FINAL REPORT

2007/315	Nuffield Australia Farming Scholars

PRINCIPAL INVESTIGATOR: Mr Jim Geltch

ADDRESS: PO Box 1385
GRIFFITH NSW 2680

DATE: 29 January 2013

OBJECTIVE:

1. The successful completion of one Nuffield Farming Scholarship by a practicing producer, each year for three years."

OUTCOMES ACHIEVED TO DATE

Through FRDC scholarships, Nuffield Australia aims to provide a significant boost to the fishing and aquaculture industry's understanding of the international forces affecting the industry and the need to adopt new technology and management practices to continue to maintain productivity growth.

The following FRDC scholarships were awarded:

2008 Lester Marshall, Port Lincoln
2009 Adam Butterworth, Port Lincoln
2010 Ian Duthie, Tasmania

In addition, and largely as a result of promotion of Nuffield scholarships within the industry as a result of this project, Ben Tyley was awarded a Sidney Myer scholarship in 2010.

Outcomes include encouragement for greater participation by younger primary producers in their industries; nurturing of a mindset amongst young primary producers to take a global perspective of their enterprises; encouraging an ethos of lifelong learning; and membership of an elite group of farmers around the world – an invaluable lifelong network of contacts and information transfer.

Non-Technical Summary

The Nuffield Australia Farming Scholars provides a select group of young Australian primary producers with Scholarships to travel internationally to expand their personal horizons while exploring industry issues and opportunities in a global context. It is focused on developing the practical, managerial and commercial capacities of the Scholar to enable them to be better producers and to make a significant contribution to

the future of Australian primary industries. Nuffield Australia farming scholarships have been awarded in Australia every year since 1950 and over recent years has increased its industry coverage beyond the traditional agricultural sectors.

The scholarship is a targeted and proven means of investing in industry people and providing opportunities to learn from other sectors, nationally and internationally, and for continued involvement by members of the fishing industry in the international Nuffield network.

Scholars undertake an innovative project of relevance and are encouraged to disseminate their learning widely.

The scholars programme involves:

- Selection – FRDC involvement and approval
- Pre tour briefing
- Global Focus programme
- Individual study programme
- Reporting and debriefing

The Global Focus Programme introduces Scholars to the major influences at a global level of their industries and individual businesses and the global network of Nuffield scholars.

The individual study component allows the scholars to study and interest specific to the scholar and their industry.

FRDC-sponsored scholars undertook the following individual study:

Lester Marshall, "How to develop a dynamic regional brand – to restore health and wealth to rural economies"

Adam Butterworth, "Integrated Multi-Trophic Aquaculture systems incorporating abalone and seaweeds"

Ian Duthie, "Shellfish Production Aquaculture Technology: Global Perspective of Bivalve Hatchery Processes"

Sidney Myer scholarship winner Ben Tyley studied "South Australian Northern Zone Rock Lobster Fishery: Rebuilding and Sustainable management"

On-going extension of the project outcomes occurs via field days and regional tours. This process is assisted by the formal use of industry nominated mentors. All scholars have provided reports on the projects undertaken. These have been provided to the FRDC, and are also available on the Nuffield Australia website.

FRDC has continued to provide scholarships through project 2009/324 "People Development Program: Nuffield Scholarship for an Aquaculture and/or Fish producer"

Appendices: Scholar reports

How to Develop a Dynamic Regional Brand

To Restore Health & Wealth to Rural Economies

A regional brand, if successful, leaves an indelible mark in what some have called 'the most valuable real estate in the world: the corner of a consumers mind'

A report for

by LESTER MARSHALL

2007 Nuffield Scholar

Completed October 2009

Nuffield Australia Project No 0813

Sponsored by: FRDC

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Preface

By Mark Cant

As Chief Executive Office of the Eyre Regional Development, one of the board's goals was to develop a regional food brand, not just another brand but a dynamic brand that positioned the Eyre Peninsula as a world re-known premium seafood destination.

The Eyre Peninsula seafood industry is unique worldwide, boasting the largest range of quality seafood produced in an untouched and pristine environment. The industry's passion for success is exemplified by its sustainable management practices, innovation, collaboration and commitment to be recognised as a world leader in premium food production.

The regions seafood industry has always operated in a competitive business environment, with limited connection to consumers and food service industry, with the products being marketed predominately in a premium commodity category to wholesalers.

The challenge for the seafood industry was to form an alliance with a common marketing goal, to increase the reputation and consumer awareness of the regions quality and diversity of seafood that is unmatched in the world.

The brand Eyre Peninsula "Australia Seafood Frontier" positions the region seafood industry as a leader in the Australia domestic market, and will continue to gain a reputation worldwide.

Consumers and the food media have only recently become aware of the regions qualities, pioneering spirit, innovation, sustainable management practices and the unexplored rawness of the region.

Individual seafood sector and enterprises have recognised the marketing benefits of branding and have invested in developing supporting brands in line with the regional seafood brand. The power of these combined brands will be the consumer connection and future purchase preferences as consumers will have both an emotional connection and positive experience with the Eyre Peninsula region.

The Eyre Peninsula Brand reflects the regions abundant natural seafood bounty, and the entrepreneurial spirit of the people.

Lester Marshall is one of the regions passionate and committed seafood producers, whose dedication to the industry is exemplified through has Nuffield Scholarship, in researching successful regional brands worldwide.

The future of the regions reputation is that it can only grow, with the dedicated willingness to search for new possibilities under the passionate leadership and characters like Lester Marshall.

Prepared by

Mark D Cant
Chief Executive Officer
Eyre Regional Development Board

Foreword

My passion for promoting EYRE PENISULA started with my involvement in South Australian Rural Youth some 25 years ago. Since those early days I have been putting my hand up for different community organisations to try and help our region prosper. It has since joining the EYRE REGIONAL DEVELOPMENT BOARD 5years ago in an attempt to build a regional brand that I have finally seen light at the end of the tunnel. Our region was well on the way to building its regional brand when I applied for my scholarship. It has been great timing to go and study this topic looking for world's best practice having seen a lot of the pitfalls that come with regional branding. I have traversed the globe looking for the holy grail of regional branding; I have eaten and drunk my way around the world. I have eaten some of the most exclusive and indulgent regional foods, one of my meals cost me $ A 360. I mainly was searching for what gave regions their identity, what they are truly famous for and how did they communicate that to the world. Having travelled to 14 different countries and numerous regions I have developed a regional branding model that will work across all regions and help rural communities prosper.

Life is a journey through which we all travel, how we travel the journey of life is what sets us apart as individuals. Some prefer a comfortable journey through life and some do not. The initiation of a Nuffield scholar through the global focus tour and then 10 week study trip is far from comfortable. This incredible journey is a once in a lifetime event that forces you out of your comfort zone and into the real world of life itself. The opinions, perceptions and prejudices that we all started out with have all been shaken to the inner core of our belief system. This remarkable experience allows us to see the world through new eyes, and gives us the confidence and conviction to help lead our community's into the future.

Acknowledgments

I would like to thank Nuffield Australia and the Fishing Research and Development Cooperation for allowing me the opportunity to participate in this once in a lifetime adventure. This experience will have long lasting effects on me, I hope in time I will be able to repay some of this back to the seafood industry and my regional community.

I would like to thank my wife Julianne for supporting me through this scholarship and to my children Kelly and Price for their understanding, it is very much appreciated. To my parents Klay and Christine for helping out where ever they were needed, filling in the gaps so to speak and for their support in giving me the confidence to give anything ago!

Thank you to my brother Kit for editing and helping with this report. He has helped put the polish on this document, his time and effort will not be forgotten.

To my fellow travelling scholars a big thank you for what was an incredible journey. It would not have been the same without the diverse mix that we had in our group.

And to all the people who helped out along the way (too numerous to mention), their help and hospitality was first rate.

A special mention should go to Angus Christian for guiding us safely through China, it was a most memorable trip.

Also to the policeman who let me off on a speeding fine while travelling through South Africa, thankyou!

And thank you to Mark Cant, Philip Arnfield and Peter Singline for showing me the way. Their guidance and professionalism is unparalleled.

Last but not least to my staff left behind to hold the fort. They all did a fantastic job, particularly my management team Brenton Dutschke, Andrew Pietsch, Jenny Scott, Karen Leurs, Simon King, and David Sampson. Each and every one of you took on more responsibility through those testing times I could not have done this scholarship without you.

Executive Summary

Background

This report will be beneficial to any region trying to become more profitable, in particular the seafood sector. Whilst on a marketing trip to Singapore back in 2001 I found myself extremely frustrated trying to explain to my customers which region in Australia I came from. The Eyre Peninsula is largely unknown and the closest they could relate to it was the Barossa Valley some 600 km away. It was then I realised we needed to develop a powerful regional brand.

The aim of this research has been to develop a regional branding model that will work across all regions of Australia, but in particular, the seafood sector. The information gathered along the way has been compiled into a working model; they are the things you have to get right in order to achieve the most profitable outcome for your region. The model shows you why you need a regional brand and how to achieve it.

The opportunity arising from this model is to develop clear and simple messages that we can communicate all the way from the producer to the consumers.

The economic flowchart for regional branding for the Eyre Peninsula demonstrates how much extra you can leverage from a powerful regional brand. Not only does it create extra profit for the regional economy, but also the property values in the region can be upgraded by at least 10% - this can amount to a lot of extra investment in the region.

Objectives

The aim of this study was to develop a working model for regional branding that will work across all regions of Australia. Although this has been developed mainly for the seafood industry, the principles will apply to the full variety of primary sectors. I have kept it as simple as possible and highlighted the things that must be done right to achieve success.

I have developed two models, one to show why a regional brand is needed, and the second on how to do it. What started out as a straight forward project has turned into a complex array of issues, the main one being the human mind! I have pursued this regional branding concept with a view to cut away the layers of complexity and develop a model of simplicity. A model that everybody can easily understand and interpret correctly, to coin a phrase, to make sure we are all on the same page!

When developing a regional brand, collaboration on all levels of production is by far and away the hardest thing to achieve. What one person in the community sees as a great opportunity to gain extra wealth another will see as a threat to their current way of life, e.g. tourism. A point I make is that we can't eat the view! We need industry to bring cash flow into the region so that we can maintain a high standard of living. By that I mean schools, hospitals, roads, communications, sporting facilities etc….. .When you market a regional brand you are not only marketing your products, you are marketing your region as a whole. You want your community to feel pride when referring to the place that they live work and play.

Key findings

The following are the key findings of the report:

- You need to build fame for your region
- You need to brand yourselves
- It's all about leverage
- The most valuable real estate in the world is in the consumers mind
- You need to own part of the consumers mind
- A brand is a collection of perceptions in the mind of a consumer
- Perceptions = feelings
- Feelings drive decision making
- Make a emotional connection with your target market
- There is no substitute for authenticity
- A niche market is all about quality
- A commodity market is all about price
- The Australian seafood industry can't communicate its point of difference
- Our point of difference is the aroma, texture and flavour that are produced from our seafood products from within the different regions of Australia.

Recommendations

- That the EYRE REGIONAL DEVELOMENT BOARD and FISHERIES RESEARCH DEVELOPMENT CORPORATION work together on developing tasting notes for the members of AUSTRALIAS SEAFOOD FRONTIER

- The tasting notes should be written in a way that has a clear and easy to understand language
- The language will describe the AROMA, TEXTURE and FLAVOUR of the regions branded seafood products
- A team of people with trained palates will be required to help facilitate this process
- A seafood story book will need to be published to communicate these findings
- When this process is completed and proves to be successful then other seafood regions across Australia can adopt this strategy piggy backing in on ground breaking work.

This comes at a time when global culinary tourism is on the rise and the new televisions series masterchef is taking the world by storm.The power of this new information that consumer's desperately want will become more evident as primary producers who adopt these principles will achieve a higher level of profitability. With the combined effort of all the seafood regions across Australia pulling together we have the ability to build fame for Australia. With this fame we can create a perception that **'Australia is the premier seafood producer of the world'**.

Introduction

What has started out as a fairly straight forward project has turned into an incredibly complex array of issues, the main one being the human mind! I have pursued this regional branding concept in order to cut away the layers of complexity and come up with a model of simplicity. A model that everybody can easily understand and interpret correctly, to make sure we are 'all on the same page'.

When developing a regional brand collaboration on all levels of production is by far and away the hardest thing to achieve. What one person in the community sees as a great opportunity to gain extra wealth another will see it as a threat to their current way of life, tourism for instance.

A point made quite often is that we can't eat the view. We need industry to bring cash flow into the region so that we can maintain a high standard of living. By that I mean schools, hospitals, roads, communications, sporting facilities etc. When you market a regional brand you are not only marketing your products, you are also marketing your region as a whole. You need your community to feel pride when referring to the place in which they live work and play.

There are two perspectives to consider. One is the perspective of the producers in the region looking out at their target market in the world. The other is the target market looking back at the region trying to perceive what the region is offering. Herein lies the problem, or opportunity; perceive!

So with this in mind, as I travelled the world, I began looking for common linkages that all successful regions use to underpin their success. I found common themes that they have all used and have compiled them into a working template. This information will help other regions to shortcut their way to building famous regional brands.

My life journey

I was born in Darwin back in 1964 and started my schooling at Alice Springs, completing years 1, 2, and 3. My father was a school teacher and we moved back to South Australia to Nuriootpa in the Barossa valley and bought 64 acres of farm land - it was here that I had my first experiences of farming.

We had a mixed farm: a dairy of some 10 cows, a vineyard, fruit trees and plethora of animal's including sheep, ducks, chooks and pigeons. All the while my father was still teaching. I still remember staying home from school to go harrowing on the old Fergie tractor to kill some weeds while dad went to school to work. I was in grade 5.

We sold up after 2 years and bought 420 acres at Eudunda in South Australia's mid north. We started a dairy of some 24 cows and moved into sheep and cropping. All the while my father was still teaching. It was here that I started to learn my skills as a businessman and entrepreneur. I started growing chooks and bucket rearing calves to grow out and sell for my pocket money. I used the school bus to sell and trade roosters and hens to other farm boys but was banned after a while because it was causing an issue of logistics. It was at this stage of my life that we used to spend family holidays at Fisherman's Bay and my love of the sea became evident.

After 5 years here we sold up again and moved lock stock and barrel to the Eyre Peninsula to a 1600 acre farm 15 km from Coffin Bay. We built from scratch a 9 aside herringbone dairy, and I had just started year 11 in Port Lincoln.

The main reason for coming to the Eyre Peninsula was to give me the opportunity to get a job in the fishing industry which I so loved. After completing year 11 and turning 16 I left school to come back on the farm to work. At this stage I joined the family business and we built our herd of some 30 cows to 120 milkers over the course of 5 years. We cleared land, built new fences and rebuilt machinery - life was lived to its fullest.

At the age of 20 we sold the farm and had a clearing sale. Mum and Dad bought a tourism business in Coffin Bay – a block of units and a shop. I helped out for a year but dealing with people instead of cows was a whole different ball game.

At the age of 21 the partnership helped me buy a small farm of 420 acres of prime land at Big Swamp with a vision of growing prime lambs for our local market. At this stage interest rates were 10% and wool and sheep prices were stable. I had borrowed a lot of money and built up my flock to 1000 breeding ewes and crossed them to horned Dorset rams. I learnt very quickly the issues facing a business trying to sell a consistent product of 20-30 lambs a week to our local butchers. If the product was not of enough quality they would crucify you.

My mentors Dave and Bill Woods, the previous owners of this farm, had a fantastic reputation for selling top quality lambs off this property. They had achieved 16 weeks in a row of the highest priced lambs, a record still to this day. I had a lot to learn and learn I did, I went on to lease another 1300 acres with interest rates starting to climb. It was around this time I married Julianne and was heavily involved with rural youth and playing football, basketball, and tennis.

My involvement with rural youth was a huge step in my personal growth and has a lot to do with where I am today. I was fortunate to win the state ambassador competition for rural youth and was invited to attend other regional functions around the state. This is where my public speaking skills evolved. It was an amazing time of my life where I managed to meet so many new people from around Australia and abroad, particularly through the exchange program. I am indebted to this association for so much; it was a formative period of my life.

After 6 years of farming at Big Swamp the wheels started falling off the economy. Interest rates went to 22%, wool and grain prices dropped dramatically and you couldn't sell sheep at all. I had to terminate my lease of 1300 acres and sell my farm to clear my debts. I dug pits and shot and buried some 1500 fat healthy sheep. These were not good times; it had a profound effect on me.

The rural community was in turmoil with family farms being lost through no fault of their own. Suicide was rife and young people had to move away from the region to find work and opportunity. Schools and sporting clubs were closing down and funding for our regions to keep open hospitals and other government run institutions was under threat. The local people were disillusioned with little or no opportunity to create wealth for themselves.

So after selling our farm my wife and I set about planning for the future. We took 3 months off and headed to Cape York in our trusty Land Rover. When we returned we would see how we felt as to what we would do.

As it happened a friend of the family had been granted a 4 hectare oyster lease in Coffin Bay and he was too ill to manage it. It was offered to us to lease, and so began my involvement in the aquaculture industry in 1992. The oyster lease was a virgin site with no infrastructure at all. We set about trialling the site and was working on farms and shearing to get by. My brother in law had been farming oysters in Coffin Bay for some time so I was able to learn from him. I also learnt from the Tasmanians who had been farming down south for approximately12 years already. These were testing times as there was no handbook on how to grow oysters commercially, a lot was trial and error.

We were not overly confident to start with so we adopted a conservative approach. As we got more experienced we invested further into the business. Aquaculture began to take off around the Eyre Peninsula, oysters particularly, but also abalone, mussels, tuna and kingfish. Farmers from the local community that started oyster growing adapted exceptionally well to the marine environment. They came up with an incredible array of new systems and machines to make the job more efficient. These were great times where money was starting to return to the regional community's and there was a feeling of excitement towards the opportunities that presented themselves.

I had applied for our own oyster farm in Coffin Bay in a new area that was regarded as being too rough and exposed. We had no idea of the impact this area would have on the oyster farming in Australia; it has become the best oyster growing region in Australia and possibly the world. Not so much for its productivity but more for its unparallel flavour which it derives from the close proximity to the continental shelf.

This was the turning point in my business career that we could invest with confidence in this industry and grow the oyster business exponentially. It was through this time that I was involved in the first oyster marketing cooperative with 90 odd shareholders. I was on the very first committee of 6 people to come up with a strategic plan to formalise this marketing company and find a name - it was exciting times.

The formation of the new company was agreed upon and the name OYSA was adopted. Directors were called for from each bay and so it was born. I had not thrown my hat in the ring to become a director as I was stretched enough already and a more suitable candidate was available. To get 90 business owners to commit and agree on this new era of oyster marketing was like herding cats, everybody had a different agenda. The idea to market collectively was sound but the business model was flawed and cracks appeared very early on. It was actually doomed from the start.

We were the second oyster company to withdraw from the coop and form a closer relationship with our customers. This has stood us in good stead to this day, but in saying that, I believe we have been working within a commodity market that has been incredibly difficult to increase our farm gate price.

In the early days the oysters that were sold from the Eyre Peninsula were called South Australian oysters and the different bays were not so important. As time evolved the different regional bays became more important and consumers started to identify with the different regions. But even as the popularity of Coffin Bay oysters became evident and grew, as did the demand, we still couldn't achieve a price differentiation from the other bays. It was quite remarkable. Here we were with oyster leases in Cowell and other bays worth about 60-80 thousand dollars a hectare and Coffin Bay was worth a staggering 400-500 thousand dollars a hectare but with no difference in price for the oysters at the retail level.

My passion to get export money back into the Eyre Peninsula economy was burning within me so I went on a trade mission to Singapore for 5 days in 2000 with Angelakis Brothers and the then premier of South Australia Mr Rob Kerin. This was to start the next stage of my business and start exporting. How hard could that be? As it turns out it was very difficult. Not so much the logistics, we found that part easy. It was the marketing that we were not ready for.

Without doubt the biggest problem after speaking to thousands of people over 5 days was not the price, nor the product. It was the lack of a regional brand that they could clearly identify with – this was a big problem. In trying to describe to our prospective customers where the product came from, i.e. Coffin Bay, Port Lincoln, Eyre Peninsula and even Adelaide; they had never heard of these places, yet one place did register and that place was the Barossa Valley.

Time and time again I used the Barossa valley as a way of describing where our products are grown and are of similar high quality, something my customers could identify with. The only problem was the Barossa is some 600 km from my region. So the scene was set. I went home with my tail between my legs knowing full well I, I mean we the people of Eyre Peninsula, had to create a regional brand that we could use as a tool to connect with our prospective customers anywhere on the planet!

As demand for our product was domestically strong and growing the need to export was not a priority, I didn't push too hard for the regional brand. But I knew full well that one day it would have to come. As chance happens if you keep asking the right questions, eventually doors will open and the path will become clear. Strangely enough, I met this guy playing basketball on the opposing team. He was a competitive chap called Mark Cant, the CEO of the Eyre Regional Development Board (ERDB). We hit it off straight away and found ourselves in deep conversation about regional issues, particularly in regional branding. Within months he had me on the fishing and aquaculture target team and after a year had me on the ERDB as a director.

Mark was already heading down the path of developing a regional brand and had already secured funding for a food development officer. He had sought the services of a regional branding consultant; enter Peter Singline of Brand DNA and David Ansett of Storm Design. Peter was one of the main drivers in developing the now famous King Island Dairy regional brand so he came well qualified. These two gentlemen scoured the region and talked with numerous groups to establish an understanding of what our brand story was within our region. This took considerable time and effort.

To be part of this process has been an invaluable experience for me and now I know what's involved, the difficulties that are in front of us but also the opportunities. I have been continually reviewing how our business can support the regional brand so we have rebranded our company from Mar-Shell Aquaculture to the Coffin Bay Oyster Farm and have set about creating new product lines in Cupid Oysters, Valentine Oysters, Casanove Oysters, King Oysters and the absolutely exclusive 315 Oysters. All this is to support our regional brand Eyre Peninsula tag line Australia's Seafood Frontier.

It was while trade marking all these brands that I was invited to apply for a Nuffield Scholarship which at the time I felt I didn't have time for. But as things have worked out, I won the scholarship and it has been an invaluable experience for me, and I hope for my community. As I traversed the globe seeking out new information and business models that supported regional branding, I have been on a quest searching for the Holy Grail of regional branding and to simplify all the information that is out there. In the end, I feel like I need to create a regional branding model – a guide to things that must be done right to capitalise on the opportunities and reap the rewards from a truly successful regional brand.

The global journey

Overview

The global focus tour took us on a journey of 24 air flights in 42 days travelling through 6 different countries. There were 11 people that went on this trip representing the following primary sectors.

- Western Australia, fruit
- Western Australia, beef
- Western Australia, grain
- South Australia, seafood
- South Australia, wine
- Queensland, vegetables
- New South Wales, livestock
- Tasmania, cheese
- New Zealand, grain and dairy
- New Zealand, farm lobbyist
- Canada, dairy

We first met in Sydney and flew to the South Island of New Zealand. We worked our way up to the North Island, looking at the wool, lamb, beef and dairy industries. We observed their parliamentary system and their quarantine controls for importing different products.

We left New Zealand and flew to Ireland for extensive tours of their agriculture sectors.

Next port of call was France where we looked at the largest markets in the world, the Rungis Markets just out of Paris.

We then headed for America and went to Washington DC. We visited the congress building and heard from a senator about their farm bill. From there we visited Maryland and headed for Oklahoma, to the pan handle and looked at the food bowl of America.

We left America at this point and headed to China for an incredible journey that took us through 5 different provinces. We covered a lot of areas including banking, food supply chains, cultural changes and how modern technology is changing their landscape.

Our last country was the Philippines and went to IRRI a rice research centre looking at the impact of rice on third world countries and the use of genetically modified rice.

This is just a snap shot of our experience, but I hope it provides a better understanding of how much information we crammed in a very short time.

My solo trip took me to 9 different countries starting with China then South Africa, Spain, France, England, Scotland, America, Japan and Singapore. I met so many people, and to utilise the networks and relationships that the Nuffield network has established over the last 61 years was a very humbling experience. The calibre of scholars I met on my travels is of the highest order and they are all very proud and passionate people. You can’t help but get swept up in the positive attitude that emanates from these people, it gives you great confidence to try new things that you would never had attempted before. To be given the responsibility to go forth and find the world’s best practice in your given interest and bring that back to your community certainly adds another dimension to your life. The friends that you make along the way is something that is impossible to describe, all of a sudden the world doesn’t seem so big anymore.

I have likened it to being James Bond, a secret service agent, slipping quietly into countries gathering information emailing it back home and moving onto the next country. I hope I have captured as best I can the information and events that have led to this report.

China

While journeying through China I tried as many local food dishes as I could and always asked of their origin. I was continually amazed as to the lengths our guide Annie Li went to, to describe the history of these regional dishes. Her passion was powerful, her pride in these dishes was evident and the story of these dishes went back hundreds of years.

We have all heard of Chinese whispers and how the story must be the same at the end of the line. I can now see how this is so true. The story’s are simple and clear, bold and strong, and will stand the test of time.

One of the most famous regional dishes is the Beijing roast duck. Its origin can be traced back to the Yuan Dynasty [1206-1368]. Once you have ordered your roast duck meal a chef will bring out and show you the whole duck. He will then slice it into 120 pieces with a bit of skin and meat on each piece. To eat it you pick up a piece of duck and dip it into the soy paste provided and place it onto the pancake wrap that is with the meal. Then place some cut bars of cucumber and shallots on top of the duck and wrap it all together. You then nibble away at this wrap and taste the flavours that are very compatible to each other.

Figure 1 – Beijing Roast Duck

In the Xuyi County in China [Jiangsu], they are using crayfish to make their region famous and to increase external investment into their region. They use a 20 day crayfish festival where 15,000 people sit down in a purpose built arena to celebrate this delicacy. They have developed a special flavoured recipe with 13 different ingredients which makes this product unique. There is no doubt they have a carefully structured plan and are working towards an end goal.

South Africa

I travelled to South Africa to specifically investigate the region of Franschhoek, meaning French Corner. Franschhoek is seen to be the poor cousin to Stellenbosch, its next door neighbour, but they have created their own regional brand over the past 20 years or so. The way they have done this is through fine dining, attracting 8 out of the top 100 restaurants in South Africa to their beautiful valley. They are now known as the gourmet capital of South Africa and are attracting high end culinary tourists from all over the world to their region. Between their magnificent wines, world class restaurants and scenic valley they have a match made in heaven and are reaping the benefits from a strong clear vision set in motion some 20 years ago.

Spain

Paella is Spain’s national dish consisting of calasparra rice or bomba rice. Other key ingredients are saffron, olive oil, green vegetables, meat, snails, beans and seasoning. Seafood paella replaces meat and snails and omits beans and green vegetables. I thought this dish was fantastic; it is served in big flat pans with handles on both ends.

Figure 2 – Paella

France

When you think of France and you think of food, typically escargot is in the forefront of your mind. This was something I just had to try. Typically the snails are removed from their shells, gutted and cooked with garlic butter and then poured back into the shells together with butter and sauce for serving. They are often on a plate with depressions for serving. Additional ingredients may be added such as garlic, thyme, parsley and pine nuts. Special tongs to hold the snails and snail forks are normally provided. I quite enjoyed this delicacy and can see why they are so popular.

Figure 3 - Escargot

England

While in Devon [England] I tried the traditional Devonshire tea, this is a combination of a cup of tea, a fresh hot scone, strawberry jam and the main ingredient, clotted cream. To the uneducated, clotted cream is the most indulgent product I have ever tasted, and guess what, Devon and Cornwall (its bordering neighbour) bicker about who invented it. There is clotted cream running through their veins in that region, they are passionate about it and rightfully so. It is their point of difference. Clotted cream is a thick yellow cream made by heating unpasteurized cows milk and leaving in a shallow pan for several hours. During this time the cream content rises to the surface and clots.

Figure 4 – Clotted Cream

Scotland

The traditional dish of Scotland is haggis, it's a dish containing sheep's 'pluck' [heart, liver and lungs] minced with onion, oatmeal, suet spices and salt. It is mixed with stock and boiled in the animal's stomach for 3 hours.

Figure 5 - Haggis

America

While travelling through America I was fortunate enough to try chicken fried steak. You might be surprised to learn that there is no chicken in chicken fried steak, it is tenderised round steak made like fried chicken with milk gravy. The traditional way to cook chicken fried steak is in a large cast iron skillet with very little oil. Served with the works means accompanied with mashed potatoes, gravy, greens, blacked eyed peas and corn bread. It is considered the state dish of Texas and is certainly a most indulgent experience.

Figure 6 – Chicken Fried Steak

Japan

The reason I travelled to Japan was to investigate the internationally renowned wagyu beef. What I found was truly remarkable, without doubt the most premium beef in the world. Interestingly, the word wagyu translates into English as Japanese beef, wa- means Japanese and gyu means beef.

Matsusaka is a small area in the mie prefecture, or region. It is renowned for the highest quality beef in Japan. Matsusaka beef only uses virgin female cows, they are taken for daily walks and brushed after being sprayed with shochu [alcohol beverage]. When they have no appetite they are provided high quality beer to stimulate eating and soothing music is played to promote better quality beef. As you can see in the picture below 5000 yen per 100 grams amounts to $731.42 Australian dollars per kilogram - an incredible amount. To guarantee authenticity they take a hair from the tail of the cow and DNA check it with a swab test on the meat in the store to make sure it has not been substituted.

Figure 7 – Wagyu Beef

Since my return I have also found another regional brand of beef called mishima beef. Mishima beef is very rare with only 20 cows a year produced on the tiny island in the Sea of Japan. With only 20 cows a year, the waiting list sometimes reaches 5-10 years for even the most exclusive guests across the globe. Mishima beef is currently reserved for royalty and ultra VIP's in Japan. I have not been able to find a price for this product but one can only imagine.

Singapore

On a stop over in Singapore I decided to find out what is Singapore's most famous product. Lo and behold, without doubt, it is one of the world's most famous cocktails The Singapore Sling. So when in Rome I went in search of one of these famous drinks and I found the home of where it was born at the long bar in the Raffles hotel. The cocktail was the creation of Ngiam tong boon, a barman working there in 1910. The original recipe used is gin, cherry brandy and Benedictine most often in equal parts. The drink is shaken and strained into a glass and filled to individual taste with club soda.

The hotel has kept its authenticity, you can still eat free peanuts at the long bar and toss the shells on the floor as it has always been. The cocktail or product itself is bold and unique, the environment that it is consumed is fun and inspiring, and the message of when the barman made it and what is in it is clear and strong. The cocktail is clearly linked to the Long Bar and the Long Bar to the Raffles Hotel, and Raffles Hotel to the regional identity Singapore. This is a strong and powerful connection that is clearly defined.

Figure 8 – Singapore Sling

The Ripple Effect

The Singapore sling cocktail is a very good example of the ripple effect. Having an amazing product experience, sitting at the Longbar, the word of mouth stories have rippled their way across the globe.

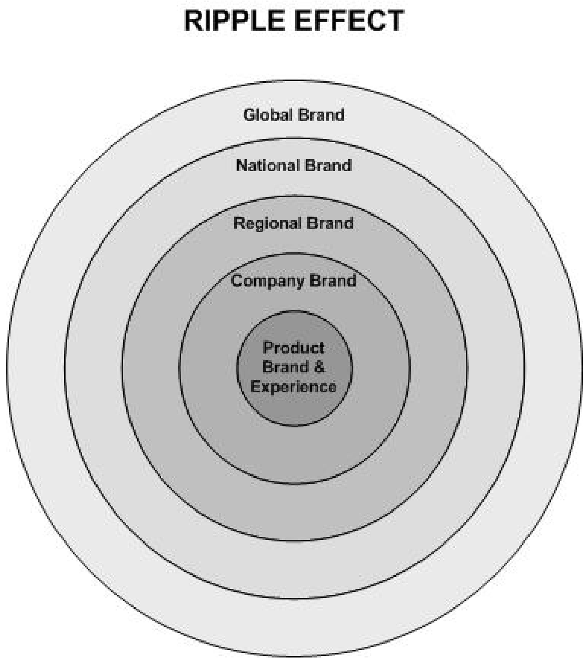

Figure 9 – The Ripple Effect

Economic drivers for regional branding

I have developed an economic flow chart for my region to explain our key economic drivers. The chart shows where most of our economic activity comes from and from where we can draw the most leverage in building a famous regional brand.

What is interesting is the collective land value of the region; $77 billion worth!! Other regions across the world that have successfully created regional brands have all commented that their regional brand influences positive outside investment by at least 10%-30%. If we can achieve half of that, it amounts to an extra $11 billion.

There is clear evidence that this is well worth doing, but there is also the extra benefit of being able to command a higher price in the market place due to perception of higher quality products. A region runs just the same as a normal business in that it has the same issues of income and expenses; it’s just a lot bigger. The main area I am interested in is capital expenditure on infrastructure investment for the future and this is typically government investment. Governments will rarely invest much into a region that has a bleak outlook, but on the other hand if you can prove to them that you have a positive outlook, this will greatly enhance the chances of government investment.

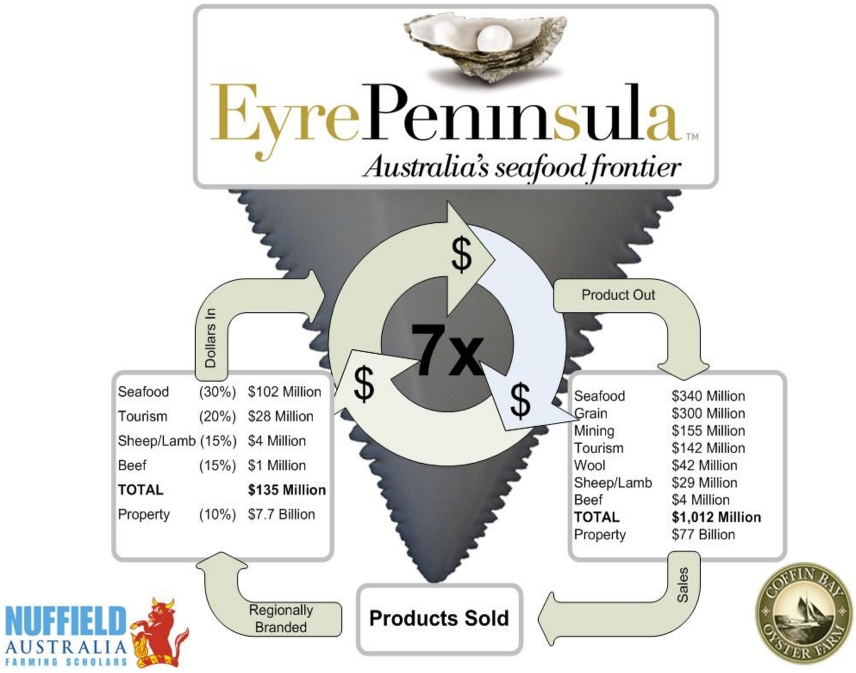

Figure 10 – Economic Flowchart for Regional Branding

Food for thought

Every region produces numerous products; it's necessary to find the best one to use as a marketing leader, one to 'hang your hat on'. It is then possible to use this marketing strategy to create a vacuum to drag along the rest of your products that you produce from within the region. It really is as simple as that, it will never work the other way around. What you are looking for is the essence of your region, what makes it tick what the community is passionate about.

There are two trains of thought. One is the thoughts of the producers in the region looking out at the world of their target market. And then there is the target market looking back at the region trying to perceive what the region is offering. Here lies the problem, or opportunity, perception!!!! Perception from both parties is the problem, because perception determines decision making and decision making is based on feelings, whether they be good or bad. So decision making is the key. How does a one get producer to produce a quality product day in day out and then get the consumers to (1) make the decision to buy the product, and (2) pay a premium for it

This is easier said than done but this is all about having a vision of what the region will look and act like when all is said and done. What we are really trying to do is live the dream, capture the passion from the region and show the world what we stand for. This is probably the most complex part of the whole project, getting people to collaborate and become part of a movement. There must be an air of excitement about the region, a purpose, full of expectation, a reason to get out of bed.

On one of my flights between continents I was able to watch the new movie Australia and couldn't believe the message I got from the movie. Here was another amazing culture that has stood the test of time, aboriginal culture and their story telling. Their storytelling through dance, rituals and ceremonies is another powerful medium to inspire and capture the imagination of their youth with what they call the Dream Time. I couldn't help but see the similarities in what we are trying to do in building story's and perceptions in our customers.

I heard along my travels another name for brand builders is dream merchants. I am convinced the mechanism of aboriginal dreamtime stories is relevant to what we are trying to achieve through regional product branding. The aboriginal story's tell of what products to eat, at what time of the year, and where to find it sound just like what we primary producers and marketers are trying to communicate to our customers. We are always attempting to create a belief system in our products and our region; it is the emotional connection that you make between the consumer and your product.

While touring China in the Xice province I was privileged to see the traditional New Zealand Maori Haka, preformed by 3 esteemed Nuffield scholars for the vice mayor Yao. The three scholars in question had been consuming large amounts of 42% rice wine for some time so the shirts came off and the performance began. Now, not withstanding that one of the performers was Scottish and really didn't know what he was doing, and one of the kiwis had done a hamstring and put in a valiant display, it was James Parsons they got up close and personal and gave it his all much to the enjoyment of his audience. On the completion of this very passionate Haka, Vice Mayor Yoa literally jumped to his feet, put his arm around James and stated very proudly to the crowd 'we are friends for life'. This was as strong an emotional connection you could get within the limited time frame that we had known Mr. Yao.

The Haka was passionate, it carried conviction, it had a belief system, it was bold and was fun. All the attributes that is required to bring a brand alive in the world today. On the bus trip later I sat with James and went over this amazing event that had just taken place, and we both felt that this could be a valuable marketing tool in bringing brands alive from a New Zealand perspective - watch this space.

When the working group of Australia's Seafood Frontier set about defining the brand and the story behind it, I quickly realised that if we were to put Eyre Peninsula's seafood on a premium pedestal then we needed to prove it. For a long time we had used the clean and green story, and also the cold water concept, that the great southern oceans cold water contributed to the incredible flavour of our seafood. But what flavour was this? We had no way of describing it apart from it being a premium taste – this is not good enough, not in this day and age.

So with this issue rattling around in my head it was with great relief that I happened to meet and hear the UKs celebrity seafood chef Mitch Tonks who gave a presentation on what was happening back home in the UK. The main point I picked up was that he had, with a group of people, developed a booklet on seafood flavours and textures of the seafood species in the UK, the ‘Youngs Lexicon of Fish’. They had developed a language very similar to that of the wine industry, commonsense really, but overlooked by the rest of the world.

Armed with this information, and travelling on my scholarship, I tracked down Mitch. All the way down to Dartmouth in Cornwall and I explained the situation we were faced with back at the seafood frontier. I can’t emphasis strongly enough the importance of being able to control the information that will help define our products to the discerning consumer. Food and lifestyle TV shows are growing in popularity, as are magazines. The need to provide this new language is vitally important. At present we describe seafood as having a fishy flavour or not such a strong fishy flavour. That’s like saying this red meat has a beefy flavour or not such a strong beefy flavour!

Regional branding model

I have created the following six-point model which may, in time, become a blueprint for regional branding across Australia.

Step 1 - Create a strong vision for the region

Form a small focused group – only 2 to 5 people are needed to get the ball rolling. They must be passionate and committed with a strong community focus. I cannot stress how important it is to have and maintain a positive attitude which can overcome all obstacles.

Create a dream – this is where it all starts and finishes, this is what is so important, how you can create enthusiasm from within your region, and can appeal to people outside your region.

Develop a mission that is clear in its objectives – the next step is vital in gaining an understanding in how you are going to achieve your dream, this is where your small group must be all on the 'same page'.

Regional development board's role – the development board will be the one to facilitate the next step in this process. They must gather industry and appropriate government leaders to sell the vision and inform them of the mission, and also to request for assistance both financially and emotionally. It is important that they feel a part of this journey and part of the team, this is a delicate process so spend a lot of time here, it will make the whole process a lot easier in the future.

Developing a funding system – now that you have industry and government agencies on board you will need government to invest in your mission, this will be in the order of $50,000 to $80,000. It is a substantial amount, but it is only a small investment when you see what can be achieved in the future. Industry will need to donate time freely at this time as an in-kind gesture.

Engage a regional brand company – start by investigating other regions that have good regional brands and see who they have used to help them get started. Be careful who you select as this will make or break it from the outset. Not only will they help design your image, but will also convince people with a negative attitude that this is a correct course of action. Confidence is everything.

Step 2 - Identify regional point of difference

What's special about your region – with the help from your branding company they will go about finding what the underlying essence of your region is. This will take some time but is all part of the journey. This could take some months and lots of consultation, but in the end you will find what makes your region special and unique.

Product hero – this is what you intuitively know is special about your region but you take it for granted. You must be able to build fame for your region and the easiest way to do this is with an exclusive product. If you want your region to stand out from the crowd you need to find a product that is second to none and you can leverage its uniqueness

Environmentally sustainable – this is a no brainer, you have to be able prove your commitment to sustainability if you want to have people feel good about buying your regional product and/or visiting it. It is a key point in this era, if you are going to 'hang your hat' on a certain product you must be able to keep producing it in the long term.

Use the 80/20 rule at all times – this is a valuable tool to help achieve as much as possible with the minimal amount of effort. You need to understand that 80% of your outcomes will come from 20% of your producers in your region. So the trick here is to pick champions from your region, don't waste your efforts on people or business who will cause you 80% of your headaches. So think 80/20 at all times.

These should all together create an X factor - the X factor is your most defining thing, it's almost an intangible, you can sense it but can't see it or measure it. It really is the core of your region, its geographical location, its people, its culture, its flora and fauna, and most of all, the pride and passion displayed by locals in its traditions and customs.

Step 3 - Identify your target market

Market intelligence – this is something that can be overlooked, make sure you have a market that wants your product and is prepared to pay for it. A good way of doing this is using farmers markets to meet your prospective customers. Get up close and personal, listen to what they want, get them to try your product and get their honest feedback. It's a cheap way of testing the market without a large financial investment.

Create a brand or promise – here is the tricky bit, you must select a name and a logo which will best communicate what your region stands for. It is easier said than done. This is where your branding company will excel, they will provide you with at least 3 examples you can run with. This is an exciting time but still a long way to go.

Check intellectual property available – once you have settled on a name and or logo you need to find out if it is available in 3 forms. The first is a business name, check it out with ASIC. The second, can you get it trademarked? This offers you the greatest protection. And third, is the website domain name available? All three of these are crucial to the future of your region.

Maintain momentum – once you have ticked all these boxes don't slow down and think that all the hard work is done. Keep up the enthusiasm and push on; a lot of people will be watching silently, waiting to see if this is going to work. Don't let your champions down, keep them informed and have some fun. Celebrate your achievements thus far.

Step 4 - Get local government, business and community buy in

Start communicating the benefits to the local community – at this point you will need to get the local community onside and gain their support. This won't happen overnight but it is a very important matter. Remember the 80/20 rule, you won't please everyone.

Skills training centre for employees – depending on what industries operate in your region it is mandatory to support those business with well trained employees.

Training workshops for business managers – as business grows in your region many owner operated business lack the expertise in managing people. This can be a huge stumbling block for many up and coming business.

Research centre – this area is crucial, particularly in helping understand the production of your products from your region. It can be an invaluable benefit to the industry's, especially when faced with unknown issues that may only be found in your region.

Innovation on all levels of production – this is an ever evolving issue as time goes by, we are constantly facing a changing world. With the development of new technologies, regions must be always on the front foot trying to maintain their competitive advantage, whatever that may be. It could be packaging, processing or even a new variety of product, the list goes on. As the world struggles to keep up with energy, water, pollution, and skills shortages we will need to change the way we do things. It is best to be proactive rather than reactive.

Step 5 - Start building fame for the region

Have fun – this is a recurring theme that I found is the most important aspect in bringing people together. You want people to want to be involved, not feel like they have to be. Keep it social, make people feel like they belong to a movement, that they can change the world. Regional branding is a powerful tool but you must be passionate and enthusiastic to get its full effect; support your champions, unleash them and it will spread like a bushfire.

Five bold gestures to bring your brand alive – here you have the chance to be creative. When bringing the brand alive in the mind of consumers you need to be almost audacious in your approach. The gestures should be appropriate for your region, like the Stockman's Hall of Fame at Longreach. There are numerous things that are possible, like the seafood and aquaculture trail on the seafood frontier, or a wine guide booklet. Sir Richard Branson would do something outlandish to get media attention, be it in a hot air balloon or fastest boat race.

Simple and clear brand story – probably the most underrated part of brand building is how and what is told to the consumer. All too often people try to cut corners and hope that a well designed image, name or logo will be enough to capture the imagination of their target customers - they are dreaming! This is an important step in building fame for your product and the region; it is probably the single most important part in the evolution of your business. The story must be told with passion and conviction; the message must be simple, clear and most of all, bold. A soft promise is just that, a bold promise captures the imagination of your intended customers. You need to refine your story so that it resonates within the minds of future investors, these investors are actually your target market. They will invest in your product and eat it, drink it, wear it, drive it, or just use it. They will be inspired enough by your product and story to convince other people to invest in your product and dream. This is done by the most powerful medium of all, word of mouth. This is by far the most valuable marketing tool available today and has not changed for thousands of years.

Target food writers – invite food writers from prominent magazines to your region free of charge and show them what you are producing. Get them involved so they feel like they are onto something new. They are always on the lookout for something new so don't let them down. Create an air of expectation around this and provide an unforgettable experience. What you are trying to do is make an emotional connection with them and hope that they convey your message to the world.

Celebrities – since time began we have been using superstars to promote our products. We call this leverage by association, we trust these supposedly respectable people that if they are going to put their name to it then it must be a good product. This happens with all manner of things; cars, sporting equipment, clothes and of course, ever increasingly, food. The rise of the celebrity chef is growing rapidly and is being prompted by consumers who want to know more about what they are eating and drinking. There is a huge opportunity for primary producers to promote through this medium.

Start a festival – this can also be seen as a bold gesture, this is a great way to get emotional connections with your prospective customers. It is a lot of work but is highly rewarding. Be aware that it's not about how many people you get to a festival, it's who you get there. If your target market is in the 40 to 60 year old bracket that has a high level of income then you shouldn't be putting on cheap side shows. If you are offering a premium product then you must offer a premium experience. It's all about exclusivity, the more the consumer feels like they are having an exclusive experience the more they will brag about it to their mates when they get home.

Step 6 - Develop supply chains to your target market

Form collaborative systems between producers - probably the hardest thing to achieve is getting producers from the region to work together in a united front. Most producers feel like their fellow producers are competitors, and in a small way they are, but on the world stage they are not. Collectively they have a major role to play in bringing the regional brand alive: they can be all powerful and all conquering.

Quality control checkpoint – to have a membership based organisation with annual fees, and a certification points system to ensure that all business have the necessary requirements to participate at high standard. You need to control and maintain the integrity of the product and experience. You can also use new web based review sites such as trip advisor, where people can place a personal account of their experiences, it can act as a third party audit system. This is an area of great responsibility for there needs to be vigilance; anyone not adhering to these standards must be dealt with accordingly.

Build relationships – another area that is often overlooked. This is what almost single handed holds everything together, it's a trust factor. You need to gain trust along the whole supply chain, everyone has a role to play in providing a safe, quality product. Every now and then problems will arise along the supply chain, and if your customers are kept informed they will stick with you, even when times are tough.

Market feedback – keep your finger on the pulse, it's important you know what's happening in and around the market place. Don't leave things to chance, always listen to complaints with an open mind and trace any problem to the source. Be proactive, not reactive. It's easy to sit back and watch the world go by but you need to get out there and walk the walk, talk to your customers and try to meet their requirements.

Deliver the promise – this is the moment of truth, can you deliver the goods. Ensure you under promise and over deliver, it's not about the money so much, it's about a fair deal and value. Consumers are happy to pay a higher price as long as their expectations are met or exceeded.

Protect your brand – once you have built brand loyalty to your customers you will start to see a real value in the brand. Other people will try and leverage off your hard earned work and will try and muscle in with similar branding and/or products. This is where your trademarking will come into its own, it offers you legal protection and you will be able to prosecute those who cross the line

Product associations

Product Lines	Market Type	Brand Linkages	Profit
Ultra Premium	Niche	Strong association between product brand and company brand and regional brand.	Poor
Premium	Niche	Strong association between product brand and company brand and regional brand.	Greatest
Basic	Commodity	No product brand, no support to regional brand.	Average
Poor Quality	Commodity	No product brand, no support to regional brand.	Poor

Product Lines

I believe that the secret to profitability is being able to have the flexibility to grade your product for its quality and put them into the branded lines accordingly. When dealing with primary products that are at the mercy of seasonal variations it is important to sell all of your product for the highest possible price. From what I have found out, I believe you need 4 product lines to achieve maximum profitability and flexibility in your own business.

Ultra premium

This brand should represent absolute exclusivity and indulgence; it should be incredibly high priced and limited in availability. This brand will drive huge recognition and consumer awareness for your company and the region, but will have little or no profit for your cash flow. It will add real value to your company

Premium

The second product line should also be a premium line but not as high in quality as the first one. This product line is the cash cow of your business if done correctly, the integrity of this product line should never be compromised. You have the ability to be a price maker with this product. The brand will also add huge recognition to your company brand and regional brand. It should be where you make most of your profit depending on the seasonal variation.

Basic

The third product line should be treated as a commodity line with little or no brand association with your company. The quality of this product should still be quite good but you will compete in a marketplace on price first and foremost.

Poor quality

The fourth product line should be classed as rubbish and treated accordingly; if you can afford to dump it, do so. This product line should be in no way associated with your company and or region at all; it will be extremely price sensitive and could help your cash flow in lean times but will add no value to your company value at all.

Conclusion

The road ahead of us is an exciting one, with global culinary tourism on the rise. There is a huge opportunity to take control of our future and shape it to our advantage. At a time when the global economic downturn has impacted heavily on our decision making we can still see light at the end of the tunnel. One of the bright lights has been the huge interest shown by consumers in the Masterchef television series. It has left me in no doubt that the time is right to develop a seafood flavour language.

I feel a tidal wave of interest is coming and we, the seafood sector, should be preparing to capitalise on this opportunity. People across the globe are becoming more conscious of what they are eating and with the advent of the internet as an information tool they are making more informed decisions.

Recommendations

- In a joint initiative between the EYRE REGIONAL DEVELOPMENT BOARD and FISHERIES RESEARCH and DEVELOPMENT CORPERATION tasting notes should be developed for the members of AUSTRALIA'S SEAFOOD FRONTIER.
- The tasting notes should be written in a way that has a clear and easy to understand language that consumers can relate to.
- The language will describe the AROMA, TEXTURE and FLAVOUR of the regions branded products.
- A team of people with trained palates will be required to facilitate this process
- A seafood story book will need to be published to communicate these findings.
- When this process is completed and proves to be successful then other seafood. regions across Australia can adopt this strategy piggy backing in on ground breaking work.

With the combined effort of all the seafood regions across Australia pulling together we then have the ability to build international fame for Australia. With this fame we can create a world class perception that 'Australia is the premier seafood producer of the world'.

Plain English Compendium Summary

Project Title:	: How To Develop A Dynamic Regional Brand
Nuffield Australia Project No.:0813	
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Objectives	To develop a model for building regional brands across Australia that will help rural communities restore health and wealth to their region
Background	While on a marketing trip in Singapore back in 2001 I found myself becoming increasingly frustrated that my prospective customers loved my product but couldn't identify from which region they came from. For my customers to buy my product they needed a regional identity to be able to communicate to their customers with confidence its authenticity. The only region they could relate to in close proximity was the Barossa valley some 600 km away, it was then that I realised that we needed to develop a powerful regional brand
Research	I have spent the last 7 years researching this subject. By doing a Nuffield scholarship on this subject over the last 2 years has fast tracked the research exponentially. I travelled to 12 different countries over a 10 month period and this has shown me the world's best practice in regional branding.
Outcomes	I have developed two models: one for why you need to build a powerful regional brand and two, how you build a powerful regional brand. Armed with this information I believe any region can use these easy set of steps to help build fame for their region.
Implications	I believe the way forward in creating tasting notes for the seafood industry has major ramifications in the way consumers will perceive our products. This will obviously create different supply chains and the opportunity for a higher price point. The seafood sector has a real opportunity to capitalise on the international fame that the new Masterchef series has created and it's all about flavour. The seafood sector has not identified the regional flavours of its seafood, the opportunity exists to create a new, easy to understand language that discerning consumers are crying out for.
Publications	.

Integrated Multi-Trophic Aquaculture systems incorporating abalone and seaweeds

A report for

NUFFIELD AUSTRALIA FARMING SCHOLARS

By Adam Butterworth

2009 Nuffield Scholar

October 2010

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Foreword

Aquaculture in Australia is a relatively new and constantly evolving industry. Having worked primarily in the fields of abalone and oyster seed production for over 10 years, it became clear that 'looking outside the square' was a necessity for solving challenging problems and for assessing new opportunities. There was possibly no better way to look outside the square than to step out of the country through the opportunity afforded by an FRDC-sponsored Nuffield scholarship. Prompted by an interest in the culture of marine plants and the potential to re-commission a 50t capacity/annum abalone farm at Louth Bay, South Australia, this study investigated seaweed and abalone culture with a view to the integrated culture of the two.

As primary producers, marine plants are critical to the oceanic food chain. Despite the crucial role of seaweeds and micro-algae in driving oceanic productivity, as well as their prevalence in the sea environment, aquaculture in many 'western' countries is dominated by monocultures of aquatic animals.

Seaweed culture has significant potential for a range of applications, but has not 'taken off' in Australia, and there are a number of reasons for this. Culture challenges are diverse and for the application as a feed source for marine grazers, the high quality and availability of artificial diets has reduced the drive to cultivate seaweed for this purpose. Also, costs of production are generally considered to be high, especially for aerated tank culture which has largely been the focus of land-based research in Australia.

The high costs associated with the production of seaweed in aerated tank culture channelled the focus of this study toward alternative systems and methods. Studies on the production of seaweeds in large paddlewheel ponds in Israel and South Africa have shown the culture of seaweed (*Ulva* spp.) using this method to have significant potential as an addition to abalone farming operations. Furthermore, the integration of seaweed culture with existing (aquatic animal) aquaculture operations has successfully been achieved in land-based contained systems. A reduction in costs associated with the production of seaweeds can be achieved by utilizing nutrients and carbon dioxide (necessary for high density seaweed culture) from aquatic animal waste water.

A new acronym in the aquaculture world, IMTA (Integrated Multi-Trophic Aquaculture) refers to the culture of aquatic organisms which interact through water in shared or connected systems. IMTA systems incorporating marine plants and aquatic animals have the potential to decrease costs, improve efficiency and productivity for a number of species and systems. Integrated aquaculture systems aim to capitalise on the benefits offered by the interactions between organisms in a normal ecology, thus mirroring natural processes in aquatic ecosystems, especially in the way that one organisms waste is another's resource.

In regard to studying seaweed culture, it soon became apparent that identifying and evaluating the reasons for growing seaweed were just as important as the methods for seaweed production. The economics of growing seaweed independently and in IMTA systems are very complicated and depend on a range of factors, especially site conditions and species cultured.

The study of IMTA focused on several aspects. The fundamentals of IMTA systems were investigated as one tool for assessing the long-term potential of land-based IMTA systems. Recirculation of water is one aspect of 'true' IMTA systems. Most of the knowledge gained on recirculation aquaculture systems (RAS) has originated from fish culture using this method, with less research having been conducted on molluscs in RAS. As a result, a major focus of this study became RAS involving marine grazers, with a particular emphasis on the health of molluscs in these systems.

A range of aquaculture operations were visited and conferences attended on the study trip in the U.S., Mexico, England, Ireland, South Africa and New Zealand. Several aquaculture facilities visited in the U.S. and China on the group's Global Focus Program also yielded useful information.

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- My wife (Hayley) for supporting and allowing me to spend 18 weeks overseas shortly after the birth of our second child
- My extended family for their interest and support throughout the program
- The South Australian Oyster Hatchery; especially the company's Directors and staff who supported me and/or worked hard on all aspects of hatchery operations in my absence
- The researchers and aquaculture operators who gave their time to assist in providing information for this study

Abbreviations

IMTA	Integrated Multi-Trophic Aquaculture
RAS	Recirculating Aquaculture System
SAABDEV	South Australian Abalone Developments

Contents

Executive Summary

This study investigated a range of aspects of land-based seaweed culture, abalone production and Integrated Multi-Trophic Aquaculture ventures in order to assess the potential for isolated seaweed and integrated abalone/seaweed aquaculture in Australia. This research was considered worthwhile due to the significant potential for the economically viable production of seaweed as an on-site food supply for marine grazers in land-based aquaculture systems in Australia. As an aspect of IMTA, water recirculation and re-use in mollusc aquaculture systems were investigated with a view to assessing their potential compared to flow-through systems (the primary method for growing abalone in Australia). Recirculation is a significant aspect of most land-based contained IMTA systems which offers several advantages and/or opportunities over single pass flow-through aquaculture systems. These aspects are discussed with a view to seeking opportunities for abalone farming operations in Australia, including an abalone farm at Louth Bay on the Eyre Peninsula, South Australia which retains potential for re-commissioning.

Background

In Australia, abalone exports hover around $A200m/annum, with the bulk of production coming from the wild catch sector. Annual quotas limit the harvestable quantities of abalone from the wild and so, aquaculture presents the only suitable option for increasing abalone production in Australia.

Land-based abalone farming is undertaken primarily in the states of South Australia, Victoria and Tasmania. The industry has progressed rapidly in the last 20 years. Innovative farmers and researchers have developed efficient and productive systems and culture methods. However, most aquaculture businesses generate products for export where competition on price is an ongoing challenge. In fact, between 2000/01 and 2007/08, abalone average-unit prices fell by 40%. The reason for this was a combination of several factors, including the appreciation of the Australian dollar during this period (ABARE, 2008). The need for maximising efficiency and maintaining or improving quality is paramount to competing in a global market where large volumes of products are supplied from overseas countries which have lower production costs.

Seaweeds (or macro-algae) are the primary food source of wild abalone and a host of marine grazers with aquaculture potential. In Australia, most abalone farms almost entirely feed abalone with an artificial pellet diet whilst most overseas operations in countries such as China and South Africa

supply abalone predominantly with seaweed collected at sea (cultured or wild). The production of seaweeds as an on-site food supply was considered as one way to improve efficiency by reducing feed costs and improving abalone health.

The production of seaweeds in land-based culture systems for the purpose of feeding abalone is gaining popularity in several countries, including South Africa, where seaweed production units are established and proving to be economically viable. Paddlewheel ponds are large rectangular raceway systems that are used to produce large quantities of the seaweed *Ulva* spp. The production of *Ulva* spp. using the paddlewheel production method has been shown to pay back the installation and running costs in the first year (Robertson-Andersson, 2006) resulting in a significant return on investment. Also, within the last 10 years there have been many inspirational models and reviews on IMTA systems (e.g. Neori et al., 2004). Overall, the objectives of this study were to investigate current research and systems with a view to utilizing this knowledge to identify opportunities in Australian conditions. The production of marine plants and integrated aquaculture systems could be the next major growth areas in the industry.

Key findings

- The green seaweed *Ulva* spp. are a suitable diet for Australian abalone (Boarder and Shpigel, 2001) that can be grown in waste water and supplemented with fertilizers to produce large quantities of feed. Paddlewheel ponds are the most efficient method for producing this seaweed species.
- Red seaweeds such as *Gracilaria* and *Grateloupia* spp. can be grown in aerated tank culture units to provide a mixed diet for abalone and to provide health benefits such as anti-bacterial activity against pathogens (Rebours, 2010)
- Recirculating aquaculture systems are much more complicated than flow-through systems, especially for molluscs. Water quality parameters such as pH and oxygen levels as well as temperature require very close monitoring. For example, pH levels below 7.6 can occur in recirculating systems due to a build-up of carbon dioxide and can cause shell erosion in abalone.
- Bacterial levels rise rapidly in recirculating aquaculture systems where artificial pellets are fed. The installation of UV sterilizer units to control bacterial levels is considered necessary due to the increase in *vibrio* levels associated with decaying feed and faeces.

- Seaweeds possess a range of anti-bacterial properties (Anggadiredja et al., 2010) which have the potential to improve gut flora and reduce the build-up of pathogenic bacteria. The use of seaweeds could actually improve the viability of water re-circulation/re-use by reducing bacterial levels within the system.
- Ozone is a highly-effective sterilizer that can be used effectively for treating top-up water in recirculating systems to prevent entry of diseases. Saltwater wells, which can be installed in some sites, provide a suitable quality of water for effective ozone treatment without any mechanical filtration (which is usually necessary for effective ozone treatment).
- Pumping costs are a significant expense for land-based abalone farms, normally accounting for over 80% of electricity costs for flow-through systems. Recirculation of water at low head heights, as opposed to pumping water from a lower point (below sea level), affords land-based aquaculture facilities the opportunity to save on pumping costs. Air lifts and propeller axial pumps can move high volumes of water at lower cost than centrifugal pumps.
- In regards to the fundamentals of IMTA systems, it is preferable to develop the culture of multiple species together. Simple logistical issues such as the layout of established facilities can prevent the addition of other culture systems, such as paddlewheel ponds to existing abalone farming operations.
- The integrated culture of abalone and seaweeds in land-based systems is complicated as the success of integrated systems relies on numerous factors. However, depending on design, seaweed culture and abalone raceway systems can be run independently.
- Abalone produce relatively low nutrient levels compared to fish culture (Neori, pers. comm., 2010). Additional nutrients need to be added to grow significant volumes of seaweed and to correct nutritional deficiencies likely in Australian seawater.
- Seaweeds in integrated abalone culture can improve water quality parameters (Yongjian et al., 2008) and can at-least form part of a water treatment system. The quantities of seaweed required for nutrient stripping, oxygen addition and carbon dioxide removal are much less than quantities required for bulk food production. Therefore, the potential for seaweeds to improve water quality parameters could be of equal or greater value than the potential of seaweed as a feed source.
- Management of seaweed cultures requires fundamental knowledge of seaweed biology. A number of management practices can ensure contamination by epiphytes are minimized, seaweed nutrition is adequate and other factors which affect growth or survival (such as photo-inhibition) are reduced.

Applications

- Overall, it is recommended that Australian abalone farms investigate paddlewheel ponds for production of *Ulva* spp. Farms which have suitable land could consider installing a trial paddlewheel system using waste water. The opportunity to recirculate water is then worth considering during parts of the year, primarily to reduce electricity costs and utilize waste nutrients.
- Recirculation could be investigated further as a method of allowing the sterilization of incoming water for mollusc culture systems, especially brood-stock and juvenile culture units. The spread of diseases is occurring at a fast rate, and is likely to have an increased effect on aquaculture productivity in the future. Systems for protecting genetic stocks are considered worthy of further investigation.
- On-site research is crucial to the development of seaweed culture systems and should be a foremost priority to any company developing seaweed culture.
- Information gathered from this study could help to recommission an on-site abalone farm at Louth Bay, South Australia. The use of heat/chill pumps to cool water for less than 14 days per year would prevent ‘summer mortality’ if abalone operations were re-commenced. In addition, the use of saltwater wells could provide cooler water from several meters below the surface. Furthermore, the selection and production of seaweeds with anti-bacterial properties could reduce vibrio levels in abalone and the culture system to improve survival during periods of stress.

Introduction

Aquaculture includes the culture of a wide range of organisms in freshwater and saltwater, from microscopic algae to large fish. Like many other primary industries, aquaculture operations in Australia must continually work toward being efficient to compete with cheaper overseas products, which are usually the result of lower labour costs and greater production volumes (economies of scale effect). Continuous improvement of methods and systems is critical to most aquaculture operations in Australia.

In recent years the sustainability of some aquaculture sectors has been brought into question. Fish meal is a component of most aquaculture feeds which are used as a diet for cultured finfish, prawns, abalone and other species. The use of fish meal to feed aquatic animals of higher market value has prompted the question of whether aquaculture is actually reducing pressure on wild stocks or just transferring one biomass into another. It is generally recognised that the world's oceans are being overfished and for a number of species, aquaculture is perhaps the only way of supplying increasing demand to take the pressure off the fishing of wild stocks. With global food security becoming an increasing concern, sustainable aquaculture will probably remain the most rapidly increasing food production system worldwide.

The culture of seaweed as an on-site feed source for marine grazers has the potential to decrease feed costs, improve abalone health and also offers other benefits which are discussed in this report. Many types of seaweed have the potential to be incorporated into artificial feeds for all aquatic animals including finfish (Pereira et al., 2010). Research has shown that seaweeds can be used as a partial replacement for fish meal, as well as a significant source of protein, carbohydrates, vitamins and trace elements.

Integrated Multi-Trophic Aquaculture (IMTA) has the potential to increase the sustainability of aquaculture across the globe. In the last 10 years there has been a shift toward viewing waste nutrients as a resource that can be recycled through plants in a range of aquaculture situations from land-based freshwater to open-ocean culture. The incorporation of plants and filter-feeding organisms can increase the viability of land-based recirculating aquaculture systems (RAS) which were investigated for their potential benefits to land-based mollusc culture in Australia.

1. Seaweed culture

1.1 Overview

Seaweeds are multi-cellular marine algae and are the fastest growing plants on earth. Like terrestrial plants, seaweeds utilize light, nutrients in inorganic form and carbon dioxide to perform photosynthesis. Although some seaweeds' have a root-like structure, this is used for attachment only. Seaweeds obtain their nutrients direct from the water through fronds.

Whilst the ocean contains billions of tons of seaweeds, wild harvest is not permitted in Australia with the exception of an introduced brown species (*Undaria* sp.). The industry in Australia is based on the collection of beach cast seaweeds, with notable companies such as seasol marketing product to agriculture and home gardeners. This is not the case in a number of countries across the globe. Acadian Seaplants in Nova Scotia harvests seaweed direct from the sea and has established a renewal resource program involving a team of scientists. The team carries out research to ensure that harvest is not damaging the biomass and that they are not impacting on the fisheries industry or the marine habitat (Nichols, pers. comm.). This is important as seaweeds are an integral part of marine ecosystems, providing food and shelter for a range of aquatic creatures.

Even if regulations change in Australia and it is possible to harvest seaweed from local sources, seaweed culture on land is likely to be the preferred method for obtaining seaweed biomass. This is for a number of reasons, including the fact that Australia's marine waters are generally oligotrophic (low in nutrients) and do not support large seaweed productivity, and that collection and transport would be a costly exercise compared to on-site production. In comparison, in Ireland, ocean upwelling brings nutrients to inshore waters, where large biomass of seaweeds is obvious along the coastline. Figure 1 highlights the productivity of the seaweed *Ascophyllum* sp.

Figure 1: Natural growth of *Ascophyllum* sp. near Galway, Ireland

1.2 Propagation

Seaweeds are rich in diversity, having evolved a range of characteristics in order to compete in the oceanic environment. They display a range of morphological features, most notably variations in colour and structure. Seaweeds are also diverse in the way in which they reproduce. Reproduction for some species is as simple as asexual reproduction involving the break-up of cells which are independently capable of becoming an adult plant. For other species, complicated lifecycles can involve an alternation of dimorphic generations and sexual reproduction involving male and female types.

Many types of seaweed can also be grown from vegetative fragments, in a similar way that cuttings are taken from terrestrial plants. The optimum method depends largely on the species in question, however, the production of spores is generally favoured even when vegetative propagation is possible, due to the large quantity of spores that can be produced into adult plants (Le Gall et al, 2004).

In Ireland at the Martin Ryan Institute, fertile fronds of *Palmaria palmata* are induced to spawn by simply desiccating the seaweed and then placing these fronds back into seawater. Once the seaweed has 'spawned', spores are collected and simply using a spray bottle can be set to ropes for sea deployment (Figure 2).

Figure 2: Sporelings of the red seaweed *Palmaria palmata*

Fortunately, most species of seaweeds that have been cultured for abalone feed have relatively simple lifecycles and can be reproduced using both spore and vegetative methods. Propagation is not considered a major impediment to seaweed aquaculture. Reproductive methods have been described by scientists for a range of species, even with very complex lifecycles.

1.3 Culture methods

In the ocean, most seaweeds are observed attached to a substrate such as rock, whilst some are epiphytic, growing on other seaweeds and seagrasses. Seaweeds can be cultured using a range of methods both on land and at sea. At-sea production usually involves rope or raft culture. Land-based seaweed production can involve a range of systems, including plastic-lined ponds and various tank designs. Conical-based tanks and paddlewheel raceway systems are two of the more popular designs. A key principle of most systems is to ensure that both water and seaweeds are in constant motion to maintain continuous exposure of seaweed to light, water for nutrient uptake and gas exchange, and to prevent settlement of organic matter or fouling organisms such as benthic micro-algae. The opinion of several scientists at the seaweed symposium in Mexico was that constant movement of water is very critical for some species, as metabolites build-up rapidly on the surface during periods of low or no water movement.

Many seaweeds are prone to fouling in contained environments. Fouling by micro-algae will occur on most species if a combination of low water movement and high nutrients occurs. At the Cape Town Aquarium, kelps are replaced on a regular basis, despite the installation of flushing devices to improve water movement, which is required to minimize particle deposition and epiphyte attachment (see figure 3). However, due to the high fish: plant ratio, seaweeds are unable to take-out the majority of nutrients, providing an ideal growing environment for benthic microalgae. Fortunately epiphytes can be managed in land-based culture systems using a range of methods. Selecting fast-growing seaweeds, maintaining high water movement and where chemical nutrients are used, pulse nutrient dosing can help minimize micro-algae growth. (Pulse nutrient dosing involves supplying nutrients every 2-3 days to the seaweeds, which have an ability to store nutrients).

Figure 3: Flushing devices and water movement systems at the Cape Town Aquarium

This study focused on two systems for the production of seaweeds, including aerated tank culture and large paddlewheel raceways/ponds. A method of production involving large, lined ponds was considered, but this method appears difficult to manage and evidence suggests that productivity is low per unit area compared with other systems. Deep aerated tanks can be used to grow a range of seaweeds, including many red species that are consumed by abalone. Paddlewheel ponds arguably present a minor breakthrough in the production of large quantities of 'fleshy' type seaweeds at low cost compared to other systems.

1.3.1 Tank culture

Aerated, deep tank systems utilize air to constantly move seaweeds to provide exposure to light and the uptake of nutrients and carbon dioxide. Figure 4 shows how red seaweeds are maintained in suspension in tank-based aerated systems.

At Abagold in South Africa, quantities of *Gracilaria* sp. are grown as part of a mixed diet for juvenile abalone (*Haliotis midae*). Species such as *Gracilaria* cannot be grown in paddlewheel ponds as string-like seaweeds clump in paddlewheel systems (Robertson-Andersson, pers. comm.). This method of growing seaweeds has potential for growing smaller volumes of feed for juveniles and to supplement the diet of adult abalone. However, mass production of seaweeds using this method has higher associated capital and running costs and is considered not to be an option for bulk food production for abalone culture in Australia. Acadian Seaplants in Nova Scotia produces red seaweed in tank systems for the Japanese food industry. The higher costs associated with tank-culture are helped by a premium received for the product.

Figure 4: Aerated/tumble culture of *Palmaria palmata*

1.3.2 Paddlewheel ponds

Paddlewheel ponds or raceways are large rectangular structures with a divider down the middle, usually lined with canvas or plastic. A paddlewheel moves water in one direction continuously within these systems. *Ulva* spp. are the most commonly grown seaweeds in paddlewheel ponds. Figure 5 shows an experimental culture unit at Abagold in South Africa.

Observation of aquatic organisms is crucial in aquaculture. In paddlewheel ponds, *Ulva* could be observed spinning in a circular motion up and down throughout the water column. This is an important feature of this system as the seaweed must be prevented from layering which prevents gas exchange and nutrient uptake. Also, many types of seaweed are negatively affected by photo-inhibition which is caused by exposure of marine plants to either sudden increases in light levels or simply exposure to high light intensity. Seaweeds possess a range of photo-protective compounds to provide protection from harmful UV rays; however, there is much variation between species (Hupel, 2010). Some species have adapted defensive mechanisms to higher light, but most species seem to perform poorly at maximum light intensity in the upper water column. Photo-inhibition is likely to be an issue when growing many seaweeds in Australian conditions where light intensities can exceed 120,000 lux. Ensuring adequate mixing will help and maintaining appropriate seaweed stocking levels can reduce the effects of photo-inhibition by the principle of 'self-shading'. Figure 6 shows the even distribution of seaweed in a paddlewheel system which is mainly due to high water movement.

Figure 5: Paddlewheel culture of *Ulva*.

Figure 6: Close-up showing *Ulva* in suspension

1.4 Species selection

Australia has the greatest diversity of seaweeds in the world. With over 2,000 species known, there is a diversity in the properties and potential products that can be generated from these seaweeds. Chiovitti et al., (2001) points out that Australian seaweeds show a chemical diversity unmatched by species from around the world. Based on presentations at the 20th Seaweed Symposium in Ensenada, Mexico, it became clear that even within species there is a huge genetic diversity for a range of traits.

The species of seaweed selected for aquaculture needs to take into account a range of factors. In particular, the species selection needs to match the culture method, site conditions as well as the application. Furthermore, the potential for genetic improvement is substantial given the genetic diversity of seaweeds, the short generation times and the ability to place a high selection intensity on traits such as fast growth.

Ulva spp. have a tendency to spawn-out in culture conditions, possibly due to changes in water temperature or other factors. This is considered a significant problem in the production of *Ulva* for human consumption (Windberg, pers comm.). When *Ulva* spawns, white patches appear where cells are released from the main frond, resulting in a patchy, unhealthy looking appearance. Whilst some loss of cells is not a significant problem for the application as abalone feed, minimizing the tendency of the *Ulva* to spawn-out is preferable. The selection of *Ulva* strains can reduce the tendency of this species to spawn (Robertson-Andersson, pers. comm.).

Whilst most overseas abalone species grow well on a range of brown species, most brown seaweeds are unpalatable to Australian abalone, possibly due to the abundance of red seaweeds in their habitat (Shepherd and Steinberg, 1992). Initially this project focused on red seaweeds due to the perception that Australian abalone prefer red seaweeds and that green seaweeds had poor food value. However, it is apparent in the literature that *Ulva* may have been considered of poor value in the past due to the low protein levels in this species when fed to abalone in these trials. There is a strong correlation between protein levels in seaweeds which can be influenced by nitrogen supply (Shpigel et al., 1999). Several trials including in Western Australia in the late 1990's showed the green seaweed *Ulva rigida* to be a suitable species for abalone culture. In one trial it was shown that there was equal growth between abalone (*H.roei*) fed *Ulva rigida* and artificial feed (Boarder and Shpigel, 1999). The combination of the fact that *Ulva* spp. fed to abalone results in suitable growth rates and that it can be grown in a low cost system, makes this species an ideal candidate for culture.

A number of trials around the world have shown that abalone fed mixed diets grow better than single species diets. The red seaweed *Gracilaria* spp. has good potential for culture as a supplementary food source for abalone. *Gracilaria* spp. tolerate higher temperatures than many other red seaweeds found in oceanic waters, making them a suitable culture species for outdoor production in southern Australian locations which can experience maximum temperatures over 40^0C. Another red seaweed, *Palmaria palmata* can contain over 30% protein and is grown in tumble culture tanks for feeding abalone. A large abalone farm in Hawaii, Big Island Abalone, reportedly produces the largest quantity of red seaweeds grown in land-based tank systems in the world. Whilst *Palmaria* sp. is an ideal abalone food, this species prefers cooler water and was observed on the study trip in cooler parts of the world, including Ireland and Oregon in the U.S. Fortunately, red seaweeds grow in a range of environments and tolerate a wide range of temperatures. *Gracilaria* (figure 7) is cultured in South Africa for abalone food and also in tropical locations for the production of agar.

Figure 7: *Gracilaria* culture in South Africa

1.5 Applications

Seaweeds have a range of applications across a range of industries. Initially this study was aimed broadly at investigating seaweed culture opportunities in Australia, with a focus on seaweed as a feed source for abalone. Direction partly changed when the 'Seaweed Cultivation Manual' (by Barry Lee) was released shortly after beginning the scholarship. A thorough review of opportunities for Australia in seaweed culture, this manual was possibly the first expansive review of seaweed culture opportunities by an Australian author. This report and subsequent publications by another Australian researcher, Pia Windberg are recommended reading for those interested in seaweed culture opportunities in Australia.

1.5.1 Seaweeds as a food source for marine grazers

Seaweeds are the natural diet of many marine grazers including abalone and sea urchins. One of the main reasons that seaweeds have not been cultured in Australia is due to the very large quantities required. Approximately 7g of live algae is required for 1g of abalone live weight gain. The weight of seaweed fed-out to abalone must be approximately 7 times the quantity of pellet for similar growth results due to the fact that seaweeds are approximately 90% water. Seaweed production systems for bulk feed must therefore be large, covering a significant surface area for light capture. Fortunately, seaweeds are the fastest growing plants on earth and some seaweeds can be harvested on 6 week rotations. One farm in South Africa produced 60% of their feed requirement from cultured *Ulva* and *Gracilaria* (Troell et al., 2006).

In terms of benefit to the aquaculture industry, the majority of Australia's abalone farms rely on commercially-produced artificial feed, costing around $3/kg. Seaweed production does not need to replace artificial diets, but can supplement the primary diet to provide a number of benefits. A decrease in tank cleaning in abalone systems could be possible, through intermittent feeding with seaweeds. Unlike uneaten pellets, seaweeds do not rapidly form mould or contribute significantly to bacterial levels in culture systems.

On abalone farms during periods of high stress, such as high water temperature, abalone feeding is normally reduced. One reason for this is that artificial diets have been shown to rapidly increase total bacteria and total *Vibrio* spp. counts. On the other hand, some seaweeds may in fact illicit the opposite effect. One experiment in the literature showed that the poly-culture of abalone with the red seaweed *Gracilaria textorii* maintained lower levels of total *Vibrio* spp., and also influenced the balance of the *Vibrio* composition (Pang et al., 2006). *Vibrio alginolyticus* was one of two secondary, moderately pathogenic microbes present in high numbers during outbreaks at SAABDEV. Pang et al., showed that *V. alginolyticus* was inhibited by *G. textorii*. The inhibition of pathogenic bacterial species by action in the gut through feeding and as this study showed, through the water column, could have profound benefits to a range of marine aquaculture businesses across the globe. The feeding of selected micro and macro-algae to marine organisms may rival the application of probiotics (pure strains of 'beneficial' bacteria) as a method of inhibiting pathogens for the purpose of reducing disease outbreaks in aquaculture hatcheries and grow-out operations.

Prawn farmers in Southeast Asia have faced major stock losses due to outbreaks of a bacterial pathogen. The use of 'green water technique' has successfully been used to reduce mortality caused by the pathogen, *Vibrio harveyi.* Green microalgae (*Chlorella sp.*) are grown in separate ponds and introduced into the prawn ponds. This algal species contains substances that have anti-bacterial effects against pathogenic species of *Vibrio.* Further studies have also shown that aged fish water (tilapia) will also reduce Vibrio levels (Eleonor, 2003). Since fish are vertebrates, they have the capacity for specific immune responses to pathogens. Both non-specific and specific immunity in the form of macrophages and bactericides in the mucous reduce concentrations of *Vibrio harveyi* in the water. This is further evidence for both the antibiotic properties of marine plants and an example of where one species can benefit another (which is part of the IMTA concept).

1.5.2 Seaweed for agriculture

Alan Critchley from Acadian Seaplants stated at the 20th seaweed symposium that seaweed extracts modify plant and animal responses at a fundamental level. The brown alga *Ascophyllum* shown in figure 1 tolerates a wide temperature range from -30^{0} C to +30^{0} C and is used to improve plant resistance to temperature extremes and resistance to drought.

Seaweeds possess a range of chemicals which are used by them as deterrents to herbivores, protection from high light levels, growth promoters and others. Some of these 'natural' chemicals can be used as pesticide additives. Natural hormones have been proven for some time to increase root development and reduce the impacts of disease. While some of these organic chemicals can be synthesized, the added benefits such as provision of trace elements can warrant the use of this natural product. Seaweed additives have been shown to improve health and increase milk production in dairy cows through supplementing their diet and altering the gut flora. AgriSea in New Zealand makes a range of products for agriculture from seaweeds. Their products are particularly focused on improving animal nutrition. Sales have increased in recent years as dairy farmers in New Zealand have observed the benefits in providing a seaweed extract to dairy cows which have become sick due to nutritional deficiencies.

Figure 8: AgriSea produces a range of products from *Ecklonia maxima*

2. Marine grazers in recirculating aquaculture systems (RAS)

2.1 Abalone culture- Australia and overseas

Abalone are a highly prized seafood throughout many parts of Asia, particularly Japan and China. In their natural environment, abalone predominantly consume marine plants including seaweed and benthic micro-algae. Methods for producing abalone vary both between and within countries. In China sea culture dominates abalone production. Cages, lantern nets and other structures contain the stock which are mainly fed seaweed grown locally on ropes. In countries such as the US, Mexico, South Africa and Europe, land-based aerated tank culture is the dominant production method, whilst in Australia, a shallow raceway tank design is most common. In NZ, one farm grows abalone in a tiered raceway system which recirculates water; however, globally most farms operate flow through systems. Figures 9 shows the shallow raceway system which dominates grow-out technique in

Australia and figure 10, the plate/aerated tank method which is prevalent in overseas land-based abalone culture systems.

Figure 9: Shallow raceway culture in Australia

Figure 10: Tank culture in Ireland

Australian abalone farming operations are viewed by some as the most efficient in the world, partly due to the low labour requirement associated with the shallow raceway systems. However, in Australia abalone farming has not been without its challenges. Site influences such as high water temperature, economic factors such as the low US dollar and more recently, the threat and outbreak of disease have challenged a number of operations.

2.2 Recirculating aquaculture systems

Water re-use involves the repeated use of water that has passed through one module such as a tank or raceway. Simply allowing water to flow from one system (via gravity) into another can be considered a water re-use system in comparison to flow-through in which water is discharged after a single pass.

In a recirculating aquaculture system a proportion of the water that has passed through a culture unit is returned to that same unit, usually by a pump. Unlike flow-through systems, recirculating aquaculture systems require water treatment to enable the water to be re-used. For basic water treatment, infrastructure or equipment are used that enable; oxygenation/carbon dioxide removal, solids removal, and biological filtration. Figure 11 shows some typical components of a water treatment system for abalone culture. These include a drum filter for removing solids, foam fractionators for removing dissolved organics, a biological filter to remove ammonia (background) and an ultraviolet light sterilizer (blue light) for disinfection.

Figure 11: Water treatment system for an abalone farm in southern Ireland

Flow-through systems have several distinct advantages over re-use and recirculating aquaculture systems. Provided the aquaculture facility is located in an oceanic site, water of consistent quality can generally be relied upon. So, why recirculate water when a continuous supply of high quality water can be pumped ashore into flow through systems?

The answer to the above question is relatively complex and depends on a number of factors. For Irish abalone farmers, recirculation is the only option for producing abalone as water temperatures are too cold for adequate growth and abalone need to be grown in greenhouses or closed structures with internal heating provided. In South Africa, the threat of harmful algal blooms has prompted several farms to consider recirculation in order to avoid drawing in toxic microalgae which have the potential to wipe-out entire stocks. It was reported at ‘Aquaculture 2010’ in San Diego that one abalone culture operation in Chile is considering recirculation as pumping water up a 15 metre cliff is an expensive option. The following sections look at several aspects of recirculating aquaculture systems involving marine grazers including; water quality management, temperature, health management and biosecurity. The ability and/or motivation to recirculate water for part or all of an abalone aquaculture operation depend on a number of factors which include risk management, system design and environmental parameters.

2.2.1 Water quality

Most abalone farms incorporate a brood-stock conditioning and spawning system, abalone nursery, juvenile system and grow-out. All sections must run smoothly and so risk aversion is a primary aim for many aquaculture operators. Water quality can turn quickly resulting in loss of stock. Poor water quality can reduce growth rates and increase the risk of bacterial diseases.

In natural conditions, abalone live in oceanic environments typically characterized by clean, cool, well oxygenated water of consistent salinity and pH. Land-based culture of abalone exposes them to conditions which they would not normally experience in their natural environment. Dissolved oxygen is normally the first parameter to become limiting in aquaculture systems, commonly reducing survival, health and growth. In flow-through systems, water is used once only in a vessel and then discharged. RAS systems generally require increased monitoring to ensure that parameters such as dissolved oxygen levels are maintained at optimum.

Oxygen uptake by abalone is affected by dissolved oxygen concentrations in the water and flow rate of water through the gills. Several trials carried-out on dissolved oxygen levels have been undertaken in tanks and have suggested abalone are very intolerant of low oxygen conditions. However, it is possible that oxygen uptake is greater in raceway systems than in tanks. Phil Heath from the Mahanga Bay facility (which is part of the National Institute of Water and Atmospheric research (NIWA)) in New Zealand is currently carrying-out trials on the effect of low oxygen levels on abalone in raceway systems. In aquaculture, it is important that site-based research is carried-out on a regular basis to monitor water quality parameters and their effects on growth and survival.

The pH tends to decrease in recirculating systems as a proportion of carbon dioxide from respiring organisms dissolves in water to form carbonic acid. A slight reduction in pH can be beneficial in some systems as at a pH of 8.3 (normal seawater), total ammonia (TAN) is toxic at very low concentrations. However, on the other hand, a pH of below 7.6 can cause shell wastage as calcium carbonate reacts readily with free hydrogen ions at this pH. The photographs in figures 12 and 13 were taken at a recirculating abalone farm in Ireland. The shell wastage is a clear sign of exposure to low pH. The abalone were obtained from another facility; calcium carbonate was used successfully to increase pH at this farm, however, the abalone take time to recover. For all species which incorporate calcium carbonate or aragonite in their shells, pH should be maintained above 7.8 at all times.

Figure 12: Abalone recirculation system

Figure 13: Close-up showing shell wastage caused by dissolution of calcium carbonate at low pH

2.2.2 Temperature

Heat/chill units use the principle of refrigeration to heat or cool water. John Seccombe has worked on a number of aquaculture operations in both New Zealand and Australia and considers that heat/chill pumps are the most efficient way of cooling water in enclosed aquaculture systems. In combination with a heat exchanger for exchanging 'top-up' water in recirculation systems and with adequate insulation, heating or cooling water could be a viable option for some closed operations. Increased cost of infrastructure and electricity can be offset to a certain extent by improved growth and survival. The ability to fully recirculate can enable ozone treatment, reducing the threat of disease entry in high risk locations. Heating and/or cooling water may be a viable option for juvenile systems which have a lower biomass and land footprint than grow-out systems.

Other methods for adjusting water temperature may have an application in Australia. OceaNZ operates a semi-recirculating system at a location on the northern most part of the north island of New Zealand. To reduce temperature in the warmer months, a cooling tower reduces incoming water by up to 3^0C. Australia has typically dry summers and low humidity, which makes evaporative cooling an effective way of reducing temperature in closed structures. Evaporative cooling could have an application in reducing temperatures in some abalone culture systems utilising recirculation.

2.2.3 Health management

By recirculating water, microbes can build-up to much higher levels than flow through conditions. There are a range of factors that influence the build-up of microbes in aquaculture systems. Organic loads particularly from faeces and uneaten food can cause significant increases in bacterial levels.

To control bacterial levels, OceaNZ has incorporated a UV sterilizer into the system which kills 99% of the bacteria in the entire flow before the water is re-pumped.

Skjermo and Vadstein (1998) describe the benefits in microbially matured water for marine larvae. ‘A diverse bacterial flora established by non-opportunists is believed to inhibit proliferation of opportunistic pathogenic bacteria in the water and the larvae’. In the US at the Aquaculture 2010 conference, Attramadal (et al., 2010), described that higher organic loads are not necessarily to blame for mortality outbreaks. Recirculation was considered as a microbial control strategy in the intensive culture of marine fish larvae. In fact, research in Norway has shown that sudden increases in organic loads can be much worse than maintaining a stable low to moderate organic nutrient load within a system. This is because most pathogenic marine bacteria are opportunistic and fast-growing. A relatively ‘clean’ system can suffer greater stock losses when a sudden organic load occurs, because of the absence of a stabilized population of bacteria.

OceaNZ grow abalone in a tiered raceway system such that water from the first raceway cascades into the second and then into the third. Reports are that abalone grow slightly faster in the second raceway. This has also been observed on Kangaroo Island Abalone farm. Reasons for this are unknown; however, one possibility is that there is some benefit in this ‘conditioned’ water, possibly that moderate bacterial levels help with digestion of feed. Maintaining a low to moderate organic load may actually improve survival.

Recirculation systems have benefits that are lesser known. Biological filters used primarily for removing ammonia from aquaculture systems can have a secondary benefit by maintaining a stable population of bacteria in a system. Taylors Shellfish in Washington State (U.S.) in conjunction with Professor Chris Langdon from the Hatfield Marine Science Centre (in Oregon) were carrying-out trials on stabilizing bacterial populations by using biofilter media to support a bacterial population (figure 14). This is not the standard use for a biofilter but shows that components of recirculating systems may have advantages. It is known by many marine hatchery operators that sterilized water can reduce mollusc larvae survival, possibly due to an absence of bacteria which are beneficial for the purposes of digesting food and competing with pathogens.

Figure 14: Biofilter for stabilizing bacteria in a marine system

Figure 15: Seaweed investigated for anti-microbial properties

The use of seaweeds in abalone culture could improve the ability to recirculate or re-use water without the need for UV sterilization, as seaweeds can not only reduce bacterial levels, but certain seaweeds can be selected to target known pathogens, identified through pathology testing. Cheng et al. (2004) showed that high water temperature causes a reduction in phagocytic activity (one of abalones' limited non-specific immune defences), leading to susceptibility to *Vibrio* and other bacterial infections. A well known specialist in health management in marine hatcheries, Ralph Elston (at 'Aquaculture 2010') described vibriosis as a recurrent problem in marine hatcheries, and stated that so far there is "no magic fix for vibriosis". In the absence of a suite of treatment options in the event of a bacterial outbreak, the combination of feeding seaweed to aquatic animals and maintaining a stable and diverse population of bacteria can help to reduce the proliferation of pathogenic bacteria which can gain a foothold in stressed animals. Figure 15 shows that a small experimental unit can be suitable for various studies.

According to Hart (2002), a (marine larvae) gut filled with vibrios' can cause symptoms that appear to be nutritional deficiencies. In the same way, a healthy, balanced gut is likely to play a significant role in the optimal gut health and digestion of food. The variation in bacterial flora in aquaculture systems could be part of the reason for commonly unexplained differences in growth between culture units.

2.2.4 Biosecurity

Sterilization of source water is one way in which pathogens can be prevented from entering an aquaculture facility. Globally, aquatic diseases are spreading at an alarming rate. Abalone stocks across the US were devastated and have been slow to recover from a deadly bacterial disease known as withering syndrome. More recently in Australia, the ganglioneuritis virus has caused losses of abalone stocks both on several abalone farms and also to wild populations. Mortality of over 80% of salmon in Chile has decimated this industry. At the Screebe fish hatchery visited in Ireland all fish are vaccinated before sending to sea, however, losses from viral infections still add up to 20%.

Ozone is a powerful oxidizing agent that is used in aquaculture to sterilize water. The potential to use ozone to prevent the entry of pathogens could be considered by some abalone aquaculture operations in Australia, especially in situations where pathogens are present locally. The Whiskey Creek Oyster Hatchery in Oregon used ozone to successfully remove an oyster pathogen *Vibrio tubiashii* from the water. Ozone is also capable of removing the toxin produced by this bacteria.

Ultraviolet light is probably the most common form of disinfectant used in aquaculture applications. Generally, it is used to reduce bacterial levels in RAS, rather than to prevent the entry of pathogens. UV sterilization is cheaper than ozonation; however there are several issues with its use as a sterilizer. UV only penetrates short distances and so shading of bacteria by particles can reduce its effectiveness. Many viruses and some bacteria require a very high dose of UV, and photo-reactivation, where bacteria repair DNA damage on exposure to light can occur (Liltved and Landfald, 1993).

Ozonation is expensive, but in some cases, costs could be offset by a reduction in stock cover insurance premiums. At some sites, saltwater wells can be used as a source of water for ozonation. A lower ozone rate is suitable for very clean water. Figure 16 shows a prawn farm in China. This farm draws 20 litres per second from an underground well. On the day we visited, the sea appeared a coffee colour (figure 17), whilst incoming water was completely clear.

Figure 16: Prawn farm in China using well water

Figure 17: Prawn farm- ocean at site

2.2.5 Water movement options for RAS

Abagold produces up to 350t of abalone per annum and is the largest abalone farm outside of China, employing 250 workers. Power is their primary running cost due to the need to pump over 2,000 litres per second to adequately supply its flow through operation. In contrast to pumping water direct from the ocean, recirculation of water on site provides the opportunity for a greater number of water distribution options. The slab tank raceway systems predominantly utilized for abalone culture in Australia are situated at ground level. Recirculation systems can be designed to minimize both pumping heights and frictional head losses as water does not need to be pumped long distances from sea level. At low head heights, axial flow propeller pumps are particularly suited to reticulating water at a lower electricity cost. These pumps (figure 18) were observed in both New Zealand and England where they are used to move high volumes of water between aquaculture ponds. Also, through the displacement of water via air, air lift systems are known to be a cheaper way of pumping water at low head heights compared to centrifugal pumps and have the added benefit of providing aeration. Connemara Abalone in Ireland uses a South African grow-out system to produce abalone for the European market. All water is recirculated via airlifts (figure 19). No pumping is required apart from drawing top-up water from the sea.

Figure 18: Axial flow propeller pump

Figure 19: Abalone grow-out airlift system

2.3 SA Abalone Developments- potential for recommissioning?

South Australian Abalone Developments (SAABDEV) located at Louth bay on the Eyre Peninsula was once a flow-through abalone farm which produced over 25 tonnes of abalone per annum. However, it was decommissioned predominantly due to 'summer mortality' rates at around 30% per annum. High water temperature beyond greenlip abalones' (*Haliotis laevigata*) normal range reduced immunity in farmed stock, leading to susceptibility to bacterial infection. Vibriosis was confirmed as the most likely cause of stress-induced mortality in abalone at SAABDEV by the following indicators; a) the effectiveness of antibiotics in controlled on-site experiments, b) the high variation in mortality rates between raceways and c) pathology testing. Data collected and analyzed on site showed that primarily, mortality was only caused by spikes over 23-24^{0}C. Extended periods at 22^0 C did not cause significant mortality, although stock losses would occur for several weeks following thermal spikes. The implications of this were that cooling of water need only occur for less than 10 days per year to potentially prevent 80% of stock losses. Before these data were collected, cooling was considered to be necessary for the entire mortality period of up to 2.5 months. The economic viability of cooling water by a few degrees for 10 days appears far more promising than 10 weeks.

Considering that such a short period of temperature reduction is required to prevent mortality outbreaks, the ability to recirculate water with minimal RAS infrastructure is a viable option. The combination of heat/chill pumps and insulation would be the main investments needed to maintain a low temperature. As the site is located on sand, bore water is available at full strength salinity. The bore water reaches a maximum temperature of around 21.5^{0}C in summer compared to an average maximum of 26^{0}C at sea (adjacent to the farm). A suitable volume of water could be obtained from a relatively large seawater well on site to assist with temperature control. Figures 20 and 21 show raceway design of the abalone grow-out system at the farm.

Figure 20: SAABDEV raceway system (1)

Figure 21: SAABDEV raceway system (2)

Urchins present another opportunity for SAABDEV. Urchin roe receives a high price on the Japanese market at around $1200/kg (wholesale). Wild harvest of urchins is not considered economical due to the inconsistency in roe (gonad). However, it has been recognized that roe enhancement can be achieved by feeding on land and at sea. Access to food is considered to be one reason linked to the inconsistency in roe harvest. In New Zealand, at Mahanga Bay Aquaculture facility, research is being conducted on several species including seaweeds, abalone, sea cucumbers and urchins. Feeding experiments involving the local sea urchin (known as kina) have shown an increase in roe yield from 3 to 10% body weight over a 10 week period. Greater than 10% roe is considered crucial to make urchin culture economically viable. Seaweeds (the natural diet of sea urchins) could be an important part of increasing roe. Also, recirculation of water can influence or control water temperature, thus further improving roe percentages. John Chamberlain runs a recirculating sea urchin hatchery and nursery in Ireland. The combination of recirculation and a greenhouse maintains temperature about 3-4C above the adjacent sea water.

3. IMTA systems

3.1 Fundamentals of IMTA

IMTA production is not a new concept. For centuries, pond poly-cultures have supplied a food source for rural communities throughout China and many other Asian countries. Figures 22 and 23 show poly-culture ponds in the Philippines and China. In these particular systems, chickens or geese are fed, with their waste providing nutrients for microalgae, which in turn provide a feed source for herbivorous and/or omnivorous fish. Products from these systems can include; poultry, plants (e.g. lotus), fish and freshwater crustaceans.

Figure 22: Poly-culture in the Philippines

Figure 23: Poly-culture in China

One of the fundamental concepts of integrated multi-trophic aquaculture is that animals and plants in the system must provide a benefit to the system and/or have significant economic value. The value of species in a system can be due to; improving water quality, reducing feed costs and/or direct sale. However, the benefits of integrated systems are not confined to economics. The environmental benefits of utilizing waste nutrients can help to prevent or reduce eutrophication of marine and freshwater bodies.

The localized eutrophication of the ocean is a continuing global problem. In the Gulf of Mexico a 25 mile anoxic zone has developed due to human impacts in the Mississippi delta. Whilst aquaculture is generally not a major contributor to large-scale eutrophication, the culture of aquatic animals can contribute to nutrient loads, which can be a problem especially in sensitive areas.

In the Mississippi delta, the pond catfish industry produces nutrients that are predominantly discharged into the Mississippi river. This practice certainly begs the question: Why can't the nutrient-rich water be used on cropping land? Discussions with researchers at Mississippi State University confirmed that crops grown on this nutrient rich water have increased yields. One of the issues is that ponds are clustered and with some farms covering 800 acres, there is a large distance required to pump water to cropping land. Turning monoculture systems into integrated systems can be difficult and it is clear that it is much better if plant and animal culture systems evolve together. During the global focus program it was realised that the majority of research and development over the past 30 years has focused primarily on independent monoculture systems, not on integrated farming systems or aspects such as waste utilization. This is one reason why integrated and waste-recapture systems have not progressed rapidly.

3.2 Abalone and seaweeds in IMTA

3.2.1 Current status

'True' IMTA culture involves interaction between plants and animals. Therefore, single pass systems in which water flows through abalone systems and then through seaweed systems prior to discharge are technically not considered IMTA systems. However, there is certainly no need to adhere to a concept. Unlike freshwater aquaponics, there are currently no known 'fully' recirculating (greater than 90% water re-use) integrated multi-trophic aquaculture systems incorporating abalone and seaweeds.

In South Africa, most abalone farms run seaweed culture units either independent to abalone culture or using wastewater prior to discharge. However, one IMTA abalone farm is running at 50% recirculation through a seaweed culture unit (Bolton et al., 2006).

3.2.2 Seaweeds for improving water quality

One of the main benefits of integrating animals and plants is the improvement in water quality by the plant component. Many seaweeds prefer nitrogen in ammonium form and all produce oxygen and remove carbon dioxide through the process of photosynthesis. With the exception of solids removal, these are the main functions of water treatment in a recirculating aquaculture system. Unfortunately, the contribution of seaweeds to improved water quality mainly occurs during light hours, as these functions which include oxygen production, carbon dioxide and ammonia uptake are predominantly correlated to photosynthesis. In a RAS, each kg of *Ulva* produces enough oxygen daily for 2 kg of fish stock (Neori et al., 2004). Based on a lower metabolic rate, 100 kg of *Ulva* could maintain enough oxygen for 500 kg of abalone. Therefore, to improve water quality parameters such as oxygen levels, a relatively low quantity of seaweed is required as a ratio to the abalone component.

3.2.3 Nutrient management

Nutrient concentrations from abalone farming systems are low owing to the high flow rates and lower metabolism of abalone compared to fish. Economic models in Israel have shown that fish/abalone/seaweed culture can be the most viable IMTA systems (Neori, pers. comm.), but this is highly dependent on the value and market of the fish component. Fortunately, nutrients can be added to seaweed culture units infrequently by pulse dosing. At Abagold ammonium phosphate and ammonium sulphate are the main fertilizers used. Every 2nd day, incoming water to the paddlewheel ponds is turned off for several hours after nutrients are added. Nutrient management is crucial to optimal production in seaweed culture systems. Research by Scheunhoff et al. (2003) showed that protein levels of 34% dry weight were achieved in a RAS fish system. Protein levels over 40% are apparently achievable according to researchers at the Seaweed symposium in Ensenada.

As mentioned previously, Australia’s coastal waters are generally oligotrophic (low in nutrients) and so little background nutrient is present. Trace elements such as iron are known to be limited in southern Australia and along with the major nutrients, nitrogen and phosphorous, may need to be added to seaweed culture units receiving abalone waste water to provide optimal seaweed nutrition. Trials by Demetropoulos and Langdon (2004) showed that a range of inorganic nutrients and trace elements could be added to seawater which is then added to abalone culture vessels without any impact on abalone growth. Similarly, based on research in freshwater aquaponics, addition of inorganic nutrients has not had adverse impacts on fish, with the exception of relatively high levels of potassium on striped bass (Rackocy, pers. comm.). Perhaps with the exception of ammonia as a fertilizer, water from seaweed culture units can be returned to abalone culture systems without concern over negative impacts from nutrient or trace element toxicity.

3.2.4 Challenges

The ocean acts as a temperature buffer, whilst significant heat gain or loss occurs when water is maintained in open culture systems on land. Seaweeds require high light levels for growth and light adds heat. This can actually be an advantage in locations where water temperatures are low. In South Africa, water temperatures remain low through summer due to cool Atlantic currents. Aeration and water storage on land raises water temperatures and increases growth rates of the abalone. However, in the warm temperate conditions of Australia, the combination of water temperatures near abalones' upper limit and maximum daytime temperatures of up to 45^0C, it's clear that it is not possible to run an outdoor integrated abalone/seaweed system during these times.

3.2.5 Economics

In IMTA systems, the economics need to consider all products from the system. Each product must have a value that makes inclusion economically sensible. The economics of IMTA systems involving abalone and seaweeds are very complicated. It was difficult to obtain information on this important aspect for a number of reasons, including that there are few integrated abalone/seaweed land-based systems operating around the world, as the concept of land-based IMTA systems incorporating abalone and seaweeds is relatively new.

One farm in South Africa produces 4mt *Ulva*/day in 32 8m * 30 m paddle ponds (Bolton et al, 2006). This is equivalent to approximately 571 kg dry weight/day which is equal to over $A500,000/year in artificial feed. Paddlewheels have 3kW motors, based on this, if the paddlewheels were run all year, electricity costs would be well under $A100,000. As the system runs on abalone discharge water, no pumping is required. That leaves labour and nutrients as the remaining primary costs. Although Australia has higher labour costs, methods for the mechanical distribution of seaweed from culture units to abalone raceways could be developed, potentially preventing the need for hand harvest.

There are a number of factors that influence the financial viability of installing paddlewheel ponds to run separately, using waste water only or as part of an integrated system. Tierry Chopin at the 20th seaweed symposium in Ensenada made the point that there is an opportunity for a premium price for aquaculture products produced in land and sea-based integrated systems. Sustainably produced products are likely to receive a similar premium as ‘organic’ products in some markets.

3.2.6 Implications for Australian abalone farms

The Fizantakraal fish farm in South Africa grows trout in a semi-recirculating system (Figure 24). This system includes both recirculation and water cascading. Water is recirculated within individual raceway systems using airlifts. A simple system using a gate controls how much water is exchanged and is dependent on ammonia concentration as no biofilter is used in the system. This type of model is one that could be used to integrate abalone and seaweed culture. Abalone waste water directed to paddlewheel ponds or other seaweed culture units could be returned (using low cost pumping methods) only when parameters were suitable. For example, during daytime when seaweeds produce oxygen, some of this water could be directed back to the abalone, resulting in a reduction in pumping costs and increase in oxygen levels to the abalone culture system. Also, elevated carbon dioxide levels in abalone water can benefit seaweed culture units. Seaweeds at-least have potential to form part of a water treatment system and it is clear there are many potential ways in which integrated abalone/seaweed culture can prove viable.

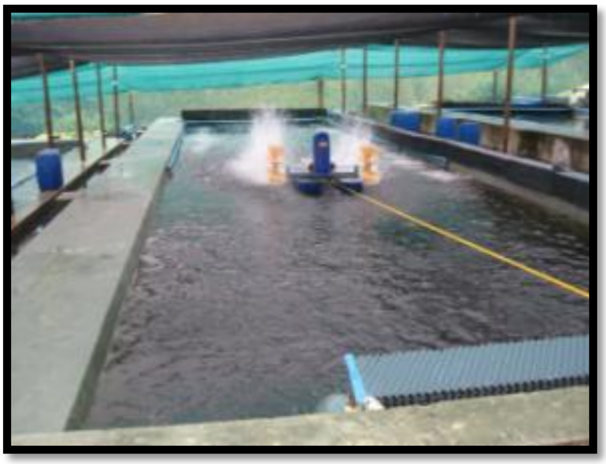

Figure 24: Semi-recirculating trout farm in South Africa

Conclusion

In summary, the study of RAS involving molluscs and the integrated culture of abalone and seaweeds highlights the diversity and complexity of challenges associated with aquatic culture of animals and plants. However, the production of seaweed as an on-site food supply, the option of reducing power costs by semi-recirculating using low energy pumps at low head heights and using seaweeds as part of a water treatment system, can help to improve efficiency for some operations. Although Australian seafood usually receives a premium in overseas markets, competition on price will be an ongoing issue for primary producers in Australia. The production of marine plants in land-based integrated and stand alone systems is likely to expand due to increasing research in this area, combined with pressures on aquaculture producers to reduce costs, utilize waste resources and improve aquatic animal health.

Aquaculture and the wild fisheries sector provide jobs right across regional Australia. In Ireland where the economy is in trouble due to the global financial crisis, a number of workers previously employed in the building industry are out cutting seaweed for export. This ability to move from one industry to another is crucial in a rapidly changing, globalised economy. The expansion of aquaculture in Australia can occur in a country with clean waters and a reputation for exporting high quality seafood. Marine plants and integrated systems can play a role in this expansion.

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Plain English Compendium Summary

Project Title:	Integrated Multi-Trophic Aquaculture Systems incorporating abalone and seaweeds
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Objectives	To investigate a range of aspects of integrated aquaculture systems incorporating abalone and seaweeds, primarily to assess the potential for seaweed production as an on-site food source for abalone.
Background	Australian abalone farms feed stock an artificial pellet, unlike most overseas operations which predominantly either collect or grow large quantities from the sea. The opportunity to produce seaweed as an on-site feed source was the basis for this study along with an interest in recommissioning an abalone grow-out facility at Louth Bay, South Australia.
Research	A range of aquaculture facilities were visited and conferences attended in the U.S., Mexico, Ireland, England, South Africa and New Zealand. The research focused on several aspects, including seaweed culture, recirculation systems incorporating abalone and sea urchins, and integrated aquaculture systems.
Outcomes	Seaweed culture has significant potential to provide an on-site feed source for abalone. The production of *Ulva* spp. in paddlewheel ponds can yield large quantities of a feed that is suitable for abalone culture. Integrated culture of abalone and seaweed culture can take advantage of the beneficial interactions between animals and plants, particularly, the uptake of nutrients via seaweeds. Recirculation of water may be an option for some farms for a range of purposes, including the ability to reduce pumping costs by opportunities afforded by lower pumping head heights
Implications	Abalone farms could consider installing paddlewheel ponds between abalone culture units and a discharge point. Waste water can be directed to these seaweed culture units to utilize waste and prevent the need to pump water for separately for the paddlewheel ponds. A range of issues discussed in this report may assist some abalone farmers interested in seaweed culture, recirculating aquaculture systems and integrated systems involving molluscs in Australian conditions. Depending on several factors, the potential to recommission a 50t capacity on site abalone farm by recirculating and cooling water during periods of high incoming water temperature appears promising.

Shellfish Production Aquaculture Technology

Global Perspective of Bivalve Hatchery Processes

A report for

NUFFIELD AUSTRALIA FARMING SCHOLARS

by Ian Duthie

2010 Nuffield Scholar

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Foreword

Shellfish (Bivalve) cultivation is a significant form of aquaculture around the world, with production at 13.9 million tonnes and continuing to grow at 5% per annum. (FAO – Facts). Bivalve cultivation is one of the earliest forms of aquaculture with records of oyster cultivation extending back to Roman times. Within Australia the commercial cultivation commenced with the Sydney Rock Oyster (*Saccostrea glomerata)*, utilising wild 'spat' settlement, to support production. Pacific Oysters (*Crassostrea gigas*), Mussels (*Mytilus galloprovincialis*) and to a far lesser degree Flat Oysters (*Ostrea angasi*) also developed this way.

Oyster production extends from southern Queensland down the coast along New South Wales, across to Tasmania and South Australia. Mussel cultivation has a limited presence in NSW, and a well-developed industry in VIC, TAS and emerging in SA. Clam and scallop cultivation is not commercially relevant as yet although interest exists and with a commercial fishery and existing public demand for these shellfish.

In the late 1970s hatchery technology was adopted by the Tasmanian Pacific Oyster (*Crassostrea* gigas) industry to secure a reliable supply of 'spat' following inconsistent, short supply of 'wild-catch'. This started the development of shellfish hatcheries within Australia. Further oyster hatchery development occurred, with oyster hatcheries now operating in NSW, TAS and SA. In 2006 a dedicated mussel hatchery was also commissioned to underpin 'spat' supply within Tasmania. The Victorian mussel industry followed this development with a government supported mussel hatchery also.

The development of industries farming these shellfish species, including the investment in the growout, processing, distribution and market development is all at risk, if a reliable consistent supply of 'spat' is not available to underpin the production processes. Therefore supporting hatchery development that is robust, and reliable in suppling sufficient quantity and quality of 'spat' is essential.

The Australian edible shellfish aquaculture industry is essentially made up of oysters producing 14,800 tonnes worth $100 million, and mussels with 3,100 tonnes and a value of $10 million. The direct employment generated by these industries is predominately in rural regional areas.

Australia has limited shellfish aquaculture development of its coastal area, particularly when compared with the intensity of development in countries such as China. The opportunity for Australia to extend its production of the existing species grown, and develop an industry with other indigenous species, particularly clams such as *Katelysia* sp. is immense (Internationally clams are worth as much as US$300 million). *Katelysia* sp. currently sells for between $18-22/kg at the Sydney Fish Market.

The continued growth and development of shellfish aquaculture in Australia is dependent upon its ability to meet ongoing challenges, and take advantage of the opportunities that present themselves. Underpinning this is a reliable, economical supply of 'spat'; it is recognised that shellfish hatcheries can meet this need. Identifying the technology, business structures, management and environment that allow hatcheries to operate as environmental and economically sustainable entities supporting the industries need for spat is critical. The technology utilised by the Australian shellfish hatcheries represents the best that is available around the world, with a mix of high intensity and low density culture practices for both larval and algae production. A focus on management that provides for reliability and efficiencies in production is still required. The 'devil is in the detail' and how these technologies are utilised. Australian oyster growers are paying as much as double for equivalent product i.e. five mm Pacific Oysters $15.50AUD in America *vs*. $26-32AUD in Australia.

The Australian oyster industry provides a good example of cooperation, with research into the development of Polyploidy, and Selective Breeding. This mirrors the best practice of industries around the world. This investigation however identifies that further cooperation will be necessary across areas such as disease management, water quality management, production difficulties and energy efficiencies.

The opportunity for the Australian shellfish hatcheries to diversify their production across a wider range of shellfish species was also very clear, with the majority of shellfish hatcheries visited supporting the production of a diversity of species, utilising essentially the same equipment and technology as exists in Australian hatcheries.

The diversity of species produced and vertical integration was also recognised as an opportunity for Australian shellfish hatcheries to mitigate risk and improve their profitability.

The ownership and management structure of international hatcheries was identified as influencing their efficiency and profitability. A number of facilities visited had 'management' buy-outs, or a variety of structures in place to retain skilled management, with 15-30 years continuous employment not being uncommon. This contrasts with the Australian experience with more than 10 years continuous service being rare. Succession planning of key management is going to be a growing challenge around the globe, with the ‘management’ buy-outs referred to above going to become more difficult as the scale and value of the businesses continues to grow.

The scale of production by international hatcheries identified during this study dwarfs that of Australian hatcheries. This scale of production appears to be a major influencing factor in the efficiency of production, and the capacity of international facilities to offer considerably discounted spat prices compared to that on offer within Australia.

An economic study into the relative merit of species and product diversification should be undertaken, identifying the opportunity for Australian hatcheries to improve their international competiveness, building efficiencies and improving profitability.

Investigations identifying and removing the impediments to develop a clam aquaculture industry within Australia are needed. Identifying further nursery and growout technology and investigating the economic, and social benefits of building this industry.

This Nuffield Scholarship Study Tour was supported by the Australian Fisheries, Research and Development Corporation (FRDC) with the intention of investigating what is the current ‘state of play’ of shellfish hatcheries and the industries they support, and what lessons are there for Australia.

Acknowledgements

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Abbreviations/Glossary

ABC Aquaculture Breeding Centre.

Algae: aquatic plants including Phytoplankton – microalgae.

Axenic indicates algae cultures that are free of any other 'contaminating' organisms.

Bivalve: mollusc having a shell of two valves that are joined by a hinge.

Byssus: thread-like filaments used by bivalves to attach themselves to a substrate.

Cilia: hair-like structures whose rhythmic beat induces a water current in bivalves.

Cultch: material used to collect bivalve spat.

Diatom: a single-celled alga of the Class Bacillariophyceae; cells are enclosed in a siliceous shell called a frustule, cells can form chains.

DNA (Deoxyribonucleic acid) is an informational molecule encoding the genetic instructions used in the development and functioning of all known living organisms and many viruses.

Diploid: the normal number of chromosomes (2n) in cells.

Downwelling: in hatchery terminology, a growing system in which the flow of water enters at the top of a spat holding container (compare with upwelling).

D-larva: the early veliger larval stage of bivalves, also known as straight-hinge larva.

Embryo: an organism in early stages of development; in bivalves, prior to larval stage .

Exotic: introduced from foreign country or geographic area.

Eyespot: a simple organ that develops near centre of mature larvae of some bivalves and is sensitive to light.

Eyed Larvae: the stage just before settlement and metamorphosis.

IFREMER: French Research Institute for Exploration of the Sea.

Metamorphosis: the stage at which the shellfish larvae transition from free swimming larvae to a settled spat.

OAT: Oyster Aquaculture Training

PCR: the polymerase chain reaction is a biochemical technology in molecular biology to amplify a single or a few copies of a piece of DNA across several orders of magnitude, generating thousands to millions of copies of a particular DNA sequence.

Spat: the juvenile stage of a bivalve shellfish, following larval stage and settlement and metamorphosis.

Tetraploid: a polyploid animal with twice the normal complement of chromosomes (4n).

Triploid: a polyploid animal with an extra set of chromosomes (3n).

Upwelling: in hatchery terminology, a growing system in which a flow of water is induced through the base of a spat holding container (compare with downwelling).

VIMS: Virginia Institute of Marine Science.

Contents

Executive Summary

Despite the Australian shellfish industry having developed hatchery technology for a variety of species, it has still been plagued by an unreliable and inconsistent supply, resulting in a shortage of supply of ‘spat’ to shellfish producers. This has stalled commercial development of both existing and ‘new’ alternative species to oysters and mussels. These ‘new’ species are closely related to those being commercially cultured around the world, with the production cycle starting within the hatchery, and strong existing domestic markets, such as with scallops and clams.

The cost of Oyster ‘spat’ to overseas growers is considerably cheaper than that offered by Australian hatcheries for equivalent ‘spat’. Investigations of the factors influencing this are important, as it may provide opportunity to improve the competitive productivity of the shellfish industry.

The need to study Shellfish Hatchery businesses from around the world, and identify both “World Best Practice” and the future trends in shellfish production is important for the future growth of the Australian Shellfish industry. Recognising the deficiencies of current technology and knowledge, that exist both in Australia and around the world is important. Looking for the business and industry structure that supports reliable, efficient and profitable supply of ‘spat’. Identifying current opportunities for technological transfer, and international collaboration and assess the structural and management systems employed by world leaders in shellfish hatcheries and integrated growers and processors.

Results

The commercial hatchery production of a diverse range of bivalve shellfish is being successfully undertaken around the world, predominately with oysters, clams, and to lesser degree mussels and scallops.

Hatchery production strategies are greatly influenced by the environmental, and social-economic environment; for example USA hatcheries utilise large scale tank production of larvae and algae, with low energy costs *compared to* UK hatcheries which utilise compact, high intensity systems for both larvae and algae, adopting energy efficient water heating and reuse, due to their relatively high energy costs. Species and product diversification was a common strategy for risk management, and optimisation of capital investment.

Collaborative efforts between, Industry, Universities, Government and Public associations have been essential in the continued development and success of shellfish businesses, with particular focus on initial species development, resource access, disease diagnosis and

management, education and training, technological development, and selective breeding and genetic (polyploidy) programs.

There is an evident shortage of supply of aquaculture-produced shellfish across all the countries visited, particularly oysters. The factors driving this include:

1. wild 'spat' catch difficulties,
2. hatchery production difficulty relating to environmental change and disease,
3. mortality and disease within the grow out of the shellfish.

There also exists across most species an almost insatiable demand for shellfish; some of this follows on from the 'heritage' of shellfish consumption as an artefact of wild fisheries. It was often commented that marketing and sales of shellfish is still really a function of 'taking of orders'.

Recommendations

Blanket recommendations relating to technological advancement for Australian shellfish hatcheries are not possible as there are too many individual considerations on existing business structures, and the various technology adopted by shellfish hatcheries overseas is dependent upon their existing cost structures and environmental location, and risk mitigation strategies, such as:

1. Species and product diversification should be adopted by shellfish businesses to mitigate risks and optimise human and capital resources. Vertical integration was also successfully demonstrated, as was synergistic 'joint-venture' relationships between shellfish hatcheries/nurseries and grow-out producers sharing similar values and attitudes.
2. Australian Industry and Government should support coordination in the areas of disease diagnosis and management, education and training, technological development, and selective breeding and genetic (polyploidy) programs.
3. New species and product development also represent important opportunities, as does diversification into clams as a strategy to insure the industry against the threat of demise of a single species or product through disease or other misfortune.
4. Building strong on-going relationships with key staff, as they are the fundamental to business success.
5. Developing a network of international shellfish hatchery producers, providing for opportunities to interact, not just at the manager level, but also between technicians, encouraging discussion of issues influencing "success".

6. Recognising the advantages of using ‘Collective Intelligence’ between hatcheries where they collaborate to find solutions to common problems. Well executed this could improve the speed at which problems are overcome, and improve the use of available resources. The difficulty of adopting a culture of information sharing and collaboration between companies in resolving common problems can be countered by investigating the real competitive advantages of different hatcheries. These typically relate to the “operational” processes that are performed by staff, and relates to technical knowledge and skill of individual staff. Competitiveness results from the overall cost structures, attention to quality and species/product produced. This allows then for the collaboration on ‘bigger’ issues that influence all producers such as: disease, water quality and treatment, selective breeding, education and training, technological development i.e. water quality treatment and management, energy efficiencies in water heating/cooling, or LED technology for algae production.
7. Encouraging staff exchanges, secondments between national and international colleagues within the shellfish industry, where issues of direct competitive pressures are not significant.

Introduction

I openly confess that I have a shellfish aquaculture addiction, and hold a passion for all aspects of the industry. I enjoy being involved with the shellfish seed from its creation within the hatchery, to the day a crop is harvested, having nurtured and cared from them throughout their time on the farm.

I have immersed myself into the Australian shellfish industry since I started studying Aquaculture at the University of Tasmania. I've worked extensively within the industry with a variety of businesses and roles from a general farmhand and research technician through to manager/owner. I also have held roles in the broader industry such as Chairman of the Tasmanian Oyster Research Council, Oyster Tasmania – steering committee, representative to the Oyster Consortium – Seafood CRC, an Honorary Associate of the School of Aquaculture, University of Tasmania, and advocacy roles as Chairman of Circular Head Shellfish Growers, and Tasmanian Shellfish Executive Council.

I have a specialised interest/experience within the hatchery production of shellfish.

My work experience has allowed me to have a significant role in bringing efficiencies and trouble shooting problems for all the Tasmanian hatcheries, and establish good working relations with South Australian, Victorian, New South Wales, Queensland and New Zealand hatchery producers.

I have a full understanding of the complexities of establishing a new operation and some of the difficulties in reforming and adjusting existing businesses to existing and future challenges and opportunities.

I was working with the University of Tasmania on Australia's initial investigations into developing technologies such as triploidy and selective breeding programs, investigations of previously uncultured clam species, developing hatchery protocols (Spawning, settlement, and growth of the New Zealand venerid *Ruditapes largillierti* (Philippi 1849) in culture).

My most recent challenge was developing the cultivation of mussels through the hatchery and nursery in commercial quantities, developing processes and technology that provides for reliable and efficient production outcomes. Spring Bay Seafoods Pty. Ltd. provided me with the opportunity as hatchery manager to do this by letting me design, build and then operate a new hatchery specifically for this task.

It was during this process that I recognised that there is still much to learn, not just with the technology, but also with the overall business philosophy. Factors not unique to a shellfish business, and common amongst other primary producers factors such as; vertical integration, risk mitigation, scale of operation, diversification, product development, research and training, future growth and cost of operations and profitability. All this sits alongside the governmental and social environment, further increasing the complexity. A global perspective, as offered through undertaking a Nuffield Scholarship, was what was needed.

Having worked with and visited all the major shellfish hatchery producers within Australia, I recognised that there is a gap in the knowledge and processes in bringing the shellfish from the hatchery through to the nursery, delivering them to the grow-out farmers. Efficiency gains in this area, I believe, will strengthen the overall industry by providing for enhanced production at a lower cost, and improve continuity of supply. This then allows hatcheries to further investigate and support the cultivation of new species, allowing for species/product diversity for existing and new producers into the future.

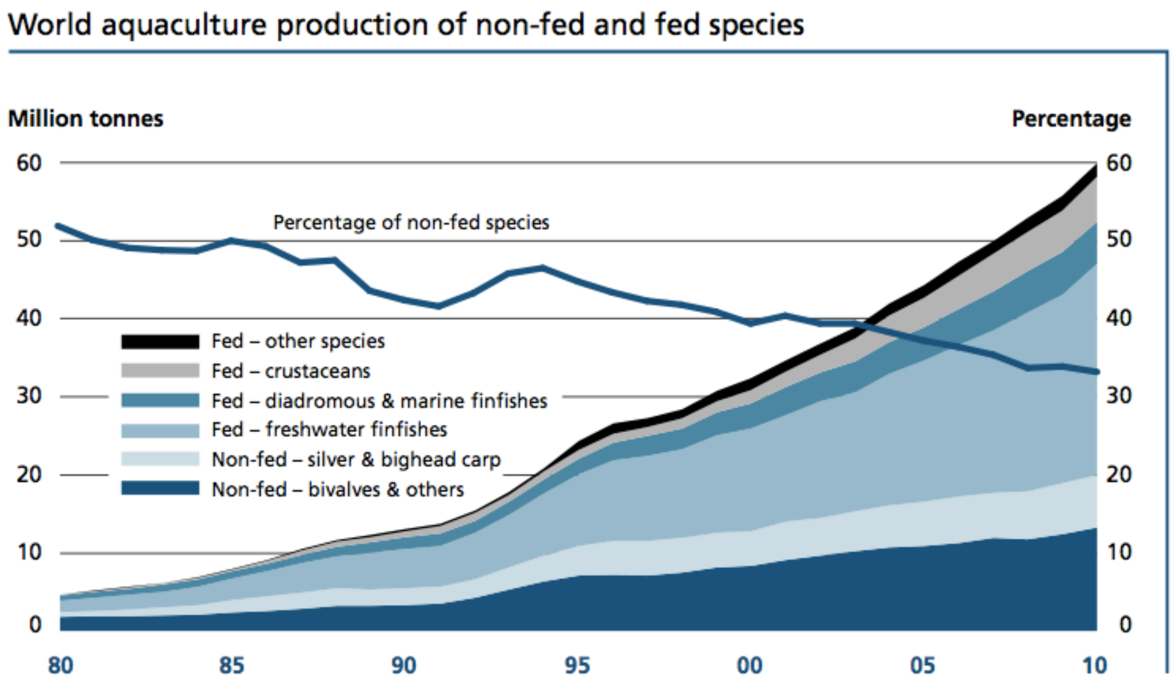
Traditional means of investigation, such as research papers, trade journals, and more recent methods such as use of the Internet and 'YouTube' were all investigated, but the best way to really see what is happening is to get out there and visit people, building the relationships and opening discussions into factors influencing successful shellfish production.

I travelled extensively during this Nuffield scholarship, visiting eleven countries specifically to investigate shellfish aquaculture. These included; United States of America, Norway, Sweden, Portugal, Spain, New Zealand, Canada, France, Guernsey, England and Scotland.

How to report or organize what was observed during this tour is a difficult challenge, there was so much across such a broad sweep of the industry. People were generally very open and sharing at the personal level, but held some concerns as to how widely distributed the information and discussions we held would be. This leaves me with a responsibility to 'generalize' some of the findings of this tour.

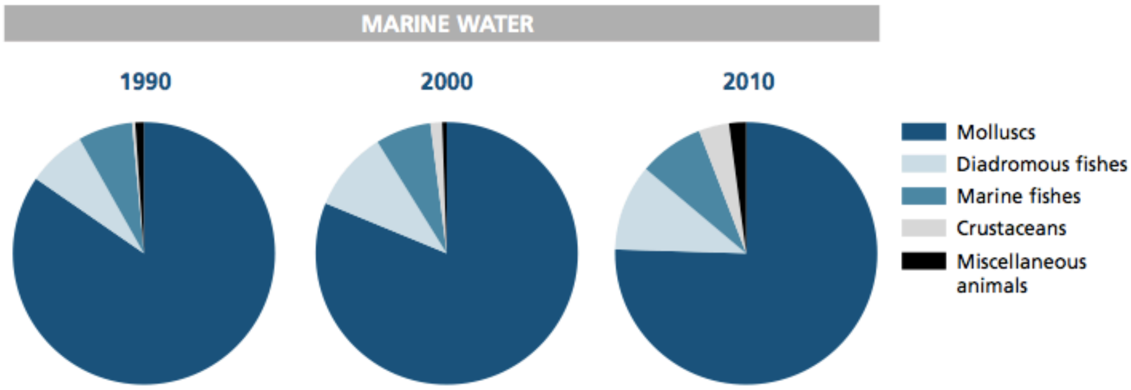
Chapter One
Global Aquaculture –Shellfish (bivalve) Production.

The Food and Agriculture Organisation of the United Nations (FAO) reports that global aquaculture production has continued to grow in the new millennium. Aquaculture has developed rapidly over the last half century or so, now reaching production comparable with capture production in terms of feeding the worlds population. Aquaculture has continued to evolve in terms of technological innovation and adoption to meet changing requirements. World aquaculture reached an all time high in 2010, with 60 million tonnes of edible production, valued at US$119 Billion. One-third of this was achieved without the use of supplementary feeding, through the production of bivalves and filter feeding carps.

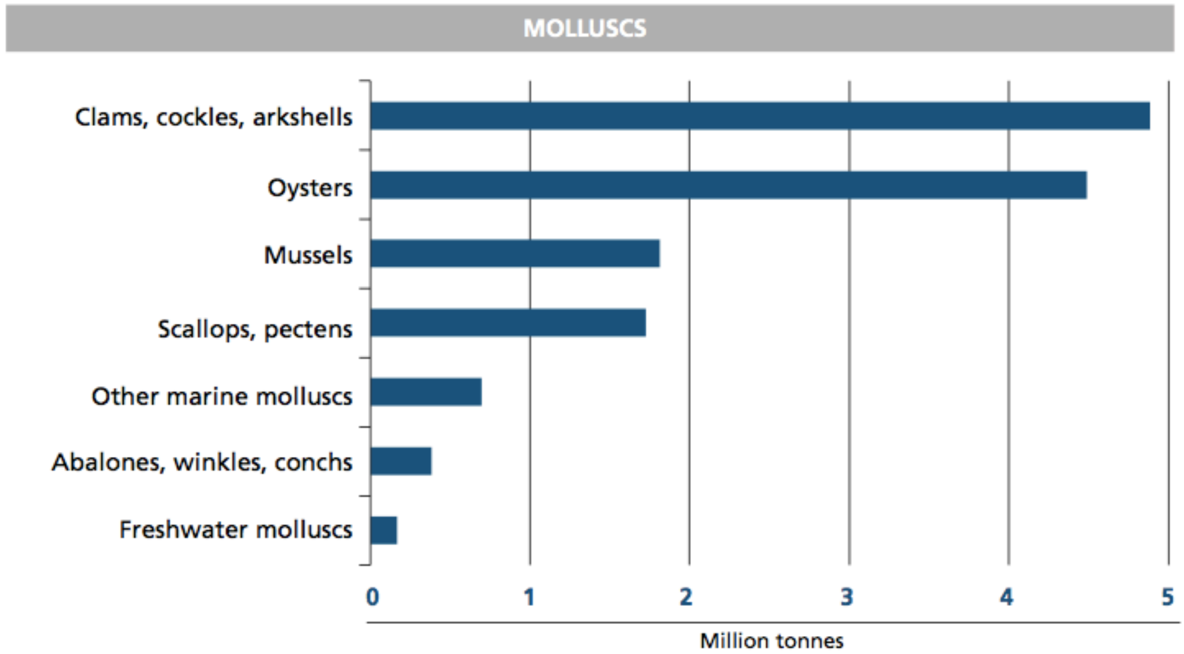


Source: FAO (2012)

Marine molluscs account for 13.9 million tonnes, or 75.5% of marine aquaculture production, although this has declined from 84.5% in 1990, and this is a reflection of the rapid growth in finfish culture in marine waters, which is growing at 9.3% per annum. Bivalve production is still growing at respectable rate of 5% per annum. Production of clams has increased much faster than that of other species groups. In 1990, clam production was half that of oysters, however by 2008 it had exceeded oysters and now represents the most produced species group of molluscs.



Source: FAO (2012)



Source: *FAO (2012)*

A significant part of the global production of marine molluscs, particularly in Europe and America, relies on the widely introduced Manila clam (*Ruditapes philippinarum*) and Pacific oyster (*Crassostrea gigas)*. China also produces large quantities of the Pacific oyster and the Atlantic bay scallop (*Argopecten irradians)* and Yesso scallop (*Patinopecten yessoensis)*.

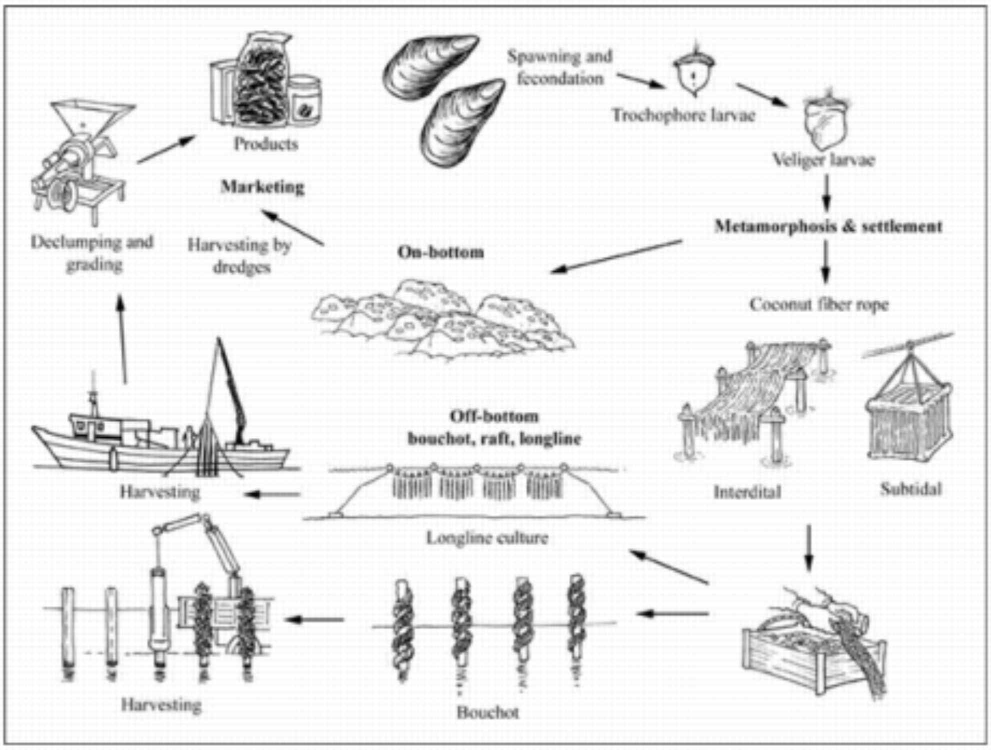
The FAO also reports that over the last five decades, world food fish supply has outpaced global population growth, and today fish constitutes an important source of nutritious food and animal protein for much of the world's population. In addition, the sector provides livelihoods and income, both directly and indirectly, for a significant share of the world's population. In fact, in the last five years for which data are available, the number of people engaged in fish farming has increased at 5.5 percent per year. This growth is faster than the

0.5% growth in employment that is seen in traditional agriculture.

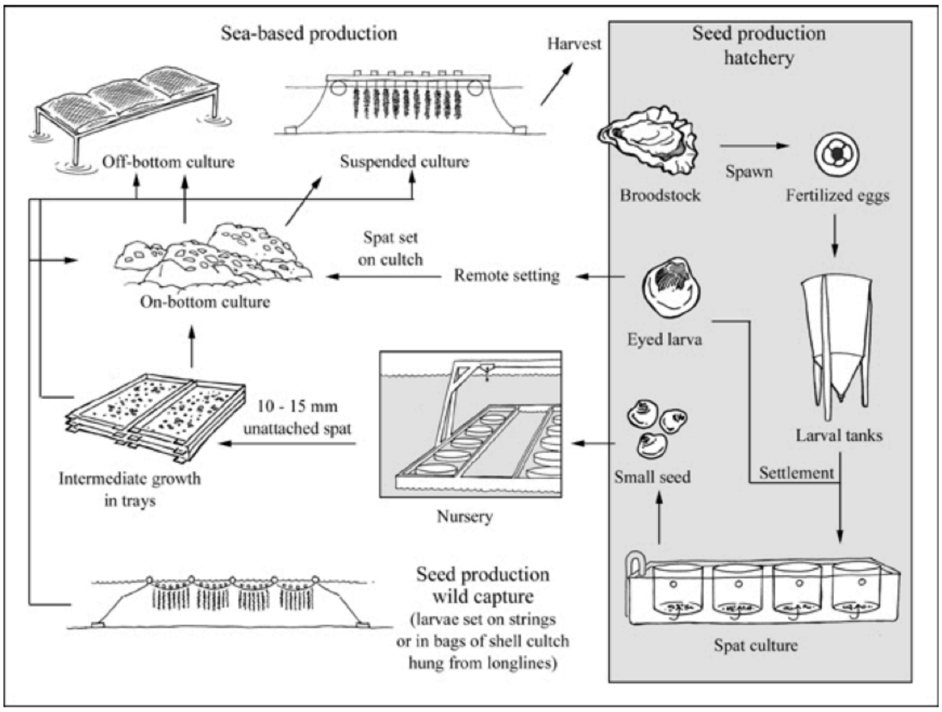
Aquaculture production keeps on expanding, with the FAO predicting it to remain one of the fastest-growing animal food-producing sectors into the next decade. A growing global population with finite natural resources, facing the continuing economic and environmental challenges will be well served by the aquaculture production of bivalve shellfish. Bivalves do not require feeding, as they filter algae and other material from the natural environment, providing the opportunity for an on-going sustainable way of providing sustenance into the future. Hatchery production of the ‘spat’ will continue to have an increasing importance to securing this opportunity to feed the world.

Chapter 2
Life Cycle of Bivalve Shellfish.

The life cycles of bivalve shellfish are remarkably similar. Generally the sexes are separate and sexual maturity is attained at a range of sizes from 20mm for clams through to 40-50mm for oysters and mussels. In the spring, as the water temperatures begin to increase, the gonads of the male and females begin to ripen. Spring typically brings increased phytoplankton levels which helps with the production of gametes. The temperature increase also stimulates the conversion of 'fat' or body reserves into gamete production. Once the individual shellfish are ripe, some stimulus, often a rapid change in temperature, but also increased quantities of phytoplankton, or current flow, will trigger a spawning. Eggs and sperm are released into the water where fertilisation occurs. Other individuals are often triggered to also spawn through the presence of gametes that have been released. The fertilised eggs develop into straight-hinge, free swimming larvae within 24 hours, which have two half shells. The typical size is between 70-90 micron shell length. These larvae are sometimes referred to as 'veligers' because they have an organ called a velum, and this lets them swim, feed and 'breath'. The larval stage typically last between 2-3 weeks, and the larvae grow to a shell length between 200-350 micron. At this point they are referred to as 'pedi-veligers' or 'eyed' larvae, because they have developed an 'eye-spot', and a 'foot' in addition to the velum. This allows them to both swim and crawl, with their foot looking for a suitable location to 'settle', or attach. At this point the strategies between oysters and clams/mussels/scallops differ. Oysters will 'cement' or adhere themselves permanently to a single place, undergoing metamorphosis, and developing gills and losing the function of both the velum and the foot, thus starting a sedentary life. Clams, mussels and scallops typically do not 'cement' themselves, but attach to a suitable substrate using 'byssal threads'. They then undergo metamorphosis, also developing gills for the function of feeding and respiration, losing the velum. However, they keep the foot, and often retain the capacity to break the byssal attachment, crawl or 'pedal-drift' and reattach themselves to a different position. Mussels though keep the byssal threads to adulthood, but often clams and scallops lose this function as they grow into juveniles.

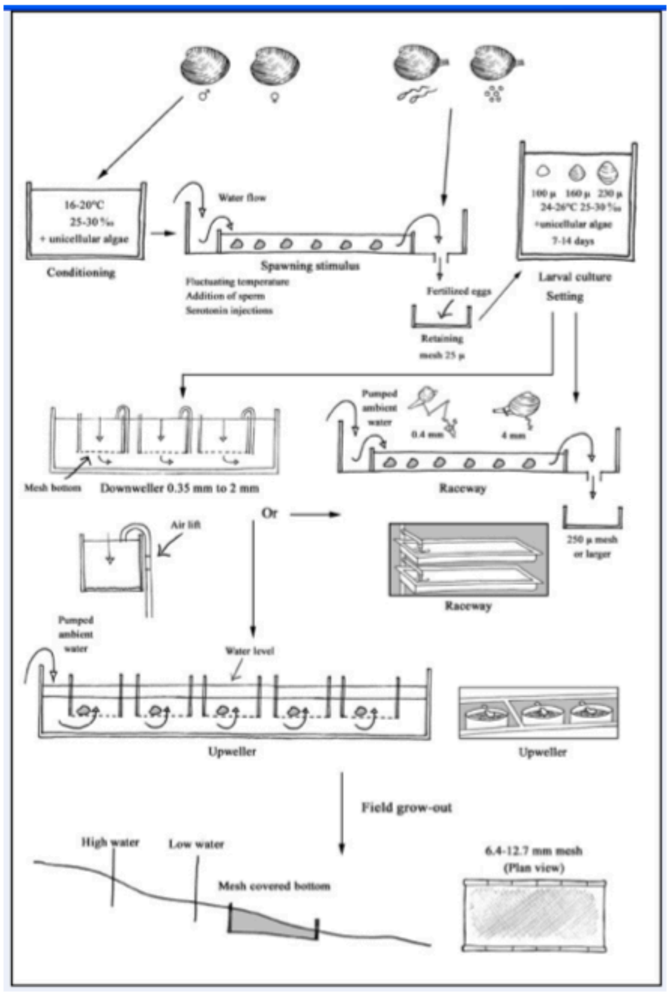


Generalisation of the Production Cycle of Mussels (FAO-website)



Production cycle of Crassostrea gigas

Generalisation of the Production Cycle of Oysters (FAO-website)



Production cycle of Mercenaria mercenaria

Generalisation of the Production Cycle of Clams (FAO-website)

Chapter 3
The Advent of Hatchery Propagation of Shellfish.

Aquaculture of bivalve shellfish developed through the manipulation of 'wild' caught spat. Moving shellfish from areas of high recruitment, and thinning out to improve growth and returns. This progressed to enhancing stock numbers by catching spat with additional substrate, initially being rocks, branches and bamboo following the natural larvae life cycle within the natural environment. This evolved into a variety of different substrate types, both natural and artificial, e.g. 'shucked' oyster shells for oysters & polypropylene ropes for mussels.

Shellfish hatchery methods have evolved significantly from the first report of successful artificial oyster spawning occurring in 1879 when Brook produced "free-swimming" oyster larvae by stripping eggs and sperm from ripe adult oysters. Attempts to grow other shellfish larvae continued, however W.F. Wells reported having successfully reared and set oysters in 1920.

The 1960s saw the development of shellfish hatcheries across Europe and the United States, pioneering the technology necessary to grow a variety of species. Knowledge of the biological requirements and technological capacity has continued to develop, with intensive production strategies being developed within purpose built hatchery and nursery facilities to support the sea-based growout.

The typical shellfish hatchery has five main components.

1. Broodstock are essential as this is the basis for all production, and are typically selected to exhibit traits that producers want to see in cultivated stock, i.e. growth, disease resistance, quality –shape, colour.
2. Larvae form the production centre of the hatchery where the shellfish are allowed to develop through their 'free-swimming' stage.
3. Settlement is a critical stage where the shellfish undergo metamorphosis and become spat, no longer free swimming.
4. Nursery is the stage where the spat are on-grown in preparation for transfer to the growout production stages.

5. Algae production underpins the entire production process delivering ‘food’ for all of the above stages.

The United States and Canada have adopted an alternative production approach to the fully integrated five stages of the hatchery process, with their oyster production. Given the scale of their production and a transition from a ‘wild’ catch farming model, they developed a process called ‘Remote Setting’ to replace the unreliable and costly collection of natural spat. This effectively married the advance hatchery production process to the existing substrate based farming systems. Jones & Jones (1988) report that Bill Budge of Pacific Mariculture did the first commercial transfer of eyed oyster larvae in the early 1970s. They were producing their larvae at Pigeon Point, California and moving them in buckets of seawater to their setting facility at Moss Landing, California. The method didn't come into widespread practice until 1978 when Lee Hanson built the Whiskey Creek Oyster Hatchery near Tillamook, Oregon, exclusively for the production of larvae for remote setting operations.

The remote setting process, as the name suggests, has the settlement occur away from the hatchery. The eyed larvae are shipped out of water in chilled moist packaging, and then added to cultch at a site remote from the hatchery, where they settle. This has allowed the centralisation of hatcheries, shipping billions of larvae around the country without the expense and risk of moving vast quantities of cultch also. Gordon and Bruce Jones (1988) provide a thorough account of the background and process in their publication, *“Remote Setting of Oyster Larvae”*.

The alternative strategy to remote setting is setting onto cultch at the hatchery, or production of ‘single-seed’ which involves settlement onto ‘micro-cultch’, very finely ground shell, of the same approximate size as the settling larvae, or using induction techniques that enable metamorphosis without the oysters attaching to a substrate. Single seed can also be produced using a substrate and then once spat being detached from the cultch, i.e. plastic slats, French tubes.

Shellfish hatcheries are effectively trying to manage biological processes, such as the husbandry of the selected species through development from egg to spat, and also the culturing of the microalgae to provide sustenance through this process. Finding the balance that meets these biological considerations while still meeting economic business requirements can be challenging.

Multiple variables need to be managed with many people referring to operating a successful hatchery as being as much about the *art* of running a hatchery as the *science*. The facilities visited demonstrated this with some being run as much by '*feel*' as by *science*, I am of the opinion that the more we discover about the factors influencing success within the production of shellfish spat, the more we can take a '*recipe book'* or scientific approach. Relying less on the *'art'* of producing shellfish spat. However, the issue still remains that, like traditional farming, it will always require a certain tenacity and resilience to really excel.

Chapter 4
Broodstock.

Broodstock are the animals from which gametes are produced, and are the start of the shellfish hatchery process. The facilities visited had a variety of strategies to ensure sufficient good quality broodstock were available across the range of species being grown.

Typically broodstock conditioning is required to extend the availability and ensure the best quality gametes are available for the hatchery production process. This often involves the temperature manipulation of the seawater to either bring on early maturation, or hold condition or development, so it can be delayed, and managed to match production scheduling. In addition to temperature control, supplemental feeding utilising a mixed microalgae diet is also undertaken.

The strategies adopted by facilities visited weren't significantly different to Australian practice. There are a number of factors that influence these strategies that may have an influence on the future production of shellfish at Australian hatcheries. These include disease screening, and establishment of quarantine facilities, allowing broodstock to be brought onto site from field sites, or farms where a variety of diseases maybe present or suspected of being present. These quarantine facilities allow stock to have initial conditioning undertaken, while they are screened or examined for a variety of applicable diseases. Horn Point Hatchery, IFREMER, ABC @ VIMS, and Hatfield Marine Science Centre are all good examples of 'public' agencies that had these facilities.

The quarantine broodstock facilities typically had a level of physical separation between themselves and production areas. This was reinforced with appropriate physical and biological security measures that extended from restricted access and signage through to disposable overalls, boot/shoe covers, footbaths, cleaning/disinfection stations. The water and material exiting the facilities underwent a variety of treatments dependant upon the assessed risk, and included water treatment with chlorination/de-chlorination, UV, ozone and in some circumstances this water and material was then collected and removed to secured landfill sites, i.e. pumped out much the same as a septic pit.

Beyond quarantine, careful consideration was also necessary with regards to the location that broodstock were collected from, particularly where the shellfish were indigenous species, necessitating an awareness of the risks of influencing the genetic 'pool' by introducing genetics from animals from a different geographical region. The American Oyster (*Crassostrea virginica*) grown in the Chesapeake area also exhibits a geographical variation of stock to adapt to low salinity or disease. This species is also the target of natural rehabilitation for environmental and conservation purposes, so management of genetic diversity is important and catering for this within the broodstock systems is critical.

The fecundity of the cultured shellfish species also influences the infrastructure and management of the broodstock systems necessary to meet production targets. The American Oyster along with the issues discussed above has a relatively low level of fecundity, particularly when compared with the Pacific Oyster. This impacts the resources, both physical and in terms of general husbandry and food production. Mussels have a similar issue with low fecundity, and a common strategy is to adapt the scale of hatchery production to optimise the natural availability of ‘farm’ conditioned broodstock. The intensive production of microalgae and infrastructure requirements necessary for managing temperature required to condition the Blue Mussel (*Mytilus edulis*) was found by the European project Blue Seed to make broodstock conditioning un-economic, and threatened the economic viability of hatchery production of this species. The New Zealand mussel industry growing the Greenshell (*Perna canaliculus*) is still predominately wild caught spat. However, investigations into the hatchery production of this species have identified the same difficulties relating to low fecundity, and the impact this has on the economic production of Greenshell within the hatchery and the subsequent ability to adopt selective breeding and triploid production. The approach they have taken is to use seawater ponds to culture a ‘natural’ mix of microalgae and use this to feed their mussel broodstock.

Chapter 5
Larvae Production – Technology.

Larvae production and the technologies surrounding it focus on providing for the requirements of the free-swimming life stage of shellfish. Maintaining water quality that matches the requirement of the species being grown is essential, and this is usually addressed when first selecting a suitable site for the hatchery, with water available that has the appropriate salinity, and is free of 'toxic' compounds, such as heavy metals. The temperature, dissolved oxygen, clarity, microbiological and general physical parameters can all be manipulated within a hatchery. The level of 'control' or manipulation depends upon the site selected, the species being cultured and the resultant economics.

Water Filtration:

Shellfish hatcheries typically undertake physical filtration of the water being used for larvae culture to remove sediments, algae, and other invertebrates. The hatcheries visited used a variety of physical filtration systems, from sand wells, sand and multi-media filters, disc filters, filter screens, filter bags and cartridges. One hatchery even used shellfish themselves in combination with a 'biological' substrate filter. They first collected water that had passed through juvenile shellfish, effectively 'cleaning' the water of almost all sediment and algae etc. before running it through the biological filter, then stored this water and used it for larvae culture.

Sand filters were commonly used but there was a growing awareness of the issues of using this style filter, with great care required to maintain their effective operation and avoid build up of detritus, with both bacterial and biological consequences, such as dissolved oxygen drops, fluctuations in pH and microbiological population growth and species alteration. Cartridge filters were also used extensively by some of the public facilities, although the on-going cost of replacement and labour for management of these was recognised as being considerable.

Temperature Control:

Typically larvae water is heated to the ambient temperature. The hatcheries in the USA had been operating in an environment of low energy costs, with water heating for larvae culture consisting of diesel and propane boilers, and the occasional electric heater. Following escalating fuel costs, (still low compared to other nations, i.e. less than $1/L diesel *vs.* $2/L for diesel in the UK) the trend is to adopt heat recovery technology, and investigate the use of electric heat/chill style systems. This need to heat the water and the implications of the cost of power is driving the adoption of heat recovery technology that has been long practiced in the UK, and Australia. The water that has been heated and then used for larval production is captured and directed through titanium heat exchangers, with new 'incoming' water being pre-heated as it runs counter-current to the out-going water. The adoption of this heat recovery has also lead to a change in the management of larvae rearing tanks (LRTs).

Typically LRTs were static batch-culture tanks, with seawater and larvae contained. The volumes in the USA started around 10,000L and went up to 50,000L. The larvae were grown at relatively low densities, with between 0.5-1 larvae/mL at settlement. The water would usually be changed every second or third day, and the larvae captured on an appropriately sized mesh screen. This compared with European practice, where a similar static batch approach was taken, but with much smaller tanks of 100-500L, usually kept within a temperature-controlled room. This static, batch-culture method of growing larvae does not optimise the opportunity to capture the heating already put into the larvae, with tanks needing to be drained at the same time as new tanks are filled, just adding to the complexity of the process, juggling tanks.

The solution to this was to adopt a continuous flow larvae production system, and this followed the development of 'High Density' systems by John Bayes of Seasalter Shellfish, with densities of greater than 130 larvae/ml at settlement possible, in LRTs of 200L. Hybrid systems have now been developed ranging in volume from 200-50,000L, with the bigger volume LRTs still keeping a relatively low density, around five larvae/ml at settlement. The advantage with regards to heat recovery has been achieved, in addition the duration between draining tanks has also been extended. This development significantly affects the two greatest costs associated with a hatchery: labour and power, making savings on both of these.

Feeding strategies across North America and Europe were consistent with the concept of 'feeding the water', that is maintaining an algae cell density within the culture water. This was typically around 20-80 cells/μl. The maintenance of this feed level was adjusted by some facilities dependent upon the age and stage of development, with the 'green-thumb' approach being just looking into the tank. Other places used more sophisticated electronic equipment from a 'fluro-meter' through to coulter counters and similar particle size analysis equipment. Manual inspection and adjustment was common, although there is ongoing development of automated systems, working on a feedback from the sensor and using computer programing to then determine and deliver the required amount of algae culture to the larvae.

This strategy of ‘feeding the water’ is very different to the commonly adopted ‘feed charts’ that Australian hatcheries use. These were developed following numerous replicated larvae cultures, with the number of algae cells being delivered to LRTs being carefully measured. This along with the size and number of larvae being cultured allowed the larvae consumption of algae cells to be determined following assessment of remaining ‘un-eaten’ algae. This is typically used by Australian hatchery producers to predict the consumption and required feeding of algae to larvae, and is used in conjunction with microscopic inspection of the ‘residual’ algae density, and condition of the larvae. This understanding of consumption when used properly provides the Australian hatcheries with a greater control of the larvae conditions, optimising growth and survival.

A common opinion offered was that mussels consume more algae than oysters. Having undertaken the studies necessary to prepare these feeding guides, it is apparent that oysters actually consume 33% more algae than mussels at settlement, and that the assumption that mussels eat more is based around them being grown at a greater density within the larvae tanks, which results in more mussels/LRT. Having a greater understanding of the specific larvae requirements is an advantage: determining the feeding strategies and requirements of species grown overseas requires interpretation the data available, such as number of larvae, and amount of algae feed and it density.

The grading and handling of larvae followed a similar process to that employed in Australia. However, handling at the larger hatcheries puts a greater focus on the efficiency of handling larvae, using volumes and weights of larvae rather than enumeration through counts. The handling of large numbers of larvae and managing numerous big LRTs has lead to the use of the refrigerator as a means to store larvae. This ability to refrigerate larvae for extended periods is the basis on which the eyed larvae oyster market is based. Mussels and clams can also be handled in a similar way.

Sue Cudd (owner) inspecting her large static larvae tanks at the Whiskey Creek Shellfish Hatchery in Oregon, USA.

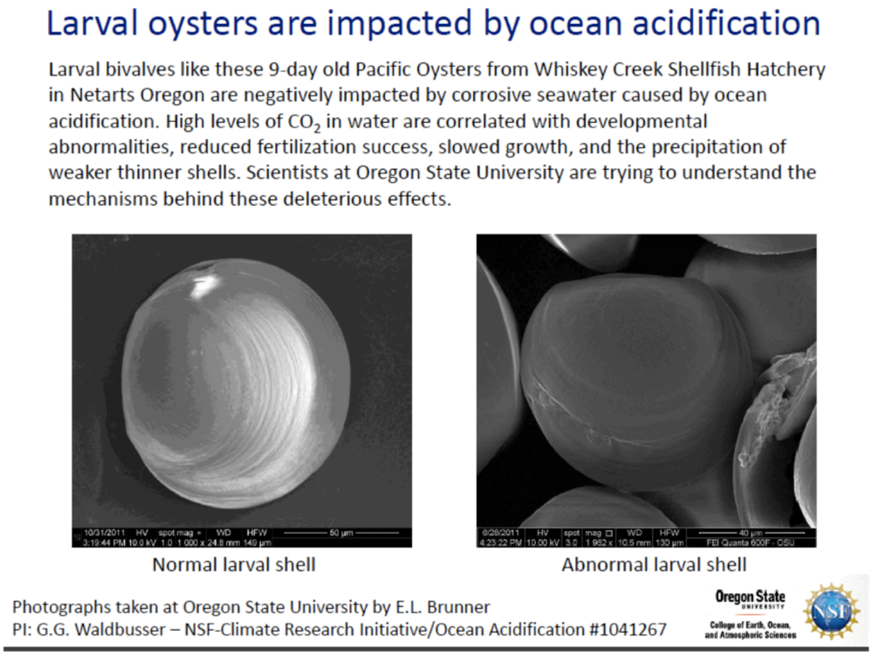
Small Larval rearing tanks – continuous flow.

Water Quality:

Water quality for larval rearing normally means having the right salinity, clear seawater low in bacterial concentration with few or no *Vibrio* sp. (this genus contains a number of pathogenic species). This is not the whole story anymore. The carbon chemistry, and pH of the water has been identified by a number of shellfish hatcheries on the west coast of the USA to be critical to successful larvae production. Hatcheries that had 30 years of continuous reliable production, with some seasonal variability, with consistency of process and management derived through continuity of the same staff, are now finding that production is severely impacted by these changes in water chemistry. Production was reduced to 25% of normal levels, and given they supplied 75% of independent growers, this was significant to the whole industry. Other hatcheries, experiencing this same problem, responded by doubling larval capacity allowing them to *almost* maintain regular production. 'Wild' settlement of oysters in Willipa Bay, a major source of cultch oysters has also been significantly affected. This change in carbon concentration and resultant lower pH has dramatic consequences for 'hatching' and early larvae, with stunted growth occurring and an inability to complete the free-swimming larval stage. This alteration in carbon chemistry and 'acidification' of the seawater occurs in conjunction with 'hypoxia', which is brought about by low dissolved oxygen concentration, and high organic loads of a process known as "upwelling." The fate of shellfish larvae and those trying to grow them is grim, when these conditions prevail.

While investigating these problems a variety of other water treatment processes were investigated to improve water quality for larvae, including foam fractionation, carbon filtration, and biological filters. The management of this problem has required real-time monitoring of the parameters that influence larval production success; these extend beyond just the water quality, to the weather patterns and wind conditions that influence the upwelling events. Treatment of water by 'buffering' the seawater and allowing the pH to increase has been successful to some degree, but to get full availability of the appropriate pCO_2 and available calcium carbonate can take a number of days post-treatment.

The experience of the West Coast USA shellfish hatcheries demonstrates that securing 'good' water quality has become more difficult, and that continued effort will be necessary to understand the growing complexity of the environment in which the hatcheries operate. Some parameters are much easier to understand and respond to, with one facility going as far as to manipulate the salinity of the water, as their production had been impacted by extended flooding, and low salinity. (Appendix 2: Ocean Acidification and Ocean Upwelling, provides further information.)



Larval Oysters are impacted by Ocean Acidification – Alan Barton, Whiskey Creek Shellfish

Settlement:

The settlement technology identified during this study tour can be separated into two general categories.

The first category represents an extension of 'natural' settlement, where the shellfish are allowed to attach to a substrate, such as cultch in the case of oysters, or rope/mesh/natural fibres for mussels.

The second methodology aims to provide for 'single-seed', and typically takes the form of using a *downweller* with shellfish retained upon a screen, and seawater directed down through the shellfish and mesh. This may also have 'micro-cultch' in the case of oysters to encourage a single-seed. This process was also being used for clams and scallops.

The recovery percentage of eyed larvae to 'spat' varied from about 12.5% through to 80% dependent upon the species and the technology being employed.

The use of *epinephrine* as a settlement inducer for single-seed oysters wasn't widespread, which was surprising, given the efficiency gains this provides. The facilities that were using this had a clear efficiency and production advantage, with lower labour requirements, and lower capital infrastructure requirements. They also experienced greater returns from eyed larvae through to spat, with up to six times greater returns. This has significant implications for operating costs and production outputs, requiring significantly less larvae and algae to be produced to reach the same objectives.

Cultch settlement processes are typically quite simple in concept, but were being undertaken on an industrial scale. The typical cultch settlement system consists of a tank suitable to hold seawater. This may have supplemental heating to manage water temperatures. These tanks are usually established outdoors in close proximity to the seawater source. The cultch, whether it is shell or rope/mesh, is stacked or hung in the tanks. Oyster or clam shells are usually held in a mesh bag, similar to an open weave 'onion' bag, or stacked in purpose-built handling frames. These tanks have aeration installed, and the capacity for flow-through seawater.

Algae paste is often used for supplemental feeding, removing the need for the remote setting operator to also grow microalgae. Some operators had sites with sufficient natural levels of microalgae, so that no supplementary feeding was necessary though the settlement stage. "*Remote Setting of Oyster Larvae*" by Gordon and Bruce Jones is a thorough review of the process of remote settlement and available from their website *(www.InnovativeAqua.com)*.

The recognition that cultch settlement systems represent a materials handling challenge was clear with the examples provided by the producers of oysters. They had developed sophisticated shell collection and cleaning systems, and then bagging/framing operations, that provided for a quicker turn around of the raw material (oyster shells), and automated cleaning and sorting processes reducing the number of people that are involved in this operation. The bulk handling of the shell post-settlement also saw innovations at some facilities with reusable frames being adopted, which removed the requirement for shell to be bagged into plastic mesh bags, and then the subsequent manual handling in moving this around, and final deployment of this onto the growing fields.

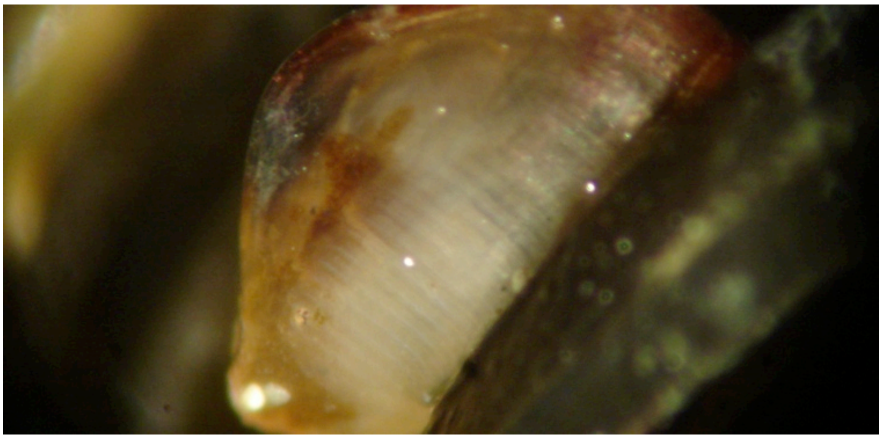
The deployment of this settled shell onto growing fields had a number of facilities demonstrating innovation in handling practices. Barges were loaded with settled cultch, and this was then distributed over the growing area using water jets from deck hoses. One facility went so far as to incorporate their settlement tanks into a refurbished dredging barge, which enabled them to reduce the post-settlement handling, and simply ‘steam’ out to the growing fields, and open the floor of the barge, distributing the settled cultch.

The adoption of remote setting and supply of eyed larvae is a significant difference between the US oyster industry and that in Australia. This is partly because of the diversification of product that the American market caters for, with both an oyster meat market and a half shell market. This contrasts with the Australian industry, where oyster meats are not produced, except in some circumstances, within the Sydney Rock industry, with oyster meats being produced as a result of misshaped ‘stick’ cultured oysters not suitable for the half shell market.

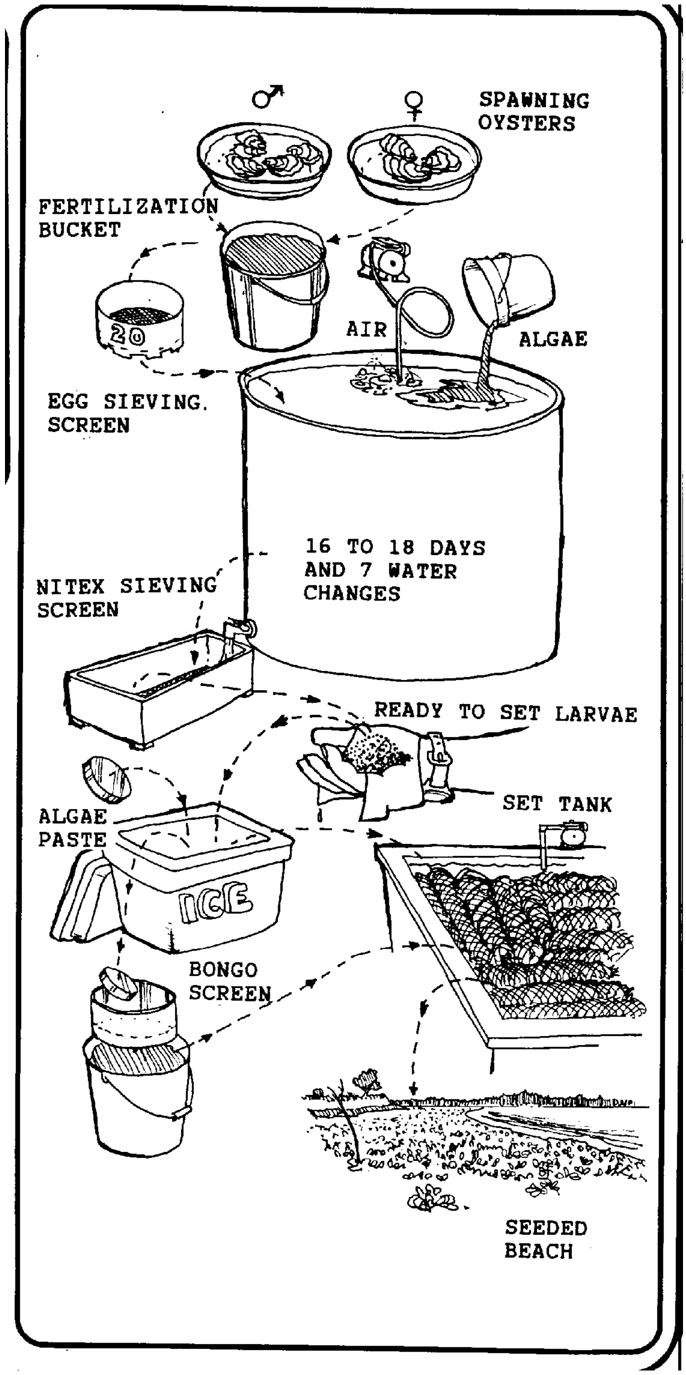
Eyed larvae were being supplied to growers directly for settlement onto cultch by the oyster growers, and to specialist growers that would also produce single seed oysters to then on sell.

Eyed Larvae of Crassostrea virginica – Horn Point Hatchery (website)

Mussel Spat settled on rope



Mussel Spat – Mytilus galloprovincialis



A simple view of hatchery operation and general systems flow for eyed larvae & cultch settlement (Jones & Jones, 1988).

Eyed Oyster Larvae being distributed onto ‘cultch’ – Horn Point Hatchery (website)

Oysters settled onto ‘Cultch’ & Single Seed Oysters

Single Seed Clam Spat - grown in upweller.

Chapter 6
Nursery Production - Technology.

The Nursery is the stage where the spat are on-grown, in preparation for transfer to the growout production stages. The process for both oysters and clams typically consists of shellfish retained within a container with a mesh base, and seawater flowing up through the container. These containers are described as ‘upwellers’, ‘pots’ and ‘bins’. Some facilities also had containers with seawater that flows up through the vessel, but the shellfish weren’t retained by a mesh screen, and the inflow had a ‘marble’ or ‘ball’ acting as a stopper on the entry orifice, with the shellfish typically being ‘fluidised’ but the ‘marble’ rolling back over the water inlet and retaining the shellfish if the water inflow stopped. This system was typically referred to as a ‘bottle’ system. Mussels and scallops can also be grown in upwellers, but were typically grown either on a substrate such as mesh or rope in the case of mussels, or attached to the bottom of tanks called ‘raceways’ (in the case of scallops) where the seawater is directed across the top of the shellfish.

Supplementing the natural seawater with microalgae was practised by some facilities, and the temperature of the water was also managed. Heating was achieved through a variety of means from propane, diesel, solar and electric, both direct and ‘heat-pump’. Heat recovery technology was being incorporated into the systems. Production timing was also managed to reduce the change in water temperature, with some facilities simply using the natural seawater, either directly from the ‘sea’ or on some occasions from ‘sand wells’. The seawater from the sand wells didn’t have supplementary algae, but did provide a consistent temperature which was not always available when drawing water direct from the sea.

The nursery stage of shellfish production oversees a rapid increase in biomass, and the shellfish typically require regular handling to maintain good husbandry conditions, to keep the shellfish free of fouling of the shell, and also (in the case of oysters) to help manage the shape of the shell. Grading is also an important consideration to maintain comparative size classes. Even though shellfish do not interact the same way that other, more mobile animals (such as fish) might, where the larger fish might ‘bully’ the smaller ones and therefore have a dominate relationship to the smaller sized fish, effectively stunting them through depriving them of food. The situation with shellfish is that the large shellfish can filter a greater amount of seawater, effectively getting a greater take of the available food, and this is further influenced by the larger shellfish having a greater density than the small shellfish. This enables them to 'sit' lower in the upwellers, nearer the 'new' water. This is clearly demonstrated when the shellfish are fluidised and there is a clear distinction visible between the various size classes.

This requirement to handle the shellfish for both general husbandry, cleaning and for grading influences the style of nursery technology adopted. The facilities visited all adopted a nursery system that utilised upwellers throughout the nursery stage, taking advantage of the handling advantages this technology offers over the enclosed 'sea-trays' which are used predominately within Australia.

The factors influencing successful upweller nursery systems relate to three main points;

1. Ease of handling
2. Availability of food
3. Costs of pumping

The upwellers varied in size from containers carrying 500 grams of shellfish through to 250 kg. The handling also varying according to the scale of the unit utilised from simply manual lifting to use of gantry systems and cranes.

The availability of food to the shellfish is influenced by the concentration of algae within the water, and the flow of that water through the shellfish. Accordingly, if the algae density in the water is low, this can be countered somewhat by increasing the flow of seawater, thereby delivering more algae. Siting the nursery at locations with good natural microalgae production capacity was well practised. A number of facilities also undertook to grow, or enhance the available algae by providing for enclosures such as ponds that retained the seawater. This was also done in order to manage the risk of disease from the broader environment.

The costs of pumping water, and the availability nursery facilities were also addressed by the adoption of FLUPSY's (Floating Upweller Systems) by many operators. The advantage of these units is that they have little of no frictional head loss associated with delivering the seawater up through the shellfish. The variety of types ranged from small floating dock styles, which were operated by solar powered 'de-icing' impeller motors. These were operated by growers purchasing small, single seed spat, from hatcheries through to large industrial FLUPSYs that had paddlewheels moving over 30,000 L/min with around 1 hp motors. These large units were being utilised by hatcheries or large growers that may also supply juvenile stock to other producers.

The alternatives to these FLUPSY's were shore-based upweller nurseries and the pumping of water was achieved via 'pool' pumps in small systems, with 500 L/minute through to axial flow pumps that lift 30,000 L/minute for around 5 kWh (KiloWatt Hours) of energy.

Guernsey Sea Farms – FLUPSY and hatchery (Aerial Photo – GSF website) – Oysters & FLUPSY in background.

Shore Based Upwellers, Crassostrea virginica - Mike Consgrove – Oyster Seed Holdings

Chapter 7
Algae Production - Technology.

Algae production is important as it underpins the shellfish production process providing the food required by the shellfish at all stages from the broodstock and larval rearing through to settlement and spat within the nursery stage.

The production of microalgae to support the culture of shellfish is an essential part of the hatchery process and it represents a significant cost. Infrastructure requirements for algae production can be substantial and operating costs can represent as much as 33% of the hatcheries production costs.

The composition of algae species was similar across all facilities. Axenic cultures aren't readily available to support industry with difficulty in getting quality stocks, some arriving with both bacteria and even ciliates.

The management priority for starter cultures varied across facilities with some employing laminar flow cabinets and axenic transfer procedures. Many simply applied 'clean' transfer methodology on bench tops, over heat. The quality control procedures with respect to microbiological monitoring of transferred stocks were generally lacking, and at a number of facilities were only something that was undertaken if a problem was suspected.

Starter cultures from test-tube and small flasks were typically autoclaved, with some using microwaves. Culture vessels from 10 L and greater often relied on chlorination/de-chlorination procedures, with some facilities utilising UV lights, or pasteurisation.

The utilisation of batch culture algae production was common, varying in vessel type and volume from carboys of 20L through to plastic bags at 200-500L through to 16,000 – 125,000L fibreglass or concrete tanks. This production process typically delivers lower density algae concentration, (1,500 cells/μL *vs*. 3,000 – 20,000 cells/μL) and has a greater risk of bacterial contamination than the semi-continuous and continuous algae production systems employed within Australia. However the technology supporting it is very simple, and although it is labour intensive, compared to alternate approaches, the skill required by the labour is lower, and new cultures are only ever a few days away if there has been a problem. A number of places utilised both continuous 'high-tech' culture systems and the batch systems and saw the batch system as having inherent safety, with it isolating the 'batch', so that a loss can occur without the risk of taking a whole system down. The typical approach to the batch systems was a scaling up in culture volume, progressing every two to three days to keep the cultures 'fresh' in the exponential growth stage. The initial capital expenditure is reduced using batch culture technology, but the operational footprint is greater as is the on-going labour requirements for the equivalent daily algal cell harvest.

The continuous algae systems adopted were all adaptations of John Bayes' SEACAP system, utilising pasteurised seawater and a variety of plastic bags. The New Zealand facilities utilised the 'skinny' hanging bags on a continuous harvest. Many European facilities were using these bags or similar, but were still using them in batch culture. One facility also operated a 'BioFence' that is a continuous algae culture system utilising chlorination/de-chlorination and small diameter acrylic tubing. The densities that this system is able to attain are quite remarkable, but the range of species that this system can be used successfully to culture is reduced, due to the physical turbulence that exists within the system. It was recognised by many that the skill and experience of the staff contributed greatly to the successful operation of these continuous algae culturing systems.

Production of microalgae requires nutrients to supplement the natural levels available within the seawater. A variety of nutrient formulas were utilised, ranging from $F_{2,}$ to Walnes, to some that were custom formulas. Many facilities took advantage of the commercially available formulas, either as a dry mix, or pre-mixed liquid solution. These pre-mix formulas were seen to provide an advantage in saving staff time and reducing human error in the preparation of the nutrient solutions.

Supplemental carbon dioxide was a regularly used to enhance algae cultures, as was supplemental lighting. The lighting typically consisted of fluorescent tubes and metal halide lamps. Many facilities utilised greenhouse structures to take advantage of naturally available sunlight. Where cultures were grown indoors the effect of the light on 'heating' the culture rooms was identified as a consistent problem. This problem with excess heat was addressed through use of air-conditioners, evaporative cooling panels, and directing freshwater onto the external surface of bag cultures, occasionally as a misting system. The electrical costs associated with supplementary lighting, and then the costs to manage temperature were recognised as being significant within the hatchery production process, so there was considerable interest in developing LED lighting solutions, with savings in direct electrical costs, maintenance, and reduced heat. All these were seen as advantages in adopting this technology. Limited progress was seen in adoption of this technology as further development is necessary to provide a commercial 'product'. This presents an opportunity to develop a product that delivers the required wavelengths for microalgae and is suited to a seawater environment potentially even submersible.

Chapter 8
Triploid & Tetraploid Shellfish Production.

Triploid and tetraploid refers to the number of chromosomes that the shellfish contain within somatic cells. Typically shellfish are diploid - that is they have two sets of chromosomes, one each from the male and female parent. Mitosis then underpins growth with cell division and DNA replication. Gametes, the eggs and sperm responsible for reproduction, recombine their chromosomes, and then lose one of their sets of chromosomes and become haploid (single set of chromosomes), this is called meiosis. Sexual reproduction can be described as meiotic recombination.

The loss of the chromosomes to become haploid occurs through a process described as meiosis I and II. In each of these stages, 'polar bodies' (packaged chromosomes) are extruded. This process occurs in many shellfish such as oysters, clams, mussels and scallops after fertilisation has occurred, with many other animals it typically occurs before fertilisation has been completed.

It is because of this occurrence of meiosis after fertilisation that the opportunity to modify the 'ploidy' of shellfish is available to producers. This is typically achieved through the blocking of the release of polar bodies at either meiosis I or meiosis II. The blocking of either of these polar body releases results in the shellfish becoming a triploid (three sets of chromosomes). The cells of a triploid can undertake mitosis in the usual way, however it infers a level of sterility as three sets of chromosomes cannot successfully recombine during meiosis.

This use of triploids presents an opportunity to shellfish producers, as triploids have larger cells due to the additional chromosomes, and this infers a level of growth advantage over diploids. The sterility of triploids also provides an advantage, with resources not being put into the development of gametes, which can then be released and lost through spawning, causing up to a 70% loss in meat yield. The development of gametes also changes the texture of the shellfish significantly, and some markets prefer the winter 'meaty' texture to that of a 'creamy' summer shellfish. In France triploid oysters are referred to as 'Four Seasons', implying that they are suitable for consumption any time of the year. The development of triploids has had significant producer and market acceptance and is seen as one of the advantages to using hatcheries for shellfish production.

The production of triploid shellfish is achieved by two different methods. The first involves the blocking of either the first or second polar body through the use of chemicals, temperature or pressure. This allows direct induction, but shows some variability of success rates, and the use of the chemicals is facing resistance, due to the toxicity of the material and OH&S considerations. The number of shellfish that are successfully produced is also reduced, due to the stress of the induction on early egg development.

The second process involves the use of tetraploids, which have four sets of chromosomes. Inhibiting the polar body release of triploid eggs that have been fertilised by a diploid male typically produces tetraploids. The tetraploid female shellfish are crossed with a diploid males and the result is 100% triploid offspring.

Dr Stan Allen pioneered this development of triploid production in shellfish, with the tetraploid production being patented and the company 4C's Breeding Technologies Inc. was established to manage the licensing and transfer of the technology. This company, managed by Tom Rossi, has been successful in striking commercial relationships with a number of hatchery suppliers globally. The French industry, with the support of IFREMER (French Research Institute for Exploration of the Sea), fought the patent and reached a settlement with 4C's that allowed them to utilise the technology. The patent on this technology is ending in 2013, and Tom Rossi is reporting that the interest in the technology has actually increased, with a number of approaches from businesses that require assistance in incorporating the processes into their production of shellfish.

IFREMER is producing tetraploid oysters, and controls their use by selling the males to the hatcheries on the condition that the males are returned, either alive or their empty shells, demonstrating they have been used for the single spawning. IFREMER is claiming a process of direct production of tetraploid shellfish, without the need to inhibit polar body release on a triploid x diploid cross.

The end of the 4C's Breeding Technologies Inc. patent will usher in a new age of tetraploid production to enable triploid production. There is considerable research to be undertaken to enhance their ability to be incorporated into selective breeding programs, with particular importance to managing disease resistance. The inheritance of specific traits, and the time taken to incorporate tetraploids into breeding programs are areas of great importance.

There is an opportunity for companies such as 4C's to bring their specific knowledge together with a variety of global shellfish hatcheries to drive further advancement in this technology. (For further explanation and description of the polyploidy process the 4C's website is: *www.4cshellfish.com*.)

Chapter 9
Disease – Shellfish Production.

There are a number of diseases influencing the production of shellfish around the world, ranging from protozoans, bacterial and viral pathogens. The disease that has the greatest consequence for the Australian oyster industry is OsHV-1, referred to locally as Pacific Oyster Mortality Syndrome or POMS. This disease is wide spread throughout Northern Europe, extending from Morocco, to France, England and Ireland. POMS has also devastated the New Zealand industry (which is largely reliant upon wild catch), taking it from a $30 million industry down to $5 million. The French industry experienced 80-90% losses, and hatchery production has grown exponentially to make up for the wild catch reduction. Farmers are buying extra stock in anticipation of having significant losses.

The disease managed to spread over such a large geographic distribution due to the 'Highway' farming techniques employed by oyster growers who move oysters and equipment around at different stages of the production cycle. Another contributing factor was that the cause of the mortalities occurring was not easily determined, so the presence and role of the virus was not known from the outset. For most of the year, with water temperatures below 16°C, the oysters were not dying and this in effect 'hid' the fact that oysters were carrying the virus, and allowed oysters that weren't symptomatic to be moved, which contributed to the spread of the disease.

The diagnostics of the virus has been an area of significant research and development, with detection moving from histopathology and electron microscopy through to PCR (polymerase chain reaction) and live PCR detection platforms. Continued development of effective and economical diagnostics is continuing and is a high priority for the countries already facing infected populations, as well as for neighbouring nations that want to provide some level of security to their existing industry.

Australia has identified POMS within selected NSW growing regions, and has an urgent need to understand the factors influencing the spread and infectivity of the disease. The opportunity exists for the Australian industry to work collaboratively with the international oyster industry in developing a greater understanding of the disease, and establish robust diagnostic and management protocols to minimise the spread and the effect of the disease. Collaboration can also contribute to the control of the impact the disease has upon the producers through identifying husbandry and alternative strategies of production that avoid or minimise the onset of the mortality of the disease.

Selective breeding is also being vigorously pursued by both the New Zealand and French industries, with the French hatcheries collaborating to develop family lines that infer a resistance to their progeny. This breeding collaboration is occurring despite the very competitive market condition of the French oyster hatchery suppliers.

Chapter 10
Selective breeding in shellfish production.

Shellfish hatcheries provide the opportunity to manage breeding, so that positive traits can be introduced or maintained in the shellfish being commercially produced. The focus of this breeding can extend to maintaining genetic diversity, through to traits that deliver a direct commercial advantage such as growth, yield and survivability. Other characteristics that provide for product differentiation, such as shape and shell colour, can also be selected.

Most facilities managed selection of broodstock to some level, even if just at the superficial selection of observable physical traits of the broodstock. There were a number of industry managed, selective breeding programs. The US West Coast industry has a program called the Molluscan Broodstock Program that focussed on the improvement of the Pacific oyster, even to the extent of bringing new Pacific oyster strains in from Japan. This program was supported by Federal Government funding, however this funding is not going to be renewed. A continuation of the program for the whole of this industry was sought but it appears that its continuation will be dependent upon individual hatchery businesses. The US East Coast has a well-established breeding program for *Crassostrea virginica* that is interesting, as the program started before the commercial cultivation, and was in fact critical to providing disease resistant lines to support a cultivated oyster industry. The Virginia Institute of Marine Science (VIMS) calls its program the Aquaculture Genetics and Breeding Technology Centre (ABC). The selectively breed oyster broodstock available from this has underpinned the establishment of the commercial cultivation of *C. virginica* and has provided resistance to diseases. This program is also responsible for providing tetraploid oysters through an agreement with 4Cs, which has enabled the industry to fully utilise triploid oysters. Management of the breeding program to also allow the incorporation of tetraploid oysters is an area of further development, with work to understand the mechanisms of inheritance within a polyploidy oyster.

ABC also investigated the introduction of alternative species of oysters that would have used the tetraploid technology to maintain a sterile population being introduced into the Chesapeake Bay. This was overruled on the basis of the precautionary principle, and unknown changes to the natural ecosystem if an introduced species took hold.

The French Pacific oyster industry has also collaborated to develop a breeding program that was established solely to develop disease resistance to the POMS.

The New Zealand mussel industry has a number of large producers that have collaborated on the establishment of a selective breeding program, while at the same time developing hatchery production processes that can be adopted into the future. This industry recognises the vulnerability it faces, being reliant upon wild settlement and the variability of supply this presents. With an increased level of value-adding and automated processing of the mussels, the consistency of characteristics throughout the growing cycle, and then at harvest, has been recognised as a distinct advantage of selectively bred hatchery produced mussels.

The opportunity for selective breeding programs to work together on the design, data management and methodologies of in-field testing to support the selection process exists. Benefits would exist for international collaboration in developing efficient technologies and processes to produce large numbers of lines through the hatchery and nursery, delivering them to in-field assessment. This would support the international trade in genetics, much the same as exists across many other agricultural industries now.

Chapter 11
Education & Training.

The focus on education and training within the shellfish industries in countries visited was refreshing. There are many University and industry collaborations building capacity in core and advanced research capacity to both existing and new entrants to the industry.

The industry was also taking a leading role with a number of facilities offering internships, providing a range of 'jobs' throughout the business. This gave the intern a very good overview of the activities required to produce shellfish through the hatchery, nursery, growout and processing, through to sales and marketing. This strategic approach to training was developing well-rounded employees that had a fuller understanding of their eventual role in the business, and enabled them to draw upon the skills and relationships they built upon during the internship.

Structured internships based around the activities of the selective breeding program were also on offer, including semester work assisting hatchery production and research work. Hatchery-specific training programs were also available, teaching algae, larvae and settlement processes while utilising the students as labour for production outcomes.

Extension programs and officers to assist existing and emerging industry were also well established, with technology development and transfer given a high priority. The outcomes of these programs were significant industry development and growth, particularly around the re-training offered to former 'watermen' and fishermen that wanted to build sustainable industries and businesses that empower them to still live and work on and around the water.

Stan Allen (Director - red shirt) & Anu Frank-Lawale (Geneticists - blue jacket) – Virginian Institute of Marine Science (VIMS) with Oyster Aquaculture Training (OAT) Program participants. Shellfish Hatchery in Background

Chapter 12
The future of Shellfish Aquaculture

My general impressions across all these countries are that the future for shellfish aquaculture is bright.

The challenges that it faces include:

- Environmental conditions, such as 'ocean acidification', pollution, 'ocean up-welling'
- Social licence, urban encroachment, conflict/competition for space.
- Disease, including existing and new and emerging types.
- Shortage of skilled, knowledgeable 'Shellfish Technicians'.

The reason I see the future as bright is that oysters in many parts of the world have a historical cultural importance, and are in short supply to the consumer. Oysters and other bivalves are being sought out not just as a source of protein, or nutrition, but because of the good-times, or experience' that they represent to the consumer. As a colleague of mine is fond of saying, *"Oysters are HAPPY food"*. This attitude, combined with the clear environmental advantages that shellfish production represents in todays world of 'carbon footprints' and environmental responsibility, leaves the industry with greater opportunities than negatives.

The questions of disease and people development are being addressed by leading scientists and motivated educators that have a passion for the humble shellfish. The challenge the industry faces is how to best attract and retain these bright young people, and provide an opportunity for them to participate in a meaningful way within the industry.

The opportunities that exist are perhaps best demonstrated by the oyster industry on the east coast of America, around the Chesapeake Bay. The Chesapeake Bay fishery once produced more oysters than all of China or France does today. The current production is a sliver of what it once produced and has been influenced by environmental conditions, overfishing and disease. The good news is that hatchery production has been able to combat the disease issue successfully, with improved survivability available through selective breeding. There is a new enthusiasm amongst 'watermen' pioneering the cultivation of oysters, developing innovative nursery and grow-out technology and processes to suit the environment of the Chesapeake Bay. There is also a passionate movement towards restoration of 'natural' beds of oysters. And all this ties into the story of oysters and shellfish being good for the water quality of the bay, and opens a new era of oystering into the future.

Recommendations

The Australian Shellfish industry would benefit by implementing and developing the following recommendations in addition to those outlined in the Executive Summary. Though coordinating our 'collective intelligence' as an national and international industry we will be in a position to continue to adapt and innovate meeting the challenges we face today and into the future.

- Coordinate the establishment of an international shellfish hatchery network, to promote communication and relationship building.
- Identify areas of significance for development, across technological development, capacity building of people.
- Prepare a 'Dummies Guide' to algae culture, larvae culture, genetics, water chemistry, system design, water pumps, nursery operations etc., supported by simple fact sheets.
- Nationally identify the factors that have influenced and allowed for growth internationally. Assess the risk and opportunities that this presents for the Australian industries.
- Coordinate International research and development across areas of 'common' interest for the shellfish hatchery industries.
- Build relationships between international producers and investigate the KPI's that influence profitability, and investigate the economics of the various production strategies. This would be supported by benchmarking and forming discussion groups and forums, which would help prioritise the areas that require further investigation and development.

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Guernsey Sea Farms - www.guernseyseafarms.com, Mark and Penny Dravers Guernsey Sea Farms Ltd.Parc Lane, Vale Guernsey GY3 5EQ Telephone: +44(0)1481 247480 Fax: +44(0)1481 248994 Email Address: oyster@guernseyseafarms.com

Horn Point Oyster Hatchery - www.hpl.umces.edu/hatchery/, Donald W. Meritt Hatchery Program Director, Phone (410) 221-8475, E-mail: dmeritt@umces.edu

Technology development for a reliable supply of high quality seed in Blue mussel farming, Blue Seed (Project no. **017729)**

The state of World fisheries and aquaculture, FAO Fisheries and Aquaculture Department, Food and Agriculture Organization of the United, Rome, 2012

4C's Breeding Technologies Inc. - P.O. Box 398, 605 Commonwealth Ave Strathmere, New Jersey 08248 USA, Phone: 609-425-2475, Fax: 609-263-5552, Email: info@4cshellfish.com, Website: www.4cshellfish.com.

Plain English Compendium Summary

Project Title: Global Perspective of bivalve hatchery processes.

Nuffield Australia Project No.:	
Scholar:	Ian Duthie
Phone:	+61 (0)409 411 322
Email:	ian-duthie@bigpond.com
Objectives	Identify the opportunities and challenges that the Australian Shellfish Hatchery industry faces, by investigating current technology and knowledge, that exist both in Australia and around the world.
Background	The need to study Shellfish Hatchery businesses from around the world, and identify "World Best Practice" and the future trends in shellfish production is important for the future growth of the Australian Shellfish industry. **Internationally there are significant disruptions to supply due to environmental and disease impacts. Identifying these and their likely solutions and consequences for the Australian Industry is important.**
Research	I travelled extensively during this Nuffield scholarship, visiting eleven countries specifically to investigate shellfish aquaculture. These included; United States of America, Norway, Sweden, Portugal, Spain, New Zealand, Canada, France, Guernsey, England and Scotland.
Outcomes	Collaboration has been essential for the European and American producers, who experienced greater than 50% reduction due to disease and environmental factors. Lessons for the Australian Industry are: • Build strong on-going relationships with key staff, as they are the fundamental to your business success. • Develop a network of international shellfish hatchery producers, providing for opportunities to interact, not just at the managerial level, but also between technicians, encouraging discussion of issues influencing "success". • Recognise the advantages of using 'Collective Intelligence' between hatcheries where they collaborate to find solutions to common problems, such as disease management, selective breeding, polyploidy and water quality. • Encourage staff exchanges, secondments between national and international colleagues within the shellfish industry, where issues of direct competitive pressures aren't significant.
Implications	Species and product diversification should be adopted by shellfish businesses to mitigate risks and optimise human and capital resources. Vertical integration was also successfully demonstrated, as were synergistic 'joint-venture' relationships between shellfish hatcheries/nurseries and grow-out producers who share similar values and attitudes. The opportunity to build a clam aquaculture industry exists with current hatchery technology existing in Australia for its immediate development.

Appendix 1
Generalised impressions across industries Visited.

Having visited so many operations, and respecting the privacy of the individual businesses who opened their doors to me, I have prepared the points below to provide for general impression of the distinguishing features of each countries' industry that I visited.

USA

- Large vertically integrated shellfish businesses, joint venture, supply arrangements with smaller producers, leveraging large businesses investments in hatcheries, processing, distribution etc.
- Geographic diversity, hatchery sites on West Coast & Hawaii.
- Family and individually owned – although considerable scale
- Strong relationship between key staff and owners, 15-33 years employment durations, allow employees to hold shellfish business interests outside of the employers business
- Knowledgeable, experienced and committed staff
- In house training, and career advancement opportunities
- West Coast Industry Breeding Program – being continued privately, due to lack of whole industry support.
- Institutional support of breeding program on the East Coast, supporting and building capacity within the industry. Many of the former employees of the program have moved onto positions of responsibility within the private sector.
- East Coast – moving to re-train/skill-up existing 'watermen' to the new industry of aquaculture. Government grants and assistance were available.
- Research focus, i.e. employ technical staff to understand issues such as water quality
- Around 50 billion eyed oysters produced each year (West Coast)
- Demand for growth, with current hatchery production seen as limiting industries development.
- Water heating uses diesel or propane – electricity is considered too expensive.
- Heat recovery of water – starting to adopt, as the pressure from power costs increasing
- Diploid and triploid production (both Tetraploid x Diploid), and direct induction (non-chemical)
- Oysters, clams and mussels produced at all hatcheries (West Coast)
- Larvae batch sizes in the vicinity of 150-250 million eyed larvae

- Big Larvae Rearing Tanks; 20-48,000 litre used predominately, both as static and flow through, relatively low larvae densities.
- Small Larvae Rearing Tanks; 200 litre run as flow through cultures with high larvae densities
- Algae culture; mix of species cultured, not as strong an emphasis on maintaining axenic cultures as Australian hatcheries, predominately production is from static batch cultures up to 125,000 litres e.g. 1 L ➔24 L ➔4,000 L

  ↙ ↘

  16,000 L 16,000 L
- Continuous algae culture; adapted from John Bayes – SeaCap is used, but not as the primary production process
- Hatchery production problems have been attributed to Ocean Acidification, Ocean upwelling and *Vibrio* sp. Wild recruitment and hatchery production of Pacific oysters has been impacted with up to a 50% reduction. Other shellfish species haven't been impacted as significantly.
- Collaborative work is being undertaken to investigate water quality chemistry issues associated with Ocean Acidification and Ocean Upwelling's

Canada

- Limited development of hatchery capacity, large dependence upon American suppliers.
- Diversity of production, with a variety of shellfish species being produced.
- Similar production strategies to the American culture protocols.
- Recognition of the importance of the shellfish industry, with the establishment of the Vancouver Island University Centre for Shellfish Research.
- Innovative producers, finding niches within the industry, with speciality species production or arrangements, and diversity of products i.e. Algae pastes.

New Zealand

- Emerging hatchery production, for mussels and oysters, building upon many years of research and development into the hatchery and nursery production of mussels and oysters and to some degree clams.
- No ‘commercial’ hatchery producers currently operate (Cawthron Institute- research trust, is currently providing oyster spat to industry at commercial rates, but would like to divest themselves from commercial production).
- Oyster Selective Breeding Program started to address POMS threat (60 families).
- Plans for industry collaboration for the production of Greenshell Mussels through a hatchery.
- Production processes being adopted are a combination of existing global shellfish hatchery technologies with an emphasis upon the high density larval and algae production methodologies.
- Oyster nursery production systems are a hybrid of French and UK systems.
- Building human capacity, with support for education programs.
- Amazing opportunity for shellfish aquaculture exits now and into the future, with sub-tidal oyster cultivation now developing.

Norway & Sweden

- Hatcheries production is limited, but follows considerable investment into infrastructure and research and development.
- Strong support within the University sector for research and human capacity building.
- There is a shortage of technical experienced personnel, but no shortage of determination and passion.
- Larval rearing and algae production tends to follow the small static and flow-thru tanks, and small volume chlorination/de-chlorination processes.
- The opportunity to fill a niche’ production need, and market accordingly exists.

Portugal & Spain

- Have a very strong shellfish sector, with community 'heritage'.
- Hatcheries had diversity of production across a variety of species.
- Larval rearing was typically small static tanks, occasionally flow-thru.
- Algae production was a mix of static and flow-thru, but typically avoided the large batch tanks systems of the USA.
- Education and Research and Development were very well supported, with specific courses being taught for shellfish aquaculture.
- Hatchery production has the opportunity to grow, supplementing or replacing the wild catch shellfish industry sectors.

Guernsey & United Kingdom

- Has a strong history in shellfish hatchery development, responsible for many of the innovations in algae, larvae and nursery production systems that have been adapted around the world.
- Strong relationships exist between businesses with many operators having worked together at some stage in their career.
- Emphasis on cost savings, in energy and labour inputs.
- Continuous algae production and larval rearing systems.
- Nursery systems utilise old 'quarries' and water impoundment to provide a level of protection from the sea and the capacity to enhance algae production as a food for nursery shellfish.
- Great depth of knowledge and experience.
- Participate in the international market for shellfish spat.

John Bayes – Seasalter Shellfish, pioneering hatchery producer, developed continuous algae systems, and intensive larval and nursery production systems.

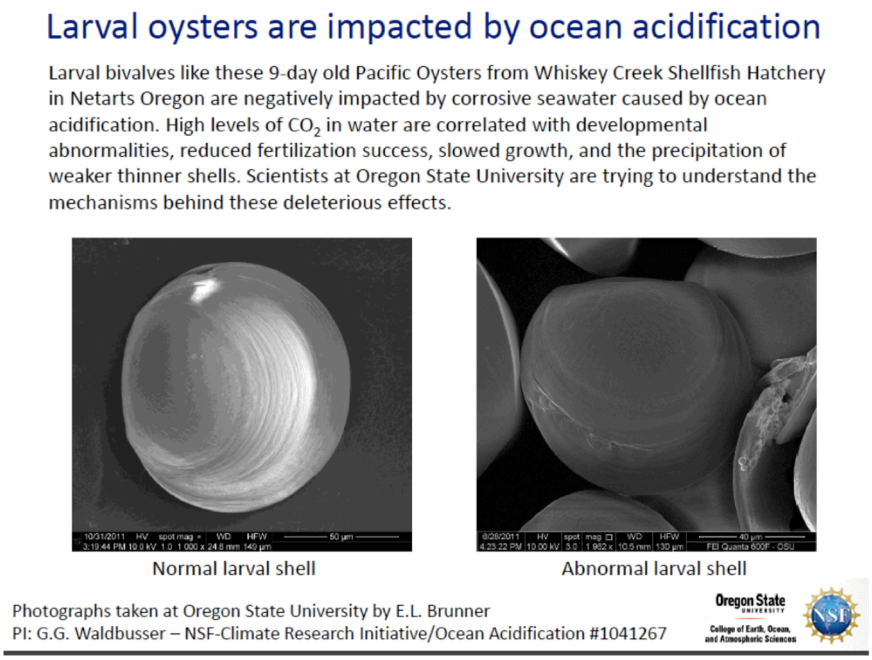
France

- Observations of the French hatchery industry are difficult as I was ‘locked-out’, as the level of mistrust and competition are immense.
- Well-supported and politically strong support from IFREMER and industry.
- Division within industry between “Traditional” oyster growers that don’t support hatchery production, and blame it for the current disease issues. As wild settlement continues to fail, demand for hatchery production has grown.
- POMS has a mortality of between 60-90% and this in conjunction with the reduction in wild settlement has seen a threefold+ increase in demand for oyster hatchery spat. With farmers putting additional oysters onto farm with expectations of having substantial losses.
- Growth in the hatchery sector is supported through European Union and French Government support.
- Nursery systems are typically shore based and have supplementary algae production.
- IFREMER and industry have strong collaboration in developing disease diagnostic capabilities.

Appendix 2
Ocean Upwelling and Acidification.

Ocean 'Upwellings' which happen to occur on the west coast of the USA, and influences the carbon chemistry of the seawater is a process where deep 'old' ocean seawater comes to the surface. This 'old' seawater has spent many years without mixing, resulting in a low oxygen concentration from aerobic and anaerobic respiration, and a high carbon concentration and resulting low pH. Carbon dioxide when dissolved in water forms carbonic acid, and this lowers the pH. This has an impact on shellfish, because as the name suggests they have a shell, and this is made mostly of Calcium Carbonate ($CaCO_3$). Calcium Carbonate can be present in variety of 'forms' and in adult oysters these are composed mainly of calcite; the shells of larvae are primarily aragonite. Following fertilisation of the eggs, and initial development in the first 1-3 days, the shells contain a significant amount of amorphous calcium carbonate, and this is quite sensitive to reduced pH. See Figure: *Larval Oysters are impacted by Ocean Acidification.*

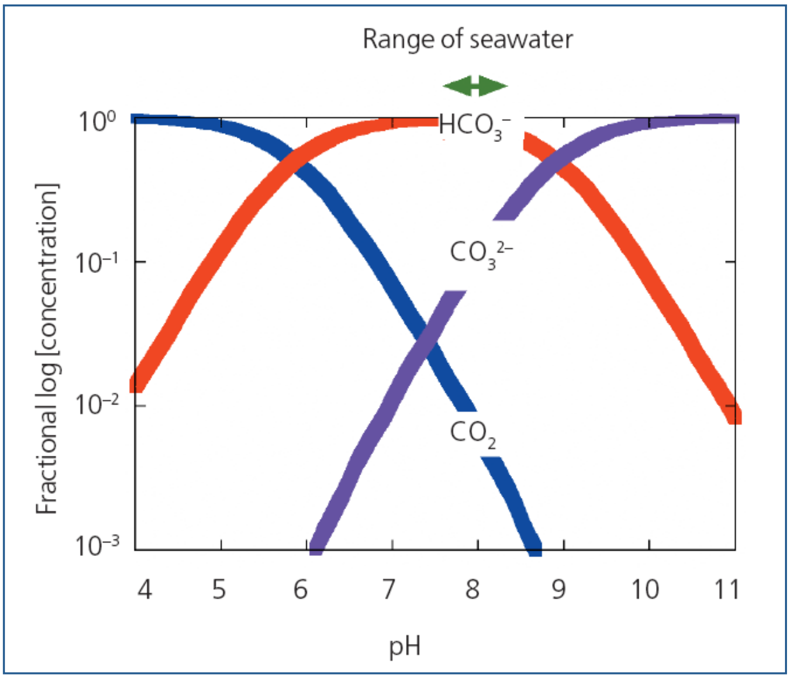
Ocean acidification refers to the observed decrease in the pH of the oceans that is caused by the uptake of carbon dioxide from the atmosphere. Recent industrialisation, burning of fossil fuels releasing carbon dioxide into the atmosphere, along with reduction in forests and other vegetation which acts as a sink for carbon has been reported to increase the levels of carbon dioxide into the atmosphere, with 33% of this 'new' carbon dioxide believed to have been absorbed into the oceans, forming carbonic acid and resulting in a measured reduction in the pH, which increases the hydrogen ion concentration making the oceans less alkaline. This changes the availability carbonate ions, which shellfish use for growing their shells. This leaves them vulnerable to degradation of their existing shells, and places metabolic 'stress' upon them in the building of new shell. This threatens the larvae and young shellfish spat, directly and makes them prone to disease.



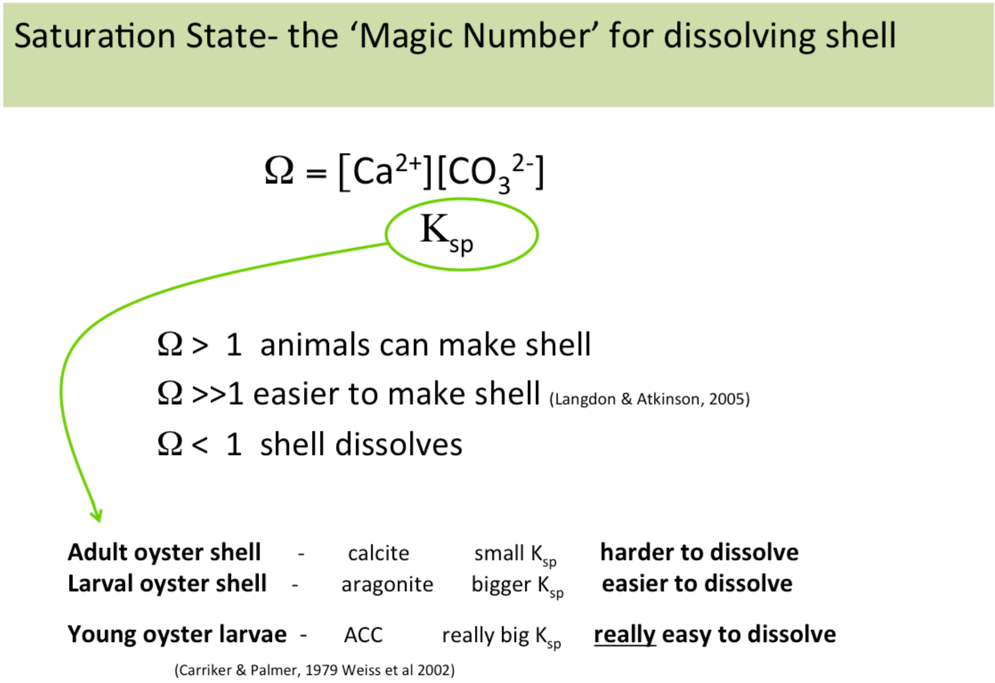
Larval Oysters are impacted by Ocean Acidification – Alan Barton, Whiskey Creek Shellfish

Oyster shell is made mostly of Calcium Carbonate ($CaCO_3$)

$$CaCO_3 \Leftrightarrow Ca^{2+} + CO_3^{2-}$$



Effect of pH on the availability of Calcium Carbonate species. – Alan Barton, Whiskey Creek Shellfish Hatchery



Saturation State of various 'species' of Calcium Carbonate (ACC=Amorphous Calcium Carbonate) – Alan Barton, Whiskey Creek Shellfish Hatchery

South Australian Northern Zone Rock Lobster Fishery

Rebuilding and Sustainable Management

A report for NUFFIELD AUSTRALIA FARMING SCHOLARS

by Ben Tyley

2010 Nuffield Scholar

March 2010

Nuffield Australia Project No 1008

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Foreword

Falling catch rates and a reducing total allowable catch has led to a reduction in viability for the northern zone rock lobster fishermen.

A period of poor recruitment of juvenile lobsters, and efficiency gains through new technologies, combined with fishermen travelling further, and fishing areas that were previously less exploited, has led to a reduction in the bio-mass.

The aim of my study is to analyze management plans and harvest strategies of some of the northern hemisphere lobster fisheries, by comparing the North American fishery that has stood the test of time and is at the moment having record catches, and the UK and Irish fisheries that are struggling to rebuild fish stocks.

Then through comparison of the management tools being used, some guidance on the way forward (or the measures not to take) can hopefully be integrated into the plan for the northern zone in South Australia.

Many fisheries around the world are facing similar stock number uncertainty, and while Australia is recognised as a world leader in fisheries management there are still many things to be learnt. Some of the projects happening in the northern hemisphere could be well adapted into the management plan here in Australia.

This Nuffield study project was funded by The Sidney Myer Fund

Acknowledgments

I would like to thank the team from Nuffield Australia and the Sidney Myer Fund for providing me with this amazing experience.

To all the people who helped along the way, giving their time, knowledge and experiences, I can't thank you enough. You all helped to personalise the experience and turned it into something that couldn't be learnt from reading a report or doing a web search.

Most importantly, to my wife Kerry for allowing me to take on this incredible experience while leaving her behind to deal with everything, and my boys Damon and Jae, thanks for making it all possible.

Abbreviations

NZ – northern zone, Western Aust. border to the Murray River mouth

TAC – total allowable catch

USA – United StatesAmerica

UK – United Kingdom

ITQ - individual transferable quota

EU – European Union

Paurulas – just hatched lobster

Executive Summary

This study is for the purpose of rebuilding the lobster stocks and sustainably managing the future harvest of primarily the Northern Zone rock lobster fishery. Over the past 10 years the total catch of the zone has been steadily decreasing to the present all time low.

The industry has in this time had a complete change of management plans, going from input controls to output restrictions, in the form of individual transferable quota. Since the shift to quota management 7 years ago the total allowable catch has been annually reduced until 2009, hoping to leave more breeding stock in the sea.

The aim of my study has been to network with fishermen, fisheries managers and scientists from the northern hemisphere, where the lobster fishery has survived since the early 1800's, and in places like Nova Scotia which are having record catches.

Travelling through Maine and Canada's east coast where in excess of 25% of the worlds annual lobster catch is caught gave me the opportunity to meet and share knowledge with significant stake holders in the industry. The UK and Ireland also have a similar length history of lobster fishing, but their stock levels are significantly lower. This made for an interesting look at different methods of management and fisheries control.

One of the major differences between the North American fisheries and the South Australian fishery is the amount of scientific research being done. Canada and the U.S. have numerous research bodies and facilities, with the fishing industry and the community (through sponsorship) funding many of these.

One of the most encouraging projects that has just been started in Canada is the study of DNA profiles in lobster. The benefits of being able to trace where a lobster egg hatches, and the path the paurulas take before settling to the sea floor could be invaluable to rebuilding stock levels in lobster fisheries all around the world.

Significant change in the way forward could come in trap design. This is something that has not been changed in the northern zone since moving from input controls when a standard trap was necessary for management purposes. Now that quota management is in place a more efficient trap would mean less time the traps are in the water, therefore less by-catch and lower mortality rates of trapped lobster. This would result in lower running costs for fishermen and more fish being left in the sea.

Another key difference between our industries is public perception. The North American fisheries have strong community support and public understanding of the value of the fishing industry. They are using some brilliant educational and promotional tools that could be well utilized by the Australian industry, to give a better understanding of the fisherman's commitment to responsible stewardship of the marine resources.

After talking to lobster fishermen and fisheries managers in other sectors of the world, South Australia's rock lobster industry needs to better promote its self to the general public. It could be said much damage was done in the 60's and 70's with the style of fishing compared to the present. Awareness of the environment and marine eco system preservation is very much a part of today's fishing practice.

Although there is always room for improvement in management plans, the Northern Zones current plan is more detailed than any I saw in the Northern Hemisphere, which I found encouraging.

Introduction

Fishing for rock lobster in South Australia began in the early 1900's, and in August 1967, following 12 months of investigation by a government committee, it was decided that a boat and trap limit would be imposed on each of the fishing zones (northern and southern) and that no new licences would be issued into the fishery.

The northern zone fishery has progressively reduced the potential fishing effort since 1968 with adjustments to the number of traps and the number of days allowed to be fished during the season (1 Nov- 31 May) where previously the fishery was managed by input controls.
In 2003 the industry moved away from input control management into an individual transferable quota management system. The season remains the same and no new licences or traps have been allowed into the fishery.

Since the change to quota management, each year the total allowable catch has been reduced to try and stop the downward trend in catch rates, which peaked in 1992 at just over 1200 tonnes, but had a long term average between 850-900 tonnes. Since the early 2000's the catch rate has been steadily declining to the current level of 310 tonnes.

The decline in the fishery has been blamed on a number of factors, rangeing from changing environmental conditions, the improvements in technology of fishing equipment, bigger and faster boats fishing grounds further away (that in the past were left alone), the higher value of licences and equipment (driving fishermen to work harder to reduce their debts), and, probably the most important, a factor that fishermen have at the moment very little control over is a period of poor recruitment of juvenile lobsters into the fishery.

The current challenge of turning this fishery around, back to the vibrant industry of the 90's is a job that the current management is struggling to achieve. A better understanding of where the juvenile lobsters are coming from so that the stock of breeding adults can be better managed is necessary.

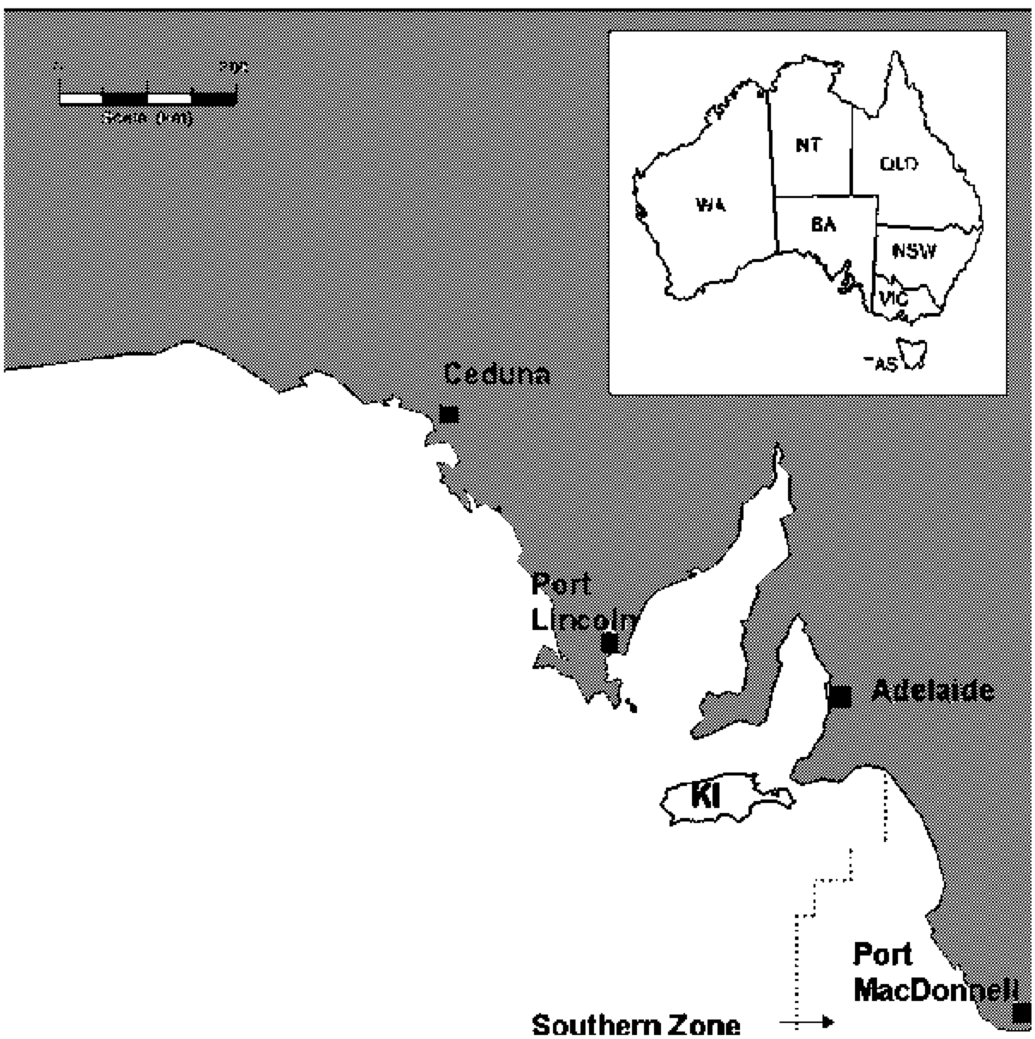
I have been involved in the Northern Zone Rock Lobster fishery for the past 21 years, starting my career as a fisherman in the family business at the age of 19 after finishing a mechanics apprenticeship. Since then I have taken over the family business and have been actively involved in industry associations and management committees, placing a great emphasis on the long term sustainability of the fishery.

There have been significant reductions in the amount of fishing effort, but an accurate and effective way of measuring or enhancing recruitment, is still a major challenge.

Many fisheries around the world are struggling with similar issues and are tackling them in a variety of different ways, some of which could be applied quite well to the N.Z. fishery.

My aims throughout this study have been to open some lines of communication with fishing industries around the northern hemisphere and compare the research and ways of management that they are employing, as well as sharing the knowledge of successes and failures through the different management plans, harvest strategies and stock enhancement projects.

NORTHERN ZONE



The Northern Zone is the area between the Western Australian boarder and the mouth of the Murray River. It encompasses approximately 3700 klm's of coastline and extends from the low water mark out to 200 nautical miles.

The fishing method used for rock lobster in South Australia generally consists of a single trap style fishing, where each trap has its own rope and set of floats on the surface. Traps are individually set on rock or reef, and commonly spread over large areas, rangeing from hard along the shore out to the continental shelf. As opposed to the Canadian style of fishing where a string of up to 20 traps are connected together and set off in lines, with a set of floats at the end.

The placement of the traps on the sea floor is much more critical in the South Australian fishery, as our lobster tend not to walk across the sand/mud to get to the trap, where as the North American lobster is quite happy in the mud.

The Life Cycle of Southern Rock Lobster

Mating between lobsters occurs between the months of April to July, shortly after the female has moulted, with most eggs hatching between September and October. The female carries the fertilised eggs externally under her tail for 4-6 months before hatching, and a large female can carry up to 400 000 eggs.

Rock lobsters have among the longest larval development known for any marine creature, developing through 14 moult stages. After hatching the Naupliosoma larvae leave the female as free swimming plankton, they migrate towards the surface where they moult into a phyllosoma larva. Phyllosoma larva disperses widely with the ocean currents and has been located hundreds of kilometres offshore. This phase of the life cycle lasts between 9 and 20 months, before they change into transparent puerulus, resembling miniature lobsters in shape. The puerulus still live in the plankton, moving up and down in the water column on a daily cycle, coming up near the surface at night and swimming deeper during the day, until they settle to the sea floor. After settlement they develop pigment and moult into bottom dwelling lobster, taking approximately 7 years to reach maturity (depending on location).

Photo's Dept. Primary Industry, Fisheries Research Branch Queenscliff. Vic

Photo B Tyley

Northern Hemisphere Fisheries

Although the American and European lobster are a different species to the lobster caught in the northern zone, the fisheries have a lot of similarities, in regard to how fishermen act and think. Fisheries managers are faced with similar challenges of increasing pressure on fish stocks due to the increasing efficiency of the fishing fleet, and the unpredictability of the climate, which determines where the juveniles travel throughout their evolution into lobsters before they settle on to the sea floor.

The most common management tool that isn't being used in South Australia which I came across was the V notching of female lobsters with eggs. A notch approximately 5mm deep is cut into one of the tail fins so that if that lobster is caught again after she has released her eggs she is protected from being able to be sold until the notch has grown out. This usually takes 2 to 3 malts, allowing time for her to breed again and hopefully be notched again when she next is carrying eggs. Egg bearing females are protected but the V notching is voluntary, although all females that have been notched are protected by law. This is a way of ensuring a good population of fertile females remain in the bio-mass. Although the program is voluntary the general consensus is that the majority of fishermen are participating, seeing that it's for the greater benefit of the fish stocks. The record keeping in this regard could be a little better, with not many fishermen having in depth log book data. The numbers of fish actually caught (size, undersize, spawning) or numbers of V notched released are not recorded accurately, with all catch data coming from the processors in the form of number of pounds landed.

One of the biggest lessons I think Australian fisheries can take from the North American fisheries is changing the public image of the fishing industry. Their fisheries seem to be highly valued by the community and the general public are well educated about the benefits the industry brings to the community as a whole. A great example of this is the Gulf Science Centre in Portland, which is a privately run facility that is funded mainly through sponsorship from the fishing industry, the general community, and a small amount of government funding for specific projects. It has a hands on educational section that every year 5/6 student in the state of Maine goes through and learns about the sustainable way fisheries are being managed, and the benefits the fishing industry brings to the whole community. There is also a scientific section and a section for developing more environmentally friendly fishing equipment. The centre also provides training in the use of these developments to fishermen.

If the Australian fishing community could educate the general population here in a similar way, it would help to dispel some of the "myths" associated with the fishing industry overexploiting the marine environment. By raising the public image of the industry and making the community aware that fishermen are responsible custodians of the resource, I feel some of the negative image could be removed.

Raising public awareness and having a cleaner public image would give the fishing industry a higher standing when it comes to dealing with the many forms of bureaucracy which become involved in management issues, and opens the door to working together to solve some of the challenges in managing the whole marine environment.

Eco Friendly

The North American fishermen have been extremely pro-active in the implementation of sinking rope leading up to their buoys. The benefits of not having rope floating on the surface greatly reduce the chances of entanglement of marine animals, such as whales and dolphins, and of other vessels using the waterways. Another innovation that is being widely used is the use of biodegradable clips to hold escape panels closed on one end of the trap. If the trap becomes irretrievable the clips rust away, opening one end of the trap, thereby making it free for animals to walk/swim straight through, and eliminating any ghost fishing of lost gear.

The trap design being used all over North America and most of Europe is vastly different to the traps being used in the South Australian nz. A long rectangular trap with multiple entries and separate parlours to provide separation between larger and smaller animals has proven to be much more efficient than the traditional wooden slat trap or the bee hive design.
It will be well worth exploring the different designs in the nz fishery, not just for the better efficiency (which seems a strange way to go about preserving stocks), but the less time the traps are in the water means lower costs for fishermen, with the added advantages of less by-catch, lower mortality rates caused by predators of the lobster caught in the traps, and a lower amount of undersize and spawning females being removed from their habitat and relocated when returned to the sea.



North American wire and wooden traps with compartments. *South Aust. Trap.*
Note the multiple side entrances and lift up door compared to the single neck entry/exit. Also the clips holding the end wire panel, and there are soft wooden slats that biodegrade quickly opening the sides of the trap if it becomes irretrievable.
Photo's B Tyley

Another innovation has been pioneered by a processing company in Canada, for storing live lobster for extended periods. This allows control over the flow of product into the market place, resulting in less price fluctuation.

The lobster are placed into individual trays stacked on racks in a refrigerated environment, then a stream of cold water is run over the animals flowing through the trays. This induces a state of hibernation, so there is no need to feed the lobster and weight loss is minimal. Also numbers of mortality are low because there is no interaction between the animals. While this is of no real benefit to stock numbers, if a processors operating costs and mortalities are down, and their profits up, that should equate to a better price the fisherman receives for their product.

The specifics of temperature control and water flow rates for this operation are closely guarded, but the benefits being achieved make further investigation of the process attractive for the nz fishery, where the price has considerable fluctuations during the season.

Management Plans

The basic management plans found in the North American lobster fisheries have not changed much since their inception in the early 1900's.

Seasons are still the same and were based on when the fishermen could go to sea due to weather conditions and ice, more than any other reason.

The fishery in Maine still has no limited entry and a 12 month open season, while the fishery on the east coast of Canada has capped licence numbers, and has been divided into 41 fishing zones. Each fishing zone has its own management plan, with variations on size limits, season length, and opening/closing of seasons.

The management rules are mainly driven by the fishing industry, and although the scientific community make recommendations, the majority of licence holders need to agree before anything can change. The number of fishermen and the amount of community support for the industry makes for a strong political force, so the government is reluctant to force change.

Some of the fishing zones in Canada have been broken into smaller management areas, where the fishermen have had to choose which area they want to fish in and then are locked into that area. As a result of this some areas are having faster progress with management changes,

resulting in legal size increases allowing more females to reach maturity and be V notched before being caught again.
The smaller management areas take away some of the challenges in getting a consensus with a large group of spread out stakeholders, but without the knowledge of where the paurulas are travelling to and from, the conservation efforts of one area might only be benefiting another area further down the coast.
One area of New Brunswick engineered a scheme to receive dollar for dollar funding from the state government, for a buyback of licences to reduce fishing effort. Government funded 50% and offered a low interest loan for 50%. The ultimate aim was to remove 10% of the traps in the water. Every licence holder sold 20% of their traps to the scheme at market value, and then had the opportunity to buy 10% back from the pool that had been acquired. This raised the money to pay back the loan and didn't cost the fishermen anything. They still had the money from the 10% of the traps forfeited to the buy back, so that could finance them to buy out retiring fisherman's licences, and build back up to their original trap number without having an actual cost to their business.

The Irish lobster fishery has a similar management plan to the state of Maine. They have a minimum size limit (Maine also has a maximum size limit); egg bearing and V notched females are protected. Their season is open for 12 months of the year and anyone with a registered boat can obtain a licence to catch lobster. There is concern about the rising effort rate, but under the current management arrangements there is no way to cap the catch or the effort. The industry has developed a more in-depth plan with the help of Dr. Oliver Tully, Irelands head crustacean scientist, based at the Marine Institute in Galway, and the staff of Bord Iascigh Mhara (Irish Sea Fisheries Board) and has driven the process of implementation, but the process has stalled at the government level, with government saying they do not have the man power or resources to implement the administration side of the plan.
However with the approaching introduction of marine parks around the Irish coast line the fishing industry needs to meet certain criteria to be allowed to keep fishing within the park areas. Hopefully this will drive the process forward for them.
In Ireland as with the UK, once outside the 6 mile coastal limit the fisheries are governed by the rules of the EU. The management plans of EU fisheries are not a focus of this study.

Stock Enhancement through Hatcheries

Pictou Nova Scotia.

The lobster hatchery in Pictou is a fairly simple set up, comprising a series of small tanks in a shed on the water's edge. There is a small area for public education about the industry and the benefits of the hatchery, but the main focus is on getting more juvenile lobsters into the environment. They have a staff of 3, a scientist, a biologist and a university grad student. The grad student is funded by government, but the rest of the costs are met by the fishing industry and community sponsorship.

Egg bearing females are caught in the wild and supplied to the hatchery by fishermen, where they are stored in a holding tank of water chilled to 4-5 degrees C. They remain there in a semi dormant state until the hatchery is ready for the eggs to hatch. Then after placing them in a hatching tank where the water is slowly warmed to 18-20 degrees C, the eggs will slowly start to hatch, taking between 10 and 14 days. The water flowing through the hatching tank exits over a high division in the tank, then through a sieve catching the newly hatched paurulas with minimum effort. From here the paurulas go into their own tank and for the first 3 days just float around, during which time they are fed on brine shrimp flakes. On day 4 they start to swim for themselves so their diet changes to live brine shrimp. Their development is quite fast and by day14 they have grown to a length of approximately 25mm, and are ready for release into the wild. The release is done by volunteer fishermen transporting them in tanks of water to suitable settlement grounds. Then using a 100mm flexible hose they are pumped to the sea floor. This system gives the juvenile lobster a lot better chance of survival than hatching in the wild, as all preditators are removed during the most vulnerable stages of their life and they are guaranteed to settle in a suitable habitat.

While there is no practical way of tracking the animals from this stage (too small to tag and too expensive to micro chip) the general consensus from diver observations is very positive. This particular hatchery has only been running for 4 years, so the first released lobsters are still 2-3 years away from legal catchable size. Considering that the survival rate for lobsters hatched in the wild is thought to be less than 1%, by the end of this summer the Pictou hatchery hopes to reach in excess of 300 thousand juvenile lobsters released into the wild.

The hatchery I visited in Padstow, Cornwall is a similar set up, run by sponsorship and money generated through their visitor centre. Here there is a lot more emphasis on educating the public and raising the profile of responsible fishing practices. Just under 47 thousand people visited the hatchery in the 09/10 financial year. While the numbers of juveniles being released is significantly lower (11056 in 09/10) there is a bigger emphasise going into researching different grow-out techniques and on research projects in conjunction with universities, one of which is examining the effects of climate change on lobster.

The hatchery work here is very labour intensive compared to the Pictou hatchery. The juveniles are caught out of the hatchery tanks with a fine net and then placed into individual compartments in the grow-out tanks. This means each one has to be fed and its compartment cleaned, but it has the advantage of better analysis of amounts of feed needed and growth rates on different diets.

The catch and release methods of the breeding stock and juveniles is the same in all the hatcheries I visited, and most of the time the females were released back to the ocean, depending on the dinner menu of the hatchery workers.

Science

The study of lobsters in the northern hemisphere has been ongoing for hundreds of years. The understanding of the life cycle, the social structure at mating time, the places they prefer to live at certain times of the year and the biology of the animals has been studied in depth by quite a number of world renowned scientists and many grad students.

They have done tagging programs, inserted tracking devices under the shell and followed them around using hydro phonic equipment on working lobster boats, with each animal tag having an individual call signal. Under-water bottom surveys have been carried out, along with low tide onshore monitoring of rock pools and rocky shoreline, counting the numbers of newly settled lobsters in known settlement areas. Surveys of the deeper waters are carried out using remote control submarines searching for areas where the big breeders like to live.

Many of the projects are carried out by non government funded facilities like the Lobster Conservatory in Maine, where fishermen and the community fund the running of the centre and donate their time and effort to keeping it running.

A tool that can be extremely useful when it comes to making decisions about managing a fishery is using science from a number of different research facilities, considering that the results of some studies tend to be in favour of those paying the bills. A system where all science is government funded tends to sometimes overlook the fisherman's interests.

Photo B Tyley

This photo shows an old "lobster pound" that has been donated to the Lobster Conservatory in Friendship Maine. Here scientist Diane Cowan studies the lifecycles of lobster in a semi natural setting. The gates to the pound are open allowing movement in and out, but a wall across the gateway stops the water from completely draining at low tide.

The project that created the most interest for me is just starting in Canada, at the Atlantic Veterinary Collage Lobster Science Centre. There they are doing studies into the blood protein levels to find the ultimate time to harvest, just before the lobster malts when the shell is at its hardest and the body full of meat. There is also work being done to tell how far away from spawning the mature females are, which stage of malt they are in and the general health of the animal. All of this information can be gained from a drop of blood, taken by the fisherman while at sea. The test can be done on board the boat by placing the blood on a slide then into a viewer, with different colours coming up in the viewer depending on the state of the lobster's health and condition. There are also tests being developed for the changing fat and starch content in the meat.

The object of the study is to harvest when the lobster is in its peak condition and gain market advantage.

Currently the work is being carried out by scientists doing trips with the fishermen, until the system is perfected and rolled out for all of industry to be involved in. While the scientists are carrying out this work they are also taking a small cutting off of one of the small fins under the tail. These samples are being stored in vials and catalogued with all the relevant data such as position caught, date, depth, size, sex, malt state and any body damage.

This is the first stage of building a DNA data base on lobster families. One of the aims of this study is to identify genetic markers in lobster that will be able to be traced up and down the coast. This will reveal where a lobster's mother lives and where the egg hatched before drifting in the currents and finally settling to the sea floor.

This kind of information will be one of the best tools available for managing and rebuilding lobster stocks. The lack of information about where the paurulas travel between hatching and settlement, is the biggest challenge of lobster fisheries management the world over.

With this information breeding stocks in certain areas will be able to be protected and ensure that a steady flow of eggs enter the fishery each year.

The collecting of the tissue sample is very simple, and by having the fishermen doing it while they are at work is very cost effective. The DNA testing technology is becoming cheaper all the time and there is an opportunity to involve university students in this part of the project. So for a relatively small cost to industry, the benefits of a project similar to this across Southern Australia could help restore lobster stocks to much higher levels than are currently being experienced.

Photo B Tyley
Scientists from the Atlantic Veterinary Collage Lobster Science Centre doing on board monitoring.

The way forward

- Public perception of the whole fishing industry in Australia needs a facelift.

Australia has some of the best fishing practices in the world, and although there is always room for improvement, the management plans already in place are a long way infront of most of our competitors on the world market.

The industry needs to be more self promotional, and to realise that no one is going to tell a good news story for us. There is a lot of misinformation and distorted facts about fish stock numbers and fishing practices that are very outdated, and the fishing industry needs to set the story straight.

Facilities like the Gulf Science Centre and the Cornwall Lobster Hatchery are doing a brilliant job of telling good news stories about the industry, and they are driven by people that realise the economic value to the whole community of the fishermen.

If some of the fisheries training facilities here in Australia could tailor an informative, educational and hands on promotional package aimed at senior primary school children, showcasing some of the well managed and sustainable fisheries, then take the package on a tour around the schools, you would be educating the target audience as well as their parents, when the kids go home and talk about what they learnt at school today. An added benefit could also be that when people know that a product is coming from an eco-friendly supply, that product will have buyer preference.

- The trap design used in the nz needs to be reviewed.

The efficiencies that could be gained for the fisherman, as well as the benefits for the whole marine eco-system are too large to be ignored. Having the traps in the water for less time can only have positive effects for all aspects of the fishery. The only down side I can find is the change it will have on catch per unit effort statistics, but that can be rectified by the fishermen continuing to use the same 3 standard research traps that they have been using previously. This would mean that all previous data collected would still be relevant and the ongoing studies would not have to change.

- The DNA work being done in Canada has the potential to be a significant help in tracking where our paurulas are coming from.

Being able to monitor and protect an area of breeding stock will help guarantee the sustainability of the fishery well into the future.

Also with the oncoming implementation of marine protected areas in the waters around the South Australian coast, this information could provide a good guide for the areas to be protected.

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Plain English Compendium Summary

Project Title:	Northern Zone Rock Lobster Fishery Rebuilding and Sustainable Management
Nuffield Australia Project No.:	1008
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Objectives	To investigate management plans and harvest strategies of northern hemisphere lobster fisheries, compare research projects and technology advances in fisheries that have been active for a much longer period of time than the northern zone.
Background	The rock lobster fishery in the northern zone of South Australia has been experiencing declining catch rates since the end of the 1990's. Various reasons have been blamed for the decline, including environmental conditions and human influences. Since the inception of management in the fishery in 1967 the plan has been constantly evolving, with the biggest change coming in 2003. This saw the removal of input restrictions and a shift to individual transferable quotas. During the period of quota management the total allowable catch has been annually decreased to an all time low of the current 310 tonnes. At its peak in the mid 90's the industry was catching just over 1200 tonnes annually. For the fishermen to remain viable in the long term both the stock numbers need to increase, the fishermen need to become more efficient and market stability needs to be achieved .
Research	Fisheries managers, research facilities, hatcheries, fisheries departments, and many fishermen were visited along the east coast of the U.S.A., Canada, Ireland and the UK. Various different management plans were researched along with the differing results of each plan.
Outcomes	Fisheries management is not a black and white issue. There are many factors that cannot be controlled when dealing with a wild creature in its natural environment. Environmental conditions play a big part in the activities of lobster, so a cautious approach is needed when making changes to long term management plans. -The most encouraging research project being undertaken is the DNA profiling in Canada. The establishment of a data base linking lobster family's and being able to trace where eggs are laid compared to where the paurulas settle on the ocean floor will go a long way in protecting breeding stocks. -The blood protein work also being done in Canada will be quite valuable in terms of delivering the best possible quality product on to the market. -A large emphasis is being placed on public education and awareness of the positive work being done by the fishing industry in terms of eco-friendly fishing practices and having a minimum impact on the environment. -efficiencies in trap design will help the profitability of the fisherman, as well as have a positive effect on the marine eco-system.
Implications	The northern zone still has a long way to go in terms of rebuilding catch rates to historic levels, but after looking at the management of other fisheries I believe it is well on the right track. With the implementation of some of the previously mentioned research programs and efficiencies in trap design, the full recovery of the resource could come about in a shorter time frame and with less financial pain to the fishermen.