Australian Government
Rural Industries Research and Development Corporation

Redclaw Selective Breeding Project

by John Stevenson; A/Prof Dean Jerry; A/Prof Leigh Owens

2012

RIRDC Publication No 12/ (added by RIRDC)
RIRDC Project No PRJ 000327

© 2012 Rural Industries Research and Development Corporation.
All rights reserved.

ISBN 978-1-74254-xxx-x (RIRDC to assign)
ISSN 1440-6845

Redclaw Selective Breeding Program
Publication No. 12/XXX
Project No. PRJ 000327

The information contained in this publication is intended for general use to assist public knowledge and discussion and to help improve the development of sustainable regions. You must not rely on any information contained in this publication without taking specialist advice relevant to your particular circumstances.

While reasonable care has been taken in preparing this publication to ensure that information is true and correct, the Commonwealth of Australia gives no assurance as to the accuracy of any information in this publication.

The Commonwealth of Australia, the Rural Industries Research and Development Corporation (RIRDC), the authors or contributors expressly disclaim, to the maximum extent permitted by law, all responsibility and liability to any person, arising directly or indirectly from any act or omission, or for any consequences of any such act or omission, made in reliance on the contents of this publication, whether or not caused by any negligence on the part of the Commonwealth of Australia, RIRDC, the authors or contributors.

The Commonwealth of Australia does not necessarily endorse the views in this publication.

This publication is copyright. Apart from any use as permitted under the *Copyright Act 1968*, all other rights are reserved. However, wide dissemination is encouraged. Requests and inquiries concerning reproduction and rights should be addressed to the RIRDC Publications Manager on phone 02 6271 4165.

Researcher Contact Details

Name: John Stevenson
Address: PO Box 302, Aitkenvale. Qld 4814

Phone: 07 4772203
Email: jhstevo@bigpond.com

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details

Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600

PO Box 4776
KINGSTON ACT 2604

Phone: 02 6271 4100
Fax: 02 6271 4199
Email: rirdc@rirdc.gov.au.
Web: http://www.rirdc.gov.au

Electronically published by RIRDC in xxxx 2012
Print-on-demand by Union Offset Printing, Canberra at www.rirdc.gov.au
or phone 1300 634 313

Foreword

This research project is important from two perspectives. Firstly, it has achieved the set objectives that were critical to the industry's survival. It has also provided proof that the industry has matured and can confidently claim that it had shed its cottage industry status and can move on to being the viable, vibrant industry that it always had the potential to be.

Virtually all Australians are prospective beneficiaries of this project, but obviously those who make their living farming redclaw will be the first to gain from the results achieved. The immediate benefits are twofold – the faster growing animals provide a significant increase in production without additional infrastructure or effort, and the new farming method – S3J Farming – increases profit and reduces labour. The boost to farmers prosperity will flow on to the community at large as well as an increase in business for associated industries.

The outcomes from the project are that a faster growing, genetically diverse strain – The Tolga Strain – of redclaw has been developed; the technology is now in place to produce disease free animals that are eligible for Specific Pathogen Free (SPF) status and a whole new approach to redclaw farming methods has been developed.

Producers should welcome these achievements and take advantage of the increase in productivity that is now possible by adopting the recommendations made. This should be encouraged by policy makers who must become aware that redclaw farming is an environmentally passive industry that is suitable to rural areas with a warm climate and an available source of fresh water.

This research project and the advances made as a result would not have been possible without the foresight exhibited by Rural Industries Research and Development Corporation in accepting the industry's application for funding. This project was funded from RIRDC Core Funds which are provided by the Australian Government

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our New Animal Products R&D program, which aims to conduct RD&E for new and developing animal industries that will contribute to the profitability, sustainability and productivity of regional Australia.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Craig Burns
Managing Director
Rural Industries Research and Development Corporation

About the Author

John Stevenson retired from a successful engineering business in 1995 to become a full time redclaw farmer. He indulged his passion for experimentation and research in this field and quickly became involved with industry organization. He has held the position of NQCFA President for 12 years and QCFA President for 5 years. Currently he is Principal Investigator for an RIRDC funded Selective Breeding Project which is nearing completion and overseeing a similarly funded Feeding and Nutrition project being managed by James Cook University

Prof Dean Jerry is Program Leader of the Aquaculture Genetics Research Group at James Cook University and has over 14 years research experience in developing genetic knowledge relevant to the design and conduct of selective breeding programs. During this time he has published a career total of 71 research articles related to the genetics of aquatic species. He has been involved in the successful instigation of selective breeding programs for two freshwater crayfish species, marine shrimp, and pearl oysters, and is recognised as a leading world authority in the application of genetic technologies to aquaculture.

Associate Professor Leigh Owens is the immediate past head of the Discipline of Microbiology and Immunology, School of Veterinary and Biomedical Sciences at James Cook University. He graduated (BSc Hons) from the University of Queensland and James Cook University (PhD). He undertook several postdoctoral positions at JCU before joining the academic staff. He has been research aquatic diseases for over 30 years. His current interests are the infectious diseases of aquatic animals and the use of bacteriophage for controlling animal diseases.

Contents

Please Check with a tick the box 'use hyperlinks instead of page numbers' when inserting your table of contents. This allows the final pdf file to be interactive.

Tables

Apply the ‘Table’ style to the table headings in your document and then generate the list (similar to the TOC generation).

Error! No table of figures entries found.**How to insert a 'Table' contents list:**

- go to *'reference'* tab
- go to *'table of figures'* tab in this 'reference' mode
- ensure that *'use hyperlinks instead of page numbers'* is checked with a tick
- Click *'options'* and then scroll in the box for correct heading to capture: eg **- table, or table caption**. (The default heading 'boxcaption' **-** or the first in the list, will appear **-** and this is the one that should be changed to the one you want).

Please place the Table Heading immediately **before** the table.

Figures

Apply the ‘Figure’ style to the figure headings in your document and then generate the list (similar to the TOC generation).

How to insert a 'Figures' contents list:

- go to *'reference'* tab
- go to *'table of figures'* tab in this 'reference' mode
- ensure that *'use hyperlinks instead of page numbers'* is checked with a tick

Click *'options'* and then scroll in the box for correct heading to capture: eg **- figure, or figure caption**. (The default heading 'boxcaption' **-** or the first in the list, will appear **-** and this is the one that should be changed to the one you want).

Please place the Figure Heading immediately **after** the figure.

Note on inserting figures:

To control file size it is best to use the 'Insert' tab from the Home page control ribbon. Then go to the 'Picture' tab and insert from file. This action has a better impact on file size than just pasting in to a word document.

Executive Summary

What the report is about

This report is about an emerging industry taking the initiative to help itself. The information detailed in this report is important, not only because of its content, but also because it is about research – the first research project undertaken by the redclaw industry for the redclaw industry. The object of the research was to produce a strain – The Tolga Strain – of redclaw that is faster growing, genetically diverse and free of disease. Along the way a new method of farming redclaw – 'S3J Farming' - was developed, transforming redclaw farming from a hobby to a business

Who is the report targeted at?

The primary target of this report is the redclaw industry itself. It is proof that research targeting identified key issues can have a major impact on whether a redclaw farm is a success or a failure. In the past many people have displayed an interest in farming redclaw but have not gone on to be successful industry participants. Major factors have been the lack of a dedicated research effort providing a platform for the development and availability of quality stock and an uncomplicated farming method. The report also targets other aquaculture industries, research organisations and revelant Government departments by sending them a message that the redclaw industry has become of age.

Where are the relevant industries located in Australia?

The redclaw crayfish is a tropical Australian animal native to the rivers that flow into the Gulf of Carpentaria. For this reason, the redclaw industry is necessarily concentrated in warmer climes. Currently most farms are concentrated along the coastal strip of Queensland and the northern inland areas of the state. The climate of the "Top End" of the Northern Territory and Northern Western Australia are also ideal for redclaw production, but few significant farms have been developed at this time

The production figures of the redclaw industry have declined from their peak of 106 tonnes per year in 2006 – an unfortunate situation that this project will reverse. Industry statistics are confusing - the gulf between the number of licence holders and serious producers is hard to rationalise. The majority of redclaw produced comes from a small number of farms. The potential for market opportunities is virtually unlimited.

This research will benefit existing farmers by markedly improving the viability of their operation. As a result, redclaw farming will be seen in a more favourable light, attracting new entrants to the industry and encouraging the expansion of existing small farms. As a flow on from this, secondary associated industries will flourish and an increased supply of this delicacy will become available to the population of the nation

Background

The background to this project spans many years and is extensively dealt with in the body of the report. The industry was started by individuals sourcing stock from the wild with no structured plan to maintain genetic diversity. As time went by the consequences of this became evident with the decline in quality and production levels. Queensland Department of Primary Industries started a breeding program which collapsed when funding was withdrawn.

Influencing factors became aligned, necessity playing a large part. Encouragement from James Cook University, the arrival of the prototype incubator from Europe and the industry reaching maturity coincided with a successful grant application to RIRDC. All were catalysts in getting the project off the ground.

Aims/objectives

The basic aims of the project were threefold and were based on the results of an industry survey conducted in 2001. All three objectives - breeding a strain of disease free animals, combating inbreeding depression and selecting for faster growth - were achieved with a high degree of success. More importantly, they were objectives that industry had identified itself as being important to the survival and wellbeing of redclaw crayfish farming enterprises well into the future.

Future generations of redclaw farmers will benefit from this research project, as not only did it result in the establishment of the improved Tolga Strain redclaw, but set the scene for a revolution in redclaw farming methods. In proving methodology and establishing protocols for hatchery production it laid the foundation for the industry to align itself with other leading aquaculture enterprises.

Methods used

The methods used involved no smoke and mirrors. Basic, proven research techniques were adopted to suit the skills of the farmers conducting the project. The work of the farmers was overseen by our mentors at James Cook University (JCU) who gave invaluable advice and encouragement. As part of the project, incubator technology from Europe was adapted to Australian conditions and to the biology of the redclaw crayfish.

Over five years, the genes of eleven genetically diverse strains of redclaw were mixed by cross breeding in strict accordance with a "Circular Mating Design". Selections were made for the subsequent year's mating on the basis of fastest growth. The eggs were stripped from the females and hatched in an incubator to break the disease cycle.

While basic, this methodology was by no means amateurish. Globally renown scientists from JCU played a huge part in the project in the areas of design, supervision and assessment of results. More technical aspects such as genetic auditing, disease surveys etc. were undertaken by JCU and supported by funds from the project grant.

Results/key findings

The results of this project show that significant gains in growth rate– typically in excess of 50% -can be achieved by a selective breeding program in a relatively short time. Results also show that ridding the animal of inherent disease by means of hatching eggs in an incubator plays a considerable part in this improvement in growth rate.

Many leads were followed to investigate significant unforseen topics such as temperature effects, freight methods etc. Some of these are detailed in the body of the report. The most innovative achievement was the expansion of the method developed to ensure genetic diversity, into a system for general farming use. The project led to the establishment of commercial hatcheries to produce quality Stage Three Juveniles to stock farm dams. The term 'S3J Farming' was coined.

It is absolutely critical that the industry as a whole has belief in and embraces the results of this project. In the recent past and in the near future a planned, determined effort has and will be made to showcase the benefits and ensure adoption of 'S3J Farming' as the way of the future.

Implications for relevant stakeholders:

The implications for existing traditional farmers are both obvious and at the same time hard to comprehend. Farmers will benefit by casting off the old ways and embracing the new farming methods developed. Redclaw farming is perceived as being a labour intensive activity – this is no longer the case.

Increasing prosperity in any field of endeavour invariably has a flow on effect to other industries and to the community as a whole. This effect is especially important in rural communities where redclaw farming is carried out.

Local markets have traditionally taken all the redclaw that is produced with little or no promotional effort. Opportunities for export action are there to be exploited once the Australian market is satisfied, although caution is advised. Industry policy makers should consider means of minimising the risk of exporting a live native animal to a competitive country with a cheap labour source.

Recommendations

It is recommended that all parties interested in the redclaw industry read this report, be they existing or potential farmers, research providers or funding bodies, government departments or seafood wholesalers. This report is an indication of an industry coming of age.

The industry needs to maintain the momentum this project has created, not only in research effort, but in a general endeavour to improve the industry profile and working together to improve their lot.

The way is now open for serious investment in professionally managed large farms.

Introduction

The lead up to this project spanned quite a number of years and tells a story of an industry totally inexperienced in formal research (although all farmers are forever trialling one thing or another) but determined to improve its lot.

In 1996, Dr. Brett Edgerton, a recent graduate from JCU studying crayfish disease, visited crayfish farms in Finland. He returned with information about the Hemputin incubator developed in Europe to combat the proliferation of crayfish plague, and suggested its use in the redclaw industry. This advice was not acted upon as it could not be seen where an incubator could improve current farming practices. Brett also promoted anecdotal evidence that artificially hatched crayfish did not carry disease.

In 1998, two North Queensland farms trialled methods of initiating redclaw breeding in the winter months. While the trial was successful in itself, when the berried females were put into the cold pond water, egg development stalled and eggs finally died, rendering the system of little value and was allowed to lapse.

Obvious in hindsight, the two innovations together were a match made to be, and was to prove the catalyst for extending the knowledge gained from the Selective Breeding Program to commercial hatcheries producing stock all year round.

As a joint initiative between the Queensland Crayfish Farmers Association (QCFA) and Queensland Department of Primary Industries (QDPI), an industry survey was conducted in 2001 and used to formulate a Strategic Development Plan for the Australian Redclaw Industry. This survey identified breeding for faster and more uniform growth as the industry priory, followed by disease management and feeding and nutrition. The report on this survey is included in this document under “Appendix 1”

In June 2003, officials of the QCFA met with officers of Queensland Department of Primary Industries and Fisheries (QDPI&F). This meeting was prompted by the announcement that the “Walkamin Strain” selective breeding project currently in progress at Walkamin Research Station was to be discontinued. The subject of this meeting was to determine a plan whereby the industry could take over the “Walkamin Strain” project and expand it to produce pathogen free, genetically improved stock for the industry. The results of the meeting were disappointing. The QDPI&F officers present, while having no objection to the proposal, showed no inclination to smooth the way for a successful transition

In 2004 the North Queensland Crayfish Farmers’ Association (NQCFA) began discussions with Dr. Dean Jerry, Aquaculture Genetics Program Leader at James Cook University (JCU). Dr Jerry strongly urged the industry to take responsibility for safeguarding itself from decline of genetic diversity and institute a program to actively improve the quality of farm stock. He proposed the possibility of a farm based genetics improvement program using the concept of a “Circular Mating Design”, a basic but effective system incorporating concepts well able to be managed on farm. At this time, NQCFA officers, while agreeing entirely with Dr Jerry’s sentiments, were overawed by the practicalities of such a move, but nevertheless kept moving forward. There were some unsupported indications that two farms were in fact displaying symptoms of inbreeding in their stock, evidenced by poor growth and lack of stamina. It is fair to say that the industry at this stage suffered from a “cargo cult mentality”**-** information on farming redclaw (not always correct) having been hand fed to the industry by QDPI since the early 1990s.

During 2005 many small steps were taken towards making the project a reality. NQCFA member Aquaverde Redclaw imported a Heputin incubator of Finnish design and commenced trials in its use. The annual conference of the QCFA was held in Townsville and speakers from JCU were heard on the subject of lack of genetic diversity impeding the progress of the industry. Further meetings were held with JCU genetics and veterinary staff. The year's progress culminated at the NQCFA meeting on 12th November when it was unanimously agreed that NQCFA would proceed with a genetic improvement program based on the Circular Mating Design.

During 2006, NQCFA gave financial and in kind assistance to Bikram Ghosh, a Biomedical Science honours student at JCU to conduct preliminary research necessary to the project. Bikram's research uncovered the fact that all populations of redclaw tested carried some or all of six generic diseases. This proved to be a real sticking point for project planners as no farmer wanted to take the risk of all diseases being introduced onto their farm. Ways and means of overcoming this problem were investigated.

Permission in principle was granted by DPI&F to use their Tank Shed at Walkamin. A meeting was held with QDPI&F officers in February to explain the whole proposal as it now stood. Reserved support was gained from the meeting. Reservations that there was not enough genetic diversity in farmed stock and the intention of NQCFA to resource the project with its meagre funds was ill advised, were expressed. There was no possibility of financial support from QDPI&F and the restrictions and cost associated with using the tank shed made that possibility untenable.

The project proposal had its share of detractors, most of whom held positions in the research community. Unfortunately these individuals spoke strongly from a position of total ignorance of what we intended to do and how we intended to go about it. They did however pose a real threat to our efforts to gain support and funding.

Aquaverde Redclaw offered the use of their incubator to hatch eggs and as a pattern for the Association to build their own. This was a critical development, as it solved the very real threat of spreading all diseases carried by farmed redclaw to every farm. Rocky Creek Redclaw offered their farm as a base for the project and were willing to have the necessary infrastructure built on their land including a mating pond, stripping shed and incubation facility. This offer eliminated the need to use the tank shed at Walkamin and allowed the project much more flexibility and to be conducted without the handicap of the conditions imposed.

NQCFA made applications to funding providers to ensure the project could be conducted in a thorough and professional manner and were successful with their application to Rural Industries Research and Development Corporation (RIRDC). The contract was signed in August 2007.

Objectives

The basic objectives of this project were based on the top priority needs of the industry as indicated in the farmer survey conducted in 2001 - that is:

- to selectively breed for faster growth
- to combat inbreeding depression
- to produce pathogen free animals.

To breed a strain of genetically faster growing animals effectively increases the production and therefore the viability of the farm without the cost of an increase or up grade to infrastructure. Existing farms become a more rewarding business and the industry is more attractive to new entrants.

To combat inbreeding depression is a critical move to eliminate the possibility of stock quality entering a downward spiral to oblivion. Common consequences are a high percentage of runts; females breeding at a small size; poor head to tail size ratio; various deformities that make the product unattractive in the market place.

To produce pathogen free animals is to produce faster growing animals as energy used for fighting disease is unavailable for growth. Specific Pathogen Free (SPF) certificates are required by overseas customers and often a regulatory requirement for movement between states of Australia. Mortalities due to health issues impact on overall production figures.

The basic aims of the project as described in the RIRDC funding contract, combine to describe an overall objective to produce a faster growing, healthier strain of redclaw that will serve the industry well, far into the future. In so doing, new innovative farming methods were developed which in turn streamlined industry practices and made redclaw farming a more attractive proposition. These methods are based on hatchery produced Stage Three Juveniles (S3J) being distributed to farms for growout in a batch in, batch out farming method termed “S3J Farming”. The hatchery is responsible for continuing to improve the quality and performance of the stock using the methods and protocols developed and proved by the project.

The scope of the project objectives have been expanded as the opportunity and need for further associated research became apparent. As is often the case, answers led to more questions. Many of these questions were able to be followed up under the umbrella of the project and valuable results were obtained from these ‘sub projects’. Some prior assumptions were able to be confirmed and many observations provided opportunities for further research. Broadening the knowledge base of how best to grow redclaw is of invaluable assistance to farmers. Some of the more significant of these “sub projects” are discussed in “Results”

Methodology

The methodology used in this project is best explained under four stages: Mating, Stripping, Incubation and Growout.

Mating Stage:

Broodstock was sourced initially from participating farms, the final result of the Walkamin Strain project and from the wild. Farmers were asked to supply stock of known age, in good health, as diverse as possible and the best performers among their peers. Walkamin Strain redclaw were sourced from Walkamin Research Station (where a pond of the final result had been kept). Wildstock were collected from Bonney Glen Station on the Palmer River, Bulimba Station on the Walsh River and Southedge Station on Rifle Creek, a tributary of the Mitchell. From these sources eleven 'families' were assembled – stock from eight farms, Walkamin, Bonney Glen and a composite Bulimba and Southedge family.

Following assembly of the stock upon which the project was to be based, JCU arranged for graduate student Karen Willows to perform a genetic audit under the supervision of Dr. Dean Jerry (see "Chapters"). The result was that the base stock had sufficient diversity to ensure the success of a long term breeding project.

In the years following this initial assembly of broodstock, participating farmers transported selected predetermined numbers of the fastest growing males and females from their growout pond (see below – "Growout") to Rocky Creek Redclaw to be used in the mating cages for the following year.

The main considerations in manipulating the animals during the mating stage were keeping the families isolated, breeding from the fastest growers from the previous generation, tracking each individual female, and in the interest of maximizing diversity, to ensure that each selected male and female contributed to the next generation only the once - that is, that only full siblings are used in the program.

To accomplish these considerations, "oyster purse" cages were purchased, a purpose built pond was constructed at Rocky Creek Redclaw incorporating support cables and winches, and paddle wheel aeration provided including an electrical supply. A shed was constructed on the pond bank with a water supply tank fed from the bore to provide a satisfactory working environment.

One male and three females were stocked to each cage in accordance with the Circular Mating Design specified by JCU. The cages are numbered by family row number and cage number for identification. This cage number, once allotted was carried right through to the end of the incubation stage.

Each year before the selected animals were placed in the cages, a sample of 40 males and 40 females were weighed and measured as precaution against inadvertently selectively breeding for an undesirable trait. These measurements were recorded and studied by JCU geneticists.

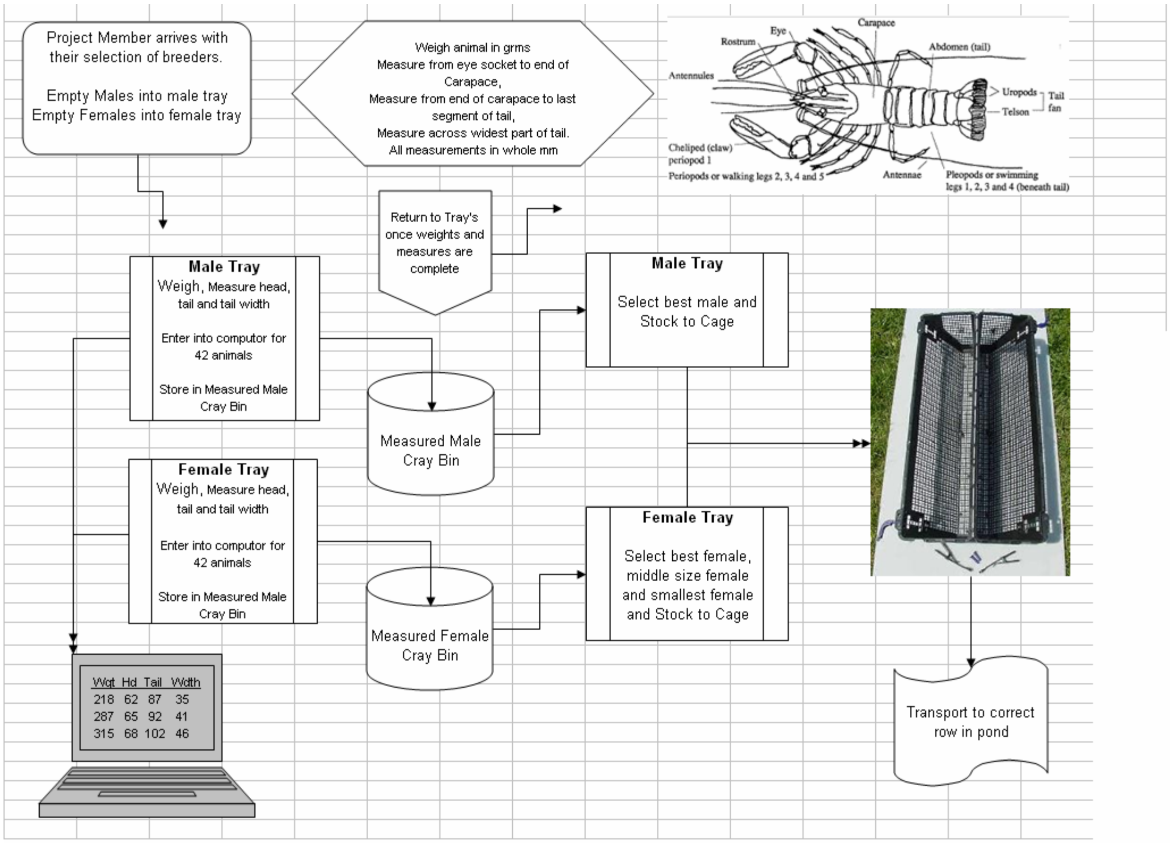


Figure 1. Mating day Flow Chart.

Figure 2. Farmers work on oyster purse cages in the mating pond

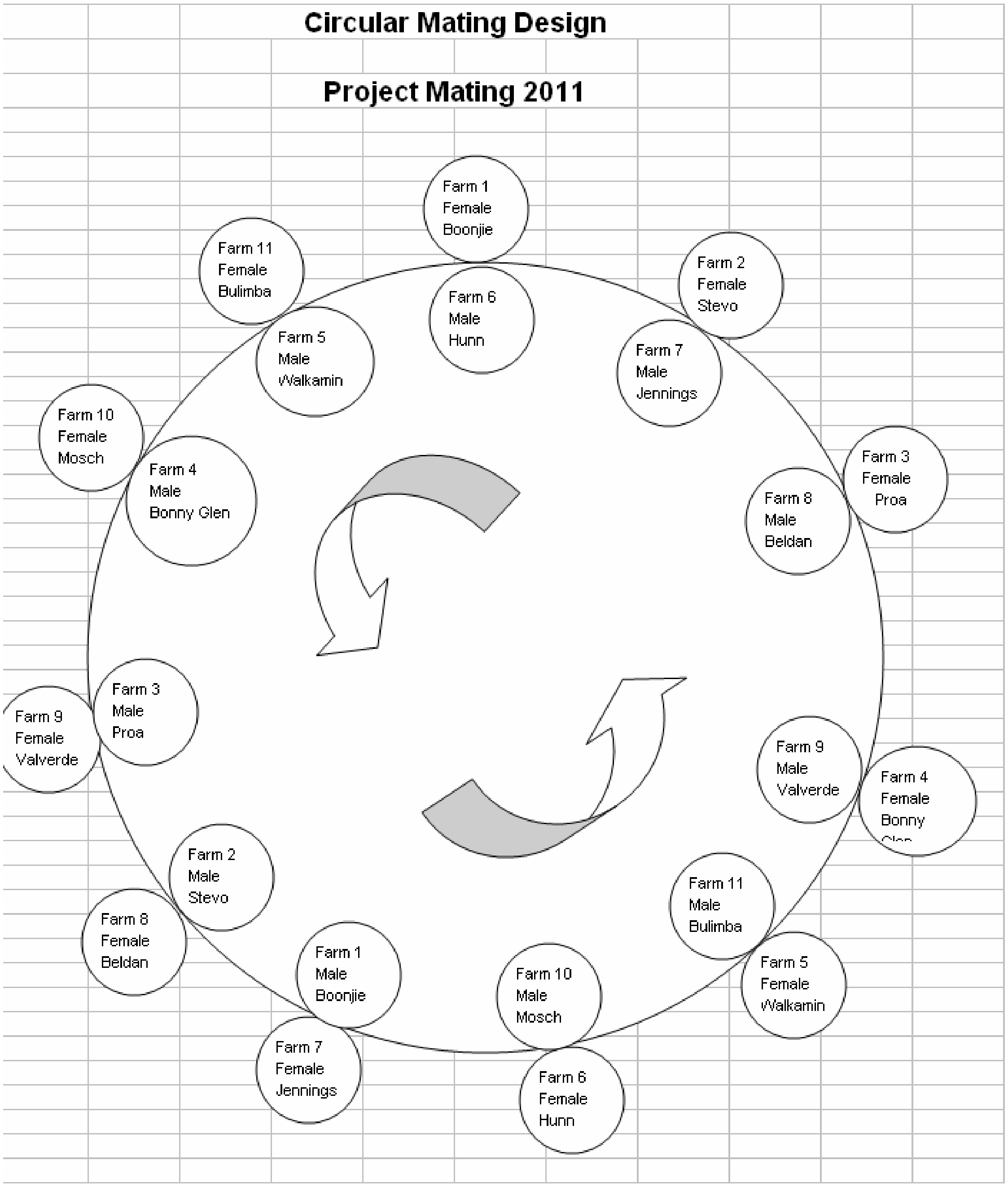


Figure 3. Circular Mating Design

Stripping Stage:

The stripping stage is undertaken approximately two months after the mating cages are stocked. The actual timing is determined by the water temperature, results of sampling the cages and from previous experience. At this stage, meticulous record keeping is necessary to ensure the integrity of the project is kept intact. It is at this stage that the greatest risk of a mistake is present which would see half sibs included in the program, compromising to an extent the genetic diversity of the population produced.

Numbered cages are removed from the pond, family at a time and opened one by one. If a cage contains females with eggs ("berried females"), they are placed in a container tagged with the same number as the cage, and moved to the custom made stripping bench. Here the eggs are stripped from the female, put in an incubator basket with the tag attached and dipped to kill any fungus spores.

The male from this cage and the females that have been stripped are deleted from the program as one of the requirements for ensuring genetic diversity.

The unberried females are reallocated to unproductive cages with males that have not contributed and replaced in the pond to be reprocessed in six weeks if required.

The stripped eggs are removed to the incubation facility.

Figure 4. Eggs being stripped from the female

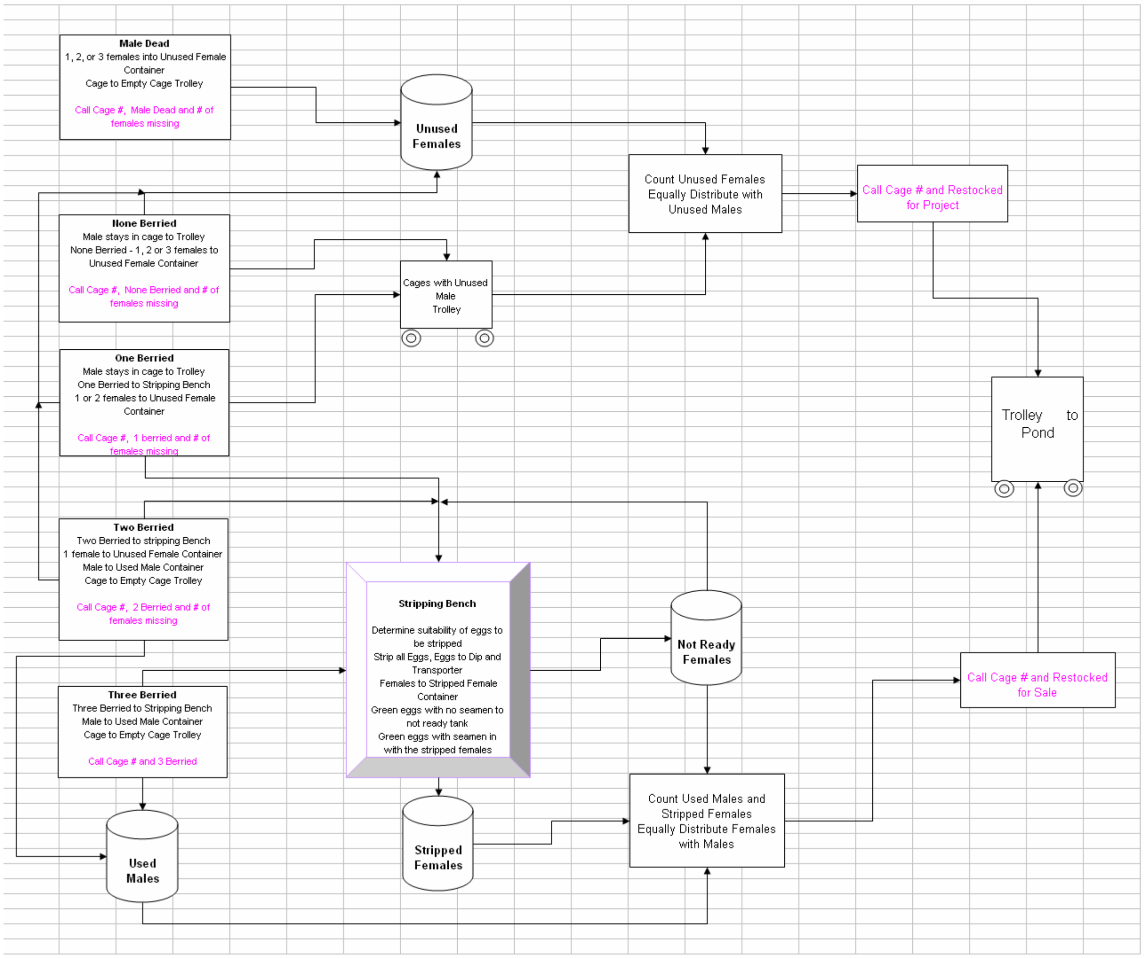


Figure 5. Stripping Day Flow Chart

Incubation Stage:

Part of the original plan was to employ a technician to run the incubation stage. Incubation of freshwater crayfish eggs on an extensive scale is a ground breaking move in this country and therefore previous expertise was not available to call upon. The experience of Finnish experts was practically useless because of the vast difference in temperature and other conditions required by the species. The original incubator design was twice extensively modified. Challenges occurred almost daily which had to be met, investigated and solved – and very quickly. To expect the dedication, initiative and appreciation of the consequences from an employee was unrealistic. Management of the incubator was undertaken by members of the project committee on a rotational basis.

Initially as a precaution, the eggs were divided between the project incubator and the facility at Aquaverde Redclaw. This proved a wise move on a couple of occasions. As confidence grew in our ability, all project Stage Three Juveniles (S3J) were produced in the Rocky Creek Redclaw incubator room

An air conditioned incubator room donated by Rocky Creek Redclaw contains two incubators built as capital items for the project. Initially, one incubator was assumed sufficient for the number of batches of eggs produced by the project. However two major considerations soon became apparent:

(a) Eggs at different stages of their development are susceptible to attack from fungus and bacteria and at these stages require treating differently.

(b) It is very desirable to coordinate development of the eggs so as to have as many as possible Stage Three Juveniles (S3J) ready for dispatch at the one time.

Consideration (a) was the subject of investigation work by Dr. Matt Payne and Dr. Alanna Cooper, both graduates of JCU, some years apart, under the supervision of A/Prof. Leigh Owens. Incubation health issues were the greatest bugbear of the project, but due to the work done and advice given by these two people they were eventually overcome.

Consideration (b), while important to the project, is even more important when producing S3J commercially. Given the overall objective of the project, it was considered necessary to trial ways of achieving this. A sub project – "Egg Synchronisation" was initiated (see details in "Results") which proved that at least two incubators running at different temperatures and undergoing different treatments were necessary.

A dedicated water tank supplies the incubator room. Water is pumped directly from the bore and is regularly circulated through an ozone absorption chamber. The incubators are cleaned and sanitized before each batch of eggs. The whole room is scrubbed with antibacterial solution between batches. Personal hygiene protocols apply to anyone entering the room. An ozonation unit and UV filter is included in the water recirculation system of each incubator. While the use of ozonation was recommended early in the piece, reliable information on its actual use in fresh water was very hard to come by. Many configurations of ozone installations were trialled before a satisfactory arrangement was designed.

The baskets of eggs from the stripping shed are placed in incubator 1 in accordance with their family lines and cage/basket numbers. A daily check of all baskets is carried out and any dead eggs are discarded to discourage the infiltration of Saprolegnia and Chytrid fungi. Full water and basket change is done once a week or when considered necessary.

When the eggs are at the point of hatching, the baskets of eggs are transferred in a fresh basket to incubator 2, which is run three degrees cooler than incubator 1. This slows their development, allowing the S3J to be sent to the farms for growout in a tighter timeframe. The lower temperature also helps to control the bacteria Aeromonas Hydrophila which proved to be a major threat at the post hatch stage.

Figure 6. Eggs hatching in the incubator

When the hatched eggs have reached Stage Three Juveniles, they are ready to dispatch to the participating farms for growout. JCU helped establish an average weight per animal of 0.018 gram, thus enabling each basket to be counted by weight. After weighing, the animals are tipped with water into a bag which is oxygenated, sealed and packed for transport to their destination. This bag can hold 10,000 S3J which is enough to fully stock a standard redclaw pond and has a shelf life of at least 48 hours. This method of transporting young redclaw is another incidental result of the project. (See "Results")

A microscope was purchased to enable operators to monitor and understand the stages of egg development.

Figure 7. Inspecting eggs under the microscope

Growout Stage:

The S3J are delivered to the participating farmer and stocked to a prepared pond which is fenced off from any other ponds on his farm to prevent stock contamination from other ponds on the farm. An ideal feeding regime is the subject of another RIRDC funded project currently being undertaken by JCU with particular attention being paid to ontogenetic requirements. Until the results of this project are known, the S3J are fed a high protein meat based diet for the first 2 months then standard redclaw feed.

The project pond is subjected to the normal farming methods adopted by the farmer. This of course varies from farm to farm and will have some impact on individual farm results. For this reason, little emphasis is placed on individual farm results, but the average of the eleven families is believed to be indicative of progress made.

As the project timelines required each cycle to take twelve months, this left eight months for the growout period. This is generally shorter that the average growout time used in general farming practice, however it has proved to be more than enough time to produce plenty large size animals, even though the growout period is largely during winter.

At the end of the growout period, the pond is harvested and the farmer records the weights and sex of a 1000 random sample. He then selects the largest 70 males and the largest 170 females and arranges transport to Rocky Creek Redclaw for the next mating cycle. Thence the process is repeated.

Chapters

Prologue:

This section of the Final Report has been written by our mentors from James Cook University, A/Prof Leigh Owens and Prof Dean Jerry. Leigh Owens is Head of Microbiology and Immunology at the School of Biomedical Sciences. Dean Jerry is Head of Aquaculture and Aquaculture Genetics Program Leader at the School of Marine and Tropical Biology. Both men played a vital role in the Project.

The disease status of crayfish, *Cherax quadricarinatus,* before and after mechanised incubators in hatcheries.

Leigh Owens
Microbiology and Immunology
Veterinary and Biomedical Sciences
James Cook University
Townsville, 4811

Introduction:

Over the years, James Cook University has provided unfunded histopathological support for the freshwater crayfish industry. This was mostly achieved with the use of students who used the results as part of their research degrees. More recently, as the crayfish farmers developed towards hatchery technology, bacterial problems have become critical, so *ad hoc* studies were commissioned to solve immediate problems. This chapter will detail the changes to the rates of various diseases believed to have occurred due to the introduction of hatchery technology. It will then briefly describe the main disease issues arising on the crayfish within the incubators.

Trends over Time:

There has been a trend for more and more pathogenic entities to be discovered in time (Table 1). Good examples of this are Cherax reovirus which was not present in the first survey, appeared in the early 2000s (Ghosh 2006) and lately, gill signet ring parvovirus, which has only just been recorded (Powell and Rusaini 2012).

When the incubators in the hatcheries were first introduced, the first survey after their introduction showed spectacular changes. Across all three farms, all three viruses fell to zero; *Psorospermium* levels were also at zero and interestingly bacteraemia levels had fallen from an average at 74% before the hatchery to 21% in hatchery-raised crayfish. This would suggest the viruses were having some effect in weakening the animals so that bacteraemia problems were elevated. Indeed, conversations with farmers had said that the average size at harvest has risen from 35g to 75g and growout time has decreased from 7 months to 6 months.

However, the last snapshot post-hatchery has shown Cherax reovirus, Gill signet-ring parvovirus, *Psorospermium* and *Coxella cheraxi* all to have returned to at least one farm at prevalence levels similar to pre-hatchery times (Powell and Rusaini 2012). This may suggest initial infection is occurring after the hatchery at the individual farm level. As this is a farm by farm situation, the industry as a whole is healthier after the introduction of hatchery technology than previously.

Table 1: Prevalence (%) of potential pathogens and histopathological changes with 95% confidence limits.

Farms	Cherax Giardiavirus	Cherax Bacilliform Virus	Cherax Reovirus	Gill Signet Ring Parvovirus?	Psorospermium	Bacteraemia	*Lagenophrys*	Temnocephala	Saprolegnia	Chytrids	*Coxiella*
(Edgerton et al. 1995) (pre-hatchery)											
A	**52.3** (37-68)	**6.8** (1.4-19)			0 (0-8)	0 (0-8)					
B	**25** (13-40)	0 (0-8)			0 (0-8)	0 (0-8)					
C	**11.4** (4-25)	**59.1** (43-74)			**9.1** (3-22)	**61.4** (45-76)					
D	**11.4** (4-25)	**52.3** (37-68)			**38.6** (24-55)	**14** (5-27)					
E	**11.8** (1.5-36)	**5.9** (0.1-29)			0 (0-20)	**43** (18-71)					
F	**6.8** (1.4-19)	**13.6** (5-27)			**6.8** (1.4-19)	0 (0-8)					
G	**13.6** (5-27)	**11.4** (4-25)			0 (0-8)	0 (0-8)					
(Ghosh 2006) (pre-hatchery)											
A	**2.3** (0.06-12)	0 (0-8)	0 (0-8)		0 (0-8)	**68.2** (52-81)					
B	**2.3** (0.06-12)	**27.3** (15-43)	**6.8** (1.4-19)		0 (0-8)	**97.7** (88-100)					
C	0 (0-8)	0 (0-8)	**11.4** (.04-25)		**27.3** (15-43)	**52.3** (37-68)					
D	0 (0-8)	0 (0-8)	**40.9** (26-57)		0 (0-8)	**72.7** (57-85)					
E	0 (0-8)	**13.6** (5-27)	**6.8** (1.4-19)		0 (0-8)	**40.9** (26-57)					
(Hayakijsokol 2008) (post-hatchery)											
A	0	0	0		0	**17.46**	46.03	3.18			
B	0	0	0		0	**31.75**	1.59	12.7			
C	0	0	0		0	**12.5**	31.25	70.3	**+**	**+**	
(Powell Rusaini 2012) (post-hatchery)											
A											**+**
B	0 (0-22)	0 (0-22)	0 (0-22)		**33** (12-62)	**27** (8-55)					0 (0-17)
C	0 (0-14)	0 (0-14)	**53** (28-77)	**21** (7-42)				**+**			
D											**50** (16-84)

Microbial Disease:

The incubators have had a number of microbial disease problems. The first hurdle to overcome was fungal problems, particularly *Saprolegnia* and chytridiomycosis of the eggs (Payne and Owens 2008). A series of dips, washes and baths containing mostly formalin (0.25ppm to 0.5% formalin) and methylene blue (0.2ppm) were recommended. Other less appropriate fungal treatments were argued against. These dips also cleared up a transient ciliate disease that was only seen once.

Bacterial Disease:

Mass mortalities caused by bacterial diseases started to become a problem. Bacteria were observed within the hindgut of animals moulting towards the stages when they would be transferred out of the hatching incubator. Subsequent culture-based analysis of the bore water at both the source and within the hatching incubator revealed the presence of a range of bacteria. This analysis was dominated by one bacterium, which subsequent phenotypic testing revealed to be a strongly haemolytic, *Aeromonas hydrophila*. This is a common pathogen in freshwater systems.

It was imperative that as much organic material be removed from the system as possible. The main recommendation was that ozonation be employed to kill bacteria and oxidise the organic load from the water prior to it entering the hatching incubator. This will effectively starve the bacteria. It is also recommended that all recirculating water be ozonated prior to re-entering the hatching incubator. We would recommend using a holding tank prior to pumping water into the hatching incubator. This holding tank must be pitch black to exclude algal growth and water must sit within this tank for at least 14 days prior to it being transferred to the hatching incubator. This should be ample time for all bacteria within the water to have exhausted the nutrient sources and subsequently died. However, it is impossible to stop aerosol re-inoculation of the water.

Antibiotic Resistance:

The use of antibiotics to control bacterial infection in the hatchery resulted in the development of resistance to oxytetracycline (OTC). OTC is a broad spectrum antibiotic registered for use in aquaculture and therefore commonly used in the aquaculture industries. Microbiological testing identified an OTC-resistant *Aeromonas hydrophila* isolate in redclaw larvae. *Aeromonas* spp. have previously been associated with the development of OTC-resistance in aquaculture settings (Rhodes et al., 2000, Schmidt et al., 2001). The bacterial infection was successfully treated with trimethoprim and the incubators treated with chlorine in an attempt to eliminate the OTC-resistant bacteria. However, the OTC-resistant bacteria re-emerged in a subsequent incubation of larvae. *Aeromonas hydrophila* is known to be highly resistant to chlorine, which is routinely used to disinfect aquatic hatcheries.

It was hypothesised that maintenance of bacteria in the hatchery despite the use of chlorine, ozone and UV treatments was due to biofilm formation on surfaces, circulating pipes in the incubators and related equipment. Biofilms are notoriously difficult to remove due to the production of protective layers of polysaccharides by bacteria to prevent the penetration of cleaning chemicals (Donlan & Costerton, 2002). Biofilms also aid in the transmission of antibiotic resistance genes between bacteria. Therefore, hydrochloric acid was used to breakdown the biofilm refugia of the OTC-resistant *Aeromonas*. This removed the OTC-resistant bacteria from the system and they were not re-isolated from moribund larvae recovered after the acid wash treatment, although other *Aeromonas* and *Pseudomonas* colonised the moribund larvae.

Feeding of Larvae:

It was felt that there was not enough nutrition available to the larvae in the near sterilized environment of the incubator and larvae were starving to death. Therefore, it was recommended to add gnotobiotic algae supplements to overcome this deficiency. *Ad hoc* experiments were tried with spirulina but the experimental replication was too incomplete to make firm conclusions about its effectiveness before funding ceased.

Specific Pathogen Free Status:

The term Specific Pathogen Free (SPF) is poorly understood by the general public, farmers and many scientists alike. Most people think that it means free of all disease (i.e. gnotobiotic). It means being free of A PATHOGEN which has been SPECIFIED (or identified) by repeated STATISTICAL TESTING. To develop specific pathogen free larvae, a more biosecure environment is needed as well as regular monitoring to make sure pathogens which are believed to have been removed have not been reintroduced. If a minimum of 44 crayfish sampled were negative for an identified pathogen, this gives a 90% chance that the real prevalence is below 5% (Cannon and Roe 1982). To be 99% sure that the real prevalence is below 1%, then 460 crayfish must be sampled. This was clearly impossible within the budget, the technology available and the technical issues around the performance of the incubator. Nevertheless it is total accurate to say that these larvae are SPF for whitespot syndrome virus, for example.

Conclusions;

The development of hatchery technology for freshwater crayfish has been a wonderful success story as the majority of diseases have decreased in intensity and prevalence. In particular, Cherax bacilliform virus (CBV) and Cherax Giardiavirus (CGV) seemed to have disappeared totally and whilst too early to declare, the industry might be SPF for CBV and CGV. *Psorospermium* initially disappeared from farms but has come back at lower levels on one farm suggesting reintroduction from the wild. Consequent bacteraemia levels have dropped. Of interest is the fact that Cherax reovirus was not found in early surveys but has become very common on one farm. Also a new entity has arisen, gill hypertrophied nuclei which needs to be researched to understand what impact it is having.
It should be noted that some pathogens are still present at low levels; some new entities have arisen; so the job is not complete but very substantial progress has occurred.

Literature Cited:

Cannon RM and Roe RT (1982) Livestock Disease Surveys: a Field Guide for Veterinarians. Aust Gov Publ Serv, Canberra.

Cooper A (2012) Identification and elimination of OTC resistant bacteria in a redclaw crayfish (*Cherax quadricarinatus*) hatchery

Donlan R, Costerton J (2002) Biofilms: survival mechanisms of clinically relevant microorganisms. *Clinical Microbiology Reviews*; 15: 167-193.

Edgerton B, Owens L, Harris L, Thomas A & Wingfield M (1995) A health survey of farmed redclaw crayfish, *Cherax quadricarinatus* (von Martens) in tropical Australia. *Proc. Astacology Soc.* 10:322 - 338.

Hayakijsokol O (2008) James Cook University Pathology Report
Ghosh B (2006) The potential genetic and pathogen impacts of ring mating design in redclaw (*Cherax quadricarinatus*) farms. BSc Hons Marine Biology & Aquaculture, James Cook University

Payne M and Owens L (2008) Report on the Investigation of Mortalities in the *Cherax* Egg Incubator. Internal James Cook University Report.

Powell S, Rusaini (2012) General Pathology Report. Internal James Cook University Report.

Rhodes G, Huys G, Swings J, McGann P, Hinney M, Smith P and Pickup RW (2000) Distribution of oxytetracycline resistance plasmids between aeromonads in hospital and aquaculture environments: implication of Tn1721 in dissemination of tetracycline resistance determinant tetA. *Applied Environmental Microbiology*; 66: 3883-3890.

Schmidt A, Bruun M, Dalsgaard I and Larsen J (2001) Incidence, distribution and spread of tetracycline resistance determinants and integron-associated antibiotic resistance genes among motile aeromonads from a fish farming environment. *Applied Environmental Microbiology*; 67: 5675-5682.

Genetic improvement of redclaw growth through targeted selection

Dean Jerry
School of Marine and Tropical Biology
James Cook University
Townsville 4811.

Background:

Aquaculture, as the fastest growing animal production industry, is still primarily based on the farming of animals which have not been subjected to systematic family-based genetic improvement programs. Indeed, Gjedrem *et al.*, (2012) estimate that less than 10% of current aquaculture production is based on genetically improved stocks, despite the average realization of genetic gain in aquaculture species being significant at 12.5% per generation. Modeling by these authors clearly demonstrates that if selective breeding practices are applied to more aquaculture species world production can be doubled over current figures within the next 20 years, adding significantly to the increased demand of animal protein as human population growth continues Gjedrem *et al.*, (2012).

Whilst there is enormous potential to boost productivity through genetic selection, undertaking breeding programs in most aquaculture species is not an easy task, primarily due to difficulties in retaining pedigree throughout the farming process and limitations posed by breeding biology. The inability to effectively determine pedigree at the time of selection can lead to severe inbreeding, as the high fecundity of many aquaculture species, coupled with differences in family growth rates, make it possible to unwittingly select many progeny from the same best performing family. Mating of these individuals without any pedigree information, therefore, can very quickly erode genetic diversity and rapidly increase inbreeding levels within farmed populations. As long-term genetic gain is underpinned by high levels of genetic diversity and low inbreeding levels it is extremely important therefore to commence selection programs in aquaculture species with high levels of genetic diversity in foundation stock and with a selection design that allows hatchery managers to access in some way the pedigree of selection candidates.

One species where there has been considerable interest in undertaking selective breeding is that of the freshwater redclaw crayfish, *Cherax quadricarinatus*. Redclaw is a species of freshwater crayfish native to the Gulf of Carpentaria and southerly flowing rivers of Papua New Guinea. Commercial redclaw farming in northern Australia commenced in the late 1980's, where positive aquaculture attributes, such as fast growth rates, relative ease of breeding in the absence of complex infrastructure, gregariousness and tolerance of poor water quality, made redclaw an attractive candidate for farmers wanting to undertake freshwater aquaculture (Jones & Ruscoe 1996). In recognition of this species' potential the Queensland Department of Primary Industries (QDPI) instigated a selective breeding program for redclaw at their Walkamin Research Station on the Atherton tablelands aimed at increasing growth rate. It was hoped that through this improvement program the achievement of genetic gains in growth would benefit individual enterprises and lead to increased industry investment in the developing industry (Jones *et al.*, 2000). Economic modeling also indicated that redclaw bioeconomics is very sensitive to growth rate and/or the required to rear the product to market was seen as the single biggest factor that would lead to a boost of the industry in Queensland. QDPI commenced a simple within-cohort (e.g production of 20 separate progeny cohorts arising from the mating of 15+ females to 10 males in a tank) selection program in 1994, which continued for four generations of selection. Over this period, a significant, but modest, improvement in growth rate of 9.5% was achieved over that of non-selected wild stocks. While this growth improvement was less than that seen in other freshwater crayfish species like the freshwater yabby, *C. destructor*, where growth improvements of around 30% were seen after two generations of selection (Jerry *et al.*, 2005), this initial breeding program demonstrated that increased productivity could result from genetic improvement of redclaw. Consequently, improved "Walkamin" stock was disseminated to the redclaw industry. However, despite the potential of the improved Walkamin stock to boost production, lack of subsequent industry growth and government investment saw the breeding program terminated in 2003, without the program being efficiently transferred to commercial industry. As a result the initial genetic gains made through the QDPI breeding program have subsequently been eroded and lost through unmanaged commercial breeding practices. Additionally, of particular concern, is whether commercially farmed redclaw populations had now become so inbred through poor broodstock management due to difficulties in pedigree retention that substantial amounts of genetic diversity had been lost which would impede any future efforts to re-instigate selective breeding in this species.time to reach market size (Hinton & Jones, 1997). Therefore increasing growth rate and reducing the time

One of the major impediments to the transfer of the QDPI breeding program to the commercial redclaw industry was how the industry could manage to continue the within-cohort selection design given their relative embryonic maturity and geographically disparate nature. The QDPI breeding program comprised the simultaneous evaluation of 20 cohorts reared in individual hapas. Industry simply did not have the capacity or resources to conduct a breeding program of this nature. Therefore any industry breeding program would have to be simple, recognize difficulties in retaining family pedigrees, maximise the capture of genetic diversity that was present, and have to be very practical given the geographic locations of the farms that wanted to participate. One of the options available to the industry was to conduct a simple breeding program based on a rotational mating scheme, whereby instead of each farm having to retain individual pedigree data, each farm itself would act as a family line and this would be the basis of recording of pedigree. To maximise the amount of genetic diversity captured within each farm a large number of the best performing broodstock would be selected each year and then individually mated with the best performing broodstock from another farm to produce the next generation. In subsequent generations males from one farm will be mated with females from a different farm ensuring that many generations of breeding have to be conducted before the initial farm mating combinations are repeated (see Figure 3). As simulated by Ghosh (2006) this simple, industry practical, breeding design would lead to genetic improvement in redclaw growth rate, whilst maximising the maintenance of the limited amounts of genetic diversity that might be still present on farms.

Consequently, this chapter reports on the results of two aspects of the RIRDC redclaw selective breeding project. It outlines a) the methodology and results of a genetic diversity audit of commercial redclaw farms in Queensland, and b) the realization of genetic gains for growth rate when redclaw were selected by industry under the auspices of an inter-farm rotational mating plan. The genetic diversity audit was undertaken prior to commencement of the breeding program to ensure that adequate levels of genetic diversity still existed within the commercial industry and to identify if additional genetic diversity may need to be introduced, while selective breeding was conducted to boost the growth rate of commercial stocks leading to increased productivity and profitability of the industry.

Methodology:

a) Genetic diversity audit.

To undertake a genetic audit for the tropical freshwater crayfish (*Cherax quadricarinatus*) pleopods were collected from 30 redclaw from each of the eight farms in the proposed improvement program, as well as from the previously selected QDPI Walkamin genetic line to establish baseline estimates of genetic diversity. DNA was extracted from pleopods using a modified CTAB DNA extraction protocol (Wilson 1987) and re-suspended in 50 µL of TE (10mM Tris–HCl, 1mM EDTA, pH 8.0). DNA quality was estimated based on gel electrophoresis, whilst quantity was assessed using a ND-1000 Spectrophotometer (Nano-Drop® Technologies). DNA was diluted to 20 ng ul^{-1} for use in polymerase chain reactions (PCR). Microsatellites were amplified in 10 µL reaction volumes containing 20 ng DNA at six microsatellite loci originally isolated for redclaw by Baker *et al.,* (2000). The microsatellite loci genotyped were CQU001, CQU002, CQU004, CQU005, CQU006, CQU007. PCR amplification conditions for all loci were the same as those reported in Baker *et al.,* (2000). PCR products were visualised on 1.5% TBE agarose gels before genotyping on a MegaBACE 1000 Genotyper (Amersham Biosciences) using a standard 400 or 900 base-pair ladder (Amersham Biosciences). Fragment Profiler Version 1.2 (Amersham Biosciences) was used to determine allele sizes. Finally generation of genetic diversity statistics were conducted using GENALEX 6.4 (Peakall & Smouse, 2006)

b) Selective breeding of redclaw

The selective breeding program for redclaw was based on eight farm populations, representatives from the Walkamin line selectively bred by QDPI, and three wild collections comprising redclaw from the Palmer, Walsh and Mitchell River systems. Wild populations were included in the selective breeding program in recognition of the results of the genetic diversity audit (see results) to inject additional levels of genetic diversity into the program. Due to difficulties for the industry participants being able to maintain individual family pedigrees throughout the program a modified rotational mating design was used whereby farms/populations were designated as family lines and males from each farm were each generation sequentially mated with females from another farm (see Figure 3 in General Methodology section). At the start of the program male and female crayfish were randomly selected from each of the farm/populations and assigned to one of 30 mating baskets per farm/population line in the ratio of one male to four females. In subsequent years, prior to broodstock selection, 1000 animals from each farm were randomly selected by farmers and weighed to obtain estimates of mean pond growth rates. The heaviest 70 males and 170 females from this sample were then selected from each of the select lines held on farms and transported to the breeding program's mating pond at Rocky Creek. As previously outlined in the methodology section mating cages were routinely checked for berried females from which eggs were stripped and subsequently raised in the egg hatching incubator. To reduce inbreeding impacts it was ensured that only progeny from one male and one female from each mating cage eventually entered the breeding program. This process ensured that a minimum of 250 full-sib families would be produced each generation that exhibited minimum levels of relatedness. The breeding program was conducted in this manner for four generations of selective breeding. After four generations of breeding the performance of the selected line of crayfish (hereafter referred to as the RIRDC line) were evaluated against that of the previously improved QDPI Walkamin line by undertaking a controlled pond trial, whereby progeny randomly selected from all farms in the RIRDC line were communally reared with progeny bred from the Walkamin line. Therefore the Walkamin genetic line represented a control line from which additional genetic response made through selection in the current breeding program could be measured. Due to difficulties in the identification of each genetic line, S3J's were initially stocked into one of two small juvenile rearing ponds and reared for 10 weeks until they had reached a size (mean weight greater than 10 g) to enable identification through the use of elastomer visual implant tags (Northwest Technologies). The number of S3J juveniles stocked for the Walkamin strain and the RIRDC select line was 3500 and 4000, respectively. After the 10 weeks grow out period juveniles were harvested from each pond. For an unknown reason survival over the 10 week period in both ponds was extremely low at ~10% and ~38% for the Walkamin and RIRDC lines, respectively. In total only 374 crayfish from the Walkamin line and 700 crayfish from the RIRDC select line were available for the subsequent long-term grow out experiment. Crayfish from these two populations where tagged with different elastomer colours and then communally stocked into a grow out pond where they were subsequently on-reared for a further 29 weeks. At the time of stocking average size of crayfish from the Walkman line were 14.7g (± 7.2g SD, n = 374 crayfish), whilst those from the RIRDC selected line were slightly, but not significantly smaller, at 12.1g (± 5.1g SD, n = 700 crayfish)($P > 0.05$). After the rearing period all crayfish were harvested from the pond using a flow trap, sexed and weighed to the nearest 0.5 g and assigned to their respective genetic line based on their elastomer colour. To obtain an estimate of whether selection had changed any other correlated growth traits measurements of the carapace, abdomen length and abdomen width were also collected using vernier calipers.

Growth data collected was assessed for normality and heteroscedasticity before statistical analyses were undertaken. ANOVA was used to determine statistical differences among genetic lines using the program Statistica. The response to selection (R) in the RIRDC selected line was calculated as R = (mean weight RIRDC selected line - mean weight Walkamin line)/(mean weight Walkamin line).

Results:

a) Genetic diversity audit

The genetic diversity audit demonstrated that farmed redclaw populations exhibited moderate levels of allelic diversity, with all loci except for CQU004 in Bonnie Glen and Jennings showing a minimum of two alleles (Figure 8). The average number of alleles per locus per farm was found to range from 2.5 (Proa) to 7.5 (Stevo), whilst the total number of alleles captured per farm varied between 15 (Proa) and 45 (Stevo) (mean = 30.3). These values are very similar to that exhibited in a survey undertaken by Baker *et al.*, (2008) in wild redclaw populations across northern Australia whereby they found between 11-40 alleles present per wild population.

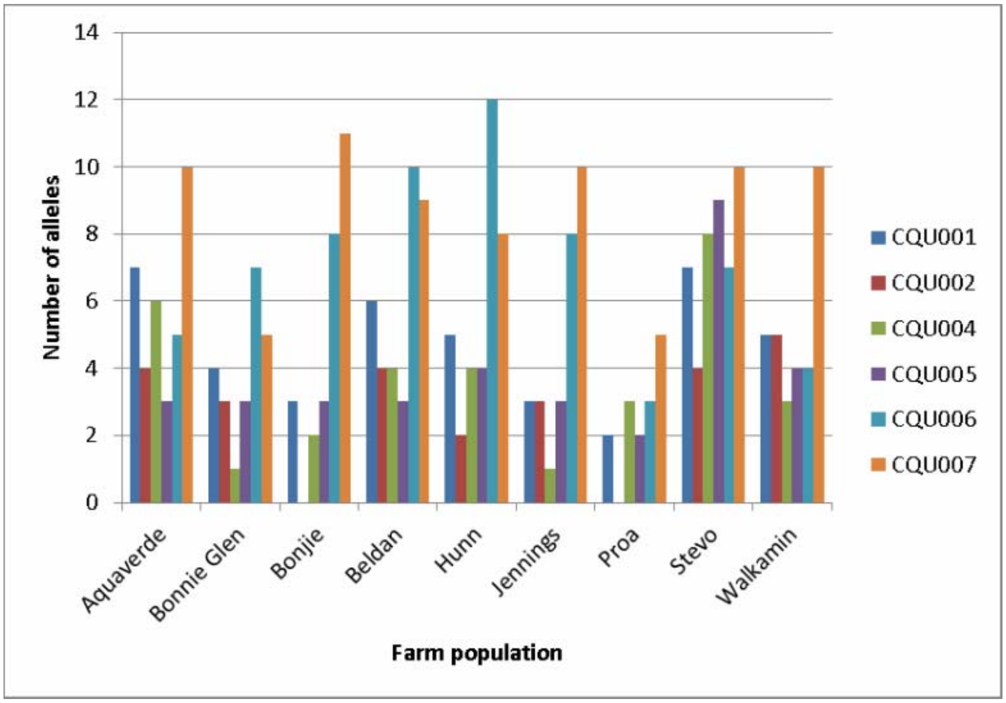


Figure 8. Allelic diversity at the six microsatellite loci genotyped in redclaw.

Estimates of observed heterozygosity within farms was moderate and ranged from 0.32 (Proa) to 0.78 (Aquaverde) (Figure 9). Heterozygosity is an estimate of what proportion of individuals carry more than one variant of an allele at a gene and will decrease rapidly due to inbreeding. Therefore low estimates of heterozygosity (< 0.5) may be indicative of non-random mating within a farm. Generally, the higher the heterozygosity the lower the expected incidence of matings of related individuals.

Besides that of the Proa population observed heterozygosity of captive redclaw populations were within the range found in wild populations (range 0.35-0.71) (Baker *et al.*, 2008). This suggests that although farm populations have been closed for some time breeding practices have occurred in a way by which inbreeding has been largely avoided.

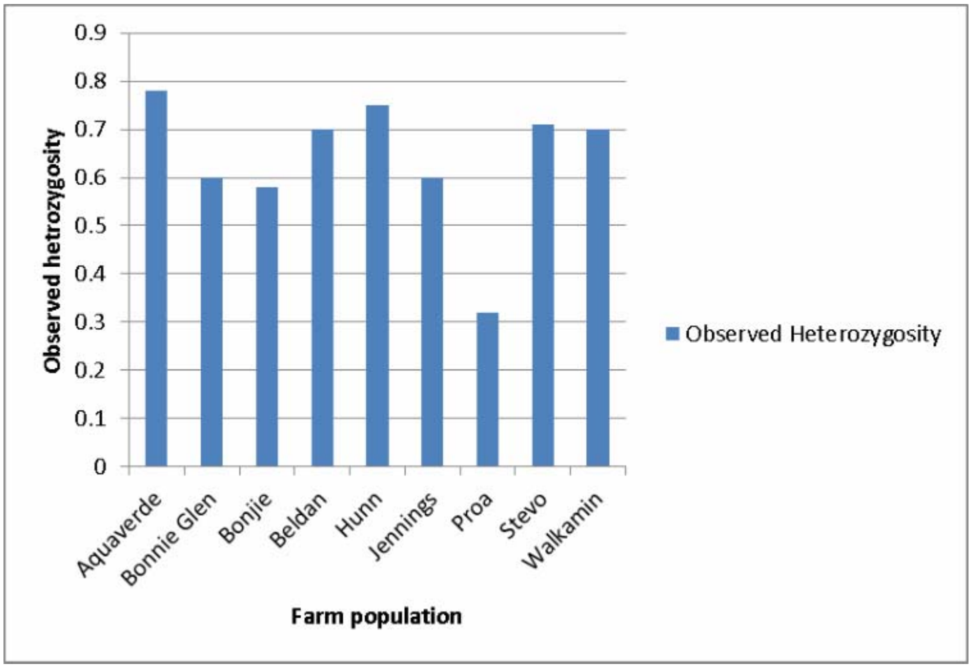


Figure 9. Mean observed heterozygosity of captive redclaw populations genotyped at six microsatellite loci

Finally, genetic similarity among the farm populations was evaluated by generation of a UPGMA tree based on pairwise F_{ST} values between farms (Table 2, Figure 10). This analysis was performed to examine the similarity of genotypic profiles between the farm populations and to provide information useful for the initial design of the circular mating scheme (ie to avoid mating closely related farms in the first genration). F_{ST} values and the subsequent UPGMA showed that five of the nine populations were reasonably similar in their genetic profile and therefore likely originating from the same foundation stock, whilst the other four populations had distinct genetic profiles.

Table 2. Pairwise F_{ST} estimates between farm populations of redclaw genotyped at six microsatellite loci.

	Stevo	Boonjie	Aquaverde	Bonnie G	Jenning	Hunn	Walkamin	Proa	Beldan
Stevo	_								
Boonjie	0.08	_							
Aquaverde	0.05	0.04	_						
Bonnie G	0.22	0.21	0.15	_					
Jenning	0.15	0.17	0.14	0.25	_				
Hunn	0.16	0.20	0.14	0.23	0.03	_			
Walkamin	0.03	0.07	0.07	0.23	0.14	0.19	_		
Proa	0.19	0.31	0.27	0.45	0.36	0.34	0.30	_	
Beldan	0.02	0.07	0.02	0.20	0.16	0.13	0.09	0.17	_

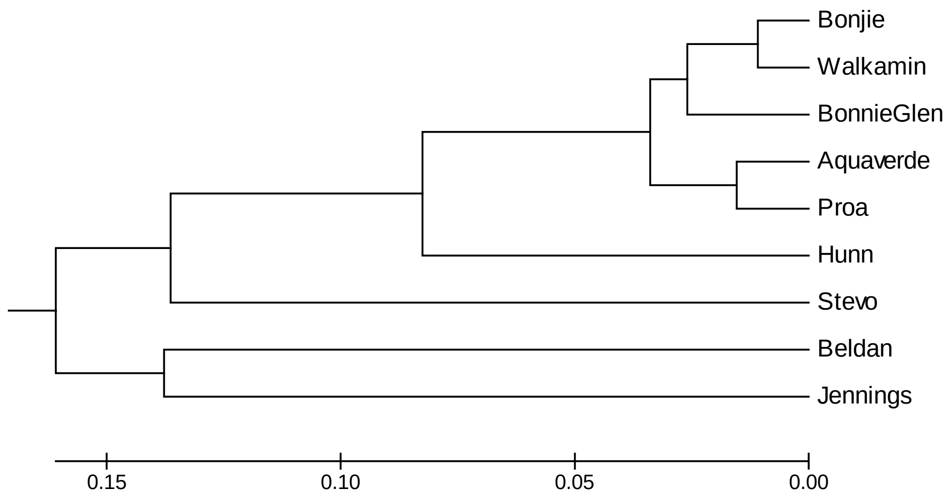


Figure 10. A UPGMA tree showing genetic similarities based on genotypes at six microsatellite loci among the eight redclaw farm populations and the Walkmin line. The distance of genetic similarity was that of Wrights $F_{ST.}$

In summary the genetic diversity audit indicates that current farm populations have maintained reasonable levels of genetic variability, although there is some evidence for common use of foundation stocks among five of the farm populations that will enter the selective breeding program. Therefore it would be prudent to introduce if possible additional genetic diversity, either in the form of genetic material from other farms, or preferable from several new wild collections.

b) Strain comparison trial:

Redclaw from the RIRDC select and Walkamin lines were communally reared for 29 weeks. At the end of the 29 week grow out period only 48 Walkamin and 95 RIRDC select line crayfish had survived. As for the initial S3J growth phase in this experiment the reason for the low survival rate is unknown. Although the numbers of crayfish left in the strain comparison experiment were less than anticipated comparisons between the genetic lines could still be made due to the fact that both genetic lines were reared together in the same environment and therefore would have experienced the same density and environmental effects on their growth. Low numbers, however, mean that results will have to be interpreted with caution.

Significant differences in average weight were observed between the control Walkamin line (mean = 90.8g ± 36.4g SD) and the RIRDC selected line (mean = 105.3g ± 41.5g SD)($P < 0.05$). Based on these values the total measurable accumulated response to selection for growth over the period of the RIRDC program is 16.0%. This response is higher and in addition to the 9.5% genetic gains achieved by Jones *et al.,* (2000). As further evidence of the overall growth improvements made in the selection program examination of size categories represented within the two genetic lines showed an obvious shift in the RIRDC selected line towards crayfish being in larger weight categories (Figure 11). This result is consistent with evidence collected on-farm from the yearly 1000 randomly collected samples which showed a consistent trend towards an increase in the population of large crayfish in the RIRDC select line (see Figure 12 in RESULTS).

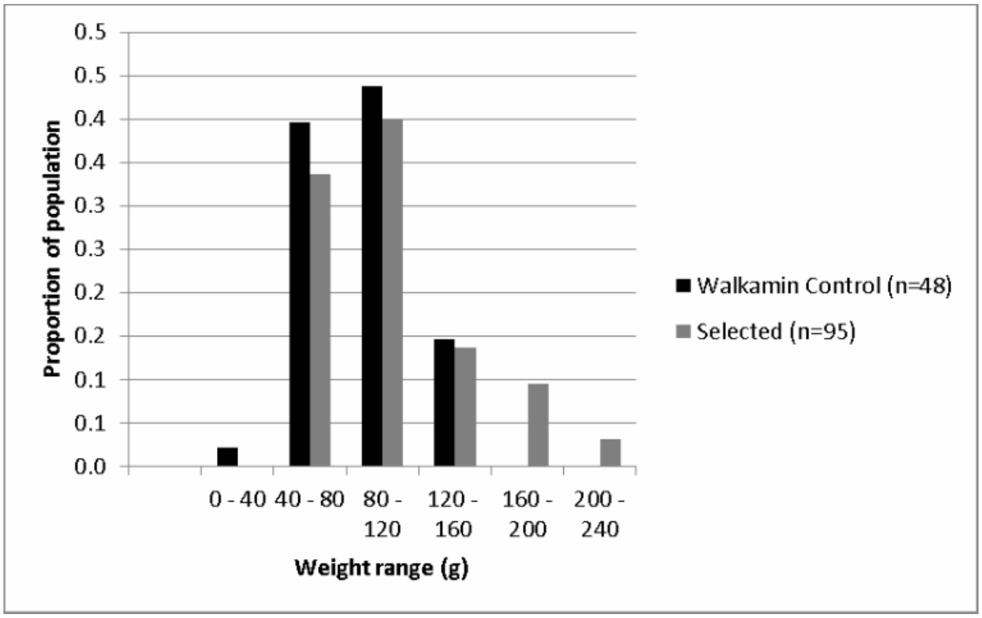


Figure 11. Proportion of redclaw within the Walkamin and RIRDC select lines assigned to 40g bins.

Selection for a primary trait like growth in the absence of knowledge on correlated genetic responses with other growth traits may lead to adverse changes in non-target traits like the ratio of carapace length to abdomen/tail length. Obviously in freshwater crayfish the tail meat is the proportion of the body that is consumed and therefore any selection program which leads to increased growth of crayfish, but negatively selects for tail size, will potentially result in a product of lower market value. Three body proportion analyses were undertaken – carapace to total body length, abdomen to body total length, and abdomen width to total abdomen length (Table 3). Minor changes were observed in body proportion ratios between the Walkman and RIRDC genetic lines, with a significant decrease in the ratio of the abdomen to total body length observed in both male and females of the RIRDC line ($P < 0.001$), and an increase in abdomen width as a proportion of abdomen length in RIRDC females ($P < 0.001$). A slight, but non-significant, increase in the proportion of abdomen width to abdomen length was also evident in RIRDC males. Although there may be some evidence for a slight change in body proportions between the selected RIRDC line and that of the Walkamin line, obviously these results need to be interpreted with caution due to the low number of crayfish available for measurement and if selection continues sustained monitoring of body proportions is advised.

Table 3. Body proportion ratios in Walkamin (control) and RIRDC selected male and female redclaw. C = carapace length, TL = total body length, AL = abdomen length, AW = abdomen width.

Genetic line	Sex	C/TL	AL/TL	AW/AL
Walkamin	Males	0.49	0.51	0.58
	Females	0.48	0.52	0.59
RIRDC	Males	0.52	0.48	0.60
	Females	0.50	0.50	0.64

Summary:

To maximize long-term genetic gains and minimize the effects of accumulative inbreeding it was imperative for the RIRDC funded redclaw selection program to start with a genetically diverse foundation base. Due to inadequate pedigree recording and broodstock management practices that were operating within the redclaw industry prior to commencement of the project, there were concerns from some that farmed redclaw had become inbred and that current genetic diversity levels were too low to achieve appreciable genetic response as a result of targeted selection. In response to this concern a genetic audit of eight redclaw farm stocks, as well as the QDPI improved Walkamin genetic line on which many farms had obtained genetic material, was conducted. This genetic audit showed that despite the lack of adequate pedigree management farm stocks of redclaw exhibited allelic diversity and heterozygosity within the range present in wild populations (alleles mean 27.5, range 11 – 40, heterozygosity mean 0.56, range 0.35- 0.71; Baker *et al.,* 2008). At the six microsatellite loci genotyped an average of 30 alleles were present in farmed and Walkamin stocks, while heterozygosity levels at these loci were relatively high (> 0.6) for all but one farm. Therefore it can be concluded that current farms stocks will possess enough genetic diversity to warrant commencement of selective breeding.

One issue demonstrated by the genetic audit, however, is that despite appreciable genetic diversity overall, F_{ST} analysis showed a close genetic relationship among several of the farms that will contribute broodstock to the genetic improvement program. This has probably arisen due to a heavy reliance on introduction of Walkamin line broodstock, as well as swapping of genetic material among farms. Given this consanguineous relationship among many of the farms it would be advisable to try to introduce new genetic material to increase the total levels of genetic diversity initially available to the program. This could be achieved by introducing genetic material from other farms that do not have a heavy reliance on the Walkamin genetic line, or ideally from several new wild collections.

Although poor survival was a major problem in benchmarking the growth performance of the selected line against that of the previously improved Walkamin genetic line, the results obtained suggested that redclaw growth rates have been further improved by 16% as a consequence of the RIRDC program. Obviously the accuracy of genetic line comparisons will be affected by poor samples sizes, however, initial indications from the strain comparison trial strongly suggest that true genetic improvement has been made. The argument for genetic response is also supported from on-farm data trends where farmers are readily harvesting heavier redclaw (see RESULTS – Breeding for Faster Growth) and the fact that surviving crayfish from the RIRDC select line were on average assignable to heavier size categories. As both genetic lines were reared communally, and thus subjected to the same environmental aspects on growth, this is additional evidence that genetic gains have indeed been achieved in the RIRDC select line, as the mean of the population has been pushed in the direction of heavier crayfish.

In summary, there is evidence for the further genetic improvement of redclaw crayfish from that of base stocks as a result of the RIRDC selection program. This result has been achieved through the implementation of a practical rotational mating strategy and through the perseverance and dedication of the Queensland redclaw crayfish industry. As the project has been solely conducted by farmers the RIRDC project has brought the redclaw industry to a stage of maturity where they now have the knowledge and resources to continue to selectively improve farm stocks into the future.

References:

Baker, N., De Bruyn, M. and Mather, P.B. (2008). Patterns of molecular diversity in wild stocks of the redclaw crayfish (*Cherax quadricarinatus*) from northern Australia and Papua New Guinea: impacts of Plio-Pleistocene landscape evolution. Freshwater Biology. 53, 1592-1605.

Baker, N., Byrne, K., Moore, S. and Mather, P. (2000). Characterization of microsatellite loci in the redclaw crayfish, *Cherax quadricarinatus*. Molecular Ecology. 9, 494-495.

Gjedrem, T., Robinson, N., Rye, M. (2012). The importance of selective breeding in aquaculture to meet future demands for animal protein: A review. Aquaculture. 350, 117-129.

Hinton, A.W. and Jones, C.M. (1997). Redclaw crayfish farming, an economic perspective. In: Redclaw Crayfish Aquaculture. New Opportunities for the Atherton Tablelands. Choices Seminar Series 1, pp. 2 10. Queensland Department of Primary Industries, Mareeba.

Jones, C.M. and Ruscoe, I. (1996). Production Technology for Redclaw Crayfish (Cherax quadricarinatus). Final Report FRDC Project 92/119. Fisheries Research and Development Corporation, Canberra.

Jerry, D., Purvis, I., Piper, L. and Dennis, C. (2005). Selection for faster growth in the freshwater crayfish Cherax destructor. Aquaculture. 247, 169-176.

Jones, C.M., McPhee, C.P. and Ruscoe, I.M. (2000). A review of genetic improvement in growth rate in redclaw crayfish Cherax quadricarinatus (von Martens) (Decapoda : Parastacidae). Aquaculture Research. 31, 61-67.

Peakall, R. and Smouse, P.E. (2006). GENALEX 6: genetic analysis in Excel. Population genetic software for teaching and research. Molecular Ecology Notes. 6, 288-295.

Wilson, K.J. (1987). Current Protocols in Molecular Biology. Wiley, New York.

Results

This project has the unique advantage of addressing its three objectives simultaneously by using the same relatively simple and uncomplicated procedures. In the interest of clarity of presentation, the progression of realizing the three objectives will be treated separately even though achievements in all three ran a parallel course.

Breeding for Faster Growth:

As explained in "Methodology" breeding for faster growth was achieved by using the biggest redclaw from each harvest as broodstock for the following year. In order to measure the project's progress, a starting point had to be established. This presented a difficulty as all families had variations in quality. It was decided to use 2004 "Walkamin" strain as a yard stick because these animals were considered the best in the world by DPI when they were developed and any comparison with them had to be seen as fair.

In no way is there any intention for the information below to compete with, replace or contradict the scientific assessment of the project's performance as described under "Chapters" by our James Cook University mentors. As project managers, industry members recorded and compiled data under the instruction of JCU for their use in assessment. From the outset, industry members were keen to be updated regularly on the progress of the project, and to this end, the data collected was interpreted in a form that could be presented to the members at Association meetings. This keen interest in following the progress of the project is an indication of how the research effort captured the attention of all redclaw farmers.

At harvest, each farmer supplied data used to calculate the average weight of the animals harvested. The average weight determined for each of the eleven participating farms was then averaged to gain a project harvest weight. We, as farmers, felt that this "average of the average" was a fair assessment of our progress and evened out discrepancies inherent in redclaw farming.

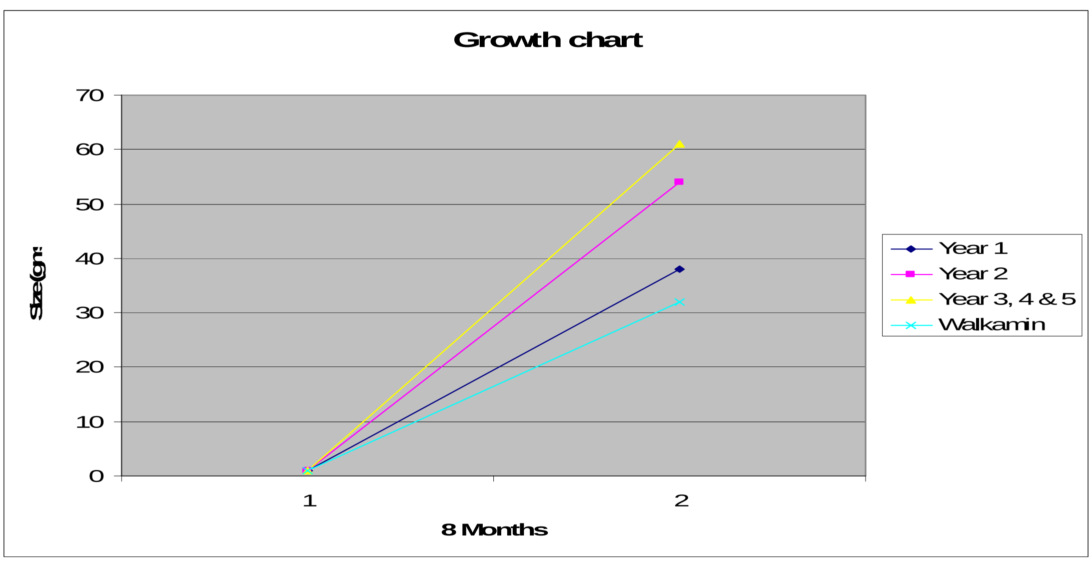


Figure 12. Graph of Project results

The graph above (Figure 12) plots these "average of the averages" results and compares them to the Walkamin Strain control stock results from 2004 as supplied to us by QDPI. All growth rates are based on average harvest weight after a eight month growout period.

Even more important to the farmer is the percentage of the harvest that is in the larger size groups and therefore more valuable at the market place. Redclaw do not grow evenly and can have a wide size variation at harvest. This is an important issue in a commercial operation as smaller animals have little value.The graph below (Figure 13) compares the size distribution of the 2011 project with the Walkamin control

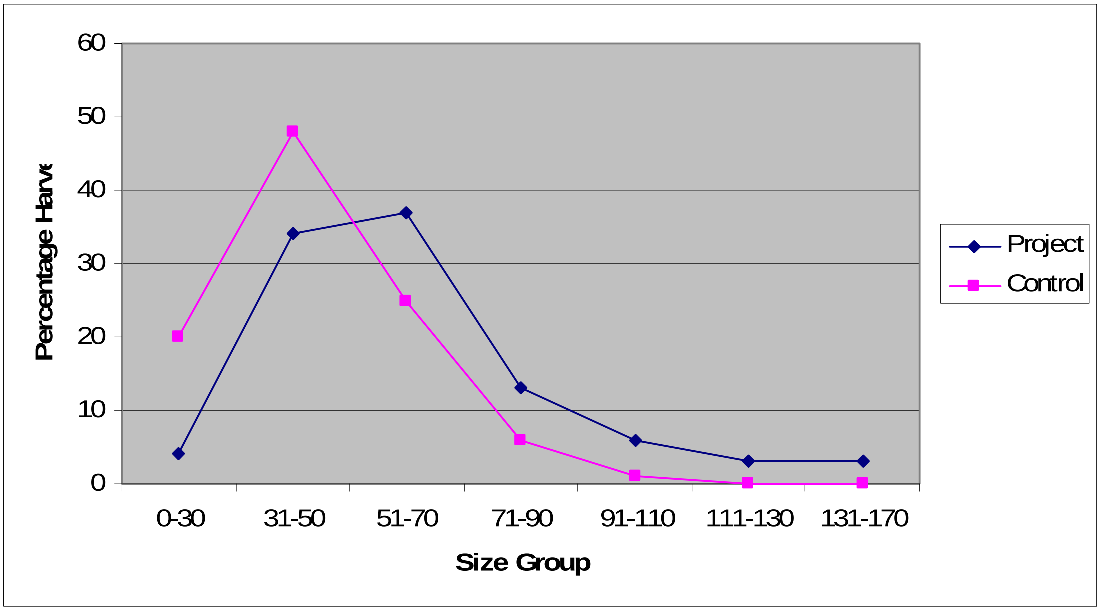


Figure 13. Size Distribution Comparison

In addition to the results compiled above, many instances of anecdotal evidence based on observation and experience were recorded. One farm that had suffered from inbreeding depression claimed a 100% improvement in growth rate from the project redclaw stocked.

Over the five years of the program, the incidence of 300 gram plus animals produced in the eight months growout period became more frequent and 200 gram animals became common. This is a hitherto unheard of occurrence.

Figure 14. A 296 gram redclaw produced in 8 months

The Incubator Effect on Growth Rate:

As explained elsewhere in this report, the main objective of this project was to increase the growth rate of redclaw by genetic improvement. The incubator was introduced primarily to facilliate control over genetic diversity. The incubator produced disease free animals which it was to be proved, grew at a significantly increased rate quite apart from the genetic improvement and in addition to it. This "Incubator Effect" is a considerable contribution towards realizing the Project's objectives and forms a legimate part of the Project's achievements. Although this was noticed during incubator trials prior to the actual commencement of genetic selection, it was not until late in the project that sufficient data was collected to show how appreciably the growth rate was enhanced. It is theorized that the energy otherwise expended combating disease was channeled into growth.

The following graph (Figure 15) shows an increase in size in the order of 50% between conventionally hatched off a berried female (BF) and incubator hatched (Inc) Walkamin strain redclaw.

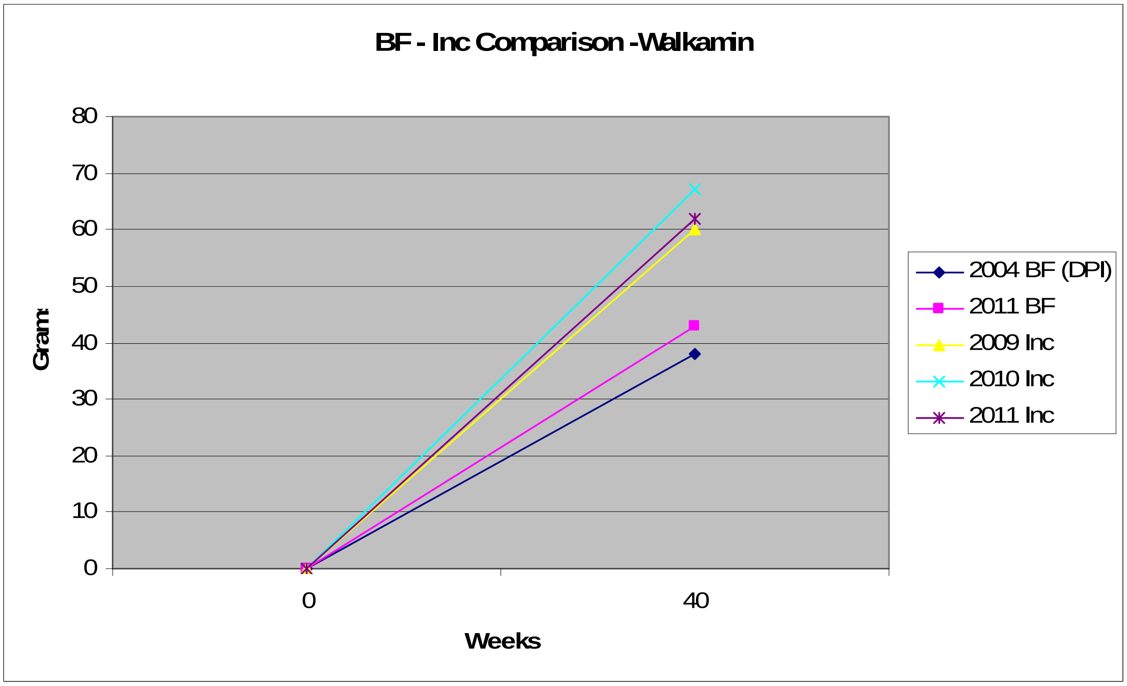


Figure 15: Growth Comparison – Conventionally and Incubator Hatched Redclaw

Combating Inbreeding Depression – Ensuring Genetic Diversity:

Redclaw breed readily in captivity. This trait has traditionally tempted farmers into adopting the unfortunate practice of continuously breeding from their original stock, which in most cases was not selected with genetic diversity in mind in the first instance. Other regrettable practices such as restocking the undersize animals from a pond harvest and breeding from a few of the best performers have promoted the possible propagation of runts and breeding between siblings.

The need for genetic diversity is easily overshadowed by the more attractive short term prospect of breeding faster growing animals. The two facets of selection are at odds with each other as the parameters for selection are quite different. The managers of this project were very conscious of this temptation and placed equal emphasis on both.

Without duplicating the initial genetic audit carried out by Karen Willows and detailed under “Chapters”, no finite assessment of our progress in this area is possible. However the Circular Mating Design recommended by JCU was adhered to and there is no reason to doubt its effectiveness. Anecdotal evidence from farms that did suffer inbreeding depression at the start of the project indicate a substantial improvement in the overall quality of their stock.

Development and Implementation of Hatchery Technology:

The overall thrust of the project, mentioned in “Objectives”, was to combine the results of the primary aims to develop systems and protocols to facilitate the establishment of a commercial hatchery. The most satisfying outcome of the project is that the industry now has a producing commercial hatchery and there is a second one under construction.

Both hatcheries will continue the selective breeding program under the guidance of JCU and have implemented a system of breeding redclaw all year round irrespective of season and ambient temperature.

The inclusion of hatcheries into the redclaw industry is instrumental in its progression towards being a major player in the aquaculture industry. It has the potential to catapult the redclaw industry into the twenty first century.

Already, the uptake of S3J from the producing hatchery, particularly from farmers in southern areas of the state, is evidence of an enthusiastic acceptance of the proposed "S3J farming" methods explained below. The advisability of accepting overseas enquiries has yet to be fully considered.

Figure 16. Environment controlled all season mating facility

Subsidiary Projects:

As mentioned in "Objectives", the mainstream work of the project gave rise to many opportunities to study areas of interest and need. As data was collected, trends observed, and the need for more information on some topics realized, trials were conducted and data collected under the umbrella of the project and its budget. Some of the results obtained were of a useful, practical nature, some led to a better understanding of the animal and others were just interesting.

A selection of the more noteworthy will be discussed and their relevance to the industry explained:

"S3J Farming":

The development of hatchery technology and its adaptation to suit the characteristics of redclaw opened the door to many possibilities which were explored as part of the project. By far the most significant of these was in fact a revolution in the way that redclaw could be farmed. Traditionally, stocking redclaw ponds was an ad hoc affair at best, depending on what stock was available at the time. The method adopted by the particular farmer varied according to his conviction of what worked best for him. Producing juvenile redclaw for stocking represented a considerable proportion of the time spent on the farm. Generally speaking, three main procedures were used:

(1) Ponds were stocked with berried females (females carrying eggs) recovered from harvesting another pond or from a dedicated breeding pond. The females were either stocked directly into the pond or into a floating cage to be recovered later. The success of this method was dependant on the number and quality of berried females available which in turn was dependant on the season. Harvest was necessarily inconsistent because it was tied to inconsistent stocking. The method required pondage to be dedicated to breeding that could be otherwise be used for production.

(2) Ponds were stocked with females and males, generally in the ratio of 4:1 and allowed to breed naturally. The success of this method was also season dependant and tied up stock that otherwise could be sold to market. The breeding was not coordinated and its degree of success was not known until harvest, this resulted in an erratic outcome and a wide spread of sizes. The larger redclaw harvested from another pond were commonly used in this method with no assurance that they were not siblings

(3) Ponds were stocked with small redclaw recovered from harvesting another pond, termed "juveniles". There is no way of determining the age of a redclaw by looking at it, so in fact a proportion of these "juveniles" could well be runts. As in the other two methods, the season had a large bearing on availability of juveniles.

To summarise, these methods are labour intensive, season dependant, fraught with the danger of inbreeding, tie up unproductive pondage, waste saleable product and lead to inconsistent and unpredictable results.

S3J Farming involves buying S3J (Stage Three Juveniles) from the hatchery and stocking them into a pond. The hatchery supplies animals of known quality and can do so all year round allowing maximum use of the premium growing season. Because the S3J are produced in an incubator they do not carry inherent diseases common to most redclaw populations facilitating improved growth rate.

Ponds can be stocked with animals all the same age on the same day. The hierarchy effect of larger animals inhibiting the growth of smaller ones is no an issue. The biomass of the pond is calculable at any time as there is a known starting point. Although redclaw do still grow at different rates, the spread of sizes at harvest is not as pronounced.

The labour to stock a pond is negligible, water use and the energy to pump it is reduced, premium stock otherwise used for breeding can be sold at a premium price and effort can be concentrated on perfecting growout methods.

Transport:

Successful transport of redclaw always has been, and still is to some degree, an unresolved problem to the industry. Movement of live animals is necessary when providing stock to new farms, providing product to some markets and interchange of stock between farms. Transport of stock to be used for stocking ponds has traditionally been done when the animals are around 5 to 10 grams. Young animals grow very quickly and therefore often are coming off or into a moult stage when their soft shell makes them vulnerable to crushing when packed in a box. At best, perhaps 500 can be packed in a box with relative safety, and even then significant deaths can be expected. The fact that they have claws preclude the use of alternate transport methods.

The project developed the use of the incubator to produce Stage Three Juveniles (S3J) which weigh 0.02 grams. Trials proved that S3J can be packed 10,000 to a bag of water and oxygen in one box and can comfortably survive a transport period of 50 hours with no appreciable losses. Transport costs are cut by a factor of twenty. Environmental advantages are gained from the massive reduction in packaging material disposal.

Figure 17. A bag of 10,000 S3J ready for dispatch.

Egg Development Synchronisation:

Coordination of delivery of S3J to farms dictated the need for a method of manipulating their development so an acceptable number would be available for dispatch at the one time. A chiller and heater were purchased to facilitate trials to establish the effect of temperature on the egg incubation period. The following table of results (Table 4) shows that a significant change to the incubation time can be achieved by relatively small temperature differences. This knowledge enabled the operators to run multiple incubators at different temperatures and thus coordinate supply.

Table 4. Development periods at various temperatures.

temp deg C	spawned	coloured	bi-polar	eyed	hatched	stage II	stage III	days	weeks
16	0	27.8	19.0	17.2	9.5	13.5	30.0	117.0	16.7
20	0	19.3	14.7	10.0	7.1	13.0	18.7	82.8	11.8
24	0	14.0	8.7	6.7	6.5	7.1	9.5	52.5	7.5
26	0	8.0	6.2	6.0	5.7	5.8	10.0	41.7	6.0

Temperature Effects:

Some work has been done in this field in the past which established that a water temperature of 27 degrees Celsius is optimum for the growth rate of adult redclaw

Further work was done using temperature data loggers in ponds in various geographical locations. The data so assembled has several practical applications. Some farmers have adopted a seasonal approach to growing redclaw based on the information resulting from these trials. It is also a practical tool for industry leaders to advise prospective farmers in their site selection. When ongoing trials on the survival of S3J at low temperatures and their tolerance to temperature change have been completed, hatchery operators will be in a position to advise farmers as to what time of year it is practical to stock S3J at their farm's location. The industry is working with JCU in relation to the consequences of climate change on aquaculture in Australia.

The following graph (Figure 18) shows an unseasonable temperature spike in July 2010. This unusual occurrence caused breeding in the project growout ponds before the animals could be harvested in August. The consequence of this was that many of the fastest growing females could not be used in the project resulting in a below average improvement in growth for that year.

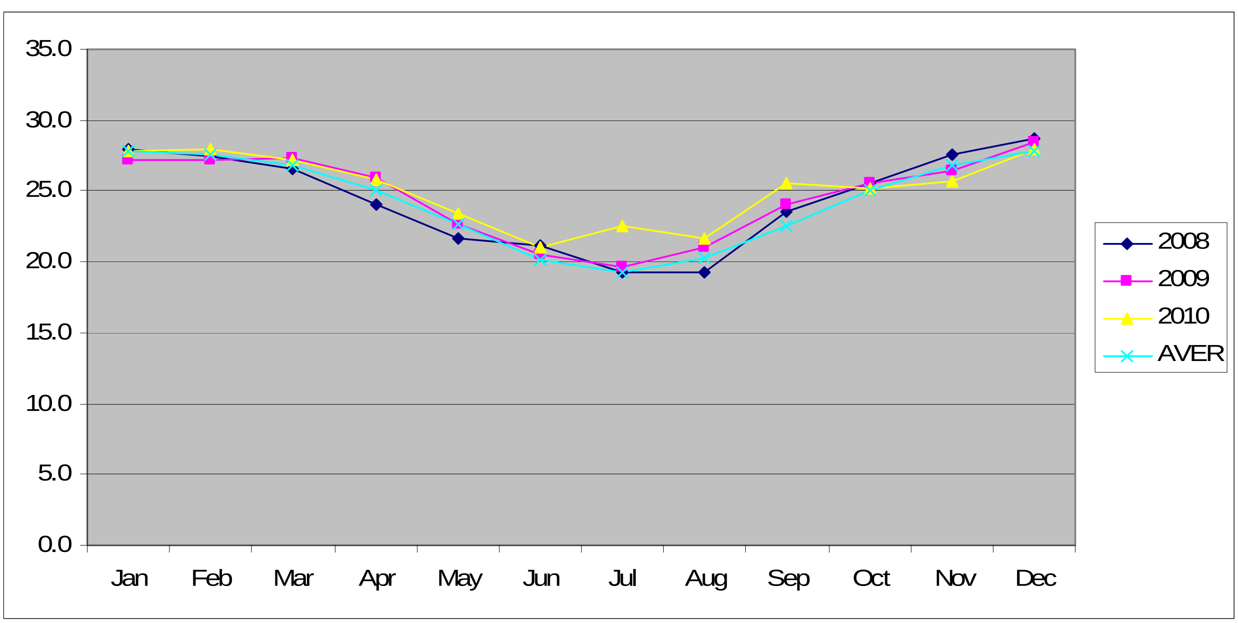


Figure 18. Monthly average temperature – Townsville.

The "Cazzonelli":

Traditionally, the production of a redclaw pond has been judged in terms of tones per hectare per year. This figure can vary from below one to above three depending on a combination of many factors, the most common being the variation in stocking regimes. This adopted yardstick has the potential to be misleading as it includes the weight of all animals harvested from the pond. Often this can include a significant percentage of animals too small for market and also includes those kept for traditional breeding operations.

The "Cazzonelli" named after the Atherton Tableland farmer who came up with the concept, is the kilograms of saleable product per 1000 S3J stocked per month of growout. Saleable product is considered anything over 30 grams. This is a practical unit of measurement that does not involve extraneous factors such as pond size, unsaleable stock etc. It provides a direct relationship between production and dollars earned using the S3J farming method and provides a simple benchmark for the farmer to use for production assessment.

The table below (Table 5)sets out some recorded examples of pond production in terms of Cazzonellis. For example, consider Pond K1 that produced 201kg of usable product compared with Pond S12 that produced 234 kg. Pond K1, although a lesser gross harvest, is the better result because its Cazzonelli value is 4.77 compared with 4.34

Table 5. Various calculations of the "Cazzonelli" value

THE "CAZZONELLI"

kg Salable Product produced per 1000 S3J stocked per month of growout

"Saleable Product" means over 30gm

Farm/Pond No.	KG >30g	1000's S3J	Months growout	Cazzonelli

Mr Cazzonelli's Average Benchmark			10	3.00
Pond S 12	234	5.5	9.8	4.34
Pond S13	242	5.5	10.7	4.11
Farm 1	76	3.4	8.1	2.76
Farm 2	134	4.3	8.1	3.85
Farm 3	111	3.6	8.1	3.81
Farm 4	80	4.4	8.1	2.24
Farm 5	222	6.3	8.1	4.35
Farm 6	60	2.9	8.1	2.55
Farm 7	240	6.3	8.1	4.70
Pond K1	201	7.8	5.4	4.77

Implications

It is no secret that the redclaw industry has been in decline since its production peaked in 2006. Industry leaders were motivated to take proactive measurers to reverse this trend, the first being to seek help to undertake research projects to improve the performance of the animal and thus the viability of the industry. It will be another year or two before the impact of this project on industry production can be measured in hard data, however existing farmers have enthusiastically embraced the results and there is no reason not to expect significant gains to be seen purely from existing farms.

The potential implications for the industry resulting from the development of S3J farming are intense. Advantages such as simplicity of farming methods and many instances of farming efficiency and associated increase in profitability clearly outweigh the perceived disadvantage of purchasing stock. A series of workshops conducted at three Association branch meetings identified probable annual increase in profit of $20,000 per hectare of pondage.

“Operation Kickstart” is an initiative of industry leaders to reactivate existing redclaw farms whose owners’ enthusiasm for the industry has waned and also attract new entrants into the industry. The concept is based on the exciting results of the Selective Breeding Project, the development of “S3J farming’ explained in Results and the proactive attitude of the industry in undertaking this and other research projects

The results of the project show that redclaw farming need not be labour intensive, that significant gains can be made by discarding stock of indifferent quality in favour of S3J from the hatchery and that it can be demonstrably profitable. It is believed that now the redclaw industry can be hauled back from the brink of declining into obscurity.

Farming redclaw can be an attractive occupation for a small or extended family unit. It is a practical second string for existing farmers, lends itself to polyculture, and is a diversity option for existing water users. Some of these options have been considered marginal in their viability. It is now believed that they can be exploited. While large farms are desirable these smaller operations all contribute to swell industry production.

QDPI has published a Scoping Analysis promoting a 50 hectare scale redclaw farm. As an aquaculture industry that has an untapped market, is not necessarily confined to the eco sensitive coastal strip and has passive environmental impacts, redclaw farming makes an intelligent choice for a major investor

An immediate impact on the industry is the development of two hatcheries and the associated gains in employment opportunities. The advances made in transport as explained under “Results” make exporting S3J for growout overseas a possibility if it is considered advisable

In general, the fact of undertaking this research project using its own members and making an impressive success of it, has raised the profile of the redclaw industry. It is now being considered a serious player on the aquaculture scene. Additionally the obvious gains as a result of this project has highlighted the need for, and potential benefit from, more research projects. A high level of enthusiasm has been achieved among industry members as they consider that the industry itself has been responsible for the first research effort in ten years.

Recommendations

Those who have been close to the project during its five year term are well aware of its spectacular success. It is now time to make the rest of the world aware. Speaking opportunities at various aquaculture industry conferences and gatherings in Queensland have been exploited over the last six months arousing a great deal of interest. Early 2013 will see the commencement of a structured publicity campaign involving all avenues available, which will culminate in a science and industry conference to be held in Cairns mid year. The conference will be used to showcase the results of the project and promote the industry in general.

As mentioned under ‘Implications’, there is now the chance to take advantage of the market opportunities overseas to provide S3J for growout farms. The industry is hesitant to take this step for fear of falling into the trap of selling a native Australian animal to other countries and creating a damaging competition. There is research being carried out in Israel to perfect breeding male only redclaw offspring. Should this be successful and a practical method developed, not only would a marketing advantage be gained in growing the more popular male animal (because of the spectacular red claws), but exported S3J could not be used to start a breeding facility in competition with the local effort. The industry would like to see Australian research organizations encourage and support those in Israel in this endeavour.

There are still some survival issues, both with broodstock in mating facilities and S3J after pond stocking. Industry has conducted several trials in an attempt to isolate the cause of mortalities without any great success. A structured research effort is required, particularly in the case of S3J survival, to lift the survival to an acceptable level. An improvement of 20% would result in an additional $2000 being earned from each pond stocked. This is not a new problem. In the past, using traditional farming methods, it was solved by simply adding more brood females to the pond.

The industry needs to support the hatcheries by embracing the concept of S3J farming. The hatcheries need to be consistently viable because it is they who have the task of continuing the selective breeding program to ensure continuous improvement in stock quality. Without a conscious effort to improve, the quality of stock will decline. The hatchery operators also face the task of perfecting year round supply of S3J by manipulating breeding conditions to enable the farms to fully exploit the advantages of S3J farming.

The research momentum needs to be maintained. Stage 1 of a Feeding and Nutrition project funded by RIRDC is in its final stages and Stage 2 funding has been approved. Other research projects are on the drawing board such as the Tracking Project for which a Preliminary Research Proposal was unsuccessfully submitted in 2009.

Appendices

Appendix 1: "Report of Survey of Queensland Redclaw Crayfish farmers" (2001)

QUEENSLAND CRAYFISH FARMERS ASSOCIATION INC.

President: Bill Keast, phone (07) 5486 7367 fax (07) 5486 7367
email ironbark@spiderweb.com.au Lot 4 Verne Rd, Wolvi, Qld. 4570.

Secretary: Ian Ross phone (07) 4668 95280 fax (07) 4668 95280
email gray-ross@bigpond.com PO Box 617, Chinchilla, Qld. 4413.

SUMMARY REPORT OF QCFA SURVEY OF QUEENSLAND REDCLAW CRAYFISH FARMERS

Prepared by Ian Jarratt (QDPI*) and Bill Keast (QCFA) June 2001

KEY POINTS

The survey was highly successful – 55 farmers participated (over 50% of active farmers) and they accounted for a very high proportion of the industry's sales.

The results will assist decision-making by individual farmers, farmer associations and other stakeholders.

Most farmers plan to increase output greatly by 2002-03 (primarily by increasing output/ha) and to invest more capital.

Industry estimates, calculated from the survey results, suggest that **the total area farmed could increase from 119 ha in 1999-00 to 188 ha by 2002-03 and total sales from 120 tonnes to 339 tonnes**. (Note: these estimates do not take account of the plans of any new entrants.)

The highest priority business aims for most farmers were ***increasing productivity of existing ponds and increasing output***

The top industry R&D priority was ***breeding for faster growth***

* The information contained in this report was supplied by Queensland crayfish farmers and collated and analysed by the Department of Primary Industries for industry services purposes. Whilst all reasonable care has been taken in compiling the information, the State of Queensland, its officers and agents disclaim all liability for any error, omission, loss, damage or injury of whatsoever nature suffered by any person or person's property as a result of the information contained in this report.

Numerous industry changes were sought but none were seen as overwhelmingly important.

Representation and information provision/exchange were the main services required from industry associations.

Small and large farmers differed significantly in the importance attached to several aims, needs etc.

BACKGROUND

In January 2001, the Queensland Crayfish Farmers Association (QCFA) conducted a postal survey of the 280 holders of a DPI licence for Redclaw crayfish farming in Queensland.

The survey was to allow them to anonymously give their views on the industry's development needs and the needs of, and plans for, their own businesses.

To allow all current and potential licensed farmers to participate in the survey, a questionnaire was sent to each licence holder for crayfish farming, although many were known to be not farming crayfish.

RESPONSES

The response was excellent. 55 survey questionnaires were returned in time for analysis from farmers in all regions and of all sizes (pond area, sales, and capital investment).

The 50 farmers who provided area information accounted for about 53% of all farms with ponds in 1999-00 and for about 46% of the industry's total pond area.

The 41 farmers who provided sales information accounted for about 55% of all farms with sales during 1999-00 and for about 84% of the industry's sales.

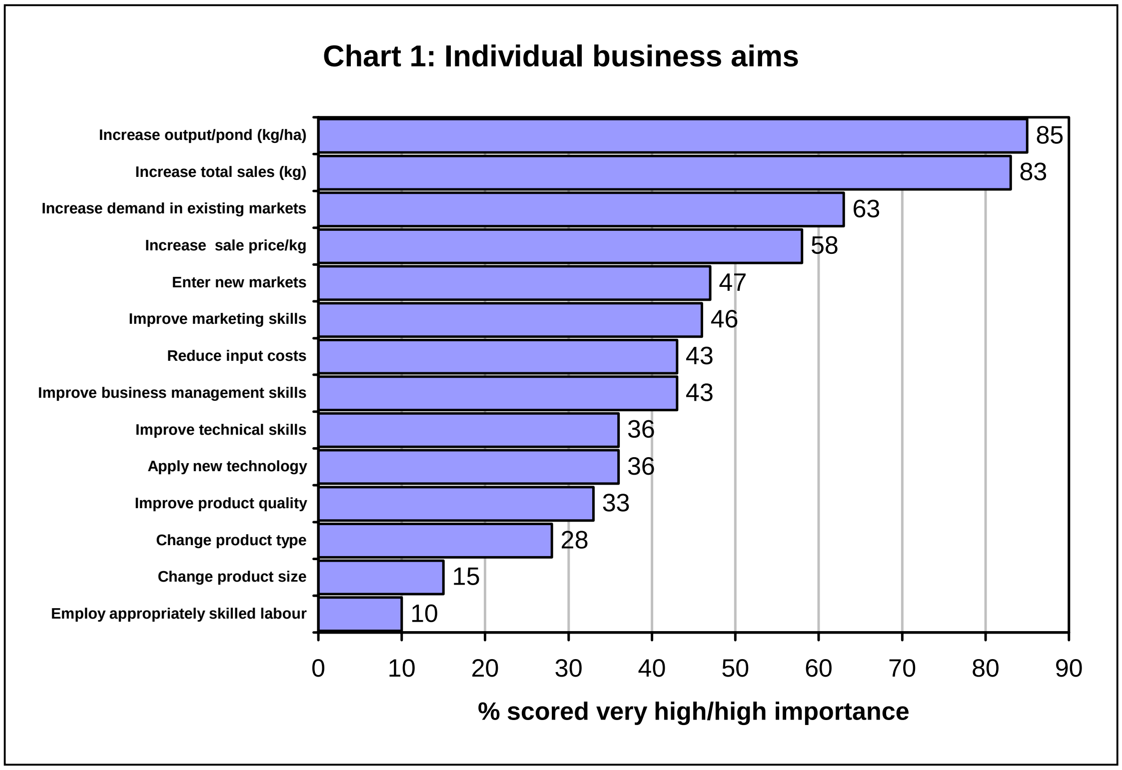
RESULTS

Only the main results are summarised in this report and presented mainly in charts. More detailed results and analysis are provided in the full report of the survey which is available on request from the Queensland Crayfish Farmers Association.

The importance of some aims/needs etc differed greatly between large and small farmers. Details of these differences are provided in the full report. Overall results only are presented in this summary report.

Individual business aims

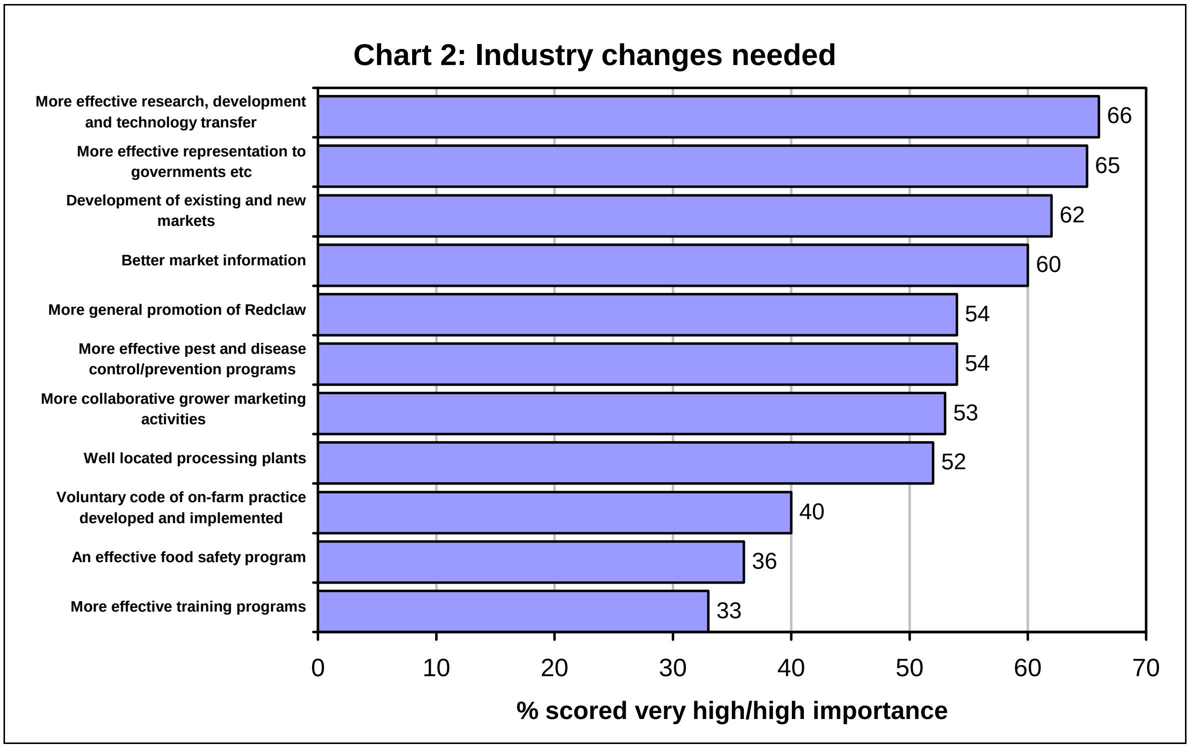
Chart 1 shows the percentage of farmers who rated each business aim as either very high or highly important.



The range was very great. The most important aims were *to increase output/pond* and *to increase total sales*, each being rated highly by over 80% of farmers. These were followed by *increase demand in existing markets and increase sale price/kg*, around 60%. There were then a large number of aims scored highly by 30-40% of farmers. The lowest rating aims were *employ appropriately skilled labour* (only 10%) and *change product size* (15%).

General industry changes

The very high and highly important ratings for industry changes needed are shown in Chart 2. The range was smaller than for individual business aims. Generally each of the changes needed was rated as very high or highly important by 50-60-% of the farmers. The 3 lowest rated changes were *more effective training programs* (33%), *an effective food safety program* (36%), and *voluntary code of on-farm practice developed and implemented* (40%).



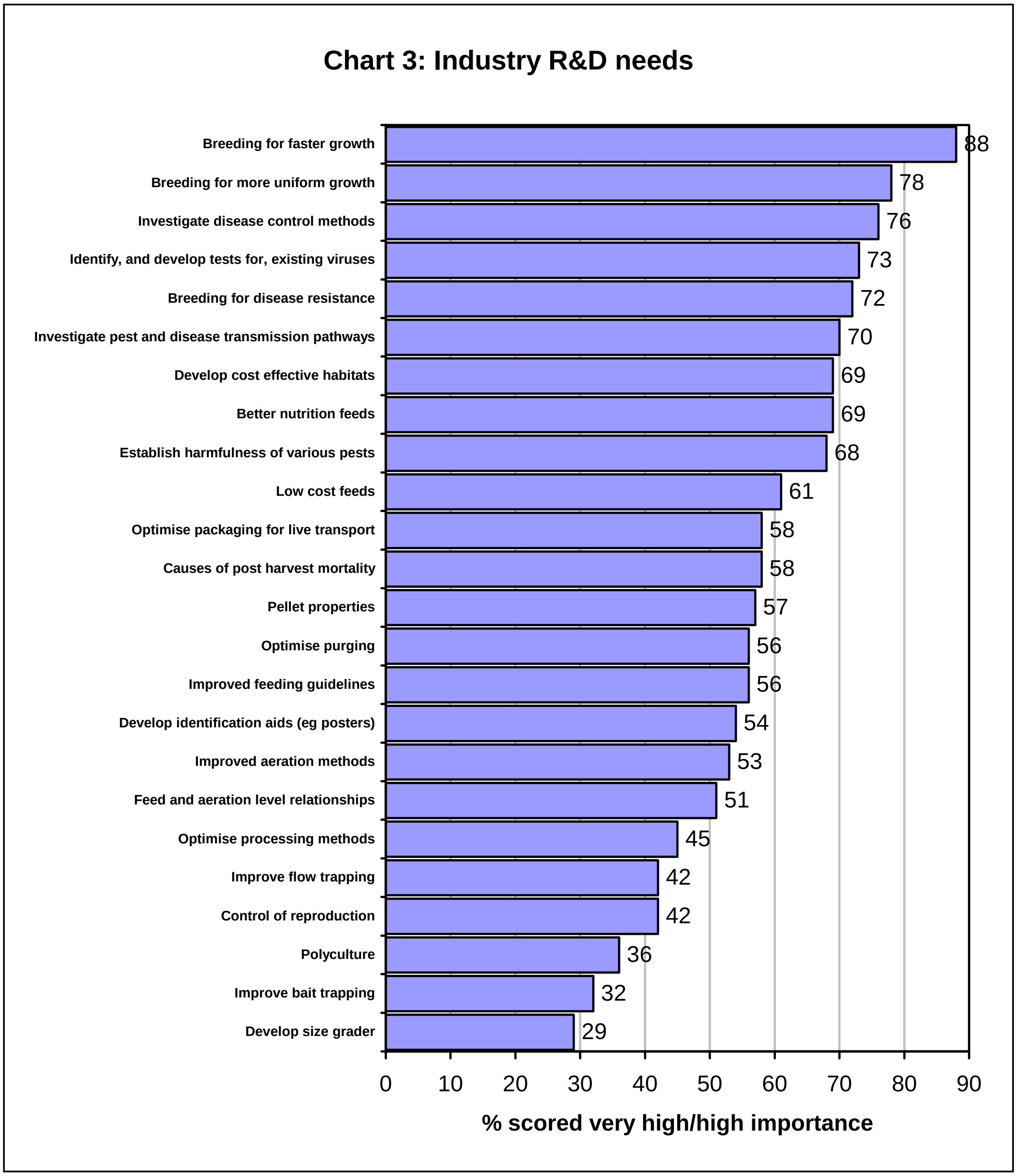
Industry research and development needs

Farmers rated specific possible industry R&D needs in the areas of: feeding and nutrition, pond productivity, post harvest, and pests and diseases. The scores of all respondents, irrespective of subject area, are shown in Chart 3.

The range in the percentage of farmers who regarded a topic as very high or highly important varied greatly, from 88% to 29%.

The single most important topic nominated for R&D was *breeding for faster growth* (88%). This was followed by 8 needs, mainly relating to pests and diseases, and improved crayfish growth, with support levels ranging from 78% to 68%.

Most of the remaining topics achieved support levels of 45% to 55%. The lowest levels of support were for *develop size grader* (29%) and *improve bait trapping* (32%).

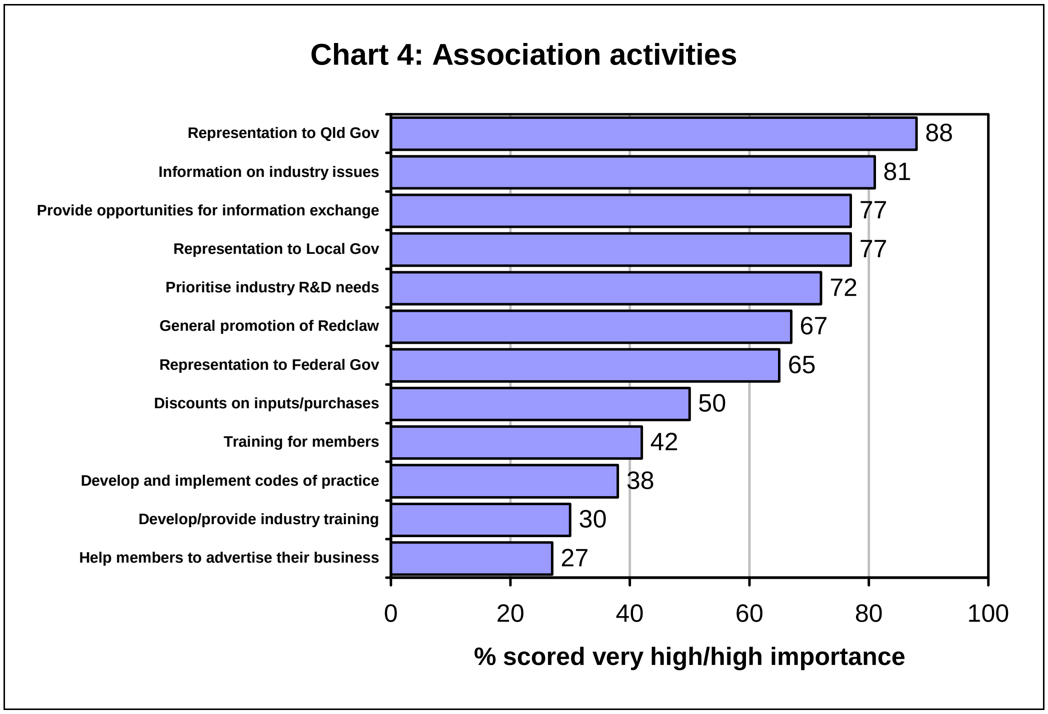


Association activities

The scores for association activities of all respondents are shown in Chart 4.

The rating of association activities as very high or highly important varied greatly, from 88% to 27%.

The most important activities, with percentages of over 75%, were: *representation to the Queensland Government, information on industry issues, providing opportunities for information exchange, and representation to local government.* *General promotion of redclaw* (67%) and *representation to the federal Government* (65%) were also rated quite highly. The other possible activities were rated much lower, the lowest was *helping members to advertise their business*, only 27%.

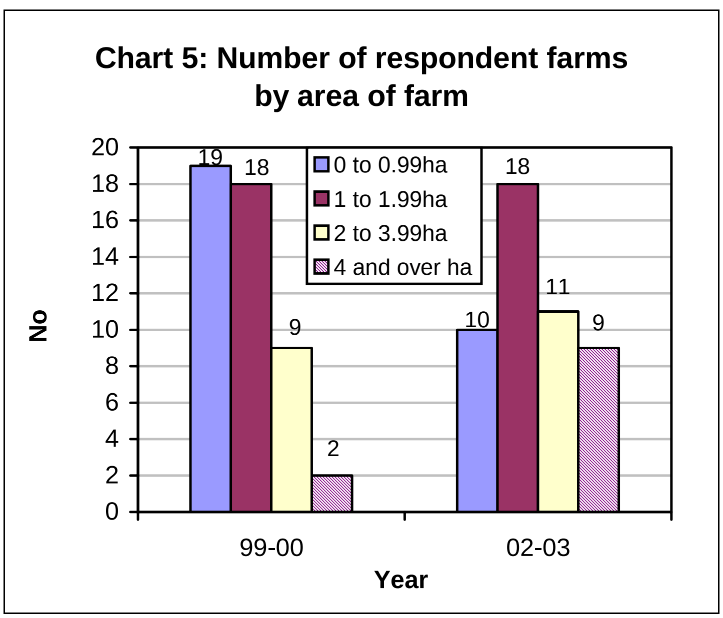


Individual business information and plans

- ***Current and future area farmed***

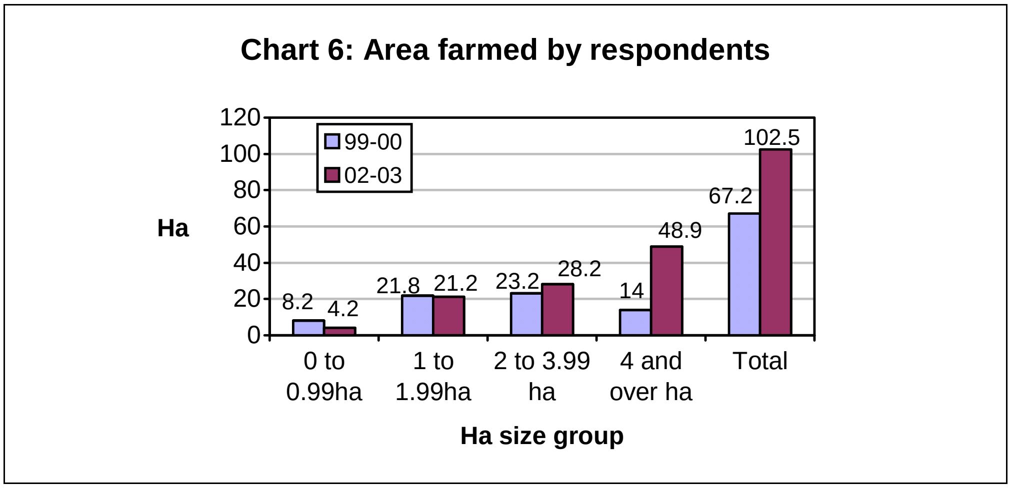
The 50 respondents who provided information about farm area (ha) farmed a total area of 72.6 ha in 1999-00. The 48 respondents who provided information about future farm area expect to farm a total of 102.5 ha by 02-03.

The expected changes in the numbers of farms in various size categories between 1999-00 and 2002-03 for the 48 farmers who provided this information are shown in Chart 5.



Among these respondents, the number of farms under 1 ha is expected to decline from 19 to 10 and the number of farms 2 ha and over to increase from 11 to 20 (about equally from the farms in the smaller size groups). Some small farms will also expand into the 1 to 1.99 ha size group.

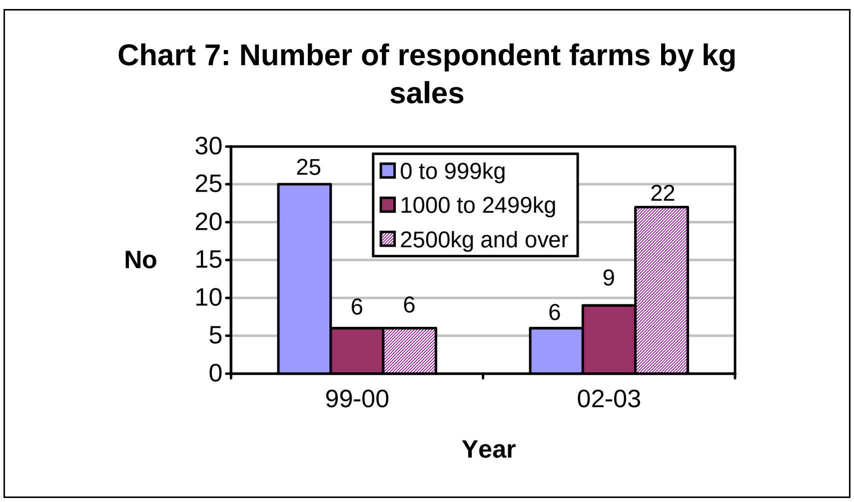
Chart 6 shows the expected changes in the distribution of area farmed among the various farm size groups for these respondents. The main change is that the area occupied by farms of 4 ha and over is expected to increase from 14 ha to 48.9 ha.



- ***Current and future sales volume***

  The 40 farmers who provided information on their sales in kg during 1999-00 sold a total of 58,363 kg. The 37 farmers who provided information about future sales expected to sell a total of 172,650 kg by 02-03.

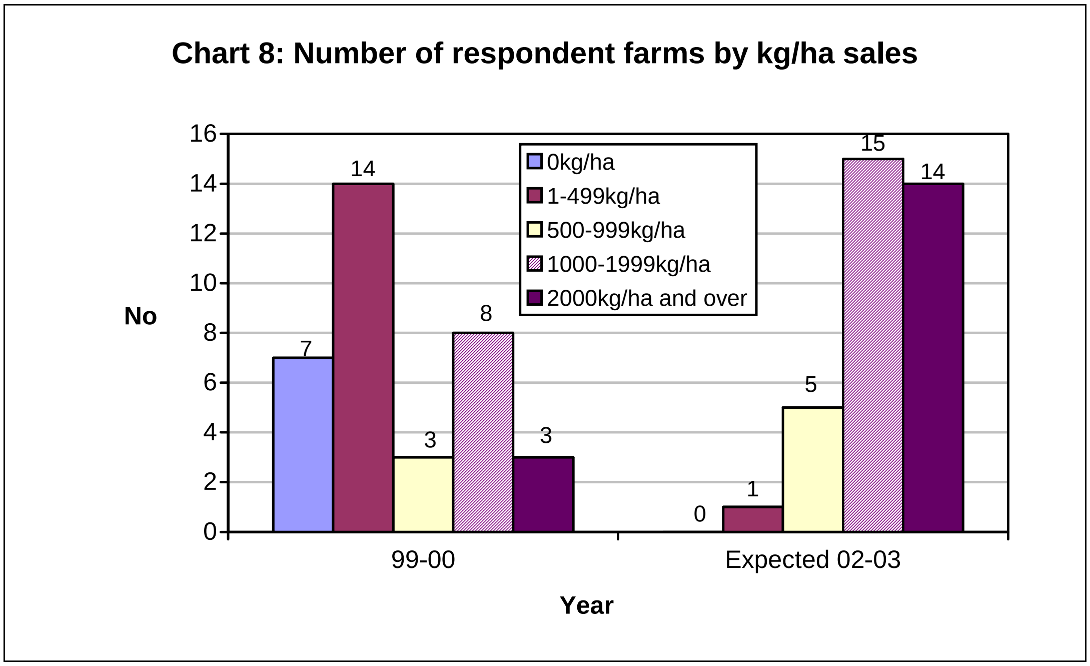
  37 farmers provided both current and expected future sales information. As can be seen from Chart 7 the number of farms selling less than 1000 kg is expected to decline greatly (from 25 to 6) and the number selling 2500kg and over is expected to increase substantially (from 6 to 22).



- ***Current and future sales/ha***

The 1999-00 sales in kg/ha could be estimated for 38 farms. The average was 581 kg/ha, and the range was from 0 to 2500. The expected 2002-3 sales/ha could be calculated for 37 farms and the mean was 1675 kg/ha with a range from 300 to 3000.

For the 35 farms which provided both sets of information, the average sales/ha in 1999-2000 was 618 kg/ha and the average expected in 2002-03 was 1690 kg/ha. As shown in Chart 8, the number of farms in the top 2 productivity groups is expected to increase greatly by 2002-03 (from 11 to 29).



- ***Current and future capital investment***

  The 41 respondents who provided information about the amount of capital invested in their crayfish enterprise had invested a total of $4.742 million to 1999-00.

  The 33 respondents who provided information about expected capital expenditure between 1999-00 and 2002-03 expect to invest $2.391 million with most of this ($1.764 million) being on farms which have already invested heavily to a total of $2.706 million. The total previous investment of the 33 farms was $3.971 million.

Estimated industry area, sales and investment by 2002-03

Current and future whole of industry pond areas, sales and investment were estimated using the survey results and DPI Fisheries' annual farm area census data. (Note: this method excludes possible involvement in the industry by persons establishing new farms or taking over existing farms and modifying the plans of the existing farmers. Also like all estimation methods, it is subject to a significant degree of possible error.)

Two estimates were made, using either 4 or 3 size groups. The averages of the results from the 2 methods are shown in Chart 9. (Note that the investment figures are to 1999-00 and from 1999-00 to 2002-03 whereas the area and sales figures are for the years indicated.)

Industry area is estimated to increase by 58% to 188 ha and sales to increase by 183% to 339 tonnes. However, investment between 1999-00 and 2002-03 is estimated to be lower than prior to 1999-00.