* grew to 20mm Orbit-caraspace length in 12-18 months and *P.zealandicus* was reared to the same size in just 9-10months. This was faster than growth rates that had been previously observed in natural populations of both species. However, the author found increased rates of mortality amongst those reared at higher temperatures (18-21°C). Mortality in both species was high (60-93%) (Jones 1981). The results from these early studies indicated that farming of koura on a commercial scale would not eventuate without further research into improving culture techniques and investment.

Jones (1982) further addressed the potential of freshwater crayfish farming by publishing an article in *New Zealand Agriculture* entitled 'The economics of freshwater crayfish farming in New Zealand'. In the study the author provides detailed economic analysis into the estimated costs of establishing and operating a freshwater crayfish farm between the sizes of 2000m² and 6000m² at a variety of different stocking densities. Jones (1982) found that only at stocking densities above 80/ m² (i.e. 80 adult freshwater crayfish per m²) and with a total pond size of at least 6000 m² would such a farm be marginally profitable. The author concluded that freshwater crayfish farming was therefore uneconomic in New Zealand at that time unless most of the costs could be written off against other farming activities.

3.2.2 Current Status

Since the early 1980s, compared with other aquaculture enterprise there has been limited growth within the koura farming industry in New Zealand. Although aquaculture production statistics do indicate some growth between 1986 and 2006 (*figure 3*), they do not reflect the growth witnessed amongst other aquacultural species such as that of King Salmon and Greenshell™ mussels. At present there are 15 licenced koura farms distributed

throughout New Zealand; 6 located in the South Island, 9 are in the North Island (source: Ministry of Fisheries). From the 15 licenced farms on record it is likely only 1 or 2 are operating commercially while the rest are experimental or developing broodstock; which can take several years. The domestic market demand for koura looks like it is about 20 tonnes per year and when we are fully up and running here we will supply 2 tonnes (P.Diver, pers.comm, 20th April 2008). Therefore we could assume that the current state of the industry is not meeting demand, further growth and development is required to supply the domestic market.

Taking into account the limited growth within the koura farming industry and the difficulties encountered in operating a commercially viable farm there is still continued interest in the potential of koura. Despite the apparent lack of growth, the Ministry of Fisheries still receives several enquiries into koura farming every week, however, only a few decide to look seriously into farming them (S.Pullan, pers.comm, 9th May 2008).

3.2.3 Planning and Legislation

3.2.3.1 Resource Consents

Resource consents are required by the Regional Council for activities other than those permitted by a statutory plan or policy. Koura farming is considered a land-based aquaculture activity therefore like many other activities often requires various resource consents to operate these consents usually relate to the take and/or discharge of water.

Applications for resource consent must include an Assessment of Environmental Effects in accordance with Schedule 4 of the Resource Management Act (1991). Schedule four specifies what must and should be included and considered in an assessment of

environmental effects. Upon granting any relevant resource consents for a proposed koura farm, the consenting authority may under Section 108 of the Act place conditions on the consent. These conditions may relate to any issue the consenting authority considers appropriate, for example in the case of a discharge permit a condition may be attached requiring the holder to adopt the best-practicable option to prevent or minimise any actual or likely adverse effects on the environment resulting from the discharge.

In the case of koura farming, obtaining relevant resource consents is a pre-requisite to applying for a fish-farming licence.

3.2.3.2 Fish-farm Licences

Koura farming is undertaken on land and is considered to be a land-based aquaculture activity. This subsequently requires a fish farm licence in order to operate legitimately. The Ministry of Fisheries is responsible for the administration and approval of fish-farm licence applications under the Freshwater Farming Regulations (1983). When applying for a fish farm licence, one must provide the Ministry of Fisheries with information regarding;

- Any resource consents required to take and/or discharge water from the fish farm. If they are not required then evidence from the council is required as proof that such consents are not needed.
- Any other resource consents required to establish the fish farm.
- Evidence the applicant has the right to use the land for the fish farming licence (e.g. a copy of the lease agreement or ownership papers).
- A fully completed application form and a client application form from the Ministry of Fisheries.

The application must also be accompanied by the relevant fee. The fee is related to the amount of time taken to process an application and the levies which are payable to cover the administration and compliance costs. The typical licence fee for 2008 is \$2000; perhaps this could act as a barrier to entry for prospective Koura farmers. The Ministry may change the associated fees and levies from year to year. Once issued fish farm licences' are valid for up to 14 years, provided licence conditions are met throughout that period.

3.2.3.3 Freshwater Fish Farming Regulations (1983)

Pursuant to the Fisheries Act (1983) (repealed) the Freshwater Farming Regulations are administered by the Ministry of Fisheries. These regulations relate to land-based or freshwater aquaculture, the Ministry regulates what fish species are legally permitted to be farmed. A gazette list of fish species that can be farmed under the Freshwater Farming Regulations is available from the Ministry. These regulations set out procedures for the licensing of fish farms and processing plants, the operation of fish farms and processing plants, disease control protocols and miscellaneous provisions such as the fees/levies associated with obtaining a fish farm licence.

There are several provisions of the Freshwater Farming Regulations that may have significance to koura farming. Firstly, in obtaining a fish-farm licence it is valid for duration not exceeding 14 years. This is arguably adequate time to establish sufficient broodstock to maintain a successful koura farm. Secondly, under Part 2, regulation 24 the fish-farm licensee is required to keep full records of all fish raised on or transferred to the fish farm and of all fish sold or otherwise disposed of by the licensee, and shall make those records available for inspection by any Mfish officer at all reasonable times. Farms used exclusively for koura or eel aquaculture are partially exempt from this regulation in that no

record of the numbers of eels or freshwater crayfish need to be kept, but records shall be kept of all transactions in respect of those eels and freshwater crayfish.

It is also important to note; that under Part 1: Regulation 12, a fish farm licence may be transferred under the listed circumstances this includes under regulation 13 the 'Carrying on of a fish farm by a personal representative of a deceased licensee or other wise'. This is of relevance to this study as one of the case study koura farms (Farm B) was bought and subsequently transferred from the deceased estate.

In recent times there has been controversy and confusion surrounding the apparent duplication of roles between the Department of Conservation administering the Freshwater Farming Regulations and the Freshwater Fisheries Regulations administered by the Ministry of Fisheries (see 3.2.3.4). As a result the Ministry had planned to abolish the Freshwater farming Regulations as part of the aquaculture reforms. These reforms focused on marine farming and land-based changes were to be made at a later stage. However the new laws require further changes to make them work properly. As a consequence, it is likely that the Freshwater Farming Regulations will be around for at least another three years, so there is unlikely to be any effect on koura farming in the near future (S.Pullan, pers.comm, 9th May 2008).

3.2.3.4 Freshwater Fisheries Regulations (1983)

Pursuant to the Fisheries Act (1983) (repealed) the Freshwater Fisheries Regulations are administered by the Department of Conservation. The Freshwater Fisheries Regulations administered by the Department have conflicted with provisions under the Freshwater Fish Farming Regulations administered by the Ministry of Fisheries. The confusion is inherent in the approaches and priorities of the two agencies as set out in their empowering

legislation. This confusion over responsibilities relates to Part 10- Indigenous fish; clause 71; Freshwater Fisheries Regulations. The clause (71) states that ‘no person shall sell or trade or have in their possession for the purposes of sale or trade any freshwater crayfish or koura (*Paranephrops* sp.). While the Freshwater Fish Farming Regulations administered by the Ministry allows land-based aquaculture of koura and their sale provided the farmer has done so through legitimate means (i.e. has a fish-farm licence and relevant consents). As a result of the confusion over the interpretation of clause 71, where it states koura cannot be sold, the Crown Law Office (CLO) was asked to review it, and the CLO determined that this only relates to wild-caught koura, meaning koura farms are free to sell their product. It does affect special permits to take koura for farming broodstock; these permits are quite restrictive when taking koura and no koura taken under these permits may be sold once on a fish farm (S.Pullan, pers.comm, 9th May 2008).

3.2.3.5 The Conservation Act (1987)

The Conservation Act is the main mandate of the Department of Conservation. The Department’s role within the freshwater environment is provided for under section 6 (ab) of the Conservation Act (1987) which states their role as being ‘to preserve so far as is practicable all indigenous freshwater fisheries and protect recreational freshwater fisheries and freshwater habitats’. Under section 26zm of the Act; relating to the transfer or release of aquatic life. No person shall transfer or release aquatic life into any freshwater, except in accordance with section 26zm. Clause (3) of section 26zm of the Act is particularly relevant to koura farming, stating; ‘the prior approval of the Minister of Conservation shall be required for the following:

- (a) The Transfer of live aquatic life to or the release of live aquatic life in a new location where the species does not already exist (including transfer of a new species in an existing or new fish farm).

This clause is particularly significant to the potential of koura farming in the Canterbury region because Canterbury is one of the only regions where both koura species exist, meaning there may be applications to farm either species in one region. This of course could pose biosecurity issues to natural wild populations if a particular species were to escape. Therefore the Department of Conservation plays a vital role in protecting freshwater ecosystems under the Conservation Act, a role that can have direct implications for the koura farming industry.

3.3 Stakeholders and Industry Agencies

The aquaculture industry in New Zealand consists of many different stakeholders and agencies, each fulfilling specific roles in the regulation and development of this ever growing sector. The future growth of the industry requires communication and collaboration amongst industry stakeholders and agencies, building on these relationships is particularly important for the often overlooked koura farming.

The relevant stakeholders and industry agencies a vested interest in koura farming are mentioned below with reference to their specific roles and responsibilities.

3.3.1 Ministry of Fisheries

The Ministry of Fisheries (Mfish) is the government department responsible for the management of New Zealand's fisheries and aquaculture. Mfish roles and responsibilities

include; advising the Government on the development of fisheries policies, developing laws to manage fisheries, administration of the Quota Management System (QMS) that regulates the New Zealand commercial fishing activity, promoting fisher compliance with fisheries laws all while giving effect to the principles of the Treaty of Waitangi as they relate to fisheries. Many organisations and individuals have a stake in the health and sustainability of our marine environment, fisheries and aquaculture, Mfish is the lead government agency in this area and work with Maori, other government agencies, commercial interests, recreational fisheries, environmental organisations and service providers.

Mfish play a vital role in the development of koura farming as they are responsible for the administration of fish farm licences for land-based aquaculture under the Freshwater Farming Regulations (1983).

3.3.2 Department of Conservation

The Department of Conservation (DoC) is the leading central government agency responsible for the conservation of New Zealand's natural and historic heritage. Its legislative mandate is the Conservation Act 1987 and other key statutes such as the National Parks Act 1980 and Reserves Act 1977. Like other government departments, DoC has the responsibility to advise Ministers and the Government and to implement policy.

The Department's key functions as set out in the Conservation Act are: to preserve as far as practicable all indigenous freshwater fisheries; protect recreation fisheries and freshwater habitats; to advocate conservation of natural and historic resources; to promote the benefits of conservation information; and to foster recreation and allow tourism to the extent that use is not inconsistent with the conservation of any natural or historic resource.

The Department also contributes to the conservation and sustainable management of natural and historic heritage in area for which it is not directly responsible. It does this through its roles as an advocate under the Conservation Act 1987 and under other statutes, including the Resource Management Act (1991), the Fisheries Acts (1983 & 1996) and the Biosecurity Act (1993) amongst others.

DoC's responsibilities towards the freshwater environment include protecting indigenous and recreational fisheries, which is clearly set out in the Conservation Act (1987) (discussed above). Note that it does this also through its advocacy functions. Consequently the Department is involved with administering the Freshwater Fisheries Regulations (1983) which are of particular relevance to koura farming (*see 3.2.3. Planning and Legislation*). Given that koura are a native freshwater invertebrate species under pressure from traditional food gathers, recreational fishers, and individuals wishing to collect wild brood stock for farming purposes. The Department holds a key position influencing the a quantity and location in which koura broodstock can be collected from the wild for farming purposes, the Department may also include specific conditions under which the broodstock must be collected to mitigate any other issues such as Biosecurity risks.

3.3.3 Regional Authorities (Environment Canterbury)

Regional councils like Environment Canterbury play a primary role in resource management. Environment Canterbury (Ecan) is the promotional name for the Canterbury Regional Council, the main role of the council is the sustainable management of natural and physical resources, primarily under the Resource Management Act (1991). The council is responsible for matters which have more than just local significance. Ecan is responsible

for the development of planning documents and reports outlining activities requiring resource consents in the Canterbury region and is also responsible for issuing resource consents and monitoring compliance. The recent aquaculture reform laws have given regional councils more responsibility in the development of aquaculture activities in marine areas. The regional council (Ecan) must identify suitable areas for marine farms called Aquaculture Management Areas (AMAs) - these are areas where proposed future aquaculture activities must occur. However, Land-based aquaculture activities such as koura farming are treated differently and are not constrained to a particular area or zone identified by the regional council. Rather, providing the Land-based aquatic farm has obtained the necessary resource consents (i.e. take and/or discharge water) then it is allowed to operate anywhere in the region. This is an obvious positive aspect of land-based aquaculture, allowing freedom as to where the aquaculturalist decides to operate. Essentially from the regional council's perspective land-based aquaculture is treated no differently to other rural agricultural activities, provided relevant consents are granted the activities may occur anywhere.

3.3.4 Local Iwi (Ngai Tahu)

Ngai Tahu is the collective Iwi for the South Island and are stakeholders in activities that involve use and development of natural resources. The relationship between Maori and the environment is provided for under section 6- Matters of national importance of the Resource Management Act (1991). Therefore any aquaculture activity marine or land-based must consult with the local Iwi to ensure their activity does not compromise Maori culture and traditions. Under the 1992 Fisheries Settlement Maori are entitled to 20% of fisheries. This settlement was necessary because at that time the QMS system was found to

breach Maori fisheries rights protected by the Treaty of Waitangi. With regards to the recent aquaculture reforms the Government decided the aquaculture settlement should be consistent with the principles of the 1992 Fisheries Settlement; meaning the Crown provides Maori with the equivalent of 20% of all marine farming space created around New Zealand coasts. At present freshwater/ land-based aquaculture activities are not provided for under the 1992 Fisheries Settlement, the freshwater settlement remains largely unresolved. Therefore until further notice land-based enterprises such as koura farming are not explicitly required to provide compensation to Maori for their exclusive rights to access freshwater and farm koura. However if a prospective koura farmer applies and subsequently is granted permission to access wild koura for broodstock, Maori are entitled to 20% of the amount obtained to be consistent with the fisheries settlement. This requirement could pose significant financial implications for prospective farmers.

Communications with Ngai Tahu representatives indicates that they generally support koura farming their only main concern being collection of wild stocks; provided they are collected sustainably then this activity would not be something Ngai Tahu would oppose (C. Pauling, pers.comm. 8th May 2008).

3.3.5 New Zealand Aquaculture Ltd.

Launched in 2006, New Zealand Aquaculture Limited is the amalgamation of the New Zealand Aquaculture Council and species groups (mussels, salmon, abalones and oysters). The new national organisation aims to represent all commercial aquaculture participants and provides one voice for aquaculture. Provision for this united body was made as part of the industry's recently released strategy, which aims to build a sustainable NZ \$1 billion industry by 2025. The development of a unified aquaculture industry organisation is the

first step set out in the New Zealand Aquaculture Strategy (2006) commissioned by the New Zealand Aquaculture Council. The strategy provides a ten-point plan for achieving the NZ \$1 billion goal.

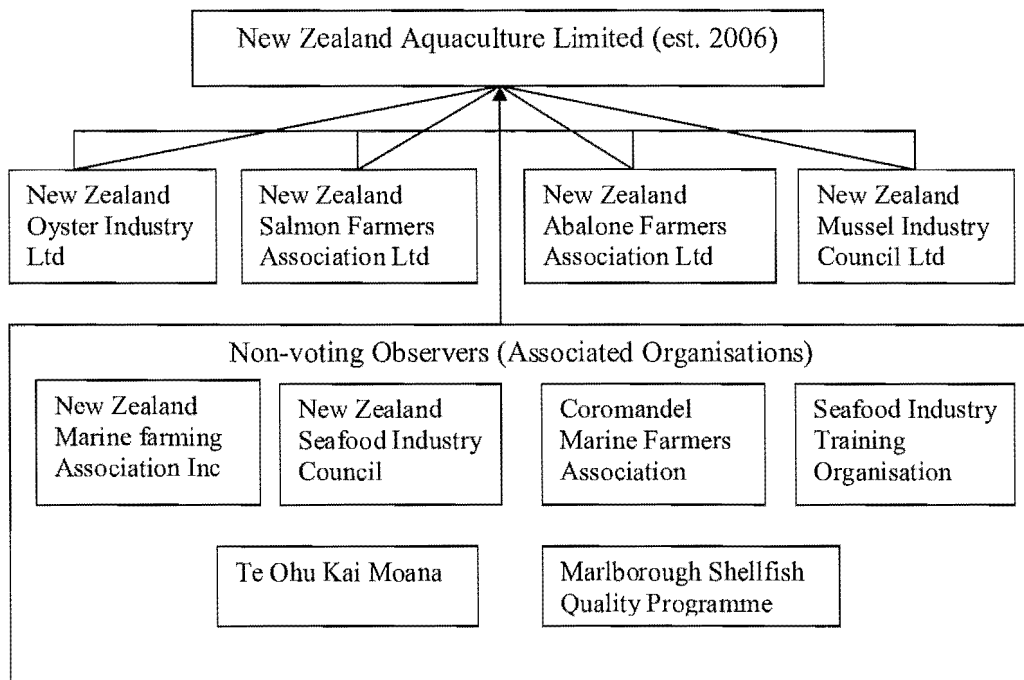
The Ten-point plan includes;

1. Establish a new national sector organisation (New Zealand Aquaculture Ltd.)
2. Strengthen the partnership with government.
3. Strengthen other stakeholder partnerships.
4. Secure and promote investment in aquaculture.
5. Improve public understanding and support for aquaculture.
6. Promote Maori success in aquaculture.
7. Development the market for New Zealand aquaculture.
8. Maximise opportunities for innovation.
9. Promote environmental sustainability and integrity of aquaculture.
10. Invest in training, education and workforce promotion.

(Source: New Zealand Aquaculture Strategy 2006)

The formation of a unified organisation to represent New Zealand Aquaculture and the development of a sector strategy is a great initiative and will contribute to the future growth of the industry. However, it is unclear as to how smaller 'niche' or undeveloped industries like koura farming will be provided for given New Zealand Aquaculture Ltd is largely run by the major species groups that promote their own agenda (*see fig.3 below*).

Figure 3- Structure of the New Zealand Aquaculture industry including the recently established overarching organisation New Zealand Aquaculture Limited.



3.3.6 Research organisations

Research is vital to the development and innovation of the aquaculture industry there are several agencies and organisations that contribute to the scientific knowledge base related to aquaculture. Some of these organisations are Universities, others private research institutes and Crown Research Institutes (CRIs). A few of the major research institutes involved in aquaculture are mentioned below.

1. *National Institute of Water and Atmospheric Research (Niwa)*

The National Institute of Water and Atmospheric Research (Niwa) is a Crown Research Institute providing expertise in the areas of aquaculture and fisheries planning,

development and research. Niwa provides advice to Regional Councils on the development of AMA's and has considerable expertise in culturing fish and shellfish, determining the capacity of areas to sustain aquaculture and evaluating any impacts of aquaculture on the environment. Niwa have conducted research into the ecology/biology of koura and actually have a resident expert specializing in koura research, they also regularly liaise with koura farmers (M.Bruce, pers.comm, 8th June 2008).

2. *Cawthron Institute*

The Cawthron Institute provides worldclass/ high quality research expertise in the fields of selective shellfish breeding, shellfish health and broodstock conditioning. Cawthron engages in commercial scale spat production and provides assistance to industry participants in relation to hatchery technology and engineering, and nursery and Marine farm technology. As part of this research I enquired as to whether the Cawthron Institute has conducted any research into koura, their response; 'we have not done any work towards koura aquaculture' (H. Kasper, pers.comm, 9th June 2008). However they did indicate they are doing a wider research project into potential aquaculture species and were interested in the outcomes of this research.

3. Crop and Food Research (CRI)

Crop and Food is also a CRI and has specific expertise in processing and packaging aquaculture products and in identifying the unique properties of raw materials from the marine environment. Their goal for this area is to maximize returns from New Zealand's sustainable fisheries resources. Crop and Food's blue skies research programmes and specific partnerships with industry represent an important contribution to New Zealand's

aquaculture knowledge base. I was unable to find out whether Crop and Food are or have conducted any research into koura farming as they were not interested in partaking in the research.

4 Methods

4.1 Case study approach

This study was undertaken using qualitative methods of research and results were analysed using the S.W.O.T Analysis technique.

4.1.1 Farm Selection

To understand the dynamics of koura farming in New Zealand it was necessary to visit koura farm operators to utilise their knowledge and farms as case studies for the purposes of this research. A list of licenced koura farms in New Zealand was obtained from the Ministry of Fisheries, at that time there were 15 licenced koura farms in New Zealand; 6 are located in the South Island. After reading various published articles on koura farming, the literature indicated there were three main koura farms in the South Island. Contact was made by telephone with the three koura farm operators; two agreed to be involved with research while the other declined due to issues relating to the commercial sensitivity. The two farms in involved in this study are representative of the wider koura farming industry; each uses a different production system and they grow different species of koura respectively.

4.1.2 Interviews with Operators

Interviews were undertaken with the Owners/ Operators from each of the two farms. The interviews were semi-structured, audio recorded and consisted of but not limited to 30 pre-prepared questions (Appendix). Note: Interviews were recorded with the permission of the interviewees; this allowed the researcher to focus on the interview rather than making notes. The interviews were semi-structured to allow two-way conversation while addressing main issues identified in the pre-prepared questions. The primary objective of the interviews with koura farm owner/operators was to establish the relative Strengths, Weaknesses, Opportunities and Threats facing koura farming as identified by the operators.

Each interview was thorough; lasting more than two hours and included a brief tour of the koura farm facilities. (see photos in appendix)

4.1.3 Farm Profiles

Once the interviews had been conducted, information relating to the unique characteristics of each farm obtained during interviews was used to develop profiles of both farms. The profiles provided a general overview of the respective size, structure and production system for both case-study farms. The profiles are useful for comparative purposes and provide a general summary of the individual characteristics.

4.2 Communication with Stakeholders

4.2.1 Selecting relevant stakeholders

The stakeholders of most relevance to koura farming were identified through literature review and via koura farm owner/operator interviews. This approach provided a balanced perspective and ensured all relevant stakeholders are addressed.

The roles and responsibilities of stakeholders and industry agencies are considered in (section 3.3- Stakeholders and Industry Agencies). The roles of stakeholders (particularly government departments) are evaluated considering their mandatory responsibilities weighed against what occurs in reality, this is achieved by comparing the legislative requirements of the stakeholder in light of what happens in practice. Issues identified through communications with stakeholders were also incorporated into the S.W.O.T Analysis.

4.2.2 Stakeholder questions

The stakeholders identified in (*section: 3.3*) were questioned via email communication. The stakeholders identified as being of particular relevance to koura farming include the Ministry of Fisheries (Mfish), the Department of Conservation (DoC), Regional Council (Ecan) and Local Iwi (Nagi Tahu). The exact questions varied according to the stakeholders mandatory responsibilities towards koura farming and with reference to any other relevant issues.

See also Appendix 9.4 for an example of email communication with Mfish.

5 Results and Analysis

5.1 Farm Profiles

5.1.1 Case Study: Farm A

Company Structure: Owner/Operator

Owner/Operators background: Both have professional science related backgrounds and hold occupations outside their koura farm.

Employees: None

Date licenced: 1992 (second koura licence issued in New Zealand)
licence renewed 2007/08 (15 year renewal)

Location of Farm: Central Otago

Species cultured: *Paranephrops zelandicus*

System of Production: Organic/extensive earthen ponds.

Farm size and structure: 4ha of land; 3ha ponds- consisting of 40 ponds each 250-300m².

Water supply: Exclusive access to artesian well ground water supply (Flow rate: 545lt/sec)

Supplements & Feeding: koura feed mainly on natural organic plant and leaf material however are fed supplementary fish meal pellets: low protein. High Ca with Magnesium, Wheat and Barley. (Feeding ratio one bucket: 2-3days).

Temperature regulation: Kept below 19°C with senses monitoring each pond, naturally regulated with stable groundwater temperature of 10 °C: cooling ponds in summer and warming them in winter.

Company vision: To get the macro koura trail up and running with 40x 50,000lt ponds running; 2-5 year vision harvesting at least 2.5 tonnes per year/40 kg per week.

5.1.2 Case study: Farm B

Company Structure: Owner/Operator

Owner/Operators background: Both have professional science related backgrounds and hold occupations outside their koura farm.

Employees: None

Date licenced: 2003

Location of Farm: North Canterbury

Species cultured: *Paranephrops planifrons*

System of Production: semi-intensive earthen ponds.

Farm size and structure: 1.4ha of land; 0.5ha of growout ponds, reared in tanks for the first year of growth.

Water supply: Initially stream fed water supply, but now ground water supply.

Water use: Minimal, ponds are essentially static, water is added to when required to account for loss through seepage and evaporation.

Supplements and Feeding: Natural feed plus additional pellets and fertilizers.

Aeration: Electric Paddlewheel aeration device.

Company vision: Essentially the operators had taken over the farm from the previous licensee who passed away as a retirement project. The main future goal being to produce a successful first harvest and supply the restaurant trade.

* Note: Photos taken at both farms illustrating the difference in production systems are located in the appendices.

5.2 S.W.O.T. Analysis

The purpose of this research is to examine the potential of koura farming in the Canterbury Region. The primary criteria for assessing this potential is through a S.W.O.T. Analysis; a technique used to structure and identify the relative Strengths, Weaknesses, Opportunities and Threats for any given topic.

Communications with industry stakeholders, koura farm operators and issues identified through literature review are used to develop the S.W.O.T. Analysis for the Potential of koura farming in the Canterbury region.

5.2.1 Strengths

Koura farming as an alternative land-use has many associated strengths, therefore there is major potential for further expansion of the industry.

The first obvious strength of koura (*paranephrops sp.*) as an aquaculture species is that they are endemic to New Zealand. Therefore are naturally suited to our climate; koura are temperate crayfish and have a broad ecological tolerance, and as a result they are found in a wide range of natural habitats (Hopkins, 1970), from sea level to sub-alpine regions (Carpenter, 1977). There are two separate species of koura (*Paranephrops planifrons*; *Paranephrops zelandicus*), each occupying a different geographical range (allopatric distribution), koura farmers are not restricted to any particular area or region. This provides a prospective koura farmer with options as to where the farm may be situated and choice as to what species to culture. Other native species have experienced tremendous success such as the Greenshell Mussels™, part of their success can be contributed to the fact they are a species not grown anywhere else in the world.

Because koura are an endemic species there is no requirement to import or introduce exotic freshwater crayfish from other countries to fuel our own aquaculture

industry. In Europe the extermination of populations of native species as the result of the introduction of North American freshwater crayfish infected with the 'crayfish plague' has resulted in a heightened awareness of the problems associated with the translocations of freshwater organisms (Horowitz 1990). One must observe the success or otherwise of some of New Zealand's introduced plants and animals to understand that focusing on native species like koura is a far safer strategy.

Koura as previously mentioned are present in a variety of habitats, understanding and replicating the biophysical and ecological characteristics of the habitats is fundamental for the production of koura under organic/extensive conditions. Case-study: Farm A in this research is a great example of how koura can be produced under organic conditions. Farm A uses organic production methods characterized by low feed inputs; no fertilizer, ponds gravity feed meaning reduced dependence on electricity to pump water between ponds and broodstock are built up to levels that can sustain periodic harvesting meaning no reliance on importing young offspring for grow-out, such is the case with Salmon farming. (*Refer to farm photos in appendix to compare production methods*). Part of the reason koura can be successfully cultivated under organic conditions is that they are non-migratory unlike their marine cousins; therefore once stocked in ponds they undergo their natural lifecycle building sustainable populations. Although Farm A is considered to operate under extensive/organic systems of production the whole farm occupies a parcel of land no larger than 4ha. Comparatively, the average size of a New Zealand dairy farm is about 146ha (Agriculture Statistics 2002); based on this data approximately 36 koura farms could operate on an average dairy farm.

Water use at Farm A is relatively low, set at a flow rate of approximately 545lt/ per second from an underground bore. The water is gravity fed through 40 ponds and then remains in a settling pond in which water naturally filters back into the underground

aquifer, given the organic approach no harmful substances enter the groundwater and no water is discharged or even leaves the site, keeping the regional council satisfied (P.Diver, pers.comm 20th April 2008). Therefore one could argue that the water is not actually 'used' per se rather it is merely redirected and then recycled through a natural process.

Adopting an organic/extensive system of koura farming is an approach that does not require intensive management, mandatory in other systems of production. The initial start-up costs of establishing an organic system are high but are paid off through savings in other areas. For example there is little reliance on pelleted/supplementary feeds, aquaculture feeds are often made from fish, dependence on marine captured fish food products to service land-based aquaculture does seem counter-productive; given the reported decreases in fisheries production (FAO 2006). Dependence on pelleted fish meal also means the farmer is subjected to any future rises in costs. Therefore an organic system reliant on providing koura with forage vegetation from nearby trees and only supplying small amounts of supplementary feed is a cost-effective and self-sufficient means of production.

Koura can also be cultured under more intensive yet still cost-effective methods. Case study: Farm B adopted the farming methods used in Western Australia to cultivate marron (*Cherax sp.*). This approach is unlike organic/extensive systems in that the initial growth phase is within tanks with grow out in ponds. A more intensive approach means better control over stocking densities with reduced demand on land area and water. This approach is particularly conservative with water reflective of the naturally low rainfall and water availability of Western Australia. Production under this approach requires ponds to be static; '...it was released that rather than flushing the water away and the nutrients with it, it made financial sense to build up the nutrients in a closed loop system keeping the static water healthy by the mechanical aeration of a paddlewheel. To farm water, we don't use

much water. Once our pond is full, the only water used is to top up for seepage or evaporation.’ (Scully 2007b). I personally found these remarks intriguing and further discussions with the operator raised an interesting theory. Due to the fact that under the Resource Management Act (1991) New Zealand’s freshwater is essentially owned by everyone, but no one in particular, unless specifically ‘permitted’. The only open access is to water used for domestic purposes, for stock and for fire-fighting, where water for these purposes is obtained from a municipal source (Harris 2004). Since we are all entitled to water for domestic purposes, Scully raised the point that through his system of production it may be possible to establish a farm without consent to take and/or discharge water. It is yet to be proven, as the farm is consented for all their activities; however, an interesting concept at the least.

Aside from the various strengths of koura farming with regard to the relevant production methods employed at the two case study farms koura farmers can have the confidence that there is a high demand and a large domestic market for their product. With arguably the most successful koura farmer stating; ‘The (domestic) market looks like it is about 20 tonnes per year and when we are fully up and running here we will supply 2 tonnes (P.Diver, pers.comm 20th April 2008). Anecdotal evidence suggests that koura are valued at about NZ\$60 per kg making the domestic market for koura farmers appear worthwhile.

5.2.2 Weaknesses

The most apparent and significant weakness of koura farming as a commercial enterprise is the high start-up costs. These are essentially a large barrier to investment in the industry

and prevent many prospective farmers from establishing a farm. The Ministry of Fisheries receives several enquiries about koura farming- probably about two per week. However, only a few decide to look at farming them (S.Pullan, pers.comm 9th May 2008

Early research investigated the economics of freshwater crayfish farming in New Zealand and concluded farming in New Zealand was uneconomic at that time unless most of the costs, such as land and wages can be written off against other farming activities (Jones 1982). Arguably the industry has not changed dramatically since the 1980's, an example being that case study farms in this study are owned and operated by people who hold occupations outside the farm, to an extent subsidizing their farming activities.

The high initial starts up costs mentioned are the first significant hurdle for prospective koura farmers. High start up costs coupled with a long term return on investment meaning the farmer is not likely to receive income from the investment in the first five to ten years, This is enough to scare away most investors.

Freshwater crayfish aquaculture like any aquaculture activity is a risky enterprise, there is very little industry support, koura farmers in New Zealand are yet to band together and create an industry association like those formed to represent other major species groups in New Zealand aquaculture; Oysters, Salmon, Paua and Mussels. Once an industry reaches a certain threshold or reaches economies of scale, sufficient to require formation of an industry association they have more industry 'clout' and can in a unified fashion provide input into issues affecting the industry. Koura farming has yet to reach this status and therefore is a small voice in an industry dominated by the major production species.

(Refer to tables 2 & 3)

Freshwater crayfish are inherently not the most easily cultured species; they are prone to mortality through temperature fluctuations (Jones 1981; Hammond et al. 2006; Verfoef & Austin 1999), cannibalism (Baird 2006), predation (pers comm. P.Diver & V.Scully),

disease (Edgerton et al. 2002; Jones & Lawrence 2001) and water pollution. Therefore the farmer must be skilled in the best practicable methods of mitigating these risks. Often the most successful techniques for culturing koura are established through trial and error (P.Diver, pers.comm 20th April 2008). Most potential koura farmers may not have the skills or knowledge necessary to operate a koura farm under these circumstances, categorizing koura farming as a high risk investment therefore unlikely to gain the support of banks and other lending institutions. This further stymies the growth of the sector making it appear as an unattractive option for potential investors. Another issue that has historically plagues the establishment of the koura farming industry has been the confusion and 'differences' that have existed under the current regulations, Although these difference are largely resolved (S.Pullan, pers.comm 9th May 2008), mycommunications with the agencies involved indicate that the differences still exist to some extent and although the Ministry of Fisheries appear to understand their role, the Department of Conservation seemed vague not providing detailed succinct responses to questions (J.Nicolson, pers.comm 10th June). The provisions relating to the sourcing of broodstock from the wild have been the subject of controversy. As provided for under the 1992 Fisheries Deed of Settlement, Maori will be allocated 20 per cent of any wild koura available for collection to improve the quality of livestock. This could be perceived as a weakness or problem for koura farmers depending on one's political persuasion.

Media coverage (Anderton 2007) and communication with government agencies would indicate legislative conflicts are supposedly resolved. However, this may not be for long; with the Ministry of Fisheries planning to abolish the Freshwater Fish Farming regulations as part of the aquaculture reforms. Although the changes are not schedules to occur in the nest few years (S.Pullan, pers.comm 9th May 2008). they indicate an uncertain future for koura farmers and the industry on a whole.

5.2.3 Opportunities

Generally speaking freshwater crayfish farmers are often innovators in their own right, developing novel methods of culture and constantly in search of way to improve their productivity. Polyculture has been recognized as an efficient use of pond space; it is a system that incorporates the stocking of several species to effectively increase pond yield. It is not a new concept various studies have investigated the potential of freshwater crayfish in polyculture including production with salmon (Holm 1988) and Nile Tilapia (Rouse and Kahn 1998). It is also important to note that the majority of crayfish production in the United States is done so under systems that could be classed as polyculture (see figure 1: Crawfish production cycle). This system incorporates cultivation of arable crops such as rice or soy beans with extensive production of red swamp crawfish (crayfish). This integrated method of culture allows the industry to exist in a sustainable and yet cost-effective fashion. On a similar note, the majority of yabbies (*Cherax albidus*) are farmed in Western Australia are done so in stock watering dams. In these dams yabbies require minimal management other than supplementary feeding and harvesting by baited traps. Although yields per dam are relatively low, the combined production from a large number of farmers results in a significant form of farm diversification (Lawrence & How 2006). This system of freshwater crayfish farming may have potential applications to koura farming in New Zealand. This approach could potentially be applied in a region such as Canterbury; a region that accounts for over half (55 per cent) of the country's water allocation, the majority used for irrigation (Ministry for the Environment 2006). This would mean that instead of competing with dairy farmers for precious water resources,

koura farmers could essentially use irrigation water for farming purposes after which time the water can be discharged onto the dairy farm for irrigation.

Koura are not only prized for their delectable taste and their status as a cultural food source. A recent article in the Christchurch Press entitled 'Blue cray rarity- the blue koura is taking the world by storm' highlights the potential of koura as an ornamental species in the aquarium trade (Davidson 2008). The excitement is due to a rare genetic mutation found in approximately 1000 koura resulting in their exoskeleton being bright blue. I was lucky enough to hold a blue koura when visiting Farm A and was astounded by the bright blue appearance in stark contrast with the usual drab brown coloured koura (*see appendix Farm A photos*). There are blue koura at Christchurch's Southern Encounter Aquarium; what excites breeders is that if you can get a blue female and a blue male, together they 'breed true' meaning 100 per cent of the offspring are blue. Some might have red eyes; the 'blue gene' appears to be related to albinism (Davidson 2008). This is yet another opportunity for koura farmers especially those operating more intensive systems with better control over genetics and breeding to supply another market other than the restaurant trade. It should be noted that ornamental fish culture contributes a significant amount to the New Zealand aquaculture sector, and koura farmers could take advantage of this lucrative sector

(See *table 3*).

As more effective intensive methods of producing freshwater crayfish are being developed (Henryson & Parnes 2000; Manor et al. 2002; Parnes & Sagi 2002), farmers are in a better position to improve their yields through selective breeding programmes and research into genetics. New Zealand scientists developed a food safe microchip, which means for the first time crayfish, which because of their moulting process cannot be tagged, now effectively can, so that a genetically fast growing strain can be developed (Scully 2006).

Already the Western Australia Department of Fisheries has established a marron research programme, involving some of the largest aquaculture experiments undertaken by the Department. Researchers worked with commercial farmers in WA and South Australia to conduct 44 commercial farm grow outs involving over 147,000 animals grown from juveniles through to sexual maturity and harvest size. Combined with experiments at the Department's research facilities this programme demonstrated the commercial viability of marron farming and increased the growth rate of marron by 100 per cent through selective breeding (Lawrence & How 2006).

Selective breeding of koura provide huge opportunities for farmers to improve their broodstock and ultimately the corresponding harvest. Although technology like the food-safe microchip was developed in New Zealand, minimal research has been undertaken in the selective breeding of koura, most breeding takes place under informal circumstances at koura farms. A collaborative approach involving several koura farms and various research organisations with the intentions of breeding for desired traits and characteristics would significantly enhance the productivity of koura as a production species.

Koura farms like other forms of aquaculture can also generate revenue by advertising and marketing their farms as a tourist attraction. There are several examples throughout New Zealand of aquaculture farms attracting tourists such as Huka Prawn Park near Taupo, Mt Cook Alpine Salmon and Anatoki Salmon situated near Nelson. All of these have taken advantage of tourists' natural intrigue for aquaculture by offering everything from farm tours to packages involving catching Salmon which are then filleted and smoked to the customers preference (Anatoki Salmon).

Koura farmers have not been ignorant to the potential of promoting their farms as a tourist attraction; both case study farms in this research has reportedly at some stage offered farms tours to interested customers.

5.2.4 Threats

A major threat to the potential of koura farming in the Canterbury region is competition for vital water resources and allocation. On a national basis, 77 per cent of the total weekly allocation of freshwater issued for irrigation and in Canterbury, Marlborough and Tasman, irrigation accounts for more than 80 per cent of water allocations (Ministry for the Environment 2006) With such high demands on water resources for the purposes of irrigation, potential koura farmers must compete with corporate backed dairy farmers for land with access to high quality groundwater sources. The huge proliferation of dairy farms throughout the region would indicate that access to land with good quality water supplies is scarce and in high demand. Even if a koura farmer does obtain access to suitable land with water they are still prone to upstream pollution or groundwater polluted from neighbouring properties.

A prime example illustrating the potential conflict that can arise between competing water users is the situation faced by a Kaikoura koura farmer in conflict with the Dairy giant Fonterra. In a recent New Zealand aquaculture magazine article the farmer describes his ordeal; 'Our farm has suddenly came under threat from Fonterra's proposed remedy to complains from discharging its nearby cheese factory waste into the ocean by a crude outfall. Instead, Fonterra will irrigate it with almost 20 per cent of the volume of water that the town uses, over land and into groundwater and hence degrade it, and onto our farm, with an adverse and unknown effect on the health of our extremely sensitive

koura' (Scully 2006). Environment Canterbury were not convinced any adverse effects of Fonterra's proposal would result in any negative impacts upon the koura farm, however, after a meeting among affected parties chaired by a third party councilor, Fonterra then agreed to toxicity tests of their waste water onto koura by an approved party such as the National Institute of Water and Atmospheric Research, for the benefit of forthcoming koura farms in the community (Scully 2007a). The cost of fighting large corporations such as Fonterra can weigh heavy upon a koura farmer trying to establish a viable enterprise. This conflict is not easily remedied with a lax regulatory authority council who permits environmentally hazardous activities by large corporate to occur. Similarly, another dispute arose between the same koura farmer and an upstream farmer who would not keep his cattle out of the creek.' Their stomping silted up the creek water and blocked the suction strainers of our pumps, which stopped frequently. On advising my neighbor of the problem, he advised me that he was there first. I complained to the regional council and after a year of battles, we seem to have won' (Scully 2007a). Conflict is almost inevitable when operating a koura farm in such close proximity to other users. This conflict and competition is a major threat to the growth of the koura farming industry in the Canterbury region.

Reduced water quality and degradation can have severe impacts on a koura farm's viability; lowered water quality can increase mortality rates in freshwater crayfish and increase susceptibility to disease. Disease is a major threat to koura farmers; little is known about the disease risks of koura. Early studies found Microsporidan parasite affecting the musculature throughout the crayfish, causing a gradual decline in locomotor activity, and it eventually can cause the death of the host (Quilter 1976). Overseas, the 'crayfish plague' has had devastating impacts on native freshwater crayfish in Europe to the point that government agencies and aquaculturalists introduced freshwater crayfish from other

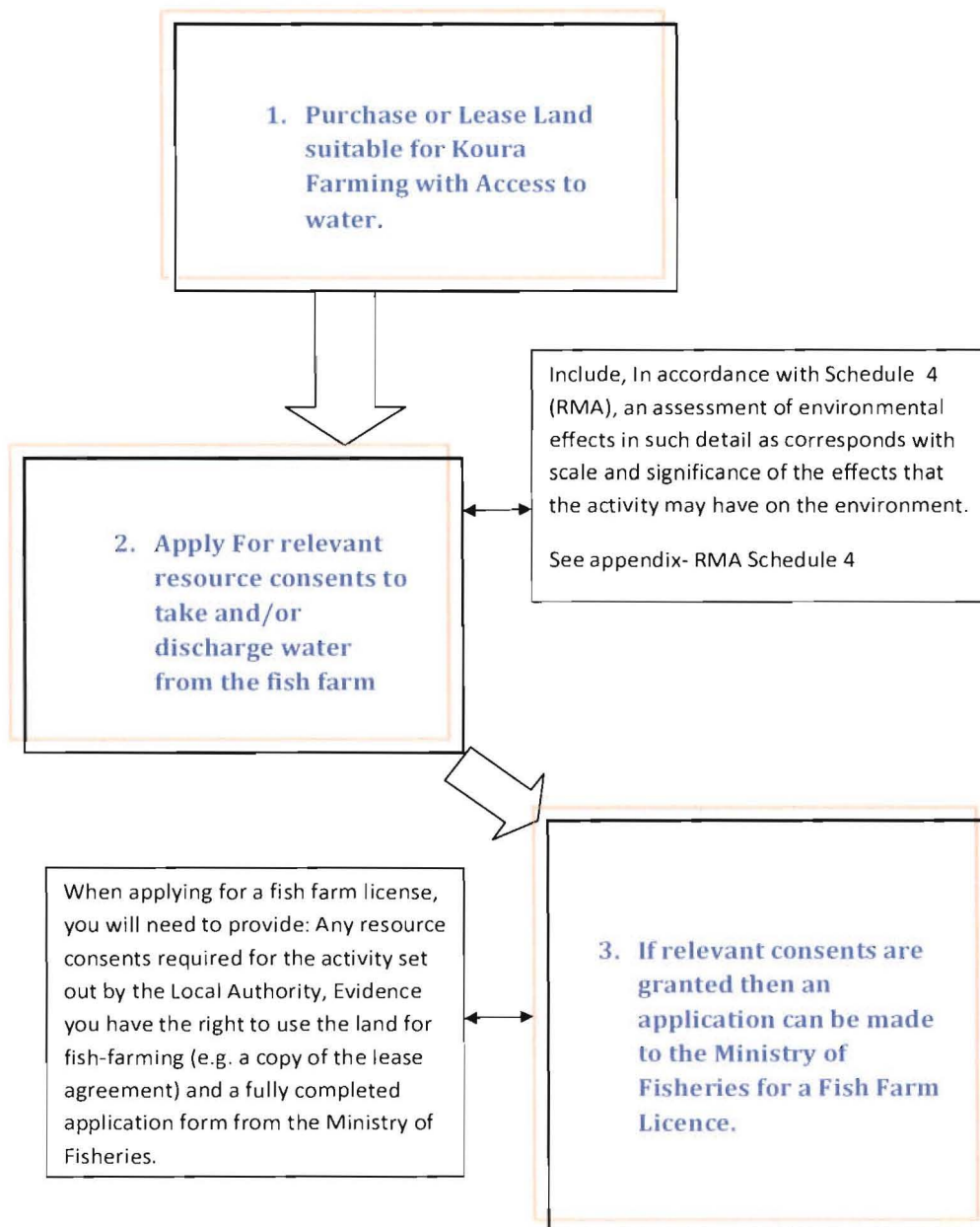
countries such as Australia and North America in an attempt to re-establish natural crayfish populations and for farming purposes (Alderman 1990). Research into freshwater crayfish diseases has also been undertaken in Australia (Edgerton et al. 2002; Jones & Lawrence 2001). Disease is an ever present threat to koura farmers and as a result farms are designed to minimize the risks of disease.

Invasive freshwater organisms such as algae, invasive fish species (e.g. trout, European perch), eels, water rats and cormorants (shags etc.) can plague koura farms if measures are not in place for their management. Perch in particular can create havoc for koura farmers, the owner/operator of Farm A found when he drained one pond in autumn he got only 30kg of koura but 150kg of adult perch and 4000 fingerlings. 'We should be getting 40kg of crayfish a year per pond, but with perch you would be lucky to get 10kg. So we had to put in place measures to prevent perch entering the system. All water is micro-filtered because the young are very small and will get through just about anything' (P.Diver pers comm., 20th April 2008.). Invasive species and predation can present major threats to the production of koura and methods of mitigating these risks can be costly and not to mention time consuming effecting profit margins and the overall success of the enterprise.

The Ministry of Fisheries has indicated that they have plans to abolish current provisions under the Freshwater Fish Farming regulations as part of the aquaculture reforms. The new reformed regulations are currently in the 'pipeline' and are likely to be implemented in the next few years (S.Pullan, pers.comm 9th May 2008). This signals an uncertain future for potential koura farmers wishing to establish a farm in the next few years. It is unknown whether the reforms will better provide for potential farmers or become more restrictive. Either way the reforms spell uncertainty among prospective investors and farmers and they may be seen as a significant risk to the future growth of the industry.

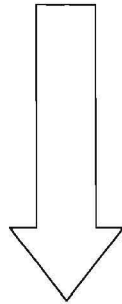
5.3 Flow Diagram

Figure 3. Flow chart for establishing a koura farm



4. Once a fish farm licence has been issued it will be necessary to obtain broodstock to stock the farm.

It is not possible to take aquatic life from natural waters (the sea, lakes rivers etc) to use as stock on a fish farm unless it is from one of the following sources: another land-based fish farm, a marine farm, licensed fish receiver, or have permission to access wild broodstock under Fisheries Act special permits. Before transferring broodstock to the farm approval from the Ministry of Fisheries is required.



5. Provided the relevant licences and consents are issued the applicant may legally establish their koura farm.

There are two different species of species of koura and given the species are geographically separated it is necessary to indicate which species is to be farmed and provide evidence the ponds are secure to prevent escape into wild. Note however, you will need approval from the Department of Conservation for the first release of each species onto the fish farm (required under section 26zm of the Conservation Act 1987).

6 Discussion

6.1 Blue Horizons: Future of koura

'Our Blue Horizon' is a document produced by the the Ministry for Economic Development (2007) acknowledging aquaculture as a fast growing sector and outlines their commitment to the future growth of Aquaculture in New Zealand. Underpinning the government's commitment to aquaculture is environmental sustainability. They consider sustainability as a necessity not an optional extra. This high level commitment to the growth of the industry can be seen as a positive step for future growth, consistent with the ambitious target set out in the New Zealand Aquaculture Strategy (2006) of building a sustainable billion dollar business by 2025. The government's commitment to aquaculture is built on five key objectives:

- Building the confidence to invest.
- Improving public support.
- Promoting Maori success.
- Capitalising on research and innovation.
- Increasing market revenues.

(Source: Our Blue Horizons Document)

Within each of these objectives the government has identified a number of targeted initiatives. The government has not released specific details relating to these initiatives. Largely this commitment to the aquaculture sector is a positive sign for the wider aquaculture industry, but I question the impact the document and these 'initiatives' will have upon the struggling koura farming sector. In communications with respective koura famers during this study, I questioned whether the government had consulted or even considered their industry in the formation of targeted initiatives. Their response indicated no incentives or initiatives were on offer, 'Our Blue Horizons' being more marine focused,

a small industry like koura farming rarely considered at higher levels. As the aquaculture industry in New Zealand grows exponentially it is likely koura farming will continue to grow as a result of hard work put in by dedicated individuals rather than through incentives and direct support from government and related agencies. Surely if the government set 'sustainability' as such a high priority for future aquaculture then koura farming would be promoted as a sustainable farming enterprise for future investment.

6.2 Importance of support services

Growth in the koura industry and the present state of the industry can be attributed to the small group of farmers who have invested heavily in their operation with little or no support from external agencies. Forging healthy relationships between koura farmers, research institutes and government departments is vital for future growth within the industry. The Fisheries Research and Development Corporation (FRDC) of Western Australia has funded a Marron research program (as mentioned in prior chapters). Researchers from the Department of Fisheries worked with commercial farmers in WA and South Australia to conduct 44 commercial farm growouts involving over 147,000 animals grown from juveniles to sexual maturity and harvest. This programme demonstrated the commercial viability of marron farming and the increased growth rate of marron by 100 per cent through selective breeding (Lawrence and How 2006). These types of programmes have not been undertaken in New Zealand for koura, essentially restricting the further growth and development of the industry. Research assessing the importance of support services available to the aquaculture industry in New Zealand as compared with Australia indicates New Zealand severely lacks sufficient support services. Current levels of government funding to aquaculture research are inadequate to meet the level of need in a rapidly growing sector of the economy. Furthermore, the delivery mechanisms for this

funding are inefficient in some ways as they are resulting in research providers being isolated from one another and some providers such as the tertiary sector have in many instances disengaged from aquaculture research (Jeffs 2002).

These issues are of great relevance to the koura farming sector and their resolution would further enable and provide for the future growth of the industry.

6.3 Provisions for koura farming

The current provisions for koura farming have been problematic, as highlighted in previous chapters the conflict surrounds the 'differences' that exist between the Department of Conservation's Freshwater Fishing Regulations and the Freshwater Farming Regulations administered by the Ministry of Fisheries. Communication with both parties established that the issues have since been resolved. A media release (March, 2007) from Fisheries Minister Jim Anderton confirmed that 'differences' exist and the proposed amendments will address these differences. Although these issues have been addressed for now, the wider reform of Aquaculture regulations this time focusing on freshwater farming will pose a greater threat to potential koura farmers than the small amendments made to regulations that in the future will be abolished.

If the previous marine farming reforms of 2002 are anything to do by then the freshwater farming industry may be due for an overhaul. Ministry of Fisheries officials say 'It is likely that Freshwater Fish Farming regulations will be around for at least another two years, so there is unlikely to be any affect on koura farming in the near future (S.Pullan, pers.comm May 9th).

6.4 Sustainability and Marketing

Sustainability is a term with a ambiguous meaning and is frequently used in modern society. In a corporate driven world sustainable business practices are promoted in

marketing campaigns to provide their customers with the confidence that their products are environmentally friendly.

The government's commitment to aquaculture is underpinned by their commitment to environmental sustainability and the New Zealand Aquaculture Strategy promotes environmental sustainability and integrity of aquaculture as a bullet-point in their ten-point plan. In a society with growing demands as to where and how their food is produced, food producing sectors are required to satisfy these demands through public disclosure, food labeling and becoming adopting a certification system such as becoming organic certified.

Koura farmers have the opportunity to take advantage of current trends and adopt a certification system like Organic certification to promote and market their products. Taking into account the methods of producing koura (as mentioned in prior chapters), one of which is based on organic production methods, it is likely to be easily certified. Of course further research into certification systems appropriate for koura farming and aquaculture is required and is a research topic in its own right.

6.5 Polyculture and Integrated Water Use

Polyculture has significant potential applications for koura farming in New Zealand.

Overseas studies have previously addressed the potential of culturing freshwater crayfish with other species such as Atlantic Salmon (Holm 1989) and Nile Tilapia (Rouse and Kahn 1998). Koura farmers are beginning to consider the potential of polyculture with one farmer stating; 'Farmed water can also be the basis for a polyculture around it, growing anything from tomatoes, whereby the total sum of the produce can be better than if each product were grown separately. For example tomatoes appreciate the nutrient rich water coming from the pond, such as polycultured sweet tomatoes from Israel that are popular in Europe. (Scully 2007b).

Yabbie farmers practice integrated methods of water-use in Western Australia; Yabbies (*Cherax albidus*) are farmed in stock watering dams. In these dams yabbies require minimal management other than supplementary feeding and harvesting. This method of yabbie farming presents a low risk to the environment because negligible amounts of water are discharges from dams, whose primary purpose is the provision of water for stock (Lawrence & How 2006).

Further research is required to assess how koura could be culture in a polyculture system and how koura farming operations could become more integrated. There may be potential in establishing koura farms within irrigation ponds used for dairy farming; this is particularly relevant in the Canterbury Region.

7 Conclusion and Recommendations

7.1 Conclusion

It has been well documented both within New Zealand and Internationally that aquaculture is one of the world's fastest growing food producing sectors (FAO 2006). The New Zealand Aquaculture Industry has traditionally focused upon three marine based species (Mussels, Salmon and Oysters) largely ignoring the potential of land-based aquaculture. Diversification of species under production spreads the risk amongst more species and promotes the development of more novel aquaculture species.

Koura farming can hardly be considered a novel idea, it has been investigated since the 1960s, however it has yet to experience the growth witnesses amongst other species. We are currently entering a phase where farms established in the early 1990s have built sufficient brood stock for sustainable harvesting furthermore techniques used to successfully cultivate Australian freshwater crayfish species are being applied to the culture of koura in New Zealand. This suggests that koura farming may currently be on the long awaited verge of becoming a fully established industry.

A S.W.O.T. Analysis was undertaken to assess the potential of koura farming in the Canterbury region; the respective Different Strengths, Weaknesses, Opportunities and Threats were identified in relation to koura farming. The strengths and opportunities appear to outweigh the weaknesses and threats, signaling that although once identified as being 'uneconomic' (Jones 1982) the industry is likely to continue growing. The extent of growth will be determined by primarily the koura farmers but also with input from research institutes, government departments and industry support agencies. This research has helped highlight some areas that require further attention for the future growth of the koura industry, these areas are provided for by the following recommendations.

7.2 Recommendations

- Ministry for Economic Development and funding agencies should provide funding for research institutes to undertake a selective breeding programme for koura to identify desirable traits for farming and improve genetics of broodstock. This programme should be conducted in conjunction with farmers.
- Regional councils such as Environment Canterbury must develop methods of allocating water that provide for users who utilise water resources in a ‘sustainable’ fashion. Instead of the current ‘first in, first serve’ approach. Incentives or preference should be given to koura farmers that can demonstrate their system of farming promotes the sustainable use of water. Likewise these principles should be applied to other water-users.
- Koura farming should ideally establish a ‘Koura farmers Association’ like other species groups. This will provide a unified voice for all koura farmers and allow for better representation at higher levels. Ideally this would provide a vehicle in which koura farmers become more recognised by larger industry organisations such as N.Z. Aquaculture Ltd.
- The Ministry of Fisheries indicated that there will be future reforms of the current land-based aquaculture regulations. These reforms should be undertaken with prior consultation with affected parties, particularly koura farmers and other land-based aquaculturalists, to ensure that their needs are provided for.

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9 Appendices

9.1 Appendix 1: Koura Farm A photos



Figure 4: Picture two young koura (P.zelandicus) right: several months old, left: approximately one year.



Figure 5: Almost market size koura (2yrs + old)



Figure 6: Recessive Blue koura sought after as an ornamental variety.



Figure 7: Recessive Blue koura sought after as an ornamental variety (Alternative view)



Figure 8: Organic material built up around pond which provides shelter and will decompose and become a food source for koura

Figure 9: View of the extensive/organic system of Farm A, note the natural appearance and the gradient: ponds are gravity feed and separated for easy management.



9.2 Appendix 2: Koura Farm B photos



Figure 10: Farm B uses a semi-intensive system of production, note the netting to keep predators out and the differences when compared with Farm A.

Figure 11: Farm B uses a semi-intensive system of production, see the waterwheel aeration device





Figure 12: Picture of the mechanical paddlewheel aerator used to maintain high dissolved oxygen levels.

*Figure 13: Young koura (*P. planifrons*) scooped from grow out pond, note lighter colouration than *p. zelandicus*.*



9.3 Appendix 3: Interview questions

Semi-structured Interview Questions

Koura farm Operators:

Company/ Farm Profile

- Name:
- Owners/Operators:
- Employees:
- Date established:
- Date licensed:
- Species cultured:
- Farm Size:
- Company vision:

Background

1. Do you have any formal qualifications/ work experience related to Koura farming or aquaculture in general?
2. How did you come to be involved with Koura Farming?
3. Is Koura farming your main occupation or do you work elsewhere?

General

4. What initially attracted you to become involved with koura Farming?
5. How does koura farming differ from other farming operations with regard to the effects on the environment?
6. Where do you see koura farming heading in the Future?
7. Are you involved with any professional associations within the koura farming industry? If so, please specify.
8. Do you find there is enough support from government agencies, local authorities, industry associations or any other relevant stakeholders?

Operations

9. How did you select a site to establish your farm?
10. How would you classify your approach to koura farming? E.g. Intensive, Extensive, Organic.
11. Where did you initially source your brood stock and how?
12. Have you been involved with any research into koura or freshwater aquaculture?

13. What do you feed your koura and how?
14. Would you consider koura farming is a sustainable enterprise? If so, Why?
15. With declining wild koura populations, is there a possibility koura farms could be used to reseed our rivers?
16. Do you provide tours of your farm? Is it a possible tourist attraction?
17. Could you identify the most common problems associated with the success of your operation? Are these site specific?
18. What measures have you taken to mitigate these problems?
19. How much water do you use and how do you maintain your water quality?
20. Do you use environmental indicators to monitor the state of your farm? If so, please specify.
21. Who is the main market for your koura?
22. How do you process your koura for sale?

Legislative/Planning

23. What Resource Consents are required to operate your Farm?
24. Are there any conditions on those consents?
25. Do you believe the current legislative framework provides for future growth of the Industry? If no, Identify problem areas on flowchart**
26. If not, how might the legislative framework better provide for the expansion of the Industry?
27. Koura are considered culturally significant to Maori, Have you consulted or been in correspondence with local Iwi with regard to your operation?
If so, How do they feel about it?
28. The Government have stated their commitment to aquaculture development in their 'Blue Horizons' document? How do you think this relates to koura farming?
29. Within your regional planning documents would you say koura farming is provided for as well as other land based activities?
30. Do you feel that I have over looked any major areas that I should include with regards to koura farming?

9.4 Appendix 4: Stakeholder communication example

Hello there,

My name is Matt Mckenna, I am a post-graduate student from Lincoln University currently working on my dissertation research as part of the Masters of Applied Science programme.

The topic of my dissertation is investigating the Potential of Koura Farming in the Canterbury Region,

I understand that MFish manages land-based aquaculture of our native koura species and therefore are stakeholders in any Koura farming enterprise.

I have a few questions about this;

In recent times there has been confusion over the responsibilities of the Ministry of Fisheries and the Department of Conservation in relation to Koura farming Have these issues been resolved? If so, how?

What is Mfish's position on Koura Farming particularly in the Canterbury region,
Also I understand there are two species of koura in New Zealand with farming potential, are there strict boundaries to where these species can be farmed? ie in the Canterbury region what species are you allowed to farm?

How many applications do you get for Koura farms are they are a frequent occurrence?

On the mfish website it mentions about future reforms in land-based aquaculture? What are these reforms and how will they affect koura farming in the future?

Any feedback will be much appreciated!!

Kind Regards

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