FINAL REPORT

aquatic animal health subprogram

Update of the AQUAVETPLAN Enterprise Manual (semi-open systems)

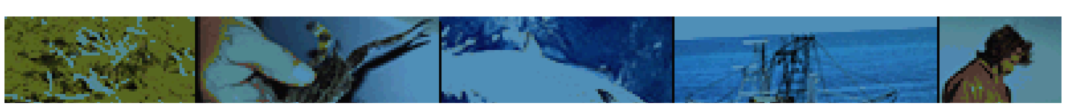
Dr. Jo Sadler

December, 2003

FRDC Project No. 2003/650

Australian Government
Department of Agriculture, Fisheries and Forestry

Fisheries Research & Development Corporation



Dr Jo Sadler

Aquatic Animal Health Subprogram: Update of the AQUAVETPLAN Enterprise Manual (semi-open systems)

The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a federal statutory authority jointly funded by the Australian Government and the fishing industry.

Printed by Dr Joanne Sadler, PO Box 457 Launceston, Tasmania, 7250, December, 2003

aquatic animal health subprogram

Update of the AQUAVETPLAN Enterprise Manual (semi-open systems)

Dr. Jo Sadler

December, 2003

FRDC Project No. 2003/650

Australian Government
Department of Agriculture, Fisheries and Forestry

Australian Government
Fisheries Research and Development Corporation

Table of contents:

Non-technical summary

2003/650 Aquatic Animal Health Subprogram: update of the AQUAVETPLAN Enterprise manual (Semi-open systems)

PRINCIPAL INVESTIGATOR: Dr Jo Sadler
ADDRESS: PO Box 457
Launceston,
Tasmania, 7250
Ph: 0423697692

OBJECTIVES:

1. To update a section (Semi-open systems) of the AQUAVETPLAN Enterprise Manual according to current industry practices
2. To seek industry endorsement of the revised edition of the Enterprise Manual (Semi-open systems)

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE:

The outcomes of the present project include a greater understanding and awareness of:

1. the structure and function of "Semi-open" aquaculture production systems currently used in Australia.
2. current production practices used within "Semi-open" culture systems that are pertinent to the management of aquatic animal health, bio-security as well as emergency disease preparedness and response.

The response of industry stakeholders to the information provided within the updated version of the Enterprise Manual (semi-open systems) has been very positive and has highlighted the benefits of the manual. In some cases, industry stakeholders that identified the need to develop a code of practice within their industry indicated that the information detailed within the Enterprise Manual articulates key issues to be considered in their formative code of practice. In other cases, industry stakeholders with an existing code of practice have indicated that the revised Enterprise manual is complementary to their existing resources and is a useful reference source.

The existing AQUAVETPLAN Enterprise Manual (Version 1, 2000) was produced by AFFA. The FRDC Aquatic Animal Health Subprogram (AAHS) identified the requirement for updating the AQUAVETPLAN Enterprise Manual as it is integral to the AAHS research plan and output.

The enterprise manual is an integral component of AQUAVETPLAN, which is a series of technical response plans that describe the proposed Australian approach to an aquatic animal disease emergency event. The manual contributes to the resources available to assist government and aquaculture industry personnel involved in the management of a potential aquatic animal disease emergency and, subsequently, the up-dated information provided in the revised version of the manual is crucial to the effectiveness of management resources.

KEYWORDS: aquaculture, production practices, aquatic animal health, finfish, shellfish, disease response

Acknowledgements

This work was funded by an FRDC minor funding grant.

I would like to thank the following people for their time and consideration of the draft document, as well as providing further technical information where required:

- Vicki Wadley, Tasmanian Salmonid Growers Association
- Pheroze Jungalwalla, Tasmanian Salmon Growers Association
- Kirsten Rough, Kailis Pty Ltd (Southern Bluefin Tuna cage culture)
- Carl Young, Australian Barramundi Farmers Association
- Martin Hernen and Simon Stone, South Australian Marine Finfish Association (Yellowtail Kingfish cage culture)
- Brett McCallum, Pearl Producers Association (Pearl oyster production)
- Scott Parkinson, Australian Seafood Industries (Pearl oyster production)
- Richard Pugh, Tasmanian Shellfish Executive Council (edible shellfish grow-out)
- Barry Ryan, Tasmanian Oyster Research Council
- Garry Zippel & Mathew Muggleton, South Australian Oyster Research Council
- Michael Whillas, South Australian Oyster Growers Association
- Rachael King, New South Wales (Oyster) Farmers Association
- Leslie Spencer & Ray Tynan, Oyster Farmers Association of NSW Ltd
- Jane Clout, Queensland Oyster Growers Association
- Mike Dredge and Tiina Hawkesford, Queensland Department of Primary Industries (Edible shellfish culture in QLD)
- Steve Rodis, Victorian Abalone Growers Association and Victorian Aquaculture Council (Edible shellfish culture in Victoria)
- Mark Gervis, Southern Ocean Pty Ltd (Abalone grow-out in Victoria)
- Simon Bennison, Western Australia Abalone Aquaculture Association and Aquaculture Council of Western Australia (Edible shellfish culture in WA)
- Daryl Evans, South Australian Abalone Growers Association
- Andy Dyer, South Australian Mussel Growers Association
- Brian Jones, Dept. Fisheries, Western Australia (Edible shellfish grow-out)

Background

The existing AQUAVETPLAN Enterprise manual (Version 1, 2000) was produced by AFFA. The FRDC Aquatic Animal Health Subprogram (AAHS) identified the requirement for updating the AQUAVETPLAN Enterprise Manual as it is integral to the AAHS research plan and output.

Need

The enterprise manual is an integral component of AQUAVETPLAN, which is a series of technical response plans that describe the proposed Australian approach to an aquatic animal disease emergency event. The manual contributes to the resources available to assist government and aquaculture industry personnel involved in the management of a potential aquatic animal disease emergency and, subsequently, the up-date of the manual is crucial to the effectiveness of management resources.

Objectives

1. To update a section (Semi-open systems) of the AQUAVETPLAN Enterprise Manual according to current industry practices
2. To seek industry endorsement of the revised edition of the Enterprise Manual (Semi-open Systems)

Methods

Dr Sadler used personal knowledge of industry codes of practice and aquatic animal health management to edit and supplement information within the original text of the "Semi-open systems" section of the AQUAVETPLAN Enterprise manual (2000). In addition, Dr Sadler liaised with key industry members to crosscheck and update information within the original AQUAVETPLAN Enterprise manual (2000), regarding industry practices, production figures and legislation. For example, in instances where additional or alternative practices had been adopted by industry since the publication of the original manual, the original manual was edited where appropriate and a written description of the altered practices was provided.

Results/Discussion

The following subsections within the existing "Semi-open Systems" section of the Enterprise manual were revised:

- "Salmonid cage culture"
- "Southern Bluefin Tuna cage culture"
- "Barramundi cage culture"
- "Pearl Oyster grow-out"
- "Edible shellfish grow-out"

Information regarding abalone and scallop grow-out was added to the "Edible shellfish grow-out" subsection (including on-land Abalone grow-out) and a subsection regarding "Yellowtail Kingfish cage culture" was drafted.

A draft copy of the revised "Semi-open Systems" section was sent to peak industry bodies for their comment, including a letter of request for additional information where required. Responses and comments were received from 24 of the 25 industry stakeholders that were contacted.

Where appropriate, industry feedback was incorporated within the final draft of the "Semi-open Systems" section and "Appendix 1 (legislation)" section of the Enterprise manual. The final draft was circulated among stakeholders to seek final endorsement.

The current project resulted in the successful revision of the "semi-open systems" section of the Enterprise Manual. Industry endorsement of the information presented within the revised section was obtained.

Benefits and Adoption

The following community groups and sectors of the Australian aquaculture industry benefit from the revised version of the Enterprise Manual (semi-open systems):

- Salmonid Growers in the states of Tasmania and South Australia
- Southern Bluefin Tuna Farmers in South Australia
- Barramundi Farmers in the states of Queensland, Northern Territory, New South Wales, South Australia and Western Australia
- Yellowtail Kingfish Farmers in South Australia
- Pearl Producers in Western Australia
- Oyster Growers in the states of New South Wales, South Australia, Tasmania, Queensland and Western Australia
- Abalone Growers in the states of New South Wales, Victoria, South Australia, Western Australia and Tasmania
- Mussel Growers in the states of New South Wales, Victoria, South Australia, Western Australia and Tasmania
- Scallop growers in Tasmania
- Aboriginal Lands Councils
- Conservation and environmental protection groups
- Government bodies at both National and state level (including agricultural and fisheries agencies, health departments)
- State Authorities and local councils
- Recreational fishers
- Commercial fishers
- Yachting/boat users
- Universities and other institutions
- Other water users

This project contributes to a greater understanding and awareness of:

1. the structure and function of "Semi-open" aquaculture production systems currently used in Australia.
2. current production practices used within "Semi-open" culture systems that are pertinent to the management of aquatic animal health, bio-security as well as emergency disease preparedness and response.

The benefits of this project include the provision of training and debriefing resources for personnel involved in the management of aquatic animal emergency disease preparedness and response. Furthermore, this project provides resources that may contribute to the sustainable management of natural resources.

Further Development

The following suggestions are outside the scope of the present project, but are directly related to the further development of the AQUAVETPLAN Enterprise Manual.

The following sections of the industry sector information presented in the original Enterprise Manual require revision:

1. Semi-closed systems
2. Closed systems
3. Open systems

In addition, the following important areas are currently omitted and need to be added to the "Semi-closed systems" section:

1. Barramundi hatchery and nursery operations
2. Yellowtail Kingfish hatchery operations
3. Pearl Oyster hatchery operations
4. Edible shellfish hatchery operations
5. Abalone on-land grow-out (some details presented in revised semi-open systems section)

Planned Outcomes

The project output includes an updated version of the AQUAVETPLAN Enterprise manual (Semi-open systems section). The Enterprise manual aims to provide brief information on current industry practices and structures and then outlines approaches that should be considered in the face of an aquatic animal disease emergency. The revised Enterprise Manual is to be distributed amongst key government and industry personnel who may be involved in emergency disease preparedness and response. The manual is designed to complement State, industry and farm operational emergency plans.

Conclusion

The Semi-open systems section of the Enterprise Manual was revised and presents information regarding the current structure, function and production practices used within "Semi-open" culture systems in Australia. This information is relevant to aquatic animal emergency disease preparedness and response.

References

AQUAVETPLAN Enterprise Manual: AQUAVETPLAN, Version 1, 2000. Ed. Linda Walker. Published by Agriculture, Fisheries and Forestry – Australia. http//www.affa.gov.au/outputs/animalplanthealth.html.

Appendix 1: Intellectual property

There is no intellectual property arising from this project.

Appendix 2: Staff

Primary Investigator and Administrator: Dr Jo Sadler

Appendix 3: Industry Contacts

Vicki Wadley
Tasmanian Salmonid Growers Association
Ph: (03) 62250904
Email: vwadley@utas.edu.au

Pheroze Jungalwalla
Tasmanian Salmonid Growers Association
Ph: 0419 898852
Email: jungalwalla@tsga.com.au

Kirsten Rough
Kailis Pty Ltd (Southern Bluefin Tuna cage culture)
Ph: (08) 86821970
Email: kirstenrough@kailis.com.au

Carl Young
Australian Barramundi Farmers Association
Ph: 0407771506
Email: carlyoung@ozemail.com.au

Martin Hernen and Simon Stone
South Australian Marine Finfish Association (Yellowtail Kingfish cage culture)
Ph: (08) 83032790
Email: mhernen@optusnet.com.au

Brett McCallum
Pearl Producers Association (Pearl oyster production)
Ph: (08) 92442933
Email: pearler@wafic.org.au

Scott Parkinson
Australian Seafood Industries (Pearl oyster production)
Ph: (03) 62436549

Richard Pugh
Tasmanian Shellfish Executive Council (edible shellfish grow-out)
Ph: 0408210672
Email: richard@shellfishculture.com.au

Barry Ryan
Tasmanian Oyster Research Council
Ph: 0419381176
Email: barry.ryan@optusnet.com.au

Garry Zippel & Mathew Muggleton
South Australian Oyster Research Council
Ph: (08) 86257022
Email: gzippel@bigpond

Michael Whillas
South Australian Oyster Growers Association
Ph: 0427511389
Email: mcwhillas@bigpond.com

Rachael King
New South Wales (Oyster) Farmers Association
Ph: (02) 82511856
Email: kingr@nswfarmers.org.au

Leslie Spencer & Ray Tynan
Oyster Farmers Association of NSW Ltd
Ph: (02) 94873566
Email: oyster@oysterfarmers.asn.au

Jane Clout
Queensland Oyster Growers Association
Ph: 0419786631
Email: jclout@kooringaloysters.com.au

Mike Dredge and Tiina Hawkesford
Queensland Department of Primary Industries (Edible shellfish culture in QLD)
Ph: (07) 32242257
Email: mike.dredge@dpi.qld.gov.au

Steve Rodis
Victorian Abalone Growers Association
and Victorian Aquaculture Council (Edible shellfish culture in Victoria)
Ph: 0407311551
Email: stever@gsw.com.au

Mark Gervis
Southern Ocean Pty Ltd (Abalone grow-out in Victoria)

Simon Bennison
Western Australia Abalone Aquaculture Association
and Aquaculture Council of Western Australia (Edible shellfish culture in WA)
Ph: 0407776439
Email: acwa@wafic.org.au

Daryl Evans
South Australian Abalone Growers Association
Ph: 0402144909

Andy Dyer
South Australian Mussel Growers Association
Ph: 0428837275
Email: andyer@bigpond.com

Brian Jones
Dept. Fisheries, Western Australia (Edible shellfish grow-out)
Email: bjones@agric.wa.gov.au

Aquatic Animal Health Subprogram:
Update of the AQUAVETPLAN Enterprise Manual
(Semi-open systems)

December, 2003

for endorsement by
Aquatic Animal Health Committee

B.2 Semi-open systems

B.2.1 Introduction

B.2.1.1 Overview of semi-open systems

Semi-open systems, generally used for culture of finfish and molluscs, are typified by water-cage/net-pen systems in which the stock are contained or controlled in a relatively uncontrolled environment. Movement and control of stock is possible but there is no control over the movement of water in, through, and around the culture system.

Finfish industries

In Australia the main finfish industries using a semi-open system include the salmonid industry in Tasmania (growing Atlantic salmon and rainbow trout), the tuna industry in South Australia (growing southern bluefin tuna) and barramundi farming in the tropics and other regions where warm water is available. There is a very young and promising industry in South Australia based on yellowtail kingfish that uses a semi-open culture system. In addition, other finfish species such as snapper and stripey trumpeter are being introduced to semi-open systems and it is likely that these new species will increase in commercial importance.

The aquatic environment of semi-open systems is not modified, rather the aquatic environment is chosen for its suitability for the culture system. The fish are reared in cages that are moored in marine, estuarine or freshwater environments. They are usually in sheltered situations. Barramundi are also reared in intensive, indoor production systems with controlled environment buildings using underground (pathogen-free) water and a high level of recirculation through biofilters (see closed systems for more details).

Due to the high stocking density of fish within cages an adequate circulation of water through the cages is essential to the well-being of the fish. There is virtually no control over the water in which the cages are located. An impermeable liner can be placed around the cage to prevent any movement of water, but such a liner also prevents any oxygen-rich water reaching the fish, and waste products (e.g. ammonia) being diluted out.

In a semi-open system excess feed can fall through the cage and be deposited on the sea/estuary bottom under and near cages. Good management minimises such losses of feed to reduce waste and pollution. Some of the excess feed is consumed by cohabiting fish species or the crab collection under the cages. Faecal material, depending on water movement, is either carried away from the site or deposited on the sea floor near the cages. Good management practices incorporate seasonal fallowing of used cage sites within a farm lease to minimise the accumulation of fish waste deposits on the substrate below used cage sites and to allow recovery of the sea floor and benthic bio-diversity.

Premises in semi-open systems are usually land-based however much of the equipment needs to be suitable for, and be able to withstand the harshness of, an open water site.

Important factors with respect to premises and equipment in semi-open systems are:

- boats are the main form of transport
- equipment used to house and contain the stock needs to be robust and strong and, in many cases, needs to be transportable either by towing or lifting onto boats
- premises can range from substantial buildings that contain machinery and stock feed, sheds, offices, mess rooms and laboratories, to simple sheds designed to protect workers from the weather.
- often there are large open on-land work areas used for maintenance and storage of nets and other equipment
- there are usually designated areas on-land for the disposal of stock mortalities and other wet waste from harvesting and processing.

Fish cultured in semi-open systems are either captured in the wild and towed to the grow-out site by boat, or, as in the case of salmonids and kingfish, transported by road from the hatchery to the grow-out site. Once fish are located at the culture site they may be transferred to net-pens by helicopter drop or fish pump and the stocked net-pens are generally moved by towing. Movement of stocked net-pens can occur between culture sites. Barramundi can be cultured in controlled environment systems anywhere in the country and barramundi fry are often transported by air.

Fish species cultured in semi-open systems have varied growth rates. Salmonids are suitable for marine culture when they are around 45 - 100 grams in weight (15 - 20 centimetres in length), and are harvested 12 - 18 months later, when they are around 2.5 – 4.5 kilograms. Tuna can be anywhere from 3 – 50 kilograms when they are captured at sea, and then are harvested later the same year when they are conditioned for market. Barramundi are moved from nursery facilities to grow out cages when they reach about 80 - 100 millimetres total length. Marketable plate-size fish (approximately 300 – 500 grams) can be attained in 6 - 8 months. Growing fish to 2 - 3 kilograms may take up to 14 - 30 months. Kingfish fingerlings are transferred to sea-cage grow-out facilities at a weight of 5 – 10 grams and harvested 18 – 30 months later at a weight of 3 – 6 kilograms.

Feed used in the culture of salmonids, barramundi and kingfish is generally processed feed made in Australia. Some processed feed or feed ingredients may be imported. Feed used for tuna is usually fresh and frozen baitfish that may be imported. Research is being conducted into the development of a domestic processed feed for farmed tuna and a commercial product may be available in the near future.

Mollusc Industries

Semi-open farming systems for molluscs usually have the shellfish either suspended from long-lines, in baskets from lines or housed in racks. Young shellfish may be harvested from the wild ‘spat-fall’ or cultured from wild-caught or domesticated brood stock in tanks in sophisticated hatcheries. Shellfish hatcheries are classified as semi-closed or closed systems.

Algae and diatom cultures are used to feed larvae during the hatchery and nursery phases. The molluscs are not actively fed during the grow-out period but rely on natural food floating through the lease.

The commercial production of molluscs for human consumption is based on oysters (mainly Sydney rock, Pacific and flat oysters), mussels, abalone and scallops.

In northern and north western Australia, pearl oysters are the basis of a large industry. Historically, the pearl industry was based on a fishery, but since the development of pearl oyster culturing techniques the industry has become the second largest dollar value aquaculture industry in Australia.

Husbandry practices and disease control

In semi-open systems, husbandry practices that are most important with respect to disease incursion control include:

- location of semi-open culture site
- location of stock source
- method of transporting and moving stock
- method of housing stock
- type of stock feed
- method of feeding stock
- handling of stock during the semi-open production phase
- practices employed to protect stock from predation and disease
- practices employed to monitor stock feeding behaviour, mortality and disease status
- method of harvesting stock
- method and schedule for removing stock mortalities from culture facilities.

B.2.1.2 Interactions of semi-open systems and the environment

There is a two-way interaction between animals farmed under semi-open systems and the environment. This means that there is no barrier between the environment within and outside the farm area and water-borne agents can move freely in and out of the cages.

The animals within semi-open systems interact directly with outside populations as wild animals are attracted to the food source on, under and within the cages or other structures. Large structures such as racks and nets quickly become substrate for complex, biofouling communities consisting of sea plants and creatures. In some instances, interaction may also occur if animals within semi-open systems escape into the wild.

B.2.2 Southern Bluefin Tuna cage culture

B.2.2.1 Introduction

The following table summarises the main features of the southern bluefin tuna industry sector.

Species	**Southern Bluefin Tuna**
Location	South Australia
Length of production cycle	2-9 months
Product	fresh (head on gilled and gutted) and deep frozen (minus 60°C)
Annual production (tonnes)	9,245 (2001 – 2002)
($ value)	260.5 million
System	Net/sea cage culture
Feed used	Fresh and frozen whole fish (can be supplemented with moist manufactured feed, and vitamin premix powder)

B.2.2.2 Practices

Farming southern bluefin tuna (*Thunnus maccoyii*) involves catching wild stock by purse seine net from the tuna fishing grounds in the Great Australian Bight, towing the fish back to a culture site and then on-growing the fish to the fatness or condition index required by the market.

Access to wild fish stocks is restricted by a quota system and the seasonal presence of tuna in South Australian waters, between November and May.

The juvenile tuna captured are usually 3 – 4 years old and weigh between 15 and 45 kilograms per fish. In some years, 2 – 5 year old stock are caught and then fish weight varies between 3 kilograms and over 50 kilograms per fish.

Once caught, the wild fish are herded/transferred into a tow-cage and then towed by boat for up to 500 kilometres, from the fishing grounds to the grow-out site. When tuna arrive at the grow-out site adjacent to Port Lincoln they are transferred from the tow-cage into 3-5 grow-out cages, which may be located on several lease sites. License conditions restrict the stocking density to a cage biomass of less than 4 kg per cubic metre at the time of stocking, and a lease biomass of less than 6 tonne per hectare.

All processes of capture and transfers are conducted by swimming the fish through an underwater video panel. Grading is not done during the grow-out cycle and the tuna are not handled until they are harvested.

During grow-out, the tuna are fed frozen or defrosted whole baitfish that is either sourced domestically or is imported by AQIS registered wholesalers. Feed is delivered to freezer stores and then to farm sites by refrigerated trucks. The feed is then transported to marine sites by boat and fed to the tuna either once, twice or continuously through-out the day.

Stocked cages are monitored daily for health status and mortalities are removed by means of diving. Mortalities are either buried in a designated area on-land or included in by-products such as fertiliser and meals for pig and poultry that are made locally.

Water quality is monitored regularly, including the identification and quantification of phytoplankton species.

All fish stocked on the farms are fattened and harvested prior to the fishing/stocking season the following year. Harvesting is done in response to fish condition or fatness, not size. Harvests of 40 to 1200 fish are conducted at the cage site by hook and line or by crowding tuna in a net and capturing them with a gaff or a diver. Fish are killed (by a spike to the head) and bled on site. The gills and viscera are removed on the boat as well. Blood and viscera are retained on the vessel for disposal on land (same means as mortalities). Fish are placed in ice-slurry bins and tanks on the vessel and if destined for airfreight or fresh product they are processed and packed-out that afternoon or the following morning, in export premises on land. Fish destined for ultra-low freezing are either transferred onto freezer vessels at sea, or unloaded to export premises on land. All fresh or frozen product is exported as a whole fish with gills and viscera removed.

Cages are emptied within two to nine months of the initial stocking and all nets are completely removed from the water, cleaned and air-dried prior to the next season's stocking. For each production cycle, new cage sites are used within a lease and lease sites are large enough to allow a cage site fallow period of at least five years.

No chemicals or anti-foulants are used at any stage of the catching or farming operations.

B.2.2.3 Premises and equipment

Fish are held in double collar polyethylene polar cirkel sea cages, custom made single collar cages or (very rarely) rubber Bridgestone ocean cages, which are 32 to 50 metres in diameter (i.e. 100 to 157 metres circumference). The most common type is the 40metre diameter (126 metre circumference) single (450 millimetres) collar cages.

Containment nets are 100 to 160 metres in circumference, 9 to 15 metres deep (to the lead line) with a mesh stretch of 75 to 200 millimetres and are made from polypropylene or nylon. Predator nets are usually 150 - 300 millimetre mesh stretch and either hang outside the containment net from the cage collar to the seafloor or are a contained bag with a floor beneath the containment net floor. Net washing is conducted in situ but may not be necessary while fish are stocked

'Hiab' type hydraulic winches are mounted on most boats to assist in changing nets, lifting weights, mooring lines etc., purse-seine type vessels also have hydraulic power blocks.

Service vessels used for feeding, harvesting and towing vary between companies and range from 12 metres to more than 30 metres in length. The same boats and trucks are used for carrying out multiple tasks. Forklifts are ubiquitous throughout industry.

Custom made feeding devices are used widely in the industry and consist of a small floating mesh cage positioned within sea cages. The purpose of the mesh cage is to contain blocks of frozen feed, which defrost and trickle feed the tuna over a 2 – 4 hour defrosting period.

All harvesting occurs on-site. All harvesting equipment is portable and is loaded onto boats prior to, and removed after, harvest. Harvest bins and processing factories are disinfected with export certified detergents after every use.

Most farms are able to fully equip a dive team with diving gear. The amount of dive gear available on each farm will depend on whether or not contract divers are used.

All farms have a fully equipped workshop at their land-based service facility. Some farms have a laboratory facility that is equipped with microscopes, dissection and water quality testing equipment.

The tuna industry maintains a central research office with laboratory facilities and scientific staff at the marina in Port Lincoln. Specialist pathology facilities are available in Adelaide, which is a 45 minute flight or overnight bus trip from Port Lincoln.

Stores

All imported feed is stored at one of the AQIS approved and registered freezer store areas located mainly in the industrial area of Port Lincoln, but some intermediate stores are located intra and interstate. Locally caught bait fish can be stored at the same AQIS approved premises or at freezer stores owned by pilchard quota holders or processors, these are mainly located in the industrial area of Port Lincoln.

There are seven factories with export approved facilities, that are used for processing the tuna as fresh or deep frozen product. These are mostly located in the industrial area of Port Lincoln.

Other equipment, such as nets, trucks, feed bins, feeding and harvest equipment etc. is stored in sheds. Each company owns or leases shed facilities in the industrial parts of the city, which are used for storage or as workshops for net and cage repairs etc.

Some companies have export processing facilities, frozen feed storage, canneries, storage sheds and large work areas all at the same site.

Vehicles

All workers live in Port Lincoln or the surrounding districts and therefore drive to and from either the factory/workshop site, the wharf, shipyard or marina facilities.

Trucks are used to transport feed from feed stores to where the boats depart. Forklifts are common at the shed/workshop areas, at feed storage freezer sites and at the processing factories.

Refrigerated trucks are used to transport export product, destined for Japan, from the processing factories in Port Lincoln to the international airports of Melbourne or Sydney. The containers of shore frozen tuna are transported by road to a shipping port for sea-freight to Japan.

Personnel

Larger farms may have up to 70 workers. Some staff of the bigger companies have qualifications in aquaculture or marine sciences. The level of training and the competency of workers is very high, and the industry has collaborated in some areas of expertise (e.g. diving) to ensure high standards and protocols are maintained.

Workers may be involved in more than one activity but, generally, there are land-based staff (for fish processing, stores duties and engineers) and sea-based crew (for diving, feeding and harvesting). Practices are similar across farms, so workers from one farm would have little difficulty moving to another farm. Contractors can be used for repairs and maintenance to farm equipment. Companies that own an export facility have a team of specialists to process the fish for market - these teams are relatively static and rarely perform tasks on the farms.

Some farms have contract divers; others have their own teams trained in commercial diving practices to do the work. Currently, divers do not disinfect themselves between dives, but this practice is achievable if necessary. Contract divers travel between net pens and between lease sites within a single workday.

B.2.2.4 System inputs

Animals

Southern bluefin tuna are captured at sea (the southern ocean), transferred into a tow-cage and towed to the grow-out site. One tow-cage can supply tuna to many lease sites but each lease site has only one company operating on it.

Adult southern bluefin tuna attain body lengths in excess of 200 centimetres, more than 200 kilograms in body weight and can live for up to 45 years. The tuna first spawn at around 8 years of age, when they are about 150cm long.

Tunas are highly migratory and the southern bluefin tuna has a circumpolar distribution between the latitudes of 30 and 50 degrees South.

Temperate tunas (i.e. southern and northern bluefin) have a unique system of cutaneous arteries and veins supplying blood to the muscle and *retia mirabilia* (heat exchangers minimising loss of heat produced by the fish's metabolism and activity). This enables them to maintain a body temperature up to 15°C higher than the ambient water temperature. However in the farm situation, basal body temperatures are mostly only 2 to 4°C above ambient water temperature.

Unlike most fish, these tuna are ram ventilators: this requires them to constantly swim up to one body length per second to breath. They are very active and powerful fish that can attain swimming speeds of 20 body lengths per second (up to 80kilometres per hour).

The gill surface area is high (it approaches that of a mammalian lung) and has an extensive array of cross-linkages and fused lamellae to allow proportionally more dissolved oxygen to be removed from the water than any other fish. These cross-linkages and fused lamellae make tuna gills particularly vulnerable to obstruction by particulate matter and fine air/oxygen bubbles, which can lead to hypoxia.

There are many other species of wild fish and shellfish seasonally or resident in the vicinity of open water cages and often many inside the cages themselves - species include schools of baitfish such as yellowtail chow, slimy or blue mackerel, tommy ruffs or Australian herring, Australian salmon, anchovies, pilchards, snapper, small blennies, seahorses, octopi, squid, scallops, razorfish, sea cucumbers/holothurians, sea urchins and various types of jellyfish etc. There is little known about the movement pattern of these fish, but it is known that some species are migratory, and some which are more permanently resident in the area. These fish can act as a food source for the tuna but can also be important vectors of disease agents. It is likely that these fish harbour potential pathogens but the extent of this is unknown.

Aquatic animal and plant communities develop on the nets. Such fouling communities include green and brown macrophytes, blue mussels, juvenile rock lobster, and multitudes of small crustacea, invertebrates and finfish.

Water

Within a lease site, cages can be located in close proximity to each other (within 50 metres). Lease sites can be as close to each other as 300 metres.

Water temperature ranges from a daily minimum of 12 – 14 °C in winter to a daily maximum of 22 – 27 °C in summer, it varies from year to year. Temperatures above 24 °C sometimes cause stress to the fish, in which case the fish are not usually fed. Weather conditions can make the water rough in exposed sites making working conditions difficult.

Current flow varies between sites, but all sites have some daily variation in current flow - therefore there are certain times in the day when attempting certain management practices (e.g. setting harvest nets) is difficult. Periods of low water current occur during neap tides.

Feed /bait used

During grow-out the tuna are fed with a mixture of frozen and defrosted whole anchovies, pilchards, herring, mackerel and squid from a variety of sources including both Australian and imported fisheries. Fresh (never frozen) locally caught baitfish are fed to the tuna when available.

Imported feed is supplied by, and stored frozen at one of a number of AQIS registered premises, many of which are in Port Lincoln. Compliance agreements are in place for all sites and companies utilising imported baitfish (as tuna feed or for other uses), these have a list of quarantine practices that must be followed and are subject to inspection and audits.

Some operators supplement this wet fish diet with a vitamin and mineral premix. Research is currently underway to develop a semi-moist manufactured diet.

Personnel

Workers do not live on-site and they travel to work each day.

On most farms the number of workers per farm remains reasonably constant. Farms and factories hire contract workers, including divers, from time to time or are on a regular basis (eg a contract dive team will undertake towing, daily underwater inspections, net cleaning and harvest diving operations for the full season).

Often teams specialise in one particular task, such as feeding, or net work etc. Each company may own a number of marine leases and in these cases personnel (including vessels and equipment) moves between each of these sites daily. Companies that own a processing and export facility have a team of specialists to process the fish for market. These teams are relatively static and rarely perform tasks on the farms.

Farm sites may have regular visitors such as recreational fishers, researchers (including fish health specialists) or other members of industry.

Equipment

Most farms have the equipment available to fully equip a dive team with diving gear however the amount of gear available depends on whether contract divers are used.

Most farms have transportable harvesting equipment, which is loaded onto boats prior to harvesting. Harvesting equipment includes a small seine net, a floating platform that carries up to 5 people and attaches to the cage collar, tables with sides and collection sumps to retain blood and mucus, plus all associated knives and processing implements.

All farms use a submersible video and panel to count fish from the tow cages into the grow-out cages at the start of the season. This equipment set-up is available from the Australian Fisheries Management Authority (AFMA) contractors throughout the year if required. Some farmers have submersible video cameras to observe sub surface feeding activity.

Some companies may own a number of marine leases and equipment moves between these sites regularly.

Stores

Feed is delivered directly from an AQIS registered premise to a cold store or to the marine sites. Pre-season, feed is stockpiled ready for when the tuna arrive. Feed types subject to restricted use can be stored from one season to the next.

All farms have a shed and paddock store where small boats, nets, weights, ropes, harvest equipment and bins, feeder cages etc are kept but the amount of gear stored at these sites varies between farms.

Vehicles

Most workers live elsewhere and so drive to the boats, factory or shed each day using personal vehicles.

Trucks are used to transport feed to stores and boat departure sites. Forklifts are used as the main on-land workhorse at the shed and freezers, cranes and truck or vessel hiabs are used on land at the vessel un/loading site.

Boats are used to transport personnel, equipment and feed to marine sites. Boats may visit different lease sites.

Recreational fishers are present in the waters between leases and surrounding tuna farm cages on a daily basis. Industry has no control over the presence, practices and movements of fishers.

B.2.2.5 System outputs

Aquatic animals

Harvesting occurs in response to fish condition (fatness), not size, therefore each marketable fish can be as small as 15 kilograms or weigh in excess of 60 kilograms, depending on the initial stocking size.

Harvests of 40 to 1200 fish are conducted at the cage site by hook and line, or by net crowding the fish and using gaffs or divers to retrieve the fish. Fish are killed (by a spike to the head) and bled on the vessel on site, with operators partly removing the gills and viscera on the boat as well. All blood and viscera are retained on the vessel for disposal at approved land premises.

Fish are placed in an ice slurry on the boats. Those destined for fresh, air-freight product are processed and packed out that day or the following morning in export factory premises on land. Fish destined for ultra-low freezing are either transferred onto freezer vessels at sea, or unloaded to export premises on land. The majority of product is exported to Japan, but small quantities also are sold in America and domestically in Australia - each fish is worth in excess of AU$1000.

Cages are completely emptied within two to nine months of the initial stocking.

Water

Fish are confined within cages and so an adequate circulation of water through the cages is essential to the well-being of the fish.

There is virtually no control over the water in which the cages are located, except if an impermeable liner is placed around the cage - such a liner prevents any movement of water, but also prevents any oxygen-rich water reaching the fish, and any water high in waste products (e.g. ammonia) being diluted out. If water conditions deteriorate the cages can be towed within the hour.

Waste materials

During the grow-out period, excess feed and fish faeces may accumulate on the substrate below sea-cages. However, cage sites are only used for 2 – 9 months of the year, allowing a remedial fallow period of 3 to 10 months every year. In addition to this, in the following season, cages are not placed in the exact location of any cage in the previous season. Each cage has its own set of moorings all of which are removed from the water after the cage is destocked.

Mortalities are either dumped in landfill or dehydrated and processed into protein supplements at Feedlink.

Gills and viscera are disposed of either as landfill, dehydrated and processed into protein supplements at Feedlink, or frozen to be used as leather-jacket bait.

Wastewater from the factories is discharged into Proper Bay after treatment at the municipal sewage treatment plant or after treatment at onsite waste-water treatment plants.

Personnel

Workers on farms usually leave the farm site at the end of each day. Boats may visit different farm sites.

Vehicles and equipment

Most workers use their own vehicles to get to and from home and the farm site. Boats are used to get between one of the three loading areas of Port Lincoln and the marine lease sites , vessels can also travel between different lease sites of the same company and across those of different companies. After the initial transfer of fish from the tow cage after capture, boats do not tow cages containing fish unless dictated by emergency situations (e.g. algal blooms, oil spills).

Each company has its own equipment and vessels, apart from processing facilities, there are very few shared facilities.

Industry has no control over the presence or movement of vessels used by recreational fishers in the vicinity of farm sites.

B.2.2.6 Groups involved

Groups involved include:

- government bodies at both a national and State level
- Tuna Boat Owners Association
- state authorities and local councils
- community groups e.g. protection/conservation groups
- recreational fishing
- yachting/boating
- commercial fishers
- universities and other institutions
- other water users.

B.2.2.7 Legislation and codes of practice

In South Australia, fish and fish diseases are covered by the *Livestock Act 1997* and the *Fisheries Act 1982.* (The *Fisheries Act* 1982, is currently under review and will soon be up-dated). The Capture fisheries in state waters are managed under the *Fisheries Act 1982*. Southern bluefin tuna is captured in commonwealth waters and brought into state waters for the purpose of aquaculture. Therefore allowable wild catch (quota) is set and managed under the Southern Bluefin Tuna Management Plan of the Australian Fisheries Management Authority, which is effective until the fish are transferred into the grow out cages on the lease sites adjacent to Port Lincoln. Primary Industries and Resources, South Australia subsequently manages them under the Aquaculture Act 2001.

See Appendix 1 for information on relevant legislation.

As at 2003, the Tuna Boat Owners Association is currently developing a code of practice.

B.2.2.8 Occupational health

Public health

The following public health issues should be considered:

- the safety of the product if it is harvested when toxic algal blooms or chemical spills are suspected
- the potential to transmit zoonotic diseases (see Appendix 2) through the product
- quality of harvested product if emergency harvested due to disease
- availability of laboratories capable of testing for public health factors
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed
- drug residues in treated fish
- worker safety.
- disposal of dead fish and product wastes where required

Worker safety

The following issues of workplace health and safety should be considered:

- the harshness of environment (e.g. bad weather conditions) can be an impediment to safe work practices
- diving is a regular activity on farms but requires specialised training and qualifications - it is illegal and extremely dangerous for untrained personnel to dive
- working 'on the water' requires experience and so can be dangerous to inexperienced personnel
- weather conditions and current flows should be considered if deploying liners (to isolate fish) or nets (to capture stock)
- ropes, nets and heavy equipment are dangerous if not used appropriately
- heavy equipment is often used
- operation of boats requires specialised qualifications and experience
- safety equipment is required
- potential threat to the safety of workers' health should be considered prior to the collection, handling and disposal of dead, decomposing or diseased stock
- the safety of workers preparing and applying chemical treatments.

B.2.3 Salmonid cage culture

B.2.3.1 Introduction

The following table summarises the main features of the salmonid industry sector (grow-out only).

Species	**Atlantic salmon**	**Rainbow trout**
Production location	Tasmania, SA	Tasmania
Length of production cycle	12-18 months	7-10 months
Product	fresh and smoked product	fresh and smoked product
Annual production (tonnes) ($ value)	14,356 (2001 - 2002) 112.1 million	1,864 (2001 - 2002) 12.9 million
System	sea-cage/net-pen culture	sea-cage /net-pen/pond culture
Feed used	dried, pelleted ration	dried, pelleted ration

The Rainbow trout (*Onchorynchus mykiss*) and Atlantic salmon (*Salmo salar*) stocks used by the Tasmanian salmonid aquaculture industry are fully domesticated and were introduced to Australia during the late 1800's and 1963 – 1965, respectively. Between 1968 and 1999, legislation prevented the importation of fresh salmonid products to Australia. There remains a moratorium for importing fresh salmonid products into Tasmania.

Atlantic salmon require water temperatures of 4 - 16°C to maintain optimal growth and good health. Temperatures above 18°C cause stress to the salmon and subsequently affect both their growth and health. Rainbow trout can tolerate slightly higher water temperatures than Atlantic salmon, but show signs of stress at water temperatures above 20°C.

B.2.3.2 Practices

Atlantic salmon cage culture

Although the following text refers to Atlantic salmon, the same systems are used for both Atlantic salmon and rainbow trout.

Atlantic salmon farming consists of a freshwater hatchery stage (see Section B.3.6 Salmon hatcheries) and an estuarine/marine grow-out stage. Young salmon (smolt or pre-smolt) are usually introduced into the marine environment when they are between 12 - 17 months old and weigh 45 - 100 grams - in Tasmania this is from May to October.

Specialised trucks are used to transport young salmon from the inland hatchery to the marine site. Fish are then either directly transferred into cages at the marine site land-base or they are air-lifted by helicopter to cages on remote marine sites. Specialised trucks are also used to transport broodstock from marine sites to the hatchery just prior to the spawning season.

Floating cages, of either individual circle or square-grid system design, are used to house the salmon in the marine environment.

A circular cage consists of a circular plastic support to which is attached a circular nylon net. The circumference of these cages is 40 - 150 metres, and the nets have a depth of 8 to 14 metres. Circular cages may be placed in close proximity to one another (up to 50 metres) within a lease.

System cages consist of a grid of plastic pontoons and steel walkways that support a number of square nets in close proximity to one another (2 – 3 metres between neighbouring cages). The nets are made of either nylon or steel. The length and width of each square net is 25 metres and the depth of each ranges from 8 - 15 metres.

All cages are moored to the sea bottom by an elaborate system of ropes and anchoring structures. The cages can be towed between mooring systems. Additional predator nets are usually installed to surround individual cages or raft systems to protect stock from large predators such as birds and seals.

Most cages are located in moderately protected areas (i.e. from wind and wave action) while the placing of cages in more exposed areas is currently being considered.

Salmon are usually on-grown in net-cages for 12-18 months. There is usually 10 000 - 60 000 fish in each cage, depending on the size of the cage and the size of the fish. This results in a stocking density of four to fifteen kg per cubic metre of water. During grow-out, salmon are graded as required which ensures fish in the same pen are of similar size.

Fish are fed a commercial dry pelleted ration produced in Australia and some farms are evaluating imported feeds. During the warmer months fish may be fed pellets of up to three percent of their bodyweight per day. During winter this feeding rate can be as low as 0.5 percent. Feed is usually delivered to the farms on trucks in one tonne or 25 kilogram bags. The method for feeding fish varies between farms. On some farms the fish are fed by automatic feeders that consist of either individual units located on each cage or a central control unit that feeds a number of cages. On other farms the fish are fed from a boat, either by hand using feed scoops or using a manually operated cannon feeder, which blows the feed into the sea cages.

Salmon are usually harvested when they have attained a weight of 2.5 - 4.5 kilograms head-on, gilled, gutted (HOGG) weight.

Some farms have a processing facility near to the marine sites and cages are towed to this site for harvesting. Other farms conduct harvesting “on the water”, using barges or boats.

During harvesting, fish are crowded in the pen, and either drawn from the water using a fish pump, or collected with a Braille net (usually 20-30 at a time) and lifted into an anaesthetic tank.

(Broodstock is handled in a similar way during seasonal maturity checks and sorting, prior to transfer to the hatchery).

During harvesting, carbon dioxide is used to anaesthetise the fish. The carbon dioxide is bubbled through a bath containing the fish. When sufficiently anaesthetised the fish are moved onto a bleeding table. The fish are cut, usually near the base of the gills, to facilitate bleeding and then, within a few minutes, placed in an ice slurry.

If the processing is on site the fish are then either processed, which involves them being eviscerated, cleaned and packaged or, forwarded on to the value adding section. If the processing site is distant from the harvesting site, the fish are trucked in bins (in ice slurry) to the processing facility. Fish may be kept in the ice slurry for up to 24 hours before processing, but usually no longer than 12 hours.

Harvest bins and equipment are sanitised between uses and processing facilities meet export standards.

Approximately 15 percent of fresh fish are exported overseas (using airfreight). These fish reach the overseas markets within 24 hours of harvesting.

A lot of the fresh fish is air-freighted to the mainland wholesale markets in Melbourne and Sydney - some go directly to restaurants and retail suppliers.

A proportion of salmon is sent to a value-adding process such as smoking (hot or cold).

At water temperatures above 18 °C salmon are more susceptible to disease agents and often farmers will not feed fish. Hence warm summers where water temperatures are high are detrimental to growth and general health. Farm personnel regularly sample a small number of live fish stock from each of the grow-out cages to inspect the fish for growth and health status.

Freshwater bath treatments are used to control amoebic gill disease. These bath treatments require plastic liners, a source of freshwater and adequate oxygen supply.

Cages are monitored for fish mortalities ("morts") on a regular basis (2 – 7 days a week) and "morts" are removed from cages by various methods including dip-net, mort retrieval devices and scheduled diving. The collected "morts" are buried in a designated area on-land.

Farmers regularly monitor water quality on estuarine and marine sites. Records may be kept of parameters such as dissolved oxygen, temperature, turbidity, pH, salinity and phytoplankton identification.

Some farms regularly fallow cage sites within a lease area for a year or more.

Rainbow trout cage culture

Culture of rainbow trout is basically the same as for Atlantic salmon cage culture, except that rainbow trout do not go through a smoltification stage. When introduced to brackish or salt water, rainbow trout immediately go through an acclimatisation stage (i.e. there is no prior phase where they 'get ready' for the transfer to salt water). As rainbow trout do not perform well in full salt water (31-35 parts per thousand salt) they are usually only grown in sites with brackish water (15-21 parts per thousand salt). Transfer to such sites usually occurs when the fish are approximately 12 months old (50 – 100 grams weight).

B.2.3.3 Premises and Equipment

On salmon farms boats are the main form of transport. Boats are used to transport and often to deliver feed around the farm, tow cages, change nets, as dive vessels, to transport personnel out to farm sites, for inspection of fish, and to help carry out day-to-day maintenance on cages and mooring systems. Most boats are made of aluminium, are 4.5-7 metres long, and have outboard motors. Larger boats and barges may be used for heavier work and are often fitted with Hiab cranes or electric winches.

Most farms have an on-land facility with offices and buildings to house staff, machinery, feed, nets and other equipment. In addition, most farms have open work areas on-land designated for the purposes of net maintenance and disposal of fish mortalities, respectively. Some farms have a dedicated laboratory, with a light microscope and equipment for taking pathology samples. Most farms have equipment for sampling live fish.

Farms have equipment for grading fish, transferring fish between cages and for freshwater bath treatments to control amoebic gill disease. Forklifts are used commonly around the land-based facilities and trucks are used to transport feed to the farm and harvested fish to processing plants. Harvesting equipment is heavy and not easily transportable, but some farms use a large vessel to transport harvesting equipment and/or conduct harvesting "on the water". Most farms have sanitising treatments to clean equipment.

Most farms have the equipment available to fully equip a dive team with diving gear however the amount of gear available depends on whether contract divers are used.

B.2.3.4 System inputs

Salmonid culture systems have a wide range of inputs that may be relevant with respect to disease. There are categorised below:

Aquatic animals

Atlantic salmon and rainbow trout to be used for culture are usually transported by land from the freshwater hatcheries to the marine sites between May and November, and may involve movement between geographical zones of different status.

Fish are most stressed after they have been transferred from freshwater to saltwater. Young salmon undergo a physiological transition (known as smoltification) to make the transition from freshwater to saltwater. (Trout can acclimatise to salt or brackish water but do not smoltify.) This transition usually takes place in spring, however with photomanipulation out-of-season smolts can be ready to go to sea as early as May. Pre-smolts (young salmon that have not fully undergone the preparation to handle the transition to seawater) can be transferred earlier to brackish water sites and achieve better growth rates than in full freshwater at the hatchery.

On some farms, fish are graded to ensure the size of individual fish is reasonably consistent within the population in any particular cage. However, handling, grading and moving fish to achieve this size consistency as the fish are growing causes stress to the fish and can make them more susceptible to disease.

Fish age

Younger fish are more susceptible to most disease and other health problems. Younger fish are also more practical to treat than older fish due to reduced costs, ease of handling and lower risk of residues compared to older fish.

Wild fish populations can act a vector for disease

There are many wild fish in the vicinity of semi-open water net-cages, and often many inside the cages themselves. Species including schools of baitfish such as yellowtail chow, slimy, blue and jack mackerel, tommy ruffs, Australian salmon, anchovies, pilchards, garr fish and small blennies etc. There is little known about the movement patterns of these fish, but there are definitely some species that are migratory, and some that are more permanently resident in the area. It is likely that these wild populations harbour potential pathogens but the extent of this is unknown.

Aquatic animal and plant communities develop on the nets even though they are changed frequently. Such fouling communities include green and brown macrophytes, blue mussels, juvenile rock lobster, cnidarians, small crustacea and finfish.

Jellyfish, including the moon jellyfish and to a lesser extent the lions mane jellyfish, have been associated with epidermal damage to live fish and fish kills in marine farm cages. The former damage may increase the susceptibility of fish to pathogens.

Predators

Predators, particularly seals and birds have a large impact on the health of fish on marine farm sites due to the stress, injury and mortality they incur on captive fish. Prevention of stock predation demands the use of anti-predator devices such as protective nets surrounding cages.

Water

Semi-open systems are located in estuaries and exposed marine areas and so there is no control on the flow of water around cages. However in some estuarine sites, freshwater flowing in from rivers can be a significant source of water. In these systems cages can be located very close to each other (within 50 metres). In some cases, such as in Macquarie Harbour, there is stratification of the water column with freshwater at 1 – 3 metres depth under conditions low wind.

In Tasmania, water temperature ranges from about 9 - 10°C in winter to 15 – 18°C or above in summer. Temperatures may rise above 18°C in summer, which causes stress to the fish and may also trigger harmful algal blooms. Generally fish are not fed during this warm weather.

Each company may own a number of leases and may transfer fish between sites. In some geographical areas, neighbouring leases owned by the same or different companies may be a distance of one kilometre apart.

Feed / bait used

All salmon are fed on a dry, pelleted, commercial ration however the size of pellet varies according to the size of the fish. The average length of the pellet is from 3-12 millimetres.

Imported fishmeal and fish oils are used in the manufacture of these pellets, and the fishmeal component can make up to 45 percent of the ration. This fishmeal and fish oil go through a heating process during manufacture and must be certified as free from known pathogens for importation.

Personnel

Practices are similar across farms, so workers from one farm would have little difficulty moving across to another farm. All farms have a ‘mess room’ or similar.

Larger farms may have up to 50 workers and at any one time, up to 30-40 of these may be out on the water. On these larger farms often teams specialise in one particular task, such as net changing or feeding. Each company may own a number of marine leases and some personnel may move between each of these sites regularly. In contrast workers on smaller farms may be involved in more than one type of activity. Companies that own a processing and export facility are an exception. They have a team of specialists to process the fish for market. These teams are relatively static and do not perform tasks on the farms.

Some of the bigger companies employ research staff and fish health technicians. Some contract work is used for repairs and maintenance to farm equipment.

Some farms have contract divers others have personnel who are trained in commercial diving practices. On-farm divers do not disinfect themselves between dives, but contract divers may disinfect and dry equipment between different farm sites.

The level of training and competency of workers is very high, and the industry has collaborated in some areas (such as diving) to ensure high standards and protocols are maintained.

Some farm sites may have regular visitors such as researchers, fish health specialists or other members of industry.

Equipment

Most farms have the equipment available to fully equip a dive team with diving gear however the amount of gear available depends on whether contract divers are used. In some cases, divers personally own their dive equipment, which may affect equipment availability and could potentially be a bio-security risk if the equipment is used off the farm site.

The type of harvesting equipment varies between farms. Some have harvesting equipment permanently installed on land or on boats. Others have transportable harvesting equipment, which is loaded onto boats prior to harvesting. Others have no harvesting equipment on site and cages are towed elsewhere to be harvested. Harvesting equipment may include crowd nets, fish pumps, Braille scoop nets, air-lift pumps, anaesthetising baths, bleeding tables, harvest bins, bin liners, aeration/oxygen stones, ice.

Most farms have equipment for sampling live fish from cages and inspecting them for weight and health status (specialised sampling nets, anaesthetic baths and recovery bins).

Forklifts are ubiquitous throughout industry. Hiab-type hydraulic cranes and winches are commonly mounted on boats to assist in changing nets, lifting weights, mooring lines etc. Grading equipment may also be available.

Most farms have some form of washing device to clean nets. In the case of raft-system farms, nylon nets are brailed above the water line and allowed to dry in the sun before re-use.

Most farms have a laboratory facility. Some of these have microscopes and pathology sampling equipment while all have fish dissecting equipment.

Most farms have plastic net/cage liners and other equipment required for conducting large-scale therapeutic freshwater bath treatments.

Some farms have a fully equipped workshop on site.

Service vessels for feeding and harvesting vary between companies and range in length from 12 metres to more than 30 metres.

On most salmon farms vehicles and boats usually have separate distinct functions, with the exception of smaller farms, where they may be multi-functional.

Some companies may own a number of marine leases and equipment may move between these sites regularly.

Stores

Feed is stored on site at the land-based facility for up to two weeks.

All farms have a store where gear is kept but the amount of gear stored on site varies between farms.

Vehicles

Most workers live elsewhere and so drive to and from the farm each day.

Trucks are used to transport feed, live fish and harvested fish. Forklifts are used as the main on-land workhorse.

Other

Most farms have available, and use, medications for the fish such as anaesthetics and antibiotics. Most farms also use freshwater as a fish therapeutant. Antifoulants are used on nets and vessels.

B.2.3.5 System outputs

Aquatic animals

Salmon are harvested when they are around 2.5 -4.5 kilograms. Harvesting is done either on site where harvesting facilities are available or the cages are towed to the harvesting site. Processing is usually done away from the farm site. Processed product may be fresh (eg. HOGG or fillets), frozen or value added (eg smoked). Processing by-products may be on-sold (eg. for inclusion in fertiliser).

Water

As there is a high stocking density of fish within cages it is important that there is an adequate circulation of water through the cages.

All areas used for salmon farming have some tidal movement of water. The water in these areas is also affected by weather (wind) and rainfall patterns (freshwater inflow).

In Tasmania, many of the farms are located in areas that are close to human habitation, and so are at the mercy of possible deleterious effects of this habitation, such as, sewerage runoff, pesticides and other toxic chemical usage, and an increased organic component in the water. Due, however, to the large water mass in which the cages are located there is a dilution effect.

There is no control over the water body in which the cages are located, unless an impermeable liner is placed around the cage. Such a liner prevents any movement of water in and out of the cage so that oxygen rich water from outside the cage is prevented from reaching the fish and water high in waste products (e.g. ammonia) inside the cage cannot be diluted out.

Waste Materials

Waste material from the farms includes excess feed, fish faeces, and treatment wastes. Some farms fallow used cage sites to minimise accumulation of wastes and allow recovery of the sea floor.

Offal is another waste material and can amount to 20-50 percent of live weight depending on the end product (i.e. whether the final product is head-on or fillets). The offal is either buried or used in fertiliser production.

Fish mortalities ("morts") are collected and buried in a designated area on-land.

Treatment of bloodwater (the water in which the fish lay while bleeding) from harvested fish ranges from rudimentary to full treatment before discharge back into the marine environment.

Personnel

Some companies may own a number of sites and some personnel may move between each of these sites regularly. Workers on farms usually leave the farm-site at the end of each day.

Feed trucks may make multiple deliveries in a day to different farm-sites.

On most farms the number of workers per farm remains reasonably constant.

Contract workers, including divers, are hired by farms from time to time. Divers may be employed on a regular basis.

Vehicles and equipment

Most workers use their own vehicles to travel between home and the farm-site. Boats are used to move between farm sites of the same company, and between farm-sites of different companies if these are reasonably close, and weather conditions permit.

Boats are used to tow cages between sites - such tows can be up to 40-50 kilometres.

Generally most equipment on a farm-site is dedicated to that site - for sites in close vicinity to each other, there may be some pooling of more expensive items of equipment such as fish pumps or boats.

B.2.3.6 Groups involved

There are many groups influencing the operation of semi-open water net-cage culture systems.

Broadly, these groups include:

- government bodies at both a national and state level
- Tasmanian Salmonid Growers Association
- State authorities and local councils
- community groups e.g. protection/conservation groups
- recreational fishing
- yachting/boating
- commercial fisherman
- universities and other institutions
- other water users.

B.2.3.7 Legislation and codes of practice

A code of practice for salmon farming (including fish-health issues) in Macquarie Harbour is being jointly developed by industry and the Tasmanian Department of Primary Industry and Fisheries.

See Appendix 1 for further information on relevant legislation.

B.2.3.8 Occupational health

Public health

The following public health issues should be considered:

- safety of the product if it is harvested when toxic algal blooms are suspected
- the potential of the product to transmit zoonotic diseases (see Appendix 2)
- the quality of harvested product if it is emergency harvested due to disease
- availability of laboratories capable of testing for public health factors
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed
- drug residues in treated fish.

Worker safety

The following worker safety issues should be considered:

- the harshness of environment and dependency on weather conditions can make the work environment dangerous and can be an impediment to safe work practices
- due to daily variation in current flow there are certain times in the day when attempting certain management practices, such as changing nets may be unsafe
- diving is a regular activity on farms but requires specialised training and qualifications - it is illegal and extremely dangerous for untrained personnel to dive
- working in the marine environment requires experience and can be dangerous for the inexperienced worker
- equipment such as ropes, nets and heavy equipment are dangerous if not handled appropriately
- operation of boats requires specialised qualifications and experience
- safety equipment is required
- collection of dead fish (‘morts’) and decomposing stock may threaten workers’ health
- contaminated water may needs appropriate disposal techniques
- preparing and applying chemical treatments may threaten workers’ health
- divers can be exposed to toxic algal blooms and jelly fish swarms.

B.2.4 Barramundi Grow-out

B.2.4.1 Introduction

The following table summarises the main features of the Barramundi industry sector (grow-out only).

Species	**Barramundi**
Location	NT, QLD, NSW, SA, WA
Length of production cycle	14 months – 2.5 years
Product	fresh or live
Annual production (tonnes)	>1210 (2001 – 2002)
($ value)	>10.7million
System	sea cages / net pens / ponds
Feed used	Dried, pelleted

The culture of Barramundi (*Lates calcarifer*) is more likely to be economically viable at water temperatures above 20°C. Barramundi can live at water temperatures as low as 12°C, but at temperatures of 16°C and below, growth ceases and the immune system is depressed making them unviable for farming.

There are three quite different methods currently used for growing barramundi fingerlings to market size:

- culture in purpose-built freshwater ponds which is the most common
- cage culture in fresh or marine waters, although relatively few companies are using this method at the present time
- intensive production indoors, in controlled environment buildings, using underground (i.e. pathogen-free) water and a high level of recirculation through biological filters (see closed systems for further details).

The controlled environment systems can be operated anywhere in the country. The capital and operating costs for these facilities are generally greater than for the equivalent level of production in outdoor cage operations. However, these systems can be sited close to markets, thus defraying costs associated with transporting product to market.

B.2.4.2 Practices

Barramundi aquaculture involves three distinct phases: hatchery, nursery rearing, and grow-out. Salt water is essential for the hatchery phase (which involves broodstock maintenance and larval rearing), while the nursery and grow-out phases can be conducted in either salt or fresh water. All three phases may take place at a single site such as at an estuary. The hatchery and nursery phases are described in the semi-closed systems section of this manual. Broodstock may be wild caught or domesticated stock.

The grow-out phase

Grow-out of Barramundi is conducted in either semi-open freshwater conditions (eg cages in Lake Argyll, WA), semi-open marine conditions (eg sea cages at Bathurst Island, NT), or in semi-closed large freshwater ponds. Although freshwater ponds are classified as semi-closed systems, they are discussed in this section because the grow-out practices are the same between the different system types.

Fingerlings are transferred to grow-out cages or ponds from nursery facilities at 80 – 100 millimetres total length (3 months of age). In some cases, fingerlings are transported to remote grow-out sites using specialised trucks and then they are transferred directly to cages or ponds. The cages may then be towed by boat to a mooring system.

Cages used for Barramundi grow-out are usually a floating square-grid system design. System cages consist of a grid of plastic pontoons and steel walkways that support a number of square nets in close proximity to one another (2 – 3 metres between neighbouring cages). The nets are made of steel mesh. The length and width of each square net is 25 metres and the depth of each ranges from 8 - 15 metres. The cages are moored to the substrate by an elaborate system of ropes and anchoring structures. The cages can be towed between mooring systems. Additional predator nets are usually installed to cover individual cages to protect stock from large predators such as birds.

Alternatively, small floating cages are occasionally used in ponds as small production units. Floating cages for use in ponds consist of plastic frames with nets made from knotless nylon mesh netting. Pond cages vary in size from 4 - 50 square metres and 2 – 4 metres deep. The netting must be changed and cleaned regularly as biofouling can reduce the size of the mesh openings, restricting water flow through the cages and leading to poor water quality.

Stocking densities in cages or ponds are usually between 15 - 40 kilograms per cubic metre, but higher densities are used on some farms.

Barramundi are fed a commercial dry pelleted ration that is produced domestically. A semi-floating pellet is widely used because it is available to the fish for a longer time and satiation is more easily observed. When first weaned, the fish are fed up to six times per day and the frequency of feeding is reduced progressively to once per day when the fish are bigger than about 100 grams. On most farms, the fish are fed by hand and not by automated feeding systems.

Feed is delivered to the farm site by truck and some remote grow-out sites may receive feed deliveries once a month. Feed is stored in air-conditioned cool rooms to lengthen the shelf life of the feed.

Water quality parameters are monitored frequently including dissolved oxygen, pH, temperature and light penetration. Aerators are used to maintain dissolved oxygen levels at greater than five parts per million. In pond culture, water exchange rates vary depending on the intensity of production.

Fish are graded or sorted according to size throughout the grow-out cycle.

Farm personnel regularly inspect the fish to determine the health status of the fish. In-feed antibiotic treatments and hyper-saline or freshwater bath treatments may be used on-site to treat live fish.

Fish mortalities (“morts”) are collected from cages by dip-net when they are evident at the water surface. Collection of “morts” by scuba diving is rarely required. “Morts” are buried within a designated area at the farms land-base.

Marketable plate-size fish (approximately 300 – 500 grams) can be attained in 6 - 8 months. However, there is a shifting focus toward producing fillet size fish of 2 – 3 kilograms, which can be grown in 14 months to 2.5 years.

Harvesting of Barramundi requires the use of a nylon “crowd” net. Fish are dip-netted from a crowded group of fish, sorted according to size and harvested fish are euthanased by immersion in ice slurry. Some farms process harvested fish on-site, whereas others transport harvested fish to an external processing plant within 24 hours by truck or air-freight. Processing involves evisceration and the fresh product is sold as HOGG, fillets or value added product.

Product may be sold direct to local customers or to domestic wholesalers in Melbourne and Sydney. Smaller producers tend to trade via the auction floor. A very small amount of fresh product is exported. There is a small live fish trade and some farms export live Barramundi to Asia.

Contract divers may be used to conduct cage and mooring system maintenance. Some farms may have skilled divers to conduct this work.

Ponds are subject to maintenance; they are drained and dried-out between production cycles.

B.2.4.3 Premises and equipment

Boats are used to transport and, in some situations, deliver feed around the farm, to tow cages, as dive vessels, to change nets, to transport personnel out to farm sites, for inspection of fish, and to help carry out day-to-day maintenance on cages and mooring systems.

Cages are moored to the substrate by an elaborate system of ropes and anchoring structures. Cages can be moved between mooring systems and the most commonly used method of moving fish around and between farms is by towing the cages.

Predator nets are deployed to surround individual cages, cage systems or ponds to protect stock from large predators such as birds.

Most farms have an on-land facility with offices and buildings to house staff, machinery and nets. Most farms have a cool store for feed. On-land farm sites also have designated areas for net maintenance and mort disposal, respectively. Some farms have a dedicated laboratory.

Harvesting equipment is heavy and not easily transportable, but at least one farm has the harvesting equipment located on board a large vessel.

Most farms have equipment for grading and sampling live fish from cages for inspection of health and growth status.

The amount of dive equipment available on farm sites varies, depending on whether contract divers are used.

Trucks are used to transport feed to the farm and harvested fish to processing facilities. Specialised trucks are used to transport young fish from the hatchery to the grow-out site. Forklifts are used commonly around the land-based facilities. Earth moving equipment may be available on sites with earthen ponds.

B.2.4.4 System inputs

Aquatic animals

Broodstock are either wild-caught or domesticated and they are fed vitamin-enriched pilchards. On some farms, broodstock are maintained on the same site as the grow-out facilities.

Larvae are transferred from the hatchery to nursery facilities to grow to fingerling size and then transported to the grow-out sites until harvest.

Wild fish, zooplankton and benthic organisms are present in the surrounds of the farm.

Water

There is generally a long distance between different barramundi farm sites. On any farm site, distance between cages or ponds is very small (2 – 3 metres). Some companies may own a number of different farm sites.

Most sea-cage sites are located in sheltered areas with strong tidal currents.

The water quality is directly affected by the local environment and tidal flows. Important water quality parameters include:

- temperature
- dissolved oxygen
- pH
- NH_3/NO_2 – ammonia, nitrates and nitrites
- salinity
- toxicants.

Freshwater ponds are subject to daily water exchange.

Feed used

Pellet feeds are commercially produced by a number of companies in Australia (these feeds are milled and heat pelleted). Fresh and frozen pilchards that are used to feed broodstock may be kept on the same premises.

Feed trucks may make multiple deliveries in a day to different farm-sites.

Personnel

With the exception of 2 - 3 larger companies, most Barramundi farms are small family-based operations.

Personnel are usually multi-skilled and may work in a number of areas on the farm.

Farm workers may live off-site and travel from home to work-site.

Some contract work is used for repairs and maintenance to farm equipment.

All farms have a mess room or similar.

Other personnel may include fish health specialists and visitors.

Recreational fishers and boat users may frequent waters surrounding farm sites.

Equipment

Equipment used includes:

- buckets
- handling nets
- cages/walkways/floats
- tanks
- feed bins, scoops, wheel barrows
- clothing/boots
- vehicles, trucks, fork-lift, earth movers
- graders
- harvesting equipment and bins
- boats
- cold room store
- water quality testing apparatus
- dive equipment
- maintenance machinery
- antibiotic treatments
- sanitising treatments for harvest bins and equipment..

Stores

Feed is stored within a cold room store, onsite at the land-based facility, for up to one month.

All farms have a store where gear is kept and the amount of gear stored on-site varies between farms.

Vehicles

Vehicles on the farms include trucks, tractors, fork lifts, six wheelers, boats/punts, and private cars plus excavators and earth moving equipment may be available. Feed trucks may make multiple deliveries in a day to different farm-sites.

B.2.4.5 System outputs

Animals

Product may be sold by the producer directly to customers and various outlets such as restaurants. Some product may be sold wholesale to fish markets. The majority of fish are sold dead but some fish may be sold live to restaurants and these are shipped in tanker trucks. Some farms export live fish to asia.

Water

Quality of effluent water from the cages depends on:

- treatments given to the cages e.g. overfeeding increases waste below cages
- water exchange (which is influenced by water flow past the cages, biofouling on the nets)

Waste materials

Waste materials include excess feed and fish faeces on the sea floor or bottom of the grow-out pond, fish mortalities and processing waste.

Ponds are cleaned and dried out between production cycles.

Stock mortalities are buried in a designated area on-land.

The quantity of processing waste depends on the size of the farm but varies from approximately 1 to 50 tonnes per annum. Processing waste may be disposed of at approved sites or on-sold as by-products.

Settlement ponds are used in pond culture systems to remove suspended solids from effluent water.

Personnel

Workers on farms usually leave the farm-site at the end of each day. Some farms have a night watch person on-site.

On most farms the number of workers per farm remains reasonably constant.

Contract workers, including divers, are hired by farms from time to time. Divers may be employed on a regular basis.

Feed trucks may make multiple deliveries in a day to different farm-sites.

Equipment

Equipment includes:

- harvest bins
- storage tanks
- transport tanks
- cold room store
- pond building/maintenance machinery
- private vehicles
- transport vehicles for product sales
- service punts/boats.

B.2.4.6 Groups involved

There are a large number of groups that are involved in the operation of semi-open water net-cage culture systems. Broadly these groups include:

- Australian Barramundi Farmers Association
- government bodies at both a National and State level
- State authorities and local councils
- community groups e.g. protection/conservation groups
- recreational fishing
- yachting/boating
- commercial fishers
- universities and other institutions
- other water users.

B.2.4.7 Legislation and codes of practice

The following codes of practice apply to barramundi grow-out:

- Australian Barramundi Farmers Association (ABFA) Code of Practice for the harvesting, processing and distribution of farmed Barramundi (website link available at www.abfa.info).
- "Industry Environmental Code of Best Practice for freshwater finfish Aquaculture" produced by the Aquaculture Association of QLD (website link available at www.abfa.info).

There is currently a code of practice being developed for barramundi hatchery production

Relevant legislation is listed in Appendix 1.

B.2.4.8 Occupational health

Public health

The following public health issues should be considered:

- safety of the product if it is harvested when toxic algal blooms are suspected
- the potential of the product to transmit zoonotic diseases (see Appendix 2)
- the quality of harvested product if it is emergency harvested due to disease
- availability of laboratories capable of testing for public health factors
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed
- drug residues in treated fish.

Worker safety

The following worker safety issues should be considered:

- the harshness of environment and dependency on weather conditions can make the work environment dangerous and can be an impediment to safe work practices
- due to daily variation in current flow there are certain times in the day when attempting certain management practices, such as changing nets may be unsafe
- diving is a regular activity on farms but requires specialised training and qualifications - it is illegal and extremely dangerous for untrained personnel to dive
- working in the marine environment requires experience and can be dangerous for the inexperienced worker
- equipment such as ropes, nets and heavy equipment are dangerous if not handled appropriately.
- operation of boats requires specialised qualifications and experience
- safety equipment is required
- collection of dead fish ('morts') and decomposing stock may threaten workers' health (for example in the event of a suspected toxic algal bloom)
- contaminated water may need appropriate disposal techniques
- preparing and applying chemical treatments may threaten workers' health
- divers can be exposed to toxic algal blooms, jelly fish swarms and large predators (crocodiles).

B.2.5 Yellowtail Kingfish cage culture

B.2.5.1 Introduction

The following table summarises the main features of the Yellowtail Kingfish industry sector.

Species	Yellowtail Kingfish
Location	South Australia
Length of production cycle	18 months – 30 months (grow-out only)
Product	Fresh or frozen
Annual production (tonnes)	1500 (2001 – 2002 figures)
System	Net-pen/sea cage culture
Feed used	Dried pelleted ration

Yellowtail Kingfish (*Seriola lalandi*) is a temperate fish with a water temperature tolerance of 10.5 – 29.0°C. However, optimal growth and health is only achieved at a water temperature range of 18.0 – 28.0°C.

Yellowtail Kingfish farming consists of a marine hatchery stage (see Section B.3.7 Yellowtail Kingfish hatcheries) and an estuarine/marine cage culture stage. Commercial hatchery culture started in 1998, whereas commercial sea-cage culture started in 2000. Yellowtail Kingfish hatchery facilities and cage culture facilities used for grow-out may be located on the same estuarine or marine farm sites.

The Yellow-tail Kingfish Industry currently consists of two hatcheries and five companies, operating 250 hectares of marine sea cage grow-out facilities at Port Lincoln, Arno Bay, Franklin Harbour and Fitzgerald Bay.

B.2.5.2 Practices

Fingerlings are transferred to sea-cage grow-out facilities at a weight of 5 – 10 grams, at 50 to 60 days post-hatch.

Purpose built tanks are used to transport fingerlings via truck and then boat from the hatchery to the marine site, where they are directly transferred to a nursery lease and placed into small sea cages well protected from bird predation. At this stage of development only plastic polar cirkels are used for Yellowtail Kingfish grow-out. A polar cirkel consists of a circular plastic support to which is attached a circular nylon net. The circumference of these cages is 80-120 metres, and the nets have a depth of 8 to 14 metres. Polar cirkels may be placed in close proximity to one another (up to 50 metres) within a lease. Currently, the use of steel netting is being trialled. System cages are not being used by the industry because of the resultant difficulty in the control of parasitic fluke infections. All cages are moored to the sea bottom by an elaborate system of ropes and anchoring structures. The cages can be towed between mooring systems. At some times of the year additional predator nets may be installed to surround individual cages to protect stock from large predators such as sharks. Kingfish are usually ongrown in net-cages for 18 months – 30 months. There is usually 8 to 25 thousand fish in each cage, depending on the size of the cage and the size of the fish. This results in a maximum stocking density of 10 kg per cubic metre of water. During grow-out, the kingfish are graded as required which ensures fish in the same pen are of similar size.

Fish are fed a commercial dry pelleted ration produced in Australia. Feed is usually delivered by sea and road freight to the on land farm site where it is stored for up to two weeks. The fish are fed by hand until 200+ grams and then a manually operated cannon feeder, which blows the feed into the sea cages.

Kingfish are usually harvested when they have attained a weight of 3 – 6 kilograms. The smaller fish supply the fine dinning sector, while the larger fish are sought after for the premium sashimi sector. Depending on the market, the fish are sold as whole or head-on gilled and gutted (HOGG) or as fillet (pin-bone in, collar on, skin on).

No farms have processing facilities adjacent to their marine operations and so farms conduct harvesting on barges or boats.

During harvesting, fish are crowded in the pen, and either drawn from the water using a fish pump, or collected with a Braille net (usually 20-30 fish at a time) and either lifted into an anaesthetic tank or stunned with a pneumatic hammer.

During harvesting, carbon dioxide may be used to anaesthetise the fish. The carbon dioxide is bubbled through a bath containing the fish. When sufficiently anaesthetised the fish are moved onto a bleeding table. The fish are cut, usually near the base of the gills, to facilitate bleeding and then, within a few minutes, placed in an ice slurry. The fish are trucked in bins (in an ice slurry) to the processing facility. Fish are usually kept in the ice slurry for less than 12 hours. Harvest bins and equipment are sanitised with certified treatments between uses and processing facilities meet export standards.

Fresh fish is transported by road and air-freight to domestic wholesale markets and some are sold directly to restaurants and other customers. Approximately 20 percent of fresh fish are exported overseas by airfreight.

At water temperatures below 14°C Yellowtail Kingfish are more susceptible to disease agents and often farmers will reduce feeding rate significantly. Hence particularly cold winters where water temperatures are low are detrimental to growth and general health.

Farm personnel regularly sample a small number of live fish stock from each of the grow-out cages to inspect the fish for growth and health status.

Therapeutic bath treatments of hydrogen peroxide are used to control skin and gill fluke infestations. These bath treatments require plastic liners and adequate oxygen supply.

Cages are monitored for fish mortalities (“morts”) regularly every one to three days. This frequency changes with season, being most frequent in the warmer months and less frequently in winter. The “morts” are removed from cages by various methods including dip-net and scheduled diving. The collected “morts” are buried in a designated area on-land.

Farmers regularly monitor water quality at all their marine sites. Daily records of parameters such as dissolved oxygen, temperature, turbidity, and salinity are kept by most farms. Phytoplankton identification and nutrient levels are monitored regularly.

B.2.5.3 Premises and Equipment

Boats are the main form of transport on marine farms. Boats are used to transport and often to deliver feed around the farm, tow cages, change nets, as dive vessels, to transport personnel out to farm sites, for inspection of fish, and to help carry out day-to-day maintenance on cages and mooring systems. Large boats and barges may be used for heavier work and are often fitted with Hiab cranes or electric winches.

Most farms have an on-land facility with offices and buildings to house staff, machinery, feed, nets and other equipment. In addition, most farms have open work areas on-land designated for the purposes of net maintenance and disposal of fish mortalities, respectively. Some farms have a dedicated laboratory, equipped with a light microscope. Most farms have equipment for sampling live fish.

Farms have equipment for grading fish, transferring fish between cages and for therapeutic bath treatments to control fluke infestations. Forklifts are used commonly around the land-based facilities and trucks are used to transport feed to the farm and harvested fish to processing plants. Harvesting equipment is heavy and not easily transportable. Some farms use a large vessel to transport harvesting equipment and/or conduct harvesting "on the water". Others utilise a dumb barge, which is moored in favourable location, and the tow the stock to be harvested to this site. Most farms have sanitising treatments to clean equipment.

Most farms have the equipment available to fully equip a dive team with diving gear, however the amount of gear available depends on whether contract divers are used.

B.2.5.4 System inputs

Aquatic animals

Yellowtail Kingfish fingerlings used for cage culture are usually transported by land from the marine hatcheries to the marine sites during November to January.

On some farms, fish are graded. However, handling, grading and moving fish causes stress to the fish and can make them more susceptible to disease.

Younger fish are more susceptible to disease and other health problems. Younger fish are also more practical to treat than older fish due to reduced costs, ease of handling and lower risk of residues compared to older fish.

There are many wild fish in the vicinity of semi-open water net-cages, and often many venture inside the cages themselves. Wild fish populations can potentially act a vector for disease, but the extent to which wild populations harbour potential pathogens is unknown.

Aquatic animal and plant communities develop on the nets even though they are changed frequently.

Predators, particularly birds and sharks, have a large impact on the health of fish on marine farm sites due to the stress, injury and mortality they incur on captive fish. Prevention of stock predation demands the use of anti-predator devices such as protective nets surrounding cages.

Water

Semi-open systems are located in bays and exposed marine areas and so there is no control on the flow of water around cages. Water temperature ranges from about 12°C in winter to 25°C or above in summer. Temperatures may rise above 27°C in summer, but this does not seem to cause stress to the fish. Generally fish are not fed during this warm weather. Research in Japan has shown that temperatures above 29°C will depress feeding and growth rate significantly.

Each company may own a number of leases and may transfer fish between sites. In some geographical areas, neighbouring leases owned by the same or different companies are required to be a distance of only one kilometre apart.

Feed / bait used

All kingfish are fed on a dry, pelleted, commercial ration. However the size of pellet varies according to the size of the fish. The average length of the pellet is from 3-11 millimetres.

Imported fishmeal and fish oils are used in the manufacture of these pellets, and the fishmeal component can make up to 45 percent of the ration. This fishmeal and fish oil must go through a pasteurising process before importation to ensure they are free from potential pathogens.

Personnel

Practices are similar across farms, so workers from one farm would have little difficulty moving across to another farm. All farms have a 'mess room' or similar.

Farm size varies significantly. At this stage of the industry development there are two larger operations and three smaller ones. Personnel numbers vary from around 30 at the grow-out to less than five. Each company may own a number of marine leases and some personnel may move between each of these sites regularly. Workers are multi-skilled and may be involved in more than one type of activity. Companies that have some ownership in a processing and export facility are an exception. The processing facilities have a team of specialists to process the fish for market. These teams are relatively static and do not perform tasks on the farms.

Some of the larger companies employ fish health technicians. Some contract work is used for repairs and maintenance to farm equipment.

Some farms have contract divers whilst others have personnel who are trained in commercial diving practices. Divers do not disinfect themselves between dives.

Some farm sites may have regular visitors such as researchers, fish health specialists or other members of industry.

Equipment

Most farms have the equipment available to fully equip a dive team with diving gear. However the amount of gear available depends on whether contract divers are used.

The type of harvesting equipment varies between farms. Some have harvesting equipment permanently installed on barges or on boats. Others have transportable harvesting equipment, which is loaded onto boats prior to harvesting.

Most farms have equipment for sampling live fish from cages and inspecting them for weight and health status.

Forklifts are ubiquitous throughout industry. Hiab-type hydraulic cranes and winches are commonly mounted on boats to assist in changing nets, lifting weights, mooring lines etc. Grading equipment may also be available. The larger farms have some form of washing device to clean nets. Most farms have a laboratory facility. Some of these have microscopes while all have fish dissecting equipment.

Most farms have plastic cage liners and other equipment required for conducting large-scale therapeutic bath treatments.

Some farms have a fully equipped workshop on site.

Service vessels for feeding and harvesting vary between companies and range in length from 10 metres to more than 30 metres.

On most kingfish farms vehicles and boats are multi-functional.

Some companies may own a number of marine leases and equipment may move between these sites regularly.

Stores

Feed is stored on site at the land-based facility for up to two weeks.

All farms have a store where gear is kept but the amount of gear stored on site varies between farms.

Vehicles

Most workers live elsewhere and so drive to and from the farm each day.

Trucks are used to transport feed, live fish and harvested fish. Forklifts are used as the main on-land workhorse.

Other

At this stage of the industry's development almost no anaesthetics or antibiotics are used. However, all farms use hydrogen peroxide for fluke infestations. Antifoulants are used on vessels, but not on nets.

B.2.5.5 System outputs

Aquatic animals

Yellowtail Kingfish are harvested when they are around 3 - 6 kilograms. Harvesting is done either on site where harvesting facilities are available or the cages are towed to a harvesting barge. Processing is usually done away from the farm site. Processed product may be fresh or frozen and whole, HOGG for fillet. Processing waste may be on-sold for by-products (eg. for inclusion in fertiliser).

Water

There is no control over the water body in which the cages are located and it is important that there is an adequate circulation of water through the cages. All areas used for kingfish farming have considerable tidal movement of water. The water in these areas is also affected by the wind, but being in an area of low rainfall with no significant streams, rainfall has little effect. Nets are changed regularly to prevent biofouling and optimise water flow through the cages.

Waste Materials

Waste material from the farms includes excess feed, fish faeces, and treatment wastes. Some farms fallow used cage sites to minimise accumulation of wastes and allow recovery of the sea floor.

Offal is another waste product from processing, which is either buried or used in fertiliser production.

Fish mortalities ("morts") are collected and buried in a designated area on-land.

Treatment of bloodwater (the water in which the fish lay while bleeding) from harvested fish ranges from full treatment to discharge back into the marine environment through purpose built settlement ponds. Outflow is measured regularly to ensure minimal environmental impact.

Personnel

Some companies may own a number of sites and some personnel may move between each of these sites regularly. Workers on farms usually leave the farm-site at the end of each day.

On most farms the number of workers per farm remains reasonably constant.

Contract workers, including divers, are hired by farms from time to time. Divers may be employed on a regular basis.

Vehicles and equipment

Most workers use their own vehicles to travel between home and the farm-site. Boats are used to move between farm sites of the same company, and between farm-sites of different companies if these are reasonably close, and weather conditions permit.

Boats are used to tow cages between sites. Such tows are rarely more than 10 kilometres.

Generally most equipment on a farm is dedicated to that location (may include multiple licence sites). For farms in close vicinity to each other, there may be some pooling of more expensive items of equipment such as harvest or bathing equipment.

Feed trucks may make multiple deliveries in a week to different farm-sites.

B.2.5.6 Groups involved

There are many groups involved in the operation of Yellowtail Kingfish cage culture systems.

Broadly, these groups include:

- government bodies at both a national and state level.
- South Australian Marine Finfish Farmers Association.
- State authorities and local councils.
- community groups e.g. protection/conservation groups.
- recreational fishing.
- yachting/boating.
- commercial fishermen.
- universities and other institutions.
- other water users.

B.2.5.7 Legislation and codes of practice

A draft Code of Practice has been completed for the industry in South Australia. This is currently undergoing final revision.

See Appendix 1 for further information on relevant legislation.

B.2.5.8 Occupational health

Public health

The following public health issues should be considered:

- the potential of any seafood product to transmit pathogens. (see Appendix 2 –none specific to Yellowtail Kingfish).
- the quality of emergency harvested product due to disease. However, quality issues can be managed if the harvesting is properly organised.
- availability of laboratories capable of testing for public health factors.
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed.

Worker safety

The following worker safety issues should be considered:

- the harshness of environment and dependency on weather conditions can make the work environmentally dangerous and can be an impediment to safe work practices.
- due to daily variation in current flow there are certain times in the day when attempting certain management practices, such as changing nets may be unsafe.
- diving is a regular activity on farms but requires specialised training and qualifications - it is illegal and extremely dangerous for untrained personnel to dive.
- working in the marine environment requires experience and can be dangerous for the inexperienced worker.
- equipment such as ropes, nets and heavy equipment are dangerous if not handled appropriately.
- operation of boats requires specialised qualifications and experience.
- safety equipment is required.
- appropriate collection and disposal processes should be used for dead fish (‘morts’), decomposing stock and fish effluent.
- preparing and applying chemical treatments may threaten workers’ health if not used properly or applied without appropriate protective clothing and safety awareness.
- divers could be exposed to jelly fish swarms and large marine predators (eg. sharks).

B.2.6 Pearl Oyster Grow-out

B.2.6.1 Introduction

The following table summarises the main features of the Pearl oyster marine farm industry sector.

Species	**Pearl Oyster**
Location	WA
Length of production cycle	8 months – 2 years (grow-out only)
Product	Pearls, Pearl shell, Oyster meat (fresh)
Annual production ($ value)	175.1 million (2001 – 2002)
System	Suspended or benthic panels
Feed used	None (filter feeders)

The majority of pearls are now produced by aquaculture techniques rather than gathered from wild stocks, as was the practice for over a century. The pearl industry is Australia's second highest dollar value aquaculture industry. The Australian pearling industry is predominantly based on the silver-lipped pearl oyster *Pinctada maxima.* There is also increasing interest in the production of half pearls and smaller round pearls from other pearl oyster species such as *P. margaritifera, P. albina* and *Pteria penguin*. The industry is predominantly located in the northern waters of Western Australia, with some production based in Northern Territory and Queensland, where water temperatures average 22 – 32°C.

The industry is based on two different culture techniques:

- collection of wild adult pearl oysters that are transferred to marine farms for further growth and used for pearl production.
- production of pearl oysters in marine hatcheries that are transferred to marine farms for grow-out and later used for pearl production.

The current section describes marine farm grow-out operations and pearl production. See section B.3 (Semi-closed Systems) for further details regarding pearl oyster hatcheries.

B.2.6.2 Practices

Adult oysters are collected under license from the wild and are subject to seeding for pearl production.

After collection, adult oysters are held in steel framed, mesh panels which are placed on the seabed near the fishing grounds. After two to four months they are retrieved and seeded by technicians. Seeding normally takes place onboard work vessels. The seeding operation involves implanting a "mother of pearl" nucleus made from freshwater mussel shell and a small piece of mantle tissue from another oyster into the gonad of the oyster to be seeded. The oysters are returned to the panels on the seafloor following seeding and the panels are intermittently turned over during a period of two months while the pearl sack forms within each of the seeded oysters. After this period the oysters are translocated to farms in coastal bays up to hundreds of kilometres from the fishing grounds. Translocation may occur by sea, land and/or airfreight.

In addition, larval oysters are produced in hatcheries for growth and use. In some cases, the hatchery may be located at on-shore facilities associated with marine farm sites. In other cases, the hatchery is distant to shore base so young oysters are transported to grow-out sites by land, sea and/or airfreight.

Young hatchery-reared oysters are transferred to marine grow-out sites at a size of 6mm shell length and age of 3 months. They are on-grown for 2 years until they reach a minimum length of 110mm and they are ready to be seeded according to gonad condition.

Hatchery reared oysters are seeded, returned to panels on the seafloor and the panels are intermittently turned over a period of two months. The oysters are then translocated to marine farming sites.

At the farm site, the oysters are usually suspended vertically in the water in mesh panels hanging from a horizontal long line between anchored buoys. A raft technique may also be used where the oysters are placed in wire baskets and hung below a floating raft.

The suspended oysters are regularly retrieved and cleaned of biofouling. For this purpose, specialised cleaning equipment is used on specialised cleaning vessels. Some farms use antifoulants on the exterior of oyster shells and on submerged equipment to minimise biofouling and maximise water flow to the oysters.

During the cleaning process, oyster mortalities (“morts”) and the remaining shells are collected. Each shell is accounted for and sold as a by-product.

Water quality is monitored regularly on farm sites, including marine algae identification on some farms.

The oysters are X-rayed at 6 months post-seeding to check that the pearl seed has not been rejected by the oyster.

Oysters producing round pearls are left in the water for 2 years, at which time they are retrieved from the water and operated on to remove the fully developed pearl and to insert a new pearl seed. Any one oyster may produce up to 3 pearls over 6 years before the oyster is removed from production. If the first pearl that an oyster produces is of poor quality, then the oyster is used for half-pearl production. Half-pearl seeded oysters are harvested 8 - 12 months after seeding. Pearl operating and harvesting is conducted onboard work vessels or at shore facilities.

The flesh of harvested oysters is generally disposed of into the sea, however some abductor muscle is sold for human consumption. Harvested pearls undergo an initial grading on-site. Pearls and shell may then be sent to processors for polishing and specialist grading before being sent to wholesalers. Alternately, polishing, grading and selling of the finished product may be conducted in-house.

The main products are pearls and pearl shell for both domestic and export markets. Pearl shell is sent to the USA, Japan, South East Asia, France and the Middle East for buttons and inlay work. Oyster meat is sold in Australia and Hong Kong.

B.2.6.3 Premises and equipment

Some of the larger companies own a number of farm lease sites.

Many farms have shore facilities, however some are only accessible by ship. Shore facilities may consist of a workshop, store sheds, offices and personnel accommodation.

Most ships or shore stations have basic laboratory facilities and diving facilities. Most farms have dive equipment, the amount of which depends on whether contract divers are used.

Pearling ships are open water vessels greater than 20 metres long. Smaller barges with handling and cleaning equipment may be used closer inshore on the farms.

Work vessels move to-, from- and between different farm lease sites.

Tractors or forklifts are available on some shore bases for moving heavy equipment.

Some farms have limited processing facilities on shore stations.

Contract workers, including pearl seeders and divers, are often used.

Due to the remote location of many of the farm sites, there are few site visitors or recreational fishers present in the vicinity of farm sites.

B.2.6.4 System inputs

Animals

Adult oysters are harvested by divers from fishing grounds. Spat is also sourced from hatcheries and contributes the majority of seed for growers.

There are many species of wild fish in the vicinity of pearl oyster farm sites. Aquatic animal and plant communities also develop on the racks and shells of the oysters, even though they are cleaned regularly.

Water

There is no control of water on open leases however many farmers hold several leases in various areas so there is the possibility of shifting the animals to different sites and therefore selecting different water conditions.

Shellfish farmers often have an intense interest in the quality of the water on their leases and many will take regular readings. Some areas have shellfish monitoring systems and monitor phytoplankton species present on marine sites.

Water temperatures on farm sites range from approximately 22 – 32 °C during the year.

Feed

Pearl oysters are filter feeders and they feed on the plankton naturally present in the water column on marine farm sites.

Personnel

The work force on leases varies between companies and with the production cycle or season. The numbers of workers on any particular lease will vary depending on the seasonal jobs being performed. Some operations are ship-based rather than shore-based. The work on leases is usually conducted in time with tides so this should be considered when trying to contact personnel.

Some personnel may work and travel between a number of different sites.

Contract workers, including pearl seeders and divers, are often used.

There are few visitors and recreational fishers in the vicinity of remote marine leases.

Due to the remote location of some farm sites, personnel may live on-site.

Vehicles

Personnel use privately owned vehicles to travel to shore stations.

Boats are used to transport personnel and equipment to marine farm sites, as well as conduct maintenance work on marine sites. Vessels move between different farm sites.

Tractors and forklifts are used on shore facilities to move heavy equipment.

Trucks may be occasionally used to make equipment deliveries to farm sites.

B.2.6.5 System outputs

Animals

The main products are pearls and pearl shell, however some abductor muscle is sold fresh for human consumption.

Stock may be moved between sites.

Waste

Pearl oysters are filter feeders and are not fed by farmers, therefore there is no feed waste associated with pearl oyster farming.

The flesh of processed oysters is generally disposed of into the sea. All pearl shell is collected, accounted for and sold.

Equipment

Equipment is usually shared between several sites.

Personnel

Some personnel may work and travel between a number of different sites.

Contract workers, including pearl seeders and divers, are often used.

There are few visitors and recreational fishers in the vicinity of remote marine leases.

Vehicles

Personnel use privately owned vehicles to travel from shore stations and farm sites every day.

Boats are used to transport personnel and equipment from marine farm sites. Vessels move between different farm sites.

Product may be transported from farm sites by sea, land and/or airfreight.

B.2.6.6 Groups involved

Groups involved in pearl production include:

- government bodies at both a national and state level
- State authorities and local councils
- Aboriginal lands councils
- environmental groups and associations
- other community groups
- Aquaculture Council of Western Australia
- Pearl Producer's Association
- Western Australian Fishing Industry Council.
- recreational fishing
- yachting/boating
- commercial fisherman
- universities and other institutions
- other water users.

B.2.6.7 Legislation and codes of practice

Legislation relevant to aquatic animals and aquatic animal health is listed in Appendix 1.

There is a policy guideline for pearl oyster aquaculture in Western Australia (website link at (www.fish.wa.gov.au/aqua/broc).

B.2.6.8 Occupational health

Public health

The following public health issues should be considered with respect to Pearl Oyster meat:

- safety of the product if it is harvested when toxic algal blooms are suspected
- the potential of the product to transmit zoonotic diseases (see Appendix 2)
- the quality of harvested product if it is emergency harvested due to disease
- availability of laboratories capable of testing for public health factors
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed

Worker safety

The following worker safety issues should be considered:

- location (the majority of pearling is carried out on the open ocean in cyclone prone areas in very isolated areas of Australia’s coast)
- the harshness of environment and dependency on weather conditions can make the work environment dangerous and can be an impediment to safe work practices
- due to daily variation in current flow there are certain times in the day when attempting certain management practices may be unsafe
- diving is a regular activity on farms but requires specialised training and qualifications - it is illegal and extremely dangerous for untrained personnel to dive
- working in the marine environment requires experience and can be dangerous for the inexperienced worker
- equipment such as ropes and heavy racks are dangerous if not handled appropriately
- operation of boats requires specialised qualifications and experience
- safety equipment is required
- handling of stock/shells can result in lacerations to the skin
- collection of decomposing stock may threaten workers’ health
- contaminated water may needs appropriate disposal techniques
- preparing and applying chemical treatments may threaten workers’ health

  divers can be exposed to toxic algal blooms, jelly fish swarms and large marine predators (eg. sharks).

B.2.7 Edible shellfish Grow-out

B.2.7.1 Introduction

The following table gives a brief summary of the edible shellfish industry sector (grow-out only).

Species	**Rock Oysters**	**Pacific Oysters**	**Mussels**	**Flat (or Mud) Oysters**	**Scallops**	**Abalone**
Location	NSW, QLD, WA (v. small)	Tas., SA, NSW	NSW, Vic., Tas., WA, SA	Tas., NSW, SA	Tas.	Tas., Vic., SA, WA, NSW
Length of production cycle (grow-out only)	2 – 3 years	1 – 2 years	7 – 15 months	1 – 2 years	18 months	3 - 4 years
Product	Live, fresh,	Live, fresh, frozen	Live, fresh, pickled	Live, fresh	fresh, frozen	fresh, frozen, canned
System	Rack, tray & stick	Racks, Long-line	Long-line	Racks, Long-line	Long-line	Tanks, Floating Barrels or submerged cages
Feed used	none	none	none	none	none	Formulated pelleted feed

The aquaculture of shellfish for human consumption has a long history in Australia. The industry based on Sydney rock oysters (*Saccostrea glomerata*) has been operational for over 100 years. However more recently there is increasing interest and success in the culture of other species of shellfish. The main species now are rock oysters (*S. glomerata*), Pacific oysters (*Crassostrea gigas*) and blue mussels (*Mytilus galloprovincialis*). There has been successful culture of flat (or mud) oysters (*Ostrea angasi*) in southern states, although production volumes remain low. In addition, there is growing interest in the aquaculture of scallops (commercial scallop: *Pecten fumatus*), and abalone, including the greenlip abalone (*Haliotis laevigata*) and blacklip abalone (*Haliotus rubra*) species. The establishment of an aquaculture industry based on Roe's abalone (*Haliotis roei)* is currently underway in Western Australia. The staircase abalone (*Haliotus scalaris*) is also considered to be a potential candidate for culture in warm water areas of WA. Experimental aquaculture of the Southern saucer scallop (*Amusium balloti*) is currently being conducted in WA and QLD. Furthermore, aquaculture development of donkey ear abalone (*Haliotis asinina)* and tropical oysters such as the black lip oyster (*Saccostrea echinata*) is progressing in Queensland (see Appendix 3).

The source of stock for the aquaculture of each species varies between species. The rock oyster, mussel and scallop industries are based on larvae acquired from natural spat fall in estuaries or production of larvae within hatcheries from wild-sourced brood-stock. Abalone are produced in hatcheries from wild-sourced and domesticated brood-stock. Pacific oysters are produced in hatcheries from broodstock collected from commercial oyster leases. Shellfish hatcheries are semi-closed systems (for more information regarding hatchery operations please see section B.3). The current section describes grow-out conditions and operations.

B.2.7.2 Practices

The techniques used for the grow-out of shellfish vary between species, however some practices used on shellfish grow-out facilities are common between species. Species specific techniques and common practices are described below.

Rock oysters

Farming of rock oysters occurs in South Eastern QLD, NSW and WA.

Rock oysters are grown on sticks, trays on racks, bags or baskets in the intertidal zone of estuaries, at depths of up to 3 metres. Grow-out can occur in either estuarine or marine waters since rock oysters can tolerate a large range in water salinity (11 – 48 parts per thousand salt). Rock oysters have a water temperature preference of 14 – 30°C.

The rock oyster industry is based on larvae acquired from natural spat fall in estuaries and the production of larvae within hatcheries from wild-sourced brood-stock. Commercial production of rock oysters selectively bred for faster growth and disease resistance is in final research phase.

Natural Spat-fall Collection

Spat (young oysters) settle on tarred hardwood sticks or PVC slats that are racked in estuaries where spatfall is most reliable. To encourage spat fall the sticks are often coated with a concrete slurry.

Traditionally, once covered in spat the sticks are then removed after 6 to 9 months to racks in a low spatfall area of the estuary where the oysters are allowed to grow for a further 18 to 30 months. Recently methods using trays or plastic mesh cylinders have been developed. Young oysters (3 - 8 millimetres) are removed from the sticks or slats soon after settlement then placed into the trays or cylinders for growth. Spat treated in this way are referred to as “single seed”, that is the oysters are not attached to each other as are oysters left to grow out on sticks.

Transfer of hatchery produced spat

The spat produced at hatcheries are transferred to tanks at nursery facilities soon after settlement. Nursery facilities may be located on the same site as hatchery facilities or the same site as grow-out facilities. The spat are fed cultured algae until they reach a size of 3 - 8 millimetres and then they are transferred to grow-out facilities. The young oysters may be transported to the grow-out site overland by truck, where they are placed into mesh bags or cylinders on racks for grow-out.

Farmers grade their single seed oysters at intervals of 3 – 5 months during grow-out, to maintain size consistency. Mesh size of grow-out bags or cylinders increases with animal size to optimise water flow to animals.

Growth to market size takes 2 - 3 years. Oysters may be relayed to an approved grow-out site and subject to natural depuration prior to harvest. Rock oysters are harvested at a shell length of 5 – 8 centimetres, which equates to a weight of 30 – 60 grams in-shell or 14 grams of edible flesh. Harvested oysters can survive up to two weeks out of water and may often be held at prescribed periods and temperatures on land before shipment for sale. Where the state’s Shellfish Quality Assurance Program stipulates, a purification process is carried out for 36 hours before sale. The purification tanks rely on filtered and UV-treated water. These facilities may be single company operations or cooperative operations, located either on-site or distant to farm operations.

Product is usually sold in-shell to fish markets, or less frequently directly from the farm gate as bottled, half-shell or in-shell product.

Most farm operations are performed from flat-bottomed barges. During the production period, oysters are often moved overland between leases either within or between estuaries.

Production levels have declined in the last 20 years due to water quality problems, disease and institutional arrangements for the management of estuaries.

Mussels

The aquaculture industry based on Blue mussels was established in 1976. It started in NSW and has since spread to Victoria, Tasmania, Western and South Australia.

Mussels are grown in marine intertidal waters, at depths of 5 – 20 metres. Mussels have a water temperature preference of 8 - 20°C. They are grown on ropes or in bags off a long horizontal rope or vertical ropes suspended from rafts. The industry is based on larvae acquired from natural spat fall in estuaries or production of larvae within hatcheries from wild-sourced brood-stock. Spat collection sites and growing sites are usually different.

Natural Spat-fall collection

Vertical collector ropes are suspended in the water from long lines between anchored buoys in late winter to catch natural spat-fall. The young mussels are stripped from the ropes in summer and put into ‘socks’ (netting bags), which are then rehung off ropes on the long lines. In addition to collection of wild spat, there is some hatchery production in Tasmania (see section B.3 for more information regarding mussel hatchery operations).

Transfer of hatchery produced spat

Vertical collector ropes are placed in hatchery tanks to allow the young mussels to settle on the ropes. The mussels are grown to a size of 0.5 millimetres and then are transported to grow-out sites by truck and boat.

Mussels are graded once or twice during grow-out. They can be moved between sites during production to maximise growth and survival for different life stages (eg spat and final grow-out).

The crop grows for 7 - 15 months and is usually harvested between July and February in response to a minimum shell size of 60mm length. Mussels are sold based on size, however, a 25 percent meat/shell ratio is usually needed by the market.

Harvested mussels can survive up to 7 days out of water and may often be held on land before shipment for sale. Mussels are generally sold live in-shell to fish markets. Some farms have processing facilities and produce value added product (eg pickled mussels). Processing facilities may be on-site or distant to on-shore facilities. Some farms may sell product at the farm gate or directly to local customers such as retail outlets.

Pacific oysters and flat oysters

Pacific oysters were first introduced to Tasmania from Japan and they are now cultured in Tasmania, South Australia and Port Stephens in NSW. Native mud or flat oysters are cultured in Tasmania, NSW and South Australia, often at the same facilities that produce Pacific oysters and rock oysters. Pacific and flat oyster spat are mainly produced within controlled hatchery conditions. Pacific Oysters are subject to selective breeding for faster growth rate, shell symmetry and higher meat content.

Spat is produced in hatcheries and supplied to farmers as ‘single seed’ spat (i.e. they are not attached to sticks). Spat are transferred to grow-out facilities at a size of 3 - 8 millimetres. Transfer of spat to farms may involve interstate movement of stock by truck or airfreight.

Rearing in estuarine leases can involve several methods. Young oysters may be placed in flat plastic trays on intertidal racks, in plastic or wire mesh bags on intertidal racks or suspended in mesh bags from vertical ropes below anchored rafts or within bags clipped to horizontal steel tensioned plastic wires which can be adjusted for depth between buoys or posts. Use of long lines provides a full sub-tidal existence, without the usual daily air exposure. Pond culture is occasionally used. The oysters can grow at depths of 2 – 20 metres and have a water temperature preference of 8 – 30°C (Pacific oysters).

Pacific oysters may be removed from the water on a regular basis for removal of excess shell margin and for grading.

Oysters are harvested at a shell length of 60-100 millimetres (in-shell weight of 60 – 100 grams or meat weight of 10-14 grams), at 18 months to 3 years of age.

Harvested oysters can survive up to 2 weeks out of water and may often be held on land before shipment for sale. Where the state's Shellfish Quality Assurance Program stipulates, a purification process is carried out for 36 hours before sale. The purification tanks rely on filtered and UV-treated water. These facilities may be single company operations or cooperative operations, located either on-site or distant to farm operations.

Harvested product is usually sold live in shell to fish markets or other local customers such as restaurants. Product is less frequently sold directly from the farm gate as bottled, half-shell or in-shell product. Product may be transported to either processing facilities or wholesale markets, by truck and airfreight. Product for export is frozen.

Abalone

Aquaculture of Greenlip abalone occurs in Tasmania, Victoria, Western Australia and South Australia, whereas Blacklip abalone is produced in NSW, Tasmania and Victoria. Greenlip and Blacklip species can naturally hybridise and the hybrid, known as "tiger abalone", is cultured in Tasmania and Victoria. The establishment of an aquaculture industry based on Roe's and Greenlip abalone is currently underway in WA.

Young abalone (spat) produced in marine hatcheries from wild-sourced or domesticated brood-stock are transferred to land based grow out tanks or in a small number of cases marine grow-out facilities at a size of 6- 15 millimetres. Spat may be transported overland by truck from hatcheries to grow-out sites.

Abalone are mainly grown in tanks on shore. Offshore grow-out is a small proportion of production and is highly varied. Grow-out can be in floating barrels or pipes moored off ropes or in specially designed submerged cages on marine leases. Various methods may be used to increase the "substrate" surface area available to animals within tanks, including the use of plastic or concrete hides.

The water temperature and depth preference of each abalone species varies. Greenlip abalone prefer water temperatures of 12 – 24°C, whereas Blacklip abalone prefer water temperatures of 10 - 20°C, although Blacklip from areas such as Port Phillip bay have a much higher temperature tolerance of between 8 - 26°C. Both species can be found at depths of up to 40 metres below which food is limiting. Roe's abalone prefer water temperatures of 14 – 26°C and depths up to 4 metres.

During grow-out abalone are fed a formulated diet (pelleted ration), which is based on agricultural products and is produced in Australia. In-feed treatments used for therapeutic purposes are available by prescription.

Some farms grade abalone at specific times during the production cycle, whereas others avoid handling stock during grow-out.

Cultured abalone is harvested in response to size after 3-4 years growth, at a shell length of 65 – 110 millimetres.

Harvested abalone can survive up to 1.5 days out of water and may often be held on land before shipment for sale. Animals to be shipped live are normally starved for 3 days or more and cooled down to between 8 - 12°C to give better transport survival. Harvested product is sent live in shell or as shucked meat directly to processing facilities or wholesale markets, by truck and airfreight. Some farms may sell product at the farm gate or directly to local customers such as restaurants. The majority of Australian product is frozen or canned and exported to Asia.

Scallops

The scallop aquaculture industry in Tasmania is based on the commercial scallop. Larvae are acquired from natural spat fall in estuaries or are produced in hatcheries from wild-sourced brood-stock.

Scallop spat are grown in subtidal marine waters at depths of 1 – 20 metres, either on ropes or in bags off a long horizontal rope. Scallops have a water temperature preference of 8 - 20°C. Spat collection sites and growing sites are usually different.

Natural Spat-fall collection

Vertical collector ropes or collector trays are suspended in the water from long lines between anchored buoys to catch natural spat-fall in September/October. The young scallops are stripped from the ropes or trays in February and transferred to netting bags, which are then rehung off ropes on the long lines. In addition to collection of wild spat, there is some hatchery production in Tasmania (see section B.3 for more information regarding scallop hatchery operations).

Transfer of hatchery produced spat

Young scallops are transferred to grow-out sites from nursery facilities at a size of size 10 - 15 mm. They are transported to grow-out sites by truck in polyboxes and by boat in lantern cages covered with wet hessian. Scallops are graded every 4 – 6 months.

Scallops are harvested at a size of 90 - 100 mm following 18 months or more of growth. They harvested in response to size, but mature gonad adds weight and, subsequently, a higher value to the product.

Harvested scallops can survive less than one day out of water and may often be held on land before shipment to the processing plant.

Scallops are generally sold as a half shell or flesh only product, fresh or frozen. Processing facilities may be on-site or distant to on-shore farm facilities. Some farms may sell product at the farm gate or directly to local customers such as restaurants or retail outlets.

Product is transported to wholesale fish markets or retail outlets by truck and airfreight. The market is domestic with no export of commercial scallops.

Experimental aquaculture of the Southern saucer scallop is currently being conducted in WA and QLD. This primarily involves the hatchery production of spat from wild-caught broodstock with a view to use spat for sea ranching. There are plans to develop grow-out techniques for the commercial production of the saucer scallop. This species of scallop has a temperature preference of 18 – 25°C and a fast growth rate with a projected grow-out period of 6 months.

Common Practices

With the exception of abalone, shellfish are not fed processed or formulated feed during grow-out. They are filter feeders and rely on the natural plankton present in the surrounding water on farm leases.

No chemicals or medical treatments are used during the production cycle.

Water quality is closely monitored on farm sites. There are shellfish monitoring systems in commercial production areas aimed at detecting toxic algae and bacterial levels.

Old shell or dead animals may be collected from farm sites and dumped in a designated area on-shore.

There may be limited processing of harvested animals on some farm sites. Alternatively, harvested animals may be transported live in-shell to distant processing facilities or wholesale markets, by truck and airfreight. Processing may involve the shucking or removal of shells and packaging of flesh. Processing sometimes includes freezing, canning or value adding of flesh, for example pickling of mussel flesh or removal of abalone viscera. Shells and viscera that are removed from animals are disposed of in a designated area at shore facilities or transported from processing facilities to an approved disposal site.

Some farms may sell product at the farm gate or directly to local customers such as restaurants.

B.2.7.3 Premises and equipment

There are marked similarities with the equipment used to produce filter feeders/bivalves of various species.

Sticks or slats are traditionally hardwood, 1.8 metres long and 25 millimetres square and often tarred or coated with a slurry of cement. Some sticks are now made of plastic, again with a cement slurry coating.

Racks are either tarred hardwood or treated pine or are plastic. Trays may be dark coloured plastic or galvanised wire. Bags, baskets or “socks” may be wire mesh, dark coloured plastic mesh or synthetic netting. Ropes are usually synthetic and buoys are painted or galvanised metal or plastic.

Most of the production practices are performed on marine leases from a barge or punt, but the operations also have a shore facility for storage, equipment service and some processing. Shore facilities usually consist of sheds and, in some cases, cool stores by the waterfront. Some shore bases may have a dedicated laboratory space equipped with a microscope. There may be a designated area on site for the disposal of processing wastes (shucked shell) and old shell. Alternatively, processing facilities may be distant to farm facilities.

Many leases are distant from the shore base and can only be reached by boat. Each company may own a number of leases and there may be many leases in various areas serviced from one shore base. Service vessels consist of aluminium punts or barges with outboard motors and are used to transport stock, personnel and equipment between different farm leases. The boats may have hydraulic or winch powered lifting equipment. They often have the ability to carry high pressure cleaning equipment.

Trucks or utility vehicles are used to transport stock overland from hatcheries to shore facilities, between grow-out sites and to market following harvest. Tractors and forklift trucks may be available at shore facilities for moving heavy equipment and conducting work at low tide.

Most operations are reasonably small and consist of 2 - 10 personnel. Personnel are multi-skilled and are involved in a number of activities throughout the production process. Contract workers may be used for equipment maintenance or diving where required.

B.2.7.4 System inputs

Animals

Young shellfish are sourced from either natural, local spatfall or from on-shore marine hatcheries. Spat may be sourced far from production sites.

Wild aquatic animals live in the immediate environment of estuarine and marine leases. Aquatic animal and plant communities develop on submerged equipment.

Water

There is no control of water on open leases however many farmers hold several leases in different areas which means they can shift the animals to different sites and therefore different water conditions.

Intertidal species can be removed from the water for some time (from days to weeks depending on species and temperature).

Shellfish farmers will often have an intense interest in the quality of the water on their leases and many will take regular readings. There are shellfish quality assurance programs operated by State Governments in Tasmania, Victoria, New South Wales, Queensland, Western Australia and South Australia to monitor biotoxins (eg. toxic algae and bacterial levels) in shellfish grow-out areas and provide contingency plans for the management of shellfish product quality. In addition there is a national shellfish quality assurance program that complements the programs operating at the state level.

The specific water temperature preferences of cultured shellfish species have been noted above in section B.2.7.2.

Feed

Bivalve shellfish are not fed processed or formulated feeds. They are filter feeders and rely on the plankton present in the surrounding water on farm leases. Hatcheries and nursery facilities may use specific algal cultures for feeding young oysters.

Abalone are fed a formulated pelleted ration which is based on plant products and is produced in Australia.

Personnel

The work force on leases varies but most are relatively small operations employing less than ten people. The work on leases is usually conducted in time with tides so this should be considered when trying to contact personnel. Personnel are multi-skilled and are involved in a number of activities throughout the production process. They move between different areas on farm leases and shore facilities. Contract workers may be used for equipment maintenance or diving where required.

There may be visitors to shellfish farm facilities, including researchers and aquatic animal health specialists.

Farmers have no control over the presence or practices of recreational fishers in the vicinity of marine and estuarine leases.

Vehicles

Personnel use privately owned vehicles to travel to work each day.

Many of the operations on water are performed from punts or barges Service vessels transport stock, equipment and personnel to estuarine and marine farm sites. Most farms have a truck or utility vehicle for transporting stock, equipment and personnel overland to various shore facilities. Tractors are used on some leases at low tide.

B.2.7.5 System outputs

Animals

Harvested animals are usually sent to fish markets or processing facilities, however a proportion may be processed and sold on site.

There are shellfish quality assurance programs operated by State Governments in Tasmania, Victoria, New South Wales, Queensland, Western Australia and South Australia to monitor biotoxins (eg toxic algae and bacterial levels) in shellfish grow-out areas and provide contingency plans for the management of shellfish product quality. In addition there is a national shellfish quality assurance program that complements the programs operating at the state level.

Waste

Bivalve shellfish are filter feeders and are not fed by farmers, therefore there is no feed waste associated with bivalve shellfish grow-out facilities.

A minimal amount of excess abalone feed contributes to the wastes produced by abalone grow-out.

There may be limited processing of harvested animals on some farm sites or at distant processing facilities. Processing usually involves the shucking or removal of shells. Processing of abalone also involves the removal of viscera.

Shells and viscera that are removed from animals are either disposed of in a designated area at shore facilities or transported from processing facilities to an approved disposal site.

Old shell and dead animals may be collected from farm sites and dumped in a designated area on site.

Equipment

Equipment is usually used between several sites. Old sticks and broken equipment are usually disposed to landfill or may be burnt.

Personnel

Personnel move between different areas on farm leases and shore facilities. Contract workers may be used for equipment maintenance or diving where required. There may be a number of visitors to farm facilities, including researchers and aquatic animal health specialists.

Farmers have no control over the presence of recreational fishers in the vicinity of marine and estuarine leases.

Vehicles

Personnel use privately owned vehicles to travel home from work each day.

Service vessels transport stock, equipment and personnel from estuarine and marine farm sites to on shore facilities. Most farms have a truck or utility vehicle for transporting stock, equipment and personnel overland from various shore facilities. Tractors and forklifts generally remain located at on-shore facilities.

B.2.7.6 Groups involved

Groups involved include:

- Queensland Oyster Grower's Association Inc.
- NSW Farmers' Association (Oyster Division)
- Oyster Farmers' Association of NSW Ltd
- South Australia Oyster Growers Association Inc.
- South Australian Oyster Research Council Ltd
- Tasmanian Oyster Research Council Ltd
- Tasmanian Shellfish Executive Council Inc.
- Victorian Abalone Growers Association
- WA Abalone Aquaculture Association
- SA Abalone Growers Association
- Abalone Industry Association of South Australia
- Victorian Mussel Grower's Association
- SA Mussel Growers Association
- Western Australia Mussel Grower's Association
- government bodies at both a National and state level
  (including agriculture and fisheries agencies, health departments)
- local councils
- environmental agencies and associations
- Aboriginal lands councils
- Other community groups
- recreational fishing
- yachting/boating
- commercial fisherman

- universities and other institutions
- other water users.

B.2.7.7 Legislation and codes of practice

Legislation relevant to aquatic animals and aquatic animal health is listed in Appendix 1.

There are shellfish quality assurance programs operated by State Governments in Tasmania (TASQAP), Victoria (VSQAP), New South Wales (NSWSQAP), Queensland (QSWAMP), Western Australia (WASQAP) and South Australia (SASQAP). These programs monitor biotoxins (eg toxic algae and bacterial levels) in shellfish grow-out areas and provide contingency plans for the management of shellfish product quality. In South Australia the program is legislated under the *Fisheries Act 1982* and in Queensland the program is incorporated in the conditional terms of shellfish farm licenses. In addition, there is a national program (Australian shellfish quality assurance program or ASQAP) which is applicable to bivalve molluscs and complements the programs operated at the state level. (Please see Appendix 1 for website links applicable to the above programs).

There are shellfish sanitation schemes and codes of practice for shellfish culture in New South Wales, including the NSW shellfish program (NSWSP; website link at www.oysterfarmers.asn.au/qap/).

South Australia has a 1997 code of practice for South Australian oyster growers. The South Australian Oyster Growers Association have launched an industry owned food safety certification program that is supported by the state's government audit arrangements and registration is conducted by PIRSA.

There is a policy guideline for abalone aquaculture in Western Australia (website link at (www.fish.wa.gov.au/aqua/broc/aqua/abalone).

Further information on sanitation schemes is available from the Australian Seafood Industry Council.

B.2.7.8 Occupational health

Public health

The following public health issues should be considered:

- safety of the product if it is harvested when toxic algal blooms are suspected. This is covered by legislation and under each states' biotoxin monitoring & contingency program
- safety of wild harvested product not regulated by food safety schemes
- the potential of the product to transmit zoonotic diseases (see Appendix 2)
- the quality of harvested product if it is emergency harvested due to disease
- availability of laboratories capable of testing for public health factors
- public access to waters adjacent to farming enterprises, especially if disease is suspected or confirmed

Worker safety

The following worker safety issues should be considered:

- the harshness of environment and dependency on weather conditions can make the work environment dangerous and can be an impediment to safe work practices
- due to daily variation in current flow there are certain times in the day when attempting certain management practices may be unsafe
- diving may occur on farms but requires specialised training and qualifications - it is illegal and extremely dangerous for untrained personnel to dive
- working in the marine environment requires experience and can be dangerous for the inexperienced worker
- equipment such as ropes and heavy racks are dangerous if not handled appropriately

- operation of boats requires specialised qualifications and experience
- safety equipment is required
- handling of stock/shells can result in skin lacerations
- collection of decomposing stock may threaten workers' health
- contaminated water may needs appropriate disposal techniques
- Divers can be exposed to toxic algal blooms, jellyfish swarms and large marine predators (eg. sharks).

Appendix 1: Summary of current legislation with relevance to aquatic animal diseases

State/Territory/Agency	*Relevant Legislation*
Australian Capital Territory	The Stock Act 1993 The Animal Diseases Act 1993 The Nature Conservation Act 1980 The Fishing Act 1967
New South Wales	The Exotic Diseases of Animals Act 1991 The Stock Diseases Act 1923 The Fisheries Management Act 1994 The Fisheries Management Act (Aquaculture) Regulations 1995 New South Wales Shellfish Quality Assurance Program (NSWSQAP) (www.safefood.nsw.gov.au)
Northern Territory	The Stock Diseases Act 1954 The Fisheries Act 1995
Queensland	The Fisheries Act 1994 The Fisheries Regulations 1995 Australian Barramundi Farmers Association Code of Practice (harvesting, processing and distribution - www.abfa.info) "Industry Environmental Code of Best Practice for freshwater finfish Aquaculture" produced by the Aquaculture Association of QLD (website link available at www.abfa.info). Queensland Shellfish and Water Assurance Monitoring Program (QSWAMP) (www.dpi.qld.gov.au/water)
South Australia	The Livestock Act 1997 The Fisheries Act 1982 The Exotic Fish, Fish Farming and Fish Disease Regulations 1984 Aquaculture Act 2001 1997 Code of Practice for South Australian Oyster Growers South Australian Shellfish Quality Assurance Program (SASQAP) (www.pir.sa.gov.au/pages/aquaculture/quality_assur/sasqap_phyto.htm) (www.foodsafetysa.com.au)
Tasmania	The Animal Health Act 1995 Inland Fisheries Act 1995 Living Marine Resources Management Act 1995 Marine Farm Planning Act 1995 Agricultural and Veterinary Chemicals (Control of Use) Act 1995

	Tasmanian Shellfish Quality Assurance Program (TASQAP) (www.dhhs.tas.gov.au/publichealth/shellfish/)
Victoria	The Livestock Disease Control Act 1994 Fisheries Regulations 1998 Victorian Shellfish Quality Assurance Program (VSQAP) (www.nre.vic.gov.au/web/root/domino/cm_da/nrefaq.nsf)
Western Australia	Pearling Act 1990 The Exotic Disease of Animals Act 1993 The Stock Diseases Regulations Act 1996 Enzootic Diseases Amendment Regulations 1999 Fish Resources Management Regulations 1994 Fish Resources Management Regulations 1995 Abalone Aquaculture in Western Australia: Policy Guideline (www.fish.wa.gov.au/aqua/broc/aqua/abalone). Pearl Oyster Culture in Western Australia: Policy Guideline (www.fish.wa.gov.au/aqua/broc). Translocation Policy (www.fish.wa.gov.au/hab/broc/translocationpolicy) Western Australian Shellfish Quality Assurance Program (WASQAP) (www.fish.wa.gov.au/aqua/broc/aqwa/mussels)
Commonwealth and International	For example: The Commonwealth Fisheries Management Act, 1991 The Fisheries Act, 1975 State Fisheries Acts and Legislation UN Agreement on Straddling and Migratory Fish Stocks, London Convention Off Shore petroleum and Minerals Exploration Acts Quarantine Act, 1908 and Ballast Water Regulations Waste processing discharges from food processing and industrial wastes, MARPOL. Black marlin Code for Commercial Fishers and the Recreational Fisheries Code of Practice Australian Aquaculture Code of Conduct (www.pir.sa.gov.au/pages/aquaculture/farm_practice/code_of_conduct.pdf) Australian Shellfish Quality Assurance Program (ASQAP) (www.pir.sa.gov.au/pages/aquaculture/quality_assurance) Australian New Zealand Food Standards Code (www.safefood.nsw.gov.au)

Electronic versions of Australian Acts and regulations can be found on the Internet at sites such as http://www.austlii.edu.au and http://www.dms.dpc.vic.gov.au.

International laws and treaties can be found on sites such as http://www.lexadin.nl/wlg/legis/nofr/legis.htm.