Northern Territory Government

DEPARTMENT OF **PRIMARY INDUSTRY, FISHERIES AND MINES**

NORTHERN TERRITORY

Barramundi Farming Handbook

Glenn Schipp, Jérôme Bosmans and John Humphrey

Foreword

This booklet represents the third revision of the NT Barramundi Farming Handbook. The first edition appeared in 1993 and the second revision was completed in 1996.

In the last ten years there have been some dramatic improvements in the way barramundi have been produced in the Northern Territory. The establishment of a large sea cage farm by Marine Harvest in 2001 was a pivotal point in the development of the local industry. Marine Harvest entered into an agreement with the NT Government for the supply of juvenile stock for their farm. This saw the establishment of an industrial scale fish nursery at the Darwin Aquaculture Centre (DAC) and the start of a period of rapid improvement in the way fish were produced.

A study tour to Europe by DAC staff in 2001, to visit universities involved in marine fish culture research and some of the world's biggest marine hatcheries, resulted in the formulation of an intensive, recirculating larval rearing system for barramundi. This system was a 'hybridisation' of many elements seen on the tour. The move from semi-intensive to intensive hatchery production has seen the output from the DAC rise to more than three million weaned fish per year, accompanied by an increase in growth rate so that now, instead of it taking 12 weeks to produce a 100 mm long juvenile, it takes less than 10 weeks.

Marine Harvest were not the only beneficiaries of this R&D. The local pond based farms also benefited from the improved quality and reliable production of juveniles from the DAC. On the back of this support the local industry had a total production of more than 1000 tonnes in 2005/06. Unfortunately Marine Harvest exited the Northern Territory in late 2006, however the legacy of improved barramundi production remains, and the local pond farms continue to go from strength to strength.

This booklet is not intended to be a comprehensive 'how to' guide for barramundi farming. The principles and practices of barramundi culture are far too complex to be captured in one book. The booklet is a guide only but will hopefully give prospective farmers an insight to the industry as well as serve as a record for the state of development in 2007.

One of the issues with completing this third revision was the rapid pace of development of hatchery techniques over the past three years. Just when the text appeared to be finalised, more noteworthy improvements were made to the method. This, coupled with the appearance of at least three new diseases, has necessitated several revisions of the revision.

I would like to personally thank Dr John Humphrey, not only for the excellent disease chapter in this booklet, but also for his professional management of aquatic animal diseases in the NT. It is largely through Dr Humphrey's efforts that the NT has some of the best biosecurity management arrangements of the Australian aquaculture industry.

Thanks also to Jérôme Bosmans and the team at the Darwin Aquaculture Centre. Their enthusiasm for aquaculture and dedication to the job have helped make the DAC one of the leading marine hatcheries in Australia and also a great place to work.

Glenn Schipp
September 2007

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General enquiries about this publication should be directed to:

Glenn Schipp
Department of Primary Industry, Fisheries and Mines
Darwin Aquaculture Centre
GPO Box 3000
Darwin NT 0801

Phone: **(08) 8924 4268**
Facsimile: **(08) 8924 4277**

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Contents

1. Barramundi 1

1.1 Barramundi - the fish 1

1.2 Barramundi aquaculture 1

1.2.1 History 1

1.2.2 History of barramundi aquaculture in the NT 2

2. Biology 3

2.1 Breeding season 3

2.2 Sexual maturity 3

2.3 Spawning grounds 3

2.4 Spawning behaviour and early life history 4

2.5 Environmental requirements 4

3. Hatchery production 5

3.1. Broodstock 5

3.1.1 Holding tanks 5

3.1.2 Diet 6

3.2 Spawning 7

3.2.1 Anaesthesia 7

3.2.2 Broodstock identification 8

3.2.3 Selection of spawners 8

3.2.4 Hormone administration 9

3.2.4.1 Injection 9

3.2.4.2 Implantation 10

3.2.4.3 Preparation of the cholesterol/ hormone mixture 10

3.2.4.4 The mould 10

3.2.4.5 Pellet manufacture 10

3.2.4.6 Example of calculations 12

3.2.4.7 Storage 12

3.2.5 Egg collection, evaluation and disinfection 13

3.2.5.1 Egg collection and evaluation 13

3.2.5.2 Disinfection: ozone treatment of barramundi eggs 14

3.2.6 Egg development stages 14

3.2.7 Care of the larvae 14

3.2.8 Packaging for transport 15

3.3 Larviculture 16

3.3.1 Intensive culture 17

3.3.1.1 Traditional intensive larviculture 17

3.3.1.2 Re-circulating, semi-automated, intensive culture 18

3.3.2 Semi-intensive or 'greenwater' production 19
3.3.3 Extensive production 21

4. Nursery 23

4.1 Nursery systems 23
4.1.1 Darwin Aquaculture Centre's intensive nursery 23
4.1.2 Oxygen 24

4.2 Cannibalism 25
4.2.1 Factors promoting cannibalism 25
4.2.2 Control of cannibalism 25

4.3 Grading 25

4.4 Counting 26
4.4.1 Weight counting 26
4.4.2 Mechanical counting 27

5. Grow-out 28

5.1 Pond culture 28
5.1.1 Design of grow-out ponds 28
5.1.2 Advantages of ponds for fish grow-out 29
5.1.3 Disadvantages of grow-out ponds 29

5.2 Cage culture 30
5.2.1 Cage farming in tropical Australia 31
5.2.2 Grow-out cages - site requirements 31
5.2.3 Advantages of grow-out cages 31
5.2.4 Disadvantages of grow-out cages 32

5.3 Grading during grow-out 32
5.3.1 Pond culture 32
5.3.2 Cage culture 32

5.4 Stocking rates 33
5.4.1 Ponds 33
5.4.2 Cages 33

6. Nutrition 34

6.1 Larval nutrition 34
6.1.1 Intensive production 34
6.1.2 Semi-intensive production 35
6.1.3 Extensive production 35

6.2 Juvenile nutrition 35
6.2.1 Weaning diets 35
6.2.2 Nursery diets 36

6.3 Grow-out nutrition 36
6.3.1 Bait fish feeds 36
6.3.2 Formulated pellet feeds 36
6.3.3 Advantages of pellets 37
6.3.4 Disadvantages of pelleted diets 37
6.3.5 Moist pellets 37
6.3.6 Growth rates 38
6.4 Feeding methods 38
6.4.1 Hand feeding 38
6.4.2 Mechanised feeders 39
6.5 Feeding rates 39
7. Disease 40
7.1 Disease prevention 40
7.1.1 Water quality 40
7.1.2 Feed quality 41
7.1.3 Quarantine 41
7.1.4 Non-infectious diseases 41
7.1.4.1 Deformities 41
7.1.4.2 Cannibalism 42
7.2 Viral diseases 42
7.2.1 Nodavirus (viral encephalopathy & retinopathy) 42
7.2.1.1 Signs of infection 43
7.2.1.2 Treatment and control 43
7.2.1.3 Prevention 44
7.2.2 Lymphocystis 44
7.2.2.1 Signs of infection 44
7.2.2.2 Treatment and control 45
7.3 Bacterial diseases 45
7.3.1 Streptococcosis 45
7.3.1.1 Signs of infection 45
7.3.1.2 Treatment and control 45
7.3.1.3 Prevention 46
7.3.2 Vibriosis 46
7.3.2.1 Signs of infection 46
7.3.2.2 Treatment and control 46
7.3.2.3 Prevention 46
7.3.3 Necrotic enteritis and peritonitis (‘bloat’) 46
7.3.3.1 Signs of infection 47
7.3.3.2 Treatment and control 47
7.3.3.3 Prevention 47
7.3.4 Bacterial gill disease 47
7.3.4.1 Signs of infection 47

7.3.4.2 Treatment and control *48*
7.3.4.3 Prevention *48*
7.3.5 Epitheliocystis 48
7.3.5.1 Signs of infection *48*
7.3.5.2 Treatment and control *48*
7.3.5.3 Prevention *48*

7.4 Fungal diseases 48
7.4.1 Red spot 48
7.4.1.1 Signs of infection *49*
7.4.1.2 Treatment and control *49*
7.4.1.3 Prevention *49*

7.5 Parasitic diseases 49
7.5.1 Cryptocaryonosis 49
7.5.1.1 Signs of infection *49*
7.5.1.2 Treatment and control *49*
7.5.1.3 Prevention *50*
7.5.2 Trypanosomosis 50
7.5.2.1 Signs of infection *50*
7.5.2.2 Treatment and control *51*
7.5.2.3 Prevention *51*
7.5.3 Oodiniosis 51
7.5.3.1 Signs of infection *51*
7.5.3.2 Treatment and control *51*
7.5.3.3 Prevention *51*

7.6 General quarantine and health requirements 51
7.6.1 Compliance with aquaculture licence 51
7.6.2 Barramundi disease control zones 52

8. Licensing and environmental impact 54

8.1 Aquaculture licence 54

8.2 Ecological Sustainable Development (ESD) 54

8.3 Environmental Management Plans 55

8.4 Environmental impacts of barramundi farming 55
8.4.1 Nutrient and waste discharge 55
8.4.2 Escapes 56
8.4.3 Fish meal in aquaculture feeds 57
8.4.4 Diseases and parasites 59
8.4.5 Chemical usage 59
8.4.6 Other impacts of barramundi farming 60

9. Selected references 1980-2006 61

List of tables

Table 3.1.	Example of quantities of cholesterol and LHRHa hormone needed to manufacture pellets for implantation	12
Table 3.2.	Pond fertilisation schedule used in extensive rearing trials	22
Table 6.1.	Approximate quantities of pelleted feed needed to raise 1 tonne of barramundi	39

List of figures

Figure 3.1.	Main features of the 70,000 L re-circulating, barramundi broodstock tank	6
Figure 3.2.	Schematic diagrams of the cannulation process	9
Figure 3.3.	Position for a liquid injection or pellet implantation in adult barramundi	9
Figure 3.4.	Method of manufacture of cholesterol/ hormone pellets	11
Figure 3.5.	Stylised drawing of barramundi egg development stages	15
Figure 3.6.	Stylised diagram of a nursery pond	21
Figure 5.1.	Simplified diagram of a small pond farm	28
Figure 5.2.	Typical water gate construction used for regulating the volume of water in a pond	29
Figure 6.1.	Growth rates of farm raised barramundi in the NT	38
Figure 7.1.	Disease Control Zones for controlling movement of barramundi into and within the Northern Territory	53

List of photographs

Photo 1.1.	Farm fresh barramundi!	2
Photo 2.1.	Prime barramundi habitat	4
Photo 3.1.	The main, 70,000 L barramundi broodstock tank	7
Photo 3.2.	PIT tags are used to individually identify broodstock barramundi	8
Photo 3.3.	Photomicrograph of cannulated oocytes from a female barramundi	8
Photo 3.4.	A mature female barramundi ready to be induced to spawn	8
Photo 3.5.	One of the 7,500 L barramundi spawning tanks showing the egg collecting skimmer and the collection net	13
Photo 3.6.	The high density rotifer culture system	18
Photo 3.7.	Some of the features of the re-circulating, semi-automated, intensive, larval rearing system	19
Photo 3.8.	Outdoor, semi-intensive larval rearing tanks	20
Photo 4.1.	Darwin Aquaculture Centre's barramundi nursery	23
Photo 4.2.	Raceway tanks	24
Photo 4.3.	Ceramic oxygen stone operating in a barramundi nursery tank	24
Photo 4.4.	Home-made PVC and acrylic grader box	26
Photo 4.5.	Features of an automatic grader	26
Photo 4.6.	Impex™ mechanical fish counter	29
Photo 5.1.	Aerial photograph of one of the NT's pond-based barramundi farms	30
Photo 5.2.	Typical example of a south east Asian floating cage farm	30
Photo 5.3.	Marine Harvest's original barramundi cage farm at Port Hurd	31
Photo 7.1.	Cannibalism in barramundi with excoriation and necrosis of integument	42
Photo 7.2.	Brain and retina of barramundi with viral nervous necrosis showing massive vacuolation in nerve tissues	43
Photo 7.3.	Tail fin of mature barramundi showing multiple pale nodular growths typical of lymphocystis	44
Photo 7.4.	Barramundi showing focal and diffuse haemorrhages in skin and a base of fins and severe exophthalmos with intra-ocular haemorrhage caused by *Streptococcus iniae*	45
Photo 7.5.	Barramundi with 'bloat'	47
Photo 7.6.	*Cryptocaryon irritans* in the epithelium of the gill	49
Photo 7.7.	Trypanosomosis showing deep ulcer	51

1. Barramundi

1.1 Barramundi - the fish

Barramundi, *Lates calcarifer* (Bloch), is an important coastal, estuarine and freshwater fish in the Indo-Pacific region.

It supports extensive commercial and recreational fisheries in Australia and Papua New Guinea and provides the basis of an expanding aquaculture industry in Australasia, where it is also subject to wildstock exploitation.

The species is distributed from the Arabian Gulf to China and Taiwan, and to Papua New Guinea and northern Australia. In Australia, barramundi are found as far south as the Noosa River (26°30' S) on the east coast and the Ashburton River (22°30' S) on the west coast.

As to be expected with a species that occupies a wide geographic range, *Lates calcarifer* comes under a diverse group of common names. Although 'barramundi' is the accepted common name in Australia (derived from the aboriginal word 'burramundi' meaning 'large scales'), it has been variously called 'giant perch' and 'cock-up'. It is also known as 'anama' in Papua New Guinea, 'kakap' in Indonesia and Malaysia, 'bulgan' in the Philippines, 'bhekti' in India and often more generally as Asian seabass in the literature.

Barramundi have been the subject of considerable research over the last three decades, most of which is clearly identifiable as either supporting the development of aquaculture or providing information relevant to wild stock management.

1.2 Barramundi aquaculture

1.2.1 History

The popularity and demand for barramundi made it an obvious candidate for aquaculture. Apart from the characteristics that endear it to the consumer; tender, mild tasting, boneless fillets, the fish is also fast-growing and euryhaline (can be grown in salinities ranging from fresh to sea water). The latter fact is seen as a valuable attribute for a species being raised in areas subject to monsoonal conditions.

Techniques for the culture of barramundi were first developed at the Songkhla Marine Laboratories in Thailand in the early 1970s and considerable progress in aquaculture techniques for the species has been achieved since that time.

During the 80s and 90s barramundi aquaculture expanded to China, India, Indonesia, Malaysia, the Philippines, Singapore, Taiwan, Vietnam, and Australia. More recently countries such as the USA, the Netherlands, the UK and Israel have also embraced barramundi farming. Many of these countries are supporting active research into culture techniques for barramundi.

Australia's involvement with barramundi culture began in 1983 with the establishment of a research program at the Queensland Department of Primary Industries' Northern Fisheries

Research Centre in Cairns. The main thrust of the initial research was to produce fingerlings for the enhancement of rivers and estuaries for recreational fishing.

Early breeding programs used eggs and sperm hand stripped from wild spawners at Weipa in North Queensland. Later, spawnings were undertaken using captive as well as wild brood fish.

The first large scale barramundi farm was established near Innisfail in North Queensland in 1986 following the public float of Sea Hatcheries Limited. Since then a number of barramundi farms have been established around Australia and in 2004-5 the industry produced nearly 3000 tonnes of fish.

1.2.2 History of barramundi aquaculture in the NT

In 1988 the Northern Territory government established a pilot barramundi hatchery, the Darwin Aquaculture Centre (DAC), at Stokes Hill in Darwin. The aim of the hatchery was to investigate and refine the techniques for barramundi breeding under Northern Territory environmental conditions. Any fingerlings produced by the hatchery were to be used to foster the development of a local barramundi aquaculture industry.

Initial investigations at the DAC focussed on improving the maturation rate of male and female fish. Hormone therapies were developed which assisted in improving the spawning performance of the fish. In 1995, a heated, re-circulating, broodstock tank was installed to give greater control over their breeding cycle. By controlling the temperature in the tank it was possible to advance and prolong the breeding season, increasing the period of availability of fertilised eggs.

Following on from the breeding success at the DAC, the Northern Territory government actively assisted the establishment of barramundi farms in the Darwin area. Production for the Northern Territory increased to nearly 100 tonnes in 1994, declining for a period as a number of farms changed to more lucrative, marine prawn production.

In 1998 the DAC was relocated to a $2.2 million, purpose-built facility, at Channel Island in Darwin Harbour. Fully funded by the Northern Territory Government, the new hatchery was designed with increased capacity for fish production and represented the latest design features for marine aquaculture.

Since 1998 local production of farmed barramundi has increased dramatically. The development of improved growing diets, and a shift in emphasis from plate sized to fillet sized fish, has resulted in improved farm economics. Following the establishment of a marine sea cage farm in 2001, accompanied by improved production from marine pond based farms, annual barramundi production in the NT surged to over 1,000 tonnes in 2004.

In 2006 the sea cage farm operated by Marine Harvest ceased operations. The drop in total production caused by Marine Harvest's closure has been partially offset by continued increase in production from the established pond producers as well as the entrance of two new farms into the industry.

Photo 1.1. Farm fresh barramundi!

2. Biology

2.1 Breeding season

Studies on barramundi in northern Australia and Papua New Guinea have identified that it has a complex life history.

The start of the breeding season for barramundi in the Darwin area coincides with the return to large spring tides and increasing water temperatures in mid to late August. The breeding season is usually completed by March, however fish kept under artificial conditions can be spawned all year round.

Populations of barramundi in southern Queensland and the central coast of Western Australia have breeding seasons of shorter duration than those of the Northern Territory and north Queensland.

2.2 Sexual maturity

Barramundi mature sexually at two to three years of age. The fish mature initially as males and participate in one or more spawning seasons before undergoing a sexual inversion (protandry), becoming functional females by the next breeding season.

Usually fish less than 80 cm in length are males and those greater than 100 cm are females. This is not always the case as sexually precocious (fish that mature and change sex at a smaller than usual size) populations of barramundi are known to occur in the NT and Queensland.

Captive barramundi have often exhibited a very short male phase becoming functional females when they reach 50–60 cm in length. The reasons for this have been variously attributed to the captive environment, increased and more regular feeding or hormone treatments used during the spawning season. Interestingly, in Queensland and the Northern Territory, male fish held under conditions of constant temperature and monthly, year round spawning, have often shown delayed sex change.

The reasons for this early sex change were also investigated by researchers from the Australian Aquaculture Cooperative Research Centre, who found that the use of high energy, formulated fish diets may have helped to shorten the time the fish spent as functional males.

2.3 Spawning grounds

Even though barramundi can live in either fresh or salt water, their eggs and early stage larvae will only survive in sea water (salinities between 22 and 40 ppt). For this reason breeding takes place in river mouths and bays near areas of suitable nursery habitat. Areas such as mangrove swamps and low-lying land that becomes flooded during spring tides and monsoonal rains provide ideal habitat for juvenile barramundi.

2.4 Spawning behaviour and early life history

There does not appear to be a definite long range spawning or post spawning migration in Australia, as there is in Papua New Guinea. Instead it is believed that mature males and females congregate locally within a river system. Other fish may arrive at the spawning grounds later in the breeding season aided by monsoonal flooding of upstream billabongs.

Spawning takes place at night around the time of the slack tide and appears to be related to the lunar cycle. The nights following full and new moons are the periods of greatest spawning activity.

Each female may release many millions of eggs (the highest reported number is 40 million, although 6–8 million is more common) as she swims in tandem with one or more males that release a cloud of sperm to fertilise the eggs in the water. The actual release of the eggs lasts only a few seconds and the males immediately 'pirouette' around the female's tail, releasing their sperm.

The eggs are capable of being fertilised for only the first few minutes before they 'water harden'. Once fertilised, the eggs will drift in the current for 12–15 hours until the larvae hatch.

Barramundi larvae live on their yolk sac for the first 36–40 hours and then feed on microscopic zooplankton. They continue to feed on plankton for a number of weeks, moving on to larger prey as they grow rapidly. Barramundi are also cannibalistic and many of the juveniles may end up being eaten by other barramundi not much larger than themselves.

The surviving juveniles may remain in their nursery habitat for most of the wet season. As water levels in the nursery swamps begin to fall, most of the young fish will move upstream into fresh water and stay there for two to three years until they mature.

2.5 Environmental requirements

Barramundi fingerlings are known to survive in water with a salinity over 50 ppt and at temperatures up to 35°C. They can also survive temperatures as low as 16°C.

The optimum temperature for growth of NT barramundi is between 28°C and 32°C and the optimum salinity range is 0–36 ppt. Available information indicates that juvenile barramundi tend to grow faster in lower salinities.

Photo 2.1. Prime barramundi habitat

3. Hatchery production

Hatchery production starts with the spawning of captive breeding fish or 'broodstock' and is completed when the small fish or 'fingerlings' are 20–25 mm long and are feeding on formulated diets.

Outside the NT, barramundi fingerlings are available from a number of hatcheries in Queensland, South Australia and Western Australia. Most hatcheries hold their breeding fish under controlled environmental conditions giving them access to a year round supply of eggs and larvae. Some time ago the Northern Fisheries Research Centre in Queensland withdrew as a major supplier of barramundi larvae and has now ceased to provide an emergency backup service.

In the Northern Territory, the Darwin Aquaculture Centre (DAC) is still the sole source of larvae and fingerlings, although this is expected to change in the near future.

3.1. Broodstock

3.1.1 Holding tanks

Barramundi broodstock at DAC are maintained in several, large, fibreglass, seawater tanks.

The main breeding fish are kept in a 70,000 L fibreglass tank operated on a re-circulating sea water system (Fig. 3.1). A 'heat 'n chill' pump is part of the re-circulation system and controls the water temperature in the tank. Water temperature is normally maintained at 30°C (corresponds to the mean water temperature during the peak, natural spawning season) the salinity at 30 ppt and artificial lighting is via halogen vapour lamps with day length set at 13 hours. The salinity in the tank is periodically changed to fresh water for disease control (see Chapter 7). Up to ten female and twenty male fish are kept in the tank with a maximum biomass of 450 kg. Some of the fish maintained in the re-circulating system have been kept in breeding condition all year round.

The other holding tanks are either 20,000 or 40,000 L in volume. These tanks are also fitted with a re-circulating seawater system with similar water quality specifications to the main tank. Again, the salinity is periodically changed to fresh water for disease control.

To assist in the control of breeding condition the broodstock tanks are periodically (once or twice a year over 8–10 weeks) changed to cooler water temperatures (23–24°C) and shorter day lengths, to simulate dry season conditions. The 'phase-shifting' or 'cycling' of temperature and light conditions (lowering the temperature and shortening the day length of each holding tank) occurs sequentially in the three holding systems. As one tank is lowered into 'winter' conditions, another is warming up to 'summer' and the third is in full summer conditions and its fish are being used to spawn. The cycling of the tanks helps provide fish in spawning condition all year round.

3.1.2 Diet

Broodstock barramundi are fed a high quality diet consisting of freshly thawed whole mullet and squid. The size of the feed is usually between 10 and 20 cm per piece. The fish are fed three days a week and tank cleaning is undertaken on the non-feeding days.

The feed for the broodstock is supplemented by a special diet additive (Fish Breed-M from INVE Aquaculture) and a vitamin mix is also injected into each piece of food. The vitamin mix is a special blend developed by Queensland Fisheries and available commercially from Rabar Pty Ltd in Queensland.

Recently INVE Aquaculture have released a pelleted form of *Fish Breed-M* and this has also been successfully used at the DAC.

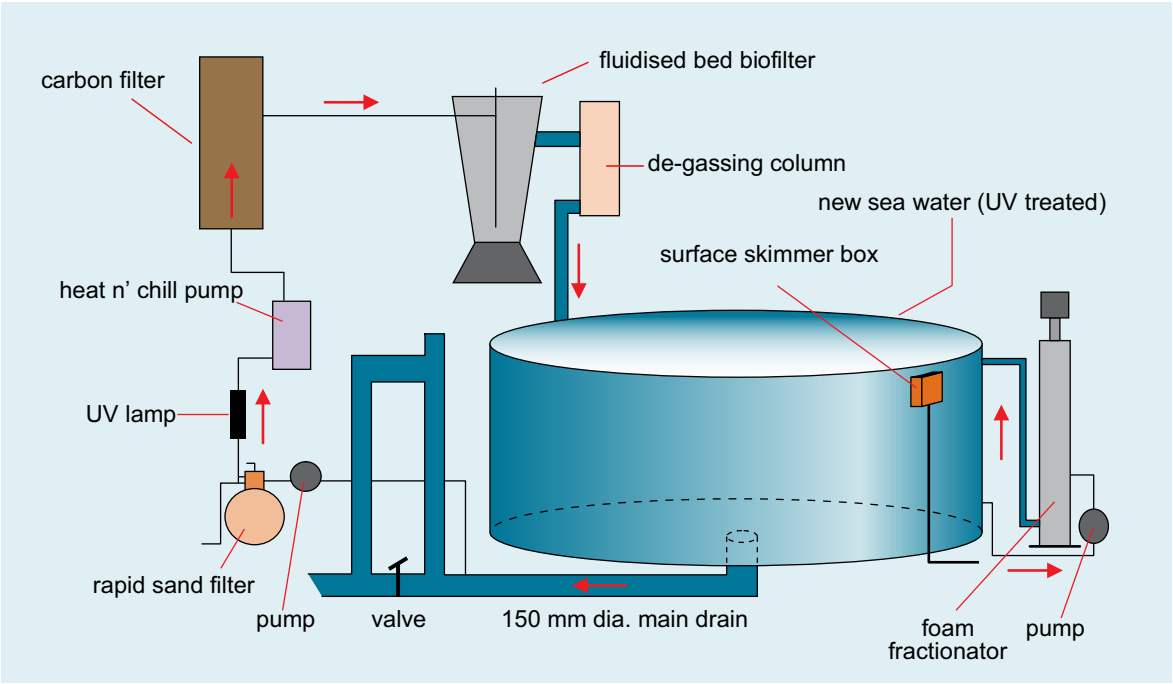

Figure 3.1. Main features of the 70,000 L re-circulating, barramundi broodstock tank. Water is drawn from the main drain, filtered through a rapid sand filter and then passed by an Ultra-Violet lamp. From there it is heated or cooled through a reverse cycle heat exchanger and then on through a carbon filter to reduce the organic content. Ammonia and nitrite are removed using a fluidised bed biofilter and the water gravity feeds back to the tank through a de-gassing column. More organic material in the water is removed using a separate foam fractionation unit. New, UV treated sea water is added at the rate of 10 L per minute. The arrows show the direction of the water movement

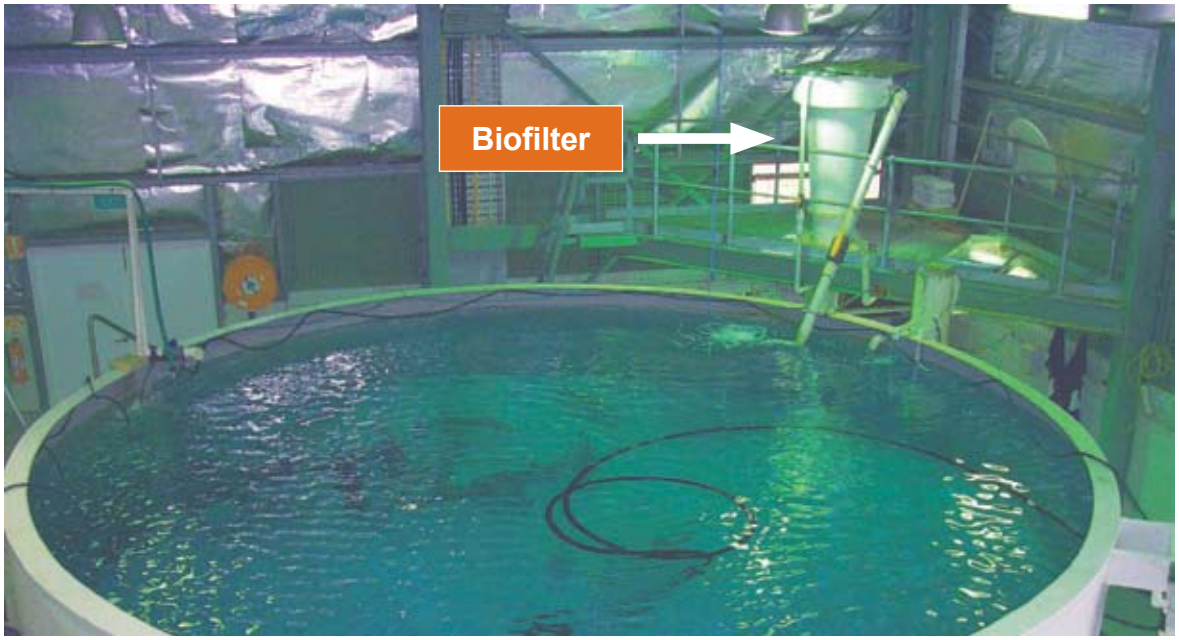

Photo 3.1. The main 70,000 L barramundi broodstock tank. The tank is now screened by a black curtain to assist with light control and to reduce disturbance to the fish

3.2 Spawning

The method described here is the one used successfully at the DAC over the past 15 years. Other hatcheries may vary in the protocols they adopt for production of larvae.

3.2.1 Anaesthesia

Prior to examination of the fish to assess spawning condition, they must first be caught and anaesthetised. Anaesthesia is necessary to reduce stress and to reduce the risk of injury to either the handlers or the fish.

The holding tank is drained to a depth of 40 cm and an anaesthetic bath and examination table are set up inside the tank. The bath consists of a 200 L fibreglass tub filled with 100 L of water from the tank, to which is added 4 mL of the fish anaesthetic 'AQUI-S'®. The concentration of anaesthetic in the bath is therefore 40 parts per million (ppm).

A fish is caught by carefully manoeuvring it into a vinyl sling and from there into the anaesthetic bath. A maximum of two fish are anaesthetised at any one time.

Sufficient anaesthesia is achieved once the fish loses orientation in the bath and floats 'belly up'. This may take five to six minutes. The fish can then be lifted onto the examination table. Examinations are usually completed within five minutes. Longer examinations may require the fish to be re-anaesthetised. After examination the fish is returned to the holding tank. Recovery is achieved by holding the fish near to a bubbling air stone and releasing it once correct buoyancy is obtained - usually within a few minutes.

3.2.2 Broodstock identification

As part of the spawning process, all broodstock in the DAC are identified with an internal tag, known as a PIT tag (Passive Integrated Transponder). These tags (the same as used to identify domestic cats and dogs) are read via an external electronic reader which detects the unique code for each fish. Tagging allows records to be kept on the spawning performance and other relevant information for each individual fish.

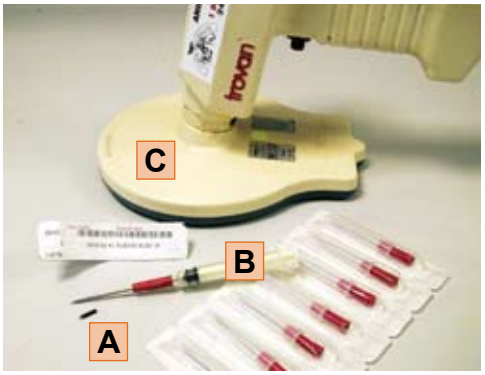

Photo 3.2. PIT tags are used to individually identify broodstock barramundi. A: PIT tag (about 4 mm long); B: tag implanter; C: tag reader

3.2.3 Selection of spawners

Female fish are examined first and are selected for spawning on the basis of a sample of oocytes removed from the ovary by cannulation (Fig. 3.2). The cannula is gently inserted through the genital opening for a distance of 6–8 cm and the plunger on the syringe is withdrawn slightly. As the plunger is withdrawn the cannula is pulled back out from the fish. If a sample of oocytes is not obtained the process may be repeated but no more than three to four times. The oocyte sample is examined under a microscope for size and shape. Suitable oocytes are greater than 400 µm in diameter, are separate from each other and spherical in shape.

If the female contains suitable oocytes she is induced straight away, otherwise another female is caught and examined. Once induced (Section 3.2.4), the female is usually transferred to a separate spawning tank. Male fish are also examined by cannulation. Providing the cannula withdraws a small sample of sperm, and the sperm swims actively when mixed with a drop of saline water, the fish is considered suitable for spawning. Male fish may also receive a hormone injection.

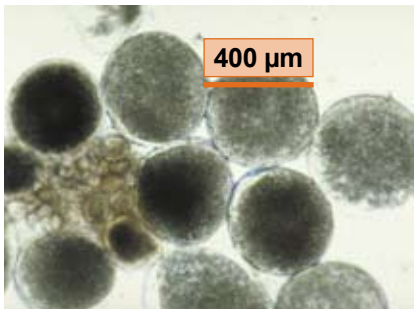

Photo 3.3. Photomicrograph of cannulated oocytes from a female barramundi. This fish is suitable for hormone induction (100 X magnification)

If a separate spawning tank is not used it is important to check that there are still male fish present in the holding tank. Sex change in barramundi can occur within the space of one month and it is a pointless exercise trying to spawn a tank with only females!

Photo 3.4. A mature female barramundi ready to be induced to spawn

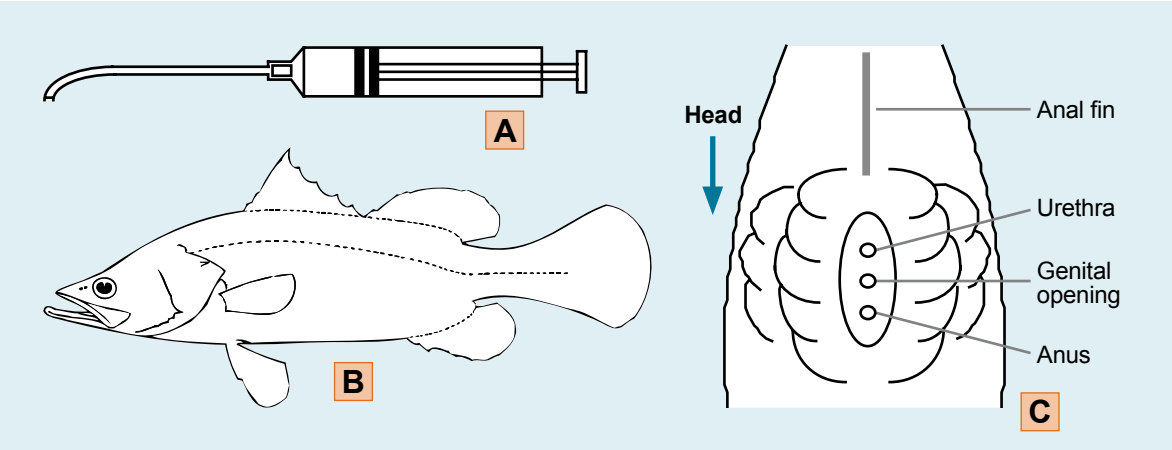

Figure 3.2. Schematic diagrams of the cannulation process. A. 12 ml syringe to which is attached a 20 gauge needle and 10 cm of polyethylene tubing (Clay Adams PE 100). B. The location of the genital opening. C. Close up of the genital area. The genital opening is positioned between the anus and the urethra and may be difficult to locate. Note: For the purposes of the diagram the genital area is enlarged, the holes are actually much smaller and closer together

3.2.4 Hormone administration

The hormone used for inducing spawning of female barramundi is Luteinising Hormone Releasing Hormone analogue (LHRHa). It may be administered to the fish either by injection in liquid form or by implantation of a slow releasing cholesterol pellet.

The dose rate administered to females is in the range of 50–100 µg per kg of body weight, with the lower end of the range being favoured. Male fish, if induced, normally receive 25 µg per kg.

3.2.4.1 Injection

The injection is prepared by dissolving the correct quantity of hormone in a few drops of 100 per cent ethyl alcohol and then diluting this to 1 mL with sterile saline. This solution is loaded into a syringe to which is attached a 25 gauge needle. The hormone is injected intramuscularly at a point approximately 3 cm down from the mid point of the first and second dorsal fin rays (Fig 3.3). The fish's scale at the injection point is gently lifted up and the needle pushed through the soft area at the base of the scale. There is no need to remove any fish scales. After injection the site is swabbed in Betadine® and the fish returned to the water.

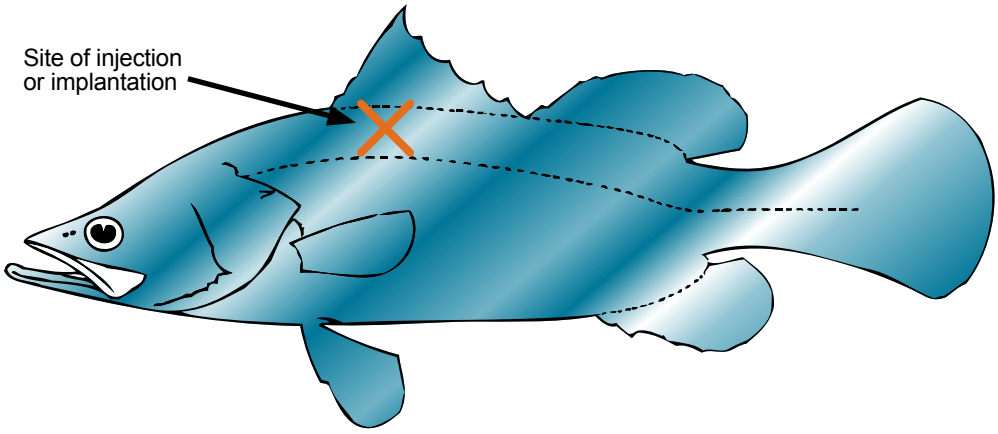

Figure 3.3. Position for a liquid injection or pellet implantation in adult barramundi

3.2.4.2 Implantation

Pellets containing a mixture of cholesterol and hormone are often implanted into the fish instead of liquid injections. The advantage of the pellets is that hormone is released slowly, rather than the sudden increase of hormone levels that follows injection. Pellets can often produce a more sustained spawning over three to four nights instead of one to two nights following an injection. Pellets manufactured using only cholesterol and hormone, without the addition of any other binder or 'matrix', are termed slow release pellets[1] and are reported to release hormone for over 30 days.

3.2.4.3 Preparation of the cholesterol/ hormone mixture

Equipment required:

- LHRH analogue. (The analogue used at the DAC is des gly-^{10}-[D-trp^{6}]-LHRH ethylamide).
- Cholesterol - purchased from Sigma Chemical Company. Cat. No. C8503.
- Small mixing bowl.
- Analytical balance.
- Micro pipette (0-500 µl).
- A pellet mould and pellet press.

3.2.4.4 The mould

The pellet mould consists of two small sheets of plexiglass measuring approximately 15 cm x 9 cm and approximately 5 mm thick. One sheet is drilled with several holes of 1 mm diameter and the other left un-drilled (Figure 3.4A). The pellet press consists of the stainless drill bit that was used to drill the holes in the plexiglass, screwed into a small handle. The blank end of the drill bit is used to 'tamp' the pellet mixture into the holes in the mould.

Once the moulds are constructed it is necessary to manufacture several 'dummy' cholesterol pellets to allow calculation of the average pellet weight. This figure is then used to calculate the required quantity of cholesterol for future pellet manufacture.

3.2.4.5 Pellet manufacture

The LHRHa used is supplied in two bottle sizes: 1 mg and 5 mg. The following description of pellet manufacture uses the 5 mg bottle.

- The correct quantity of cholesterol is pre-weighed to the nearest 0.1 mg using a fine analytical balance.
- The LHRHa is dissolved by injecting 1 mL of 100 per cent ethanol into the bottle containing the hormone. This gives a hormone concentration of 5 µg/ µl. The required volume is extracted with a micro pipette and mixed thoroughly with the cholesterol.
- Once mixed, the cholesterol/ hormone mixture is left to air dry for one to two hours before being packed into the hormone mould.
- To make a pellet, the drilled plexiglass is placed directly on top of the plain plexiglass and both are supported on a bench top. The cholesterol hormone mixture is pressed into the holes of the mould using the pellet press. Firm pressure is used during the packing process to ensure a solid pellet (Figure 3.4B).
- After the pellets are packed into the mould the top plexiglass sheet is raised (in our case on two small blocks of wood) and the completed pellets forced out using the pellet press. (Figure 3.4C).

[1] Sherwood, N. M., Crim, L. W., Carolsfeld, J., Walters, S. M., 1988. Sustained hormone release. I. Characteristics of *In Vitro* release of gonadotropin-releasing hormone analogue (GNRH-A) from pellets. Aquaculture, 74: 75-86.

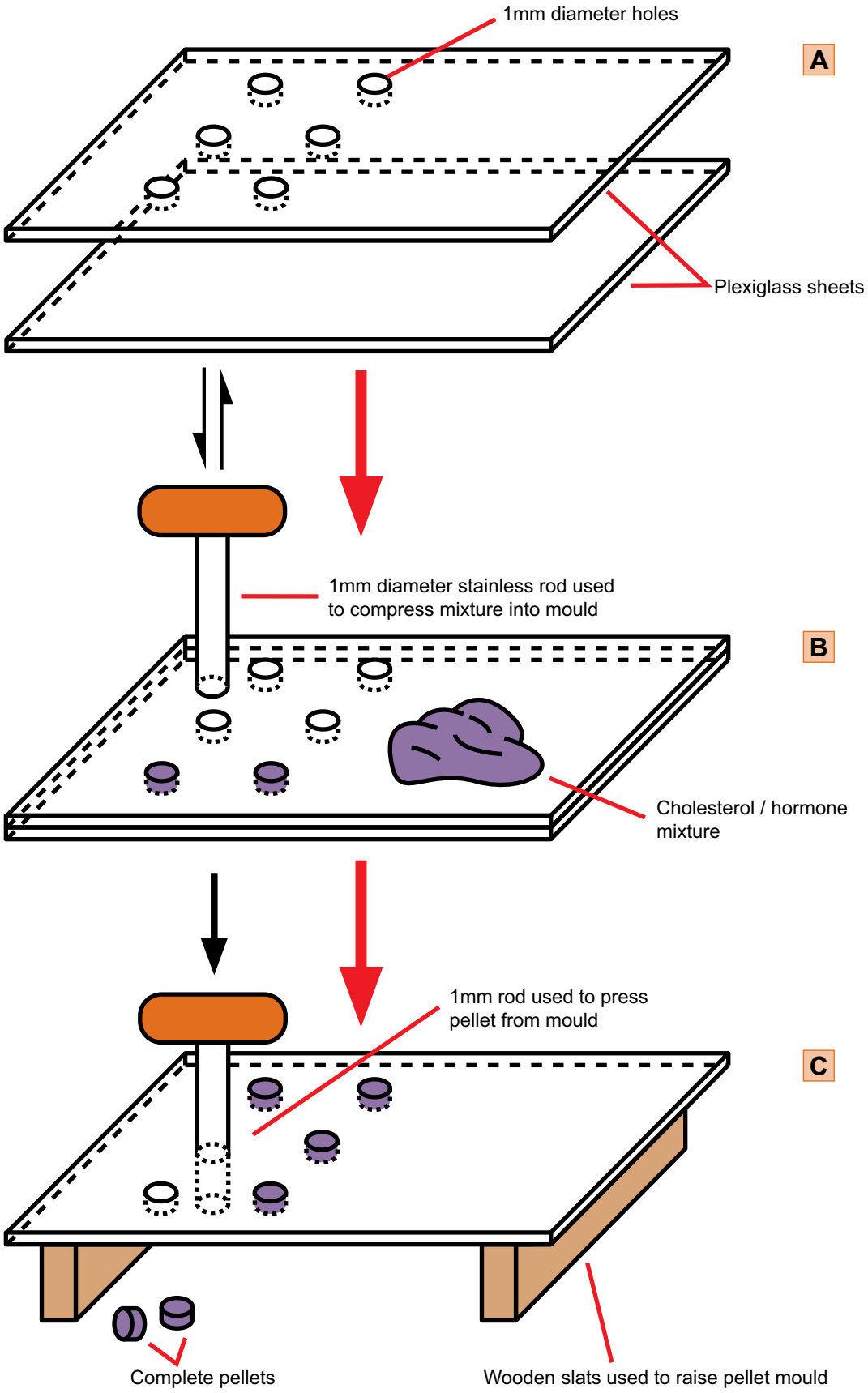

Figure 3.4. Method of manufacture of cholesterol based hormone pellets. A), the two sheets of plexiglass are placed together on a bench top; B) the hormone/ cholesterol mixture is pressed into the mould; C) the top plexiglass sheet is supported on two small wooden blocks and the pellet press (1 mm rod) is used to force out the pellets

The following example may help to clarify the calculations used during the manufacture process.

3.2.4.6 Example of calculations

The aim is to implant two female fish, one weighing 16 kg and the other 18 kg, with LHRHa/ cholesterol pellets at an approximate dose rate of 50 µg LHRHa per kg body weight.

The fish should receive: 800 and 900 µg of LHRHa respectively. It is easier to average the weight of the fish and make one concentration of pellet than to manufacture pellets of specific concentrations for each fish. Each fish will receive 850 µg LHRHa which equals 53 µg per kg for fish #1 and 47 µg per kg for fish #2. This variation in dosage is considered to be insignificant.

It is important to note that during the normal manufacture of pellets at the DAC approximately 10 per cent of the mixture is wasted (it is impossible to pack all the mixture into the mould as some sticks to the mixing bowl etc) and it is therefore necessary to calculate the required weights of cholesterol and hormone then add 10 per cent. The other important figure in the calculations is that pellets manufactured at the DAC have been measured to have an average weight of 15.83 mg.

The calculations for the cholesterol and hormone weights required are shown in Table 3.1

Table 3.1. Example of quantities of cholesterol and LHRHa hormone needed to manufacture pellets for implantation

Fish Weight (kg)	LHRHa Total µg	Cholesterol (mg)
16	850	15.83
18	850	15.83
Total = 34.0 kg	1700	31.66
+10 % wastage	170	3.17 34.83 minus weight of hormone (1.870 mg) =
Totals	**1870 µg** (1.870 mg)	**32.96 mg of cholesterol**

Using a fine analytical balance, 32.96 mg of cholesterol is weighed and to this is added, 374 µl of the stock solution of LHRHa/ ethanol which has a concentration of 5 µg/ µl (1870 ÷ 5 = 374). These two are mixed and left to air dry.

3.2.4.7 Storage

Once manufactured, the pellets are stored at -18°C until required. Pellets should be manufactured close to the time of implantation. Storage of longer than six months is not recommended.

3.2.5 Egg collection, evaluation and disinfection

3.2.5.1 Egg collection and evaluation

The fish are usually spawned in small fibreglass tanks, 3.4 m in diameter x 1 m deep, containing 7,500 L of water. Two tanks are normally used and each has a slot cut in the tank wall for skimming the water surface. The buoyant fertilised eggs are carried through the skimmer by an overflow of water and are trapped in a 250 µm net suspended in a water-filled collecting basin (Photo 3.4). One female is usually paired with two to three males.

On some occasions the induced female is left to spawn with all available males in the main holding tank. In this case eggs are airlifted into floating cages fitted with 250 µm mesh nets.

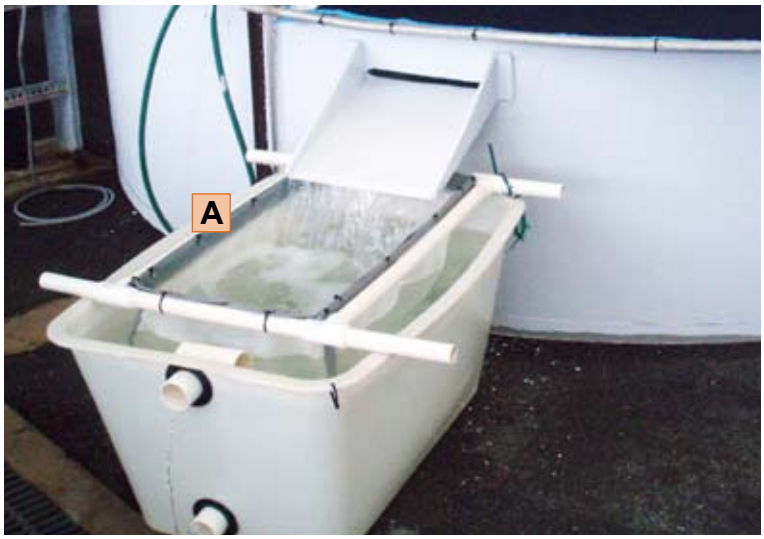

Photo 3.5. One of the 7,500 L barramundi spawning tanks showing the egg collecting skimmer and the collection net. The shade cover on the tank helps to reduce stress to the fish. The eggs are skimmed off from the surface of the water and collected inside the 250 µm mesh net (A)

The eggs can stay in the collection net for several hours but are usually collected by 05:00 hr the following morning. Eggs are scooped up with a 150 µm soft, mesh net and immediately transferred to a basin of sea water at the same salinity and temperature as the spawning tank. A sample of eggs is examined microscopically for quality, size and egg development stage. High quality eggs have a high fertilisation rate, are between 800 and 850 µm in diameter and have a single oil droplet. Another indicator of egg quality is that they should float strongly in a beaker of sea water. Weakly floating or sunken eggs are usually discarded.

Suitable eggs are taken into the hatchery, rinsed with filtered sea water and treated in a bath of ozonated sea water (see next section 3.2.5.1) before being transferred to a 1,000 L hatching tank. The hatching tank is supplied with filtered, UV-treated sea water at a flow rate of about five litres per minute. Gentle aeration is supplied from four, 25 mm airstones and the central outlet of the tank is screened by a 250 µm mesh net to prevent any loss of eggs. Up to 2,000,000 eggs can be placed in to a 1,000 L tank (2,000 eggs per L). Estimates of egg number can be taken by counting the number of eggs in small sample volumes taken from the tank. It is important that the eggs are thoroughly mixed in the tank prior to sampling otherwise false estimates will be obtained.

3.2.5.2 Disinfection: ozone treatment of barramundi eggs

Nodavirus (see Chapter 7. Disease) can often cause serious losses of marine fish larvae and fry during the hatchery phase. It has been demonstrated that ozone treatment of halibut eggs was an effective method for controlling nodavirus in this species[2]. Although there is still some debate about whether the virus can always be found on the egg's surface or that this is the only route of infection it was decided at the DAC to adopt this technique as a precautionary measure and as a result ozone treatment of fertilised barramundi eggs has been standard procedure since 2001. The eggs are normally ozone treated when they are at the embryo stage and still have at least two hours to go before they hatch.

Ozone treatment of the eggs is effected by bathing them for two minutes in sea water that has been prepared with ozone at a concentration of about 0.5 mg/ litre. The concentration of the ozone is measured using a colorimetric test kit before the eggs are added and again immediately after they are removed. The CT score (Concentration x Time) for the treatment is then calculated as follows:

$$CT = (Oz^S + Oz^E)/2 \times T$$

where CT = average Concentration of ozone in mg/l multiplied by the Time (in minutes) of the exposure to ozone; Oz^S = ozone concentration in mg/l at the start; Oz^E = ozone concentration in mg/ l at the end; T = time in minutes.

The aim is to expose the eggs to a CT score of between 0.8 and 0.9. This has been determined as a safe dose for barramundi. A higher CT score may result in egg/ larvae deformation and a reduction in hatch rate.

Extreme care are must be taken when using ozone as it can be very hazardous to human health if inhaled. The egg disinfection takes place in a well ventilated area and staff are equipped with rubber gloves and a respirator mask to protect them from contact with the ozone.

3.2.6 Egg development stages

The key stages of egg development at 30°C are shown in Figure 3.5. The time taken for the larvae to hatch depends on the water temperature.

3.2.7 Care of the larvae

Two to three hours after the larvae hatch, the water and air flow to the tank are stopped, and the water in the tank gently swirled. This helps the egg shells settle into the centre of the conical based tanks, from which they can be siphoned to waste. After swirling the shells are left to settle for fifteen to twenty minutes. After siphoning the air flow and water flow to the tank are resumed.

The larvae are kept in these incubation tanks until they are either packed for shipment to other farms or stocked into larval rearing tanks. If the larvae are to be shipped they are normally packed within 36 hours of hatching and are transported before their mouths open. Larvae to be used for culture at the DAC are kept in their hatching tanks for up to 36 hours and are stocked into the larval rearing tanks just prior to their mouth opening.

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[2] Grotmol, S.; Totland, G. K., 2000. Surface disinfection of Atlantic halibut *Hippoglossus hippoglossus* eggs with ozonated sea-water inactivates nodavirus and increases survival of the larvae. Diseases of Aquatic Organisms Vol. 39, no. 2, pp. 89-96.

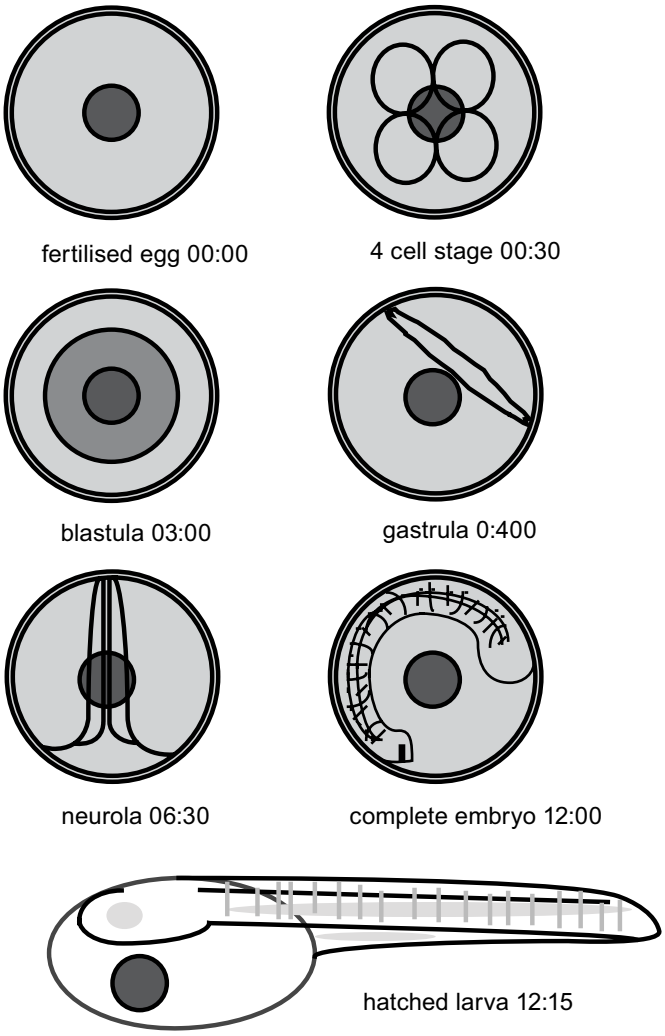


Figure 3.5. Stylised diagram of barramundi egg development stages at 30°C. The numbers following the stage description indicate the approximate time in hours and minutes, post fertilisation. The actual time of development depends on water temperature and the actual appearance of the eggs varies according to their orientation under the microscope. Egg diameter = 760 to 820 µm and the length of a newly hatched larva is approximately 1500 µm

3.2.8 Packaging for transport

The equipment needed to prepare the larvae for transport includes:

- Small basins (9 L)
- Oxygen cylinder and regulator (industrial oxygen is sufficient)
- Styrofoam boxes - air freight approved if sending by air
- Transport bags of suitable size and shape to fit the Styrofoam boxes (usually 30 L volume)
- Box liner plastic bags
- Elastic bands
- Graduated pasteur pipette
- Petri dishes
- Slide viewer / back light box
- Supply of clean UV-disinfected sea water (UVSW) and an airline fitted with a fine airstone
- Packing tape
- Plastic jug (5 L)

Preparation:

The larvae are gently collected in a soft, 150 micron net, and a small cup is used to transfer them from the net into one of the small basins. This is a delicate part of the operation because the larvae are easily damaged and must be in the water at all times. Repeated scoops of larvae are placed in the basin until it is estimated that sufficient have been collected (usually a maximum of 200,000 larvae). An airstone is added to the basin and the water is gently agitated to distribute the larvae as evenly as possible. A 2 mL sub-sample is then withdrawn from the basin using a pasteur pipette and the number of larvae counted onto petri dishes with the aid of the back light provided by a slide viewer. This is repeated five to six times to obtain an average density, from which can be calculated the approximate number of larvae in the basin. The density of larvae in the basin can be adjusted up or down depending on requirements.

Packing:

The 30 L plastic bags are first rinsed with freshwater, then with UVSW and finally pre-filled with five litres of UVSW of the same salinity as the larval holding tank. The larvae and the water from the basin are carefully poured into the bag and the volume of water adjusted to eight litres per bag.

All air is expelled from the bag and it is filled to capacity with pure oxygen. Packing is completed by tying the neck of the bag in a 'gooseneck' and securing with an elastic band or elastrator® ring. The bag is placed inside another bag and it too is secured with an elastrator® ring. The 'double-bagged' larvae are placed into the styrofoam box which has been pre-lined with a thick plastic bag and the box is taped up ready for shipment.

The number of larvae that can be packed into a bag depends on the size of the bag and the distance to the destination. It is best to seek advice before packing larvae for the first time. As a guide, a bag containing eight litres of water and 25 L of oxygen can be used to transport 50,000 larvae for a period of up to ten hours.

Once the larvae reach the destination farm, they are slowly acclimatised to the receiving water by placing each bag into the farm's water, whether it is a pond or a tank, and gently released after fifteen to twenty minutes (after the temperature difference between the transport water and receiving water is minimal).

3.3 Larviculture

The culture of larvae or larviculture, is defined as the period from hatching until the fish metamorphose into their final 'fish' shape and eat (wean onto) a formulated diet. For barramundi, the larviculture phase is generally completed once the fish reach a size of 15–20 mm (3–4 weeks). Ideally the first two weeks of the larviculture must be done at a salinity of 25–35 ppt and a water temperature range of 27 to 31°C.

There are currently three main methods used for the production of 15–20 mm fish.

3.3.1 Intensive culture

This is the preferred method for modern marine fish larval culture. The larvae are kept under controlled conditions in either flow through or re-circulating saltwater systems. The larvae are fed a diet of zooplankton, usually rotifers and *Artemia*, for the first two to three weeks and are then weaned on to a formulated diet.

The intensive culture system imitates a small food chain. Pure strains of microalgae are fed to zooplankton cultures. The plankton is in turn, harvested and fed to the fish larvae. Because of the high concentration of animals in a relatively small volume, the whole process is very dependent on adherence to a strict hygiene and management routine.

Intensive larval culture techniques can be further sub-divided into two methods:

3.3.1.1 Traditional intensive larviculture

For the traditional larviculture method, live foods (algae, rotifers and *Artemia*) are grown in batch culture and larvae are kept in small (1,000–10,000 L) tanks. New sea water is added regularly to control water quality in the larval tanks. The larvae in this system are fed several times throughout the day by harvesting zooplankton from the batch cultures. The nutritional quality (particularly the essential marine oil content) of the harvested zooplankton is boosted by using one of a number of commercially available products. After boosting, the zooplankton is thoroughly rinsed to remove oily residue and to reduce bacterial contamination and then the feed is added in the required quantity to the larval tanks.

The traditional method involves the commitment of large amounts of time and labour to care for the algae, zooplankton and larvae and is usually expensive. Most of the effort is spent on producing the enormous numbers of zooplankton necessary to feed the rapidly growing larvae. At the DAC it has been estimated that during an intensive larval rearing run 80 per cent of the time was spent on maintaining algal and zooplankton cultures.

The culture of algae requires the operation of two areas. Stock cultures (flasks of 200 mL volume) of single algal species are maintained indoors under sterile conditions in a laboratory. During a production run of fish, the algae in the laboratory are scaled up in volume, from 2 L flasks, to 20 L carboys and then up to 300 L in plastic bags. From here the algae is transferred outside to mass culture tanks of up to 20,000 L volume.

The scale up process, from 200 mL flasks to the mass culture tanks takes 3–4 weeks. The speed of the process is temperature dependent. The higher the temperature, the faster the scale up. The quality of mass cultures of algae in the Darwin area is closely related to the climate. During the dry season, where outside temperatures and sunlight are relatively stable, it is possible to maintain high quality cultures for several weeks. In the wet season the varying levels of sunlight, humidity and rainfall make the mass culture process very unpredictable and hence unreliable.

Because this method depends on mass cultured algae it is therefore innately risky (especially in the humid tropics) and there is the possibility of feed cultures ‘crashing’ (failing) and the larvae being left with nothing to eat. It is also well documented that the nutritional quality of the zooplankton diet is vitally important for the growth and survival of the larvae. Despite the best efforts to enrich the larval diet, variability can still occur which can lead to increased problems with the larvae, particularly with increased rates of deformities and reduced survival.

In a typical intensive hatchery, the culture areas of algae, zooplankton and larvae are segregated. The larval rearing area and the live feed area are kept isolated to minimise the introduction of disease. The water supply is filtered to 1.0 µm or less and in most hatcheries it is also sterilised by ultra violet radiation. All equipment used to care for the larvae is routinely cleaned and the whole rearing area is sterilised once the run is finished. It is also recommended that a hatchery should be thoroughly dried out between batches to reduce build up of viral/ bacterial particles and to lower the chances of infection in subsequent runs.

3.3.1.2 Re-circulating, semi-automated, intensive culture

From 2001 to 2004, the DAC developed an intensive culture system for barramundi larvae that was more reliable and more cost effective than traditional intensive culture while at the same time producing higher quality juvenile fish.

One of the keys to the success of this method was the construction and operation of a high density, rotifer culture system (Photo 3.6). The high density system utilises water exchange to manage water quality as opposed to the static, batch-culture rotifer system. Small daily water exchange is coupled with the use of a concentrated algal paste, made from a brackish water algal species - chlorella. 'Super Fresh chlorella-V12®' is purchased from the Pacific Trading Company, Japan. The algal paste is enriched with essential fatty acids so no further steps are needed to obtain high quality rotifers. Using the algal paste, instead of mass cultured algae, dramatically simplifies the rotifer culture process and improves its reliability, productivity and quality. In the high density system rotifers can be maintained at a density of 1,500–2,000 per mL which is significantly more than the 100–300 per mL previously achieved in batch culture rotifer systems at the DAC.

The relative stability of the bacterial populations, and the low numbers of harmful bacteria are features of the intensive rotifer method. When a rotifer tank is freshly started, the numbers of potentially harmful bacteria, such as *Vibrio* species, rapidly increase. These pathogenic bacteria are opportunists and quickly out-compete beneficial non-pathogenic bacteria. Microbiological studies have shown that within two weeks of the high density rotifer culture units being started, the bacterial population in the water stabilizes to a point where the numbers of pathogenic bacteria have declined to very low levels and beneficial (or non-harmful) bacteria proliferate.

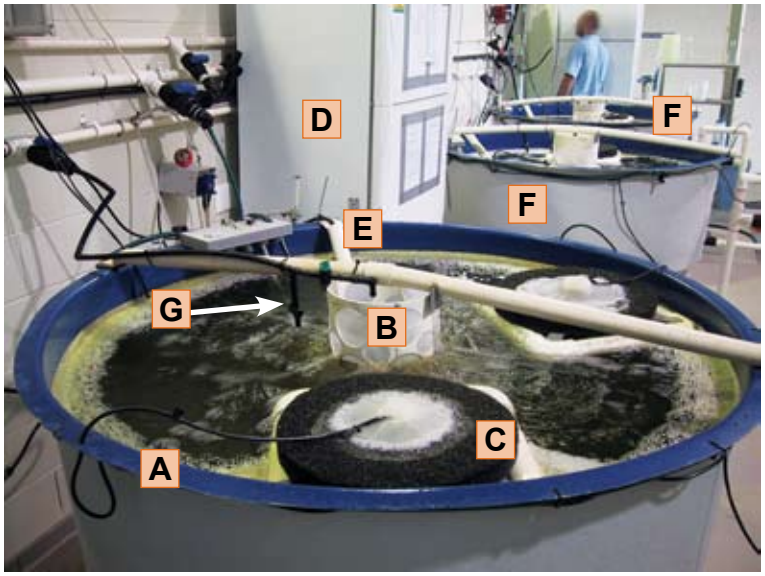


Photo 3.6. The high density rotifer culture system. The main components of the system are: A – rotifer tank (1,000 L); B – central 60 micron mesh screen; C – floc trap (sediment filter) and air lift; D – refrigerator (contains the algal paste that is dosed into the tank via a peristaltic pump); E – feed lines for algal paste, oxygen and suction line for pump that sends rotifers to the larval rearing tanks; F – duplicate, rotifer tanks; G – new water supply

At this point the rotifers can be directly pumped into larval rearing tanks without the requirement for time consuming rinsing to 'clean' the rotifers and without adverse side effects to the fish larvae.

The other key component of the larval rearing system is the larval rearing tanks (Photo 3.7). The two 6,000 L tanks are re-circulated for control of water quality, particularly temperature, ammonia, nitrite and bacterial flora. The management of live feed in the larval rearing tanks is simplified by the constant addition of rotifers from the rotifer culture system and also by the use of algal paste continuously pumped directly in with the larvae to maintain the nutritional status of any uneaten rotifers. As noted before, the use of algal pastes has meant that on-site mass culture of algae has been eliminated, representing a significant cost saving.

Further refinements to the larval rearing system are continually being made. Recent developments have included the use of a newly formulated, commercially available, larval micro-diet (Gemma Micro® from Skretting) that has helped reduce *Artemia* usage by more than 95 per cent. This diet has proven to be more attractive and beneficial to the fish, with the result that weaning onto a dry diet is now complete by day 16–20 post hatch, an advancement of up to two weeks compared to previous diets. The weaned larvae are transferred to the nursery by day 25–28.

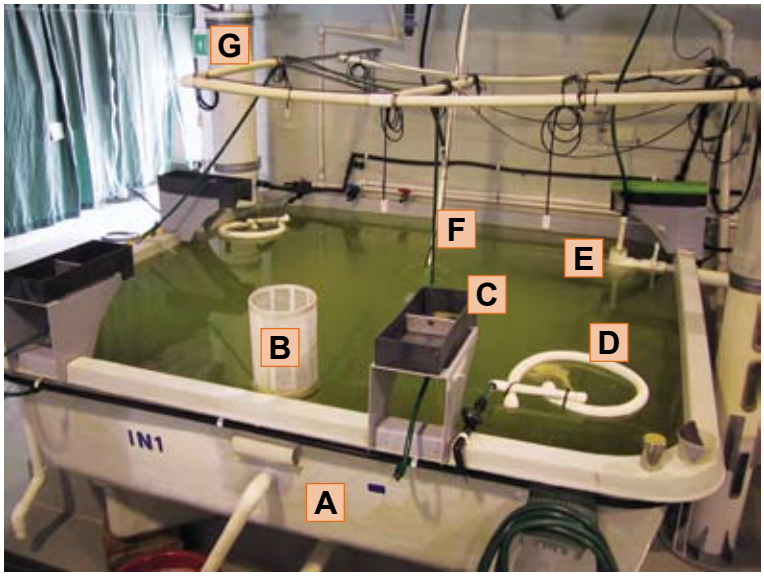


Photo 3.7. Some of the features of the re-circulating, semi-automated, intensive, larval rearing system. A = 6 000 L, fibreglass tank; B= overflow screen; C = clock-driven belt feeder for distribution of formulated larval diets; D = water surface skimmer; E = self-cleaning screen and return line to sump; F = distribution line for algal paste and rotifers; G= degassing and oxygenation column

The indoor tanks are normally stocked with 600,000 larvae (100 per L) of which an average 50 per cent (range 40–60 per cent) survive through to weaning. This compares to the traditional intensive larval rearing system which was stocked at only 20–30 larvae per L and also had an average survival rate of 40–50 per cent. This means that the new system produces more than 3–5 times the number of fish per volume!

3.3.2 Semi-intensive or 'greenwater' production

In the mid to late 1990's, the DAC developed a semi-intensive system for the production of marine fish larvae. The system used large volume, outdoor, larval rearing tanks (>20,000 L) that were stocked with larvae at a medium to low density (4–5 per L). The principle features for the operation of this system were:

- The tanks were filled with chlorine-disinfected sea water up to a week before the first-feeding larvae were added.
- Microalgae and fertiliser were added to the tanks soon after filling and then rotifers added to the developing algal bloom a day or two ahead of the larvae.
- Once the larvae were added the whole system was managed according to the daily densities of algae and zooplankton and water quality readings. If plankton numbers were low more algae and /or rotifers were added to maintain the desired density. If water quality deteriorated water exchange was started or increased.

- Feeding on rotifers was followed by *Artemia* and, after 21 days post-hatch, by weaning onto a formulated diet. Weaning usually continued through to days 30–35 but the fish were harvested and transferred to the nursery by day 28 to try and manage cannibalism.

There were several advantages to the semi-intensive larval rearing system. In particular the growth rate of the larvae was usually faster than the rate achieved in any of the indoor systems.

The system was also relatively simple to maintain. One person was required for only three to four hours a day monitoring and maintaining the tanks. This type of system has also been successfully used at the DAC for the culture of copepods and the production of difficult-to-rear reef fish such as golden snapper, *Lutjanus johnii*.

The main disadvantages of the 'semi-intensive' system were that the tanks occupied a larger area of land than intensive systems; fish growth was often very uneven, leading to increased cannibalism; and the tanks were difficult to operate during the cooler months of the year because of temperature loss. Maintaining water temperature during the cool, northern, dry season was a problem because of the need to add large volumes of new water to maintain water quality. It was impractical to heat the new water and expensive to operate immersion heaters in the tanks. The result was that often the tanks were operated at temperatures that were less than optimal which caused slower growth, increased size variation, lower survival and increased incidence of disease. Clear plastic sheeting over the tanks at night time coupled with a lower rate of water exchange helped reduce temperature loss but did not eliminate it as a problem.

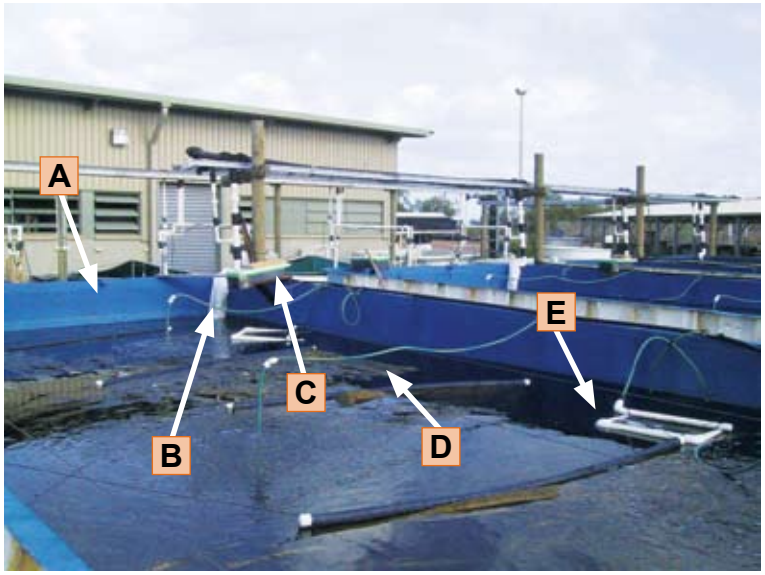


Photo 3.8. Outdoor, semi-intensive larval rearing tanks. Some features of the tank are indicated as follows: A – 40,000 L fibreglass tank (8 m x 4 m x 1.3 m deep); B – sea water inlet screened through a 1 micron filter bag; C – clock-driven belt feeder; D – airline and airstone; E – air-driven water surface skimmer. Out of picture to the right is a retractable shade cover used to control light intensity over the water during the early stages of production

The outdoor tanks were normally stocked with 200,000 larvae (5 per L) of which up to 90 per cent survived through to weaning (survival range varied between 20–90 per cent). Weaning was not easy in the large outdoor tanks, and significant losses of fish were often experienced during weaning, usually from fish that failed to commence feeding on the dry diet. The large size of the tank was thought to be a contributing factor in the poor weaning response.

The intensive recirculating system has yet to be trialled with reef fish larvae, so for the moment at least, outdoor culture in large tanks remains the method of choice for reef fish.

3.3.3 Extensive production

Extensive larval rearing of barramundi was developed in the early 1990s by the Queensland Department of Primary Industries and Fisheries (QDPI&F) in association with researchers from the USA and was based on the technique used for the production of red drum in Texas. First feed larvae (larvae that had almost fully absorbed their yolk sac and had their mouths open) were added directly into brackish or salt water ponds that had previously been prepared with a plankton bloom. Organic and inorganic fertilisers were added 4–5 days prior to the addition of the larvae to encourage the formation of a bloom of algae and zooplankton. More fertiliser was then added at regular intervals during the larval rearing period to maintain plankton cultures.

The recommended stocking density for this method was approximately 100,000 larvae per megalitre of pond and Queensland farmers reported a survival rate to 30 mm as high as 60 per cent and growth rates up to double that achieved in intensive systems. Survival rates achieved in the NT were routinely around 25–30 per cent.

The obvious benefits of this method were the relatively low cost of production and high growth rates. The main disadvantage with the method is that the number of fish surviving was unknown until a total harvest was performed at the end of the larval rearing period plus it utilises a large area of land.

In the NT the recommended size of larval rearing ponds was 0.1 to 0.2 hectares with an average depth of 1.5 metres (Fig 3.6).

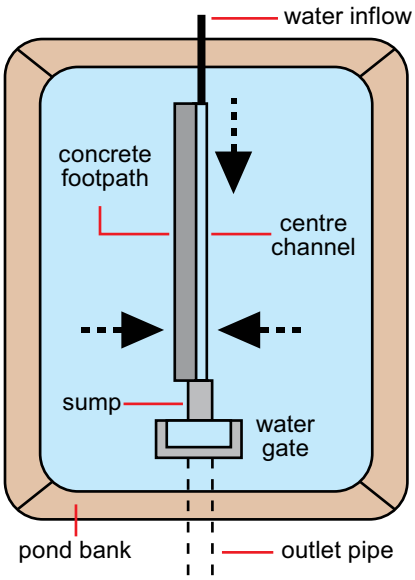


Figure 3.6.Stylised diagram of a nursery pond. The arrows indicate the direction of the slope of the pond floor. The presence of the centre channel and concrete sump assists with the complete harvest of the fish

Trials completed in the Northern Territory during the 1990s confirmed the benefits of pond rearing of juvenile barramundi. The best success in the NT was achieved in 0.1 hectare ponds that had been fertilised according to the schedule shown in Table 3.2. The fertilising schedule differed from that used in Queensland in that inorganic fertiliser was added more frequently during the rearing period. The time period from when the pond was filled and fertilised to when the larvae were added was also shorter.

Table 3.2 should be used as a guide only. Additions of Di-Ammonium Phosphate increase the levels of toxic ammonia in the pond and care must be taken to ensure that ammonia levels are kept under control and fertiliser is not added when ammonia levels are already high. This is also true for additions of urea.

Table 3.2. Pond fertilisation schedule used in extensive rearing trials.

Day No.	Treatment
1	Start with a thoroughly sun dried pond. Ponds that cannot be totally dried may need an addition of lime to act as a sterilising agent in the wet areas. (The previous recommendation for general addition of dolomite lime over the entire pond base has been discontinued).
2	Commence filling pond through 150–250 µm mesh netting to trap potential predators and competitors. Add Di-Ammonium Phosphate (DAP) at the rate of 50 kg per hectare and Dynamic Lifter (DL) at the rate of 450 kg per hectare. The DAP and DL are dissolved in water before addition to the pond and the DL can be soaked in water for 1–2 days before spreading. Urea at 30 kg per hectare may also be added.
4	Add first feed larvae
6	DAP (same rate as previous)
9	DAP + DL + urea
12	DAP
16	DAP + DL + urea
19	DAP
22	DAP
24+	Harvest fingerlings any time after this day.

Another problem with the extensive method was the inconsistent supply of zooplankton during the latter stages of the rearing period. As the barramundi larvae grew, their requirement for live feed increased dramatically, and often the natural reproduction rate of the zooplankton, such as copepods, failed to keep pace with the increasing appetite of the fish. Two possible solutions to this were supplementation with newly hatched *Artemia* (an expensive process in a large pond) or addition of extra plankton by pumping from other fertilised ponds. Neither of these solutions proved to be practical on a large scale.

The extensive method used to be the preferred method for barramundi fingerling production around Australia. Today it has progressively been replaced and most hatcheries use either the intensive or semi-intensive methods, forgoing the high growth rates of extensive culture for the higher predictability and the better productivity of the more intensive methods.

The QDPI has published a full technical report on extensive barramundi culture: Rutledge, WP; Rimmer, MA, 1990. Culture of larval barramundi, *Lates Calcarifer* (Bloch), in saltwater rearing ponds in Queensland, Australia. Information series, Department of Primary Industries (Queensland).

4. Nursery

4.1 Nursery systems

The nursery phase for barramundi can be defined as the growth period between 15 mm and 100–120 mm in length. It encompasses the completion of the process of weaning the fish from a live food diet onto formulated feeds and it is also the stage at which there may be a problem with cannibalism. At 50–60 mm the fish are usually sent to grow-out farms. At the DAC many of the fish are grown up to 100–120 mm for stocking directly into sea cages or ponds.

Historically there have been a number of different nursery techniques trialled in the NT, including extensive nurseries where the fish were released into small ponds that had been previously prepared with plankton blooms, net cages within large tanks and nursery systems that relied on the use of fresh food (shrimp, fish and squid) instead of formulated diets. Today, most nurseries around the country use an intensive nursery system where the fish are kept at high densities, fed a formulated pelleted diet and are graded regularly to control cannibalism and improve growth rates.

Photo 4.1. Darwin Aquaculture Centre's barramundi nursery

In 2000 the NT Government constructed an intensive fish nursery at the DAC to assist the establishment of industrial scale barramundi farming.

4.1.1 Darwin Aquaculture Centre's intensive nursery

The DAC fish nursery (photo 4.1) has the capacity to produce more than 2 million, 100 mm long fish per year. The nursery was designed around the need to regularly grade the fish to control cannibalism (section 4.2) and also uses pure oxygen to increase stocking densities and efficiency of operation (see 4.1.2).

The nursery has two different tank systems:

1. *Raceways*: Fourteen, 4 m long shallow, fibreglass, raceways are used to hold the fish immediately after they come out of the larval rearing system (Photo 4.2).

The raceways were chosen because they provide easy working height access to the fish and improve the efficiency of the grading operation. In these tanks the fish are graded through specially built box graders every three to four days (see section 4.3).

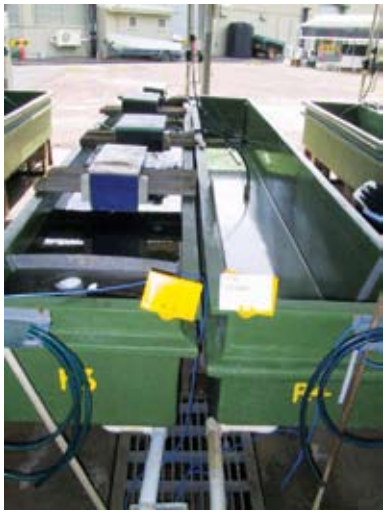


Photo 4.2. Raceway tanks. These are used to house the fish when they first arrive from the larval rearing system

2. *Round tanks*: The fish stay in the raceways until they are 30–35 mm in size (one–two weeks) then they are transferred to one of ten 10,000 litre, circular, fibreglass tanks.

The raceways and the circular tanks are set up with new sea water flowing through at an exchange rate of 100–300 per cent per hour and 70–100 per cent per hour respectively. The tanks are also fitted with automatic feeders and a pure oxygen supply. Emergency oxygenation is available if required.

The maximum stocking density in the raceway system is 30 kg/m^3 and 80 kg/m^3 in the round tanks. These high stocking densities can only be achieved using high water exchange and pure oxygen delivered to the tanks via ceramic airstones.

4.1.2 Oxygen

The barramundi nursery has a reticulated pure oxygen system. A bulk liquid oxygen vessel was installed adjacent to the nursery and the gaseous oxygen produced by this unit is plumbed throughout the nursery in 19 mm copper pipe and delivered to each tank through up to six, Point Four® brand, ceramic oxygen stones (Photo 4.3). Flow meters attached to the stones are regulated to maintain the ideal dissolved oxygen concentration of 6–7 mg.l (100—110 per cent saturation).

The liquid oxygen/ ceramic stone system was chosen for several reasons but the main reason was that it has no moving parts and is not dependent on electricity supply. If there is an electrical failure and/ or the sea water pumps fail then the oxygen continues to flow to the tanks.

The ceramic stones are considered to be 30–40 per cent efficient at transferring oxygen to the water. This is less efficient than some of the more expensive systems available (e.g. oxygen saturators are more than 90 per cent efficient at transferring oxygen to the water) but these other systems rely on water being pumped and are therefore susceptible to power failure.

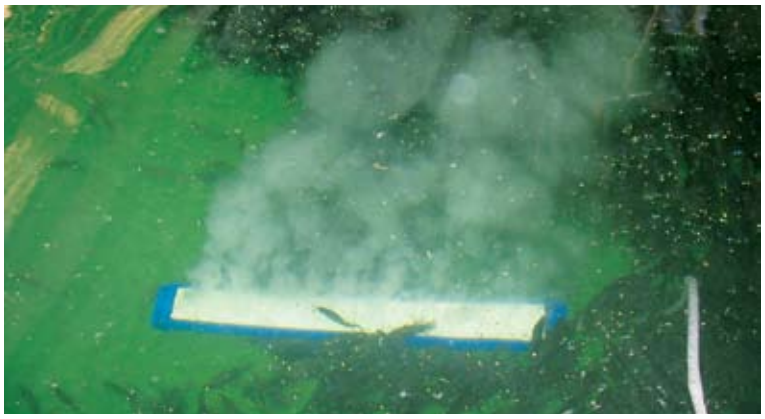


Photo 4.3. Ceramic oxygen stone operating in a barramundi nursery tank. The stream of oxygen from the stone can be clearly seen

The level of dissolved oxygen in the tanks is monitored by an Oxyguard™ Programmable Logic Controller (PLC) system which also has the ability to control oxygen flow. Even though this part of the system is ‘electricity dependent’ if the power should fail, the default position is that the flow of oxygen will continue at its maximum level.

4.2 Cannibalism

Cannibalism is a significant cause of mortality in juvenile barramundi and is particularly a problem in fish up to 150 mm in size. Juvenile barramundi are capable of eating and/or causing mortal injuries to fish up to 75 per cent of their own body length.

4.2.1 Factors promoting cannibalism

Cannibalism is promoted by two main factors.

- Rapidly growing juvenile fish have a high energy requirement. If the need for energy is not satisfied by supplemental feeding the fish may look for extra energy sources such as other fish in the tank. Barramundi are also naturally aggressive and look to strike at other fish within close proximity to themselves.
- The widely differing growth rates within the same age class of barramundi means that some fish quickly reach the size where they are capable of capturing and ingesting other, smaller fish.

It is believed that larger fish are also more aggressive and successful at feeding when supplementary food is added. This then gives the larger fish a further growth advantage.

It does not take long for a thousand or more cannibals, each eating at least two small fish per day, to have a significant impact on the numbers of fish in the nursery tanks.

4.2.2 Control of cannibalism

The two main ways to control cannibalism are:

1. Regular grading - during the early nursery stage (20–35 mm) the fish need to be graded every three to four days. Larger fish (50–100 mm) need to be graded weekly. This is the single most effective method for reducing cannibalism.

2. Maintaining optimal feeding. If the fish are fed regularly and effectively it reduces the number of fish that are hungry and may decrease the number of ‘strikes’ they make on their tank mates.

4.3 Grading

Grading of juvenile barramundi involves collecting all the fish in the tank and placing them into a grading box or mechanical grader.

Grading boxes come in a variety of shapes and sizes but the principle of operation is the same. The smaller fish are able to swim out of the box through narrow openings and the larger fish that are left behind are transferred to another tank. The DAC manufactures its own grader boxes using welded PVC and clear acrylic rods (Photo 4.4).

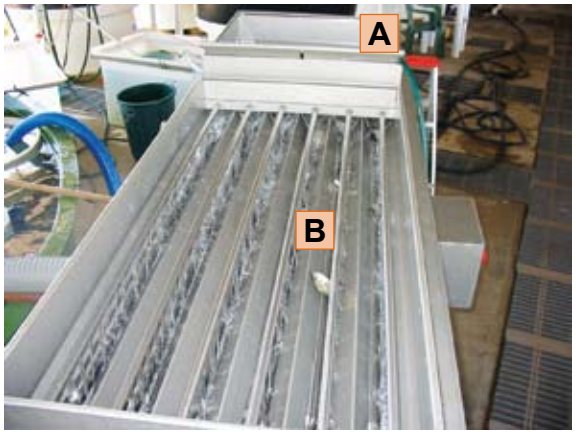
Care must be taken during grading to ensure that the fish are stressed as little as possible. This can be achieved by minimising the time the fish spend out of the water, not collecting too many fish in the scoop net at one time and performing the whole operation as quickly and efficiently as possible.

Photo 4.4. (above) Home-made PVC and acrylic grader box. The box floats in the tank (acylic rods to the bottom) and the fish are added through the open top

Mechanical graders use various means such as diverging belts or rotating rods that separate the smaller fish from the larger fish (Photo 4.5). The principle for most mechanical graders is the same.

The fish are put into a hopper with flowing water at one end of the machine. They are then carried along the length of the grader by gravity and/ or mechanical action and drop through into a collection chamber as the space between the grader bars becomes wider than their bodies. Finally the fish get flushed from the grader into separate collection nets or tanks. The fish are kept wet through the whole process by spray bars and/ or flowing water pumped from the destination tank.

Photo 4.5. (below) Features of an automatic grader: A: hopper, B: roller bars (the distance between the bars increases with distance from the hopper, C: discharge hoses (the fish are flushed from the grader into collection nets)



4.4 Counting

The successful operation of the nursery depends on accurate counts of the standing stock of fish. Only with an accurate knowledge of fish numbers is it possible to work out stocking and feeding rates. Accurate counts are also required by the buyers of the fish and they need to have confidence that they are getting what they pay for.

The DAC uses two counting methods, one uses a total weight measurement and the other is a mechanical counter.

4.4.1 Weight counting

A sub sample of fish (300–400) are manually counted into a small container of aerated water that has previously been tared on a weigh scale. After the fish are added the container is re-weighed and the difference in weight represents the total weight of the sub-sample of fish. The weight of the fish is divided by the number of fish to give an average weight.

Photo 4.6. Impex™ mechanical fish counter. Fish are added to the basin (A) and flushed from here, down past the sensors (B), and counted

The remainder of the fish in the tank are then weighed in tared containers of water and the total weight of the fish is obtained. The total weight is divided by the average weight to give the number of fish in the tank.

Up to 200,000 fish per hour can be counted using this method and it has been found to be reasonably accurate (± five per cent). It is now generally only used for very small fish (<25 mm) in the nursery or at the completion of the larval rearing before transferring the fish to the nursery.

4.4.2 Mechanical counting

Fingerlings greater than 30–35 mm are now counted using a mechanical counter at the rate of 10,000 to 30,000 fish per hour (Photo 4.6).

There are a number of commercial fish counters available on the market. The DAC uses two different sized counters from Impex™ that have proven to be reliable and accurate for counting small fish.

These counters are basically a floating basin into which the fish are placed. Flowing water flushes the fish from the basin down past one of two electronic sensors that count the fish. Accurate counting depends on correctly matching the size of the aperture leading to the counting sensor and the flow rate of the water flowing through the counter with the size of the fish being counted.

If these machines are set up correctly and properly managed (not too many fish at the one time) they have a proven accuracy of ± two per cent and a counting speed of up to 30,000 fish per hour for the small counter (fish 30–60 mm) and up to 10,000–15,000 fish per hour for the larger counter (fish 60–140 mm).

5. Grow-out

The grow-out phase for fish production can be defined as the growth of fish greater than 100 mm in length. Depending on the final market size, grow-out can be as short as three months for an entrée size fish of 250 grams or up to 18 month for a fish of more than 3 kg suitable for filleting. There are two methods employed for the grow-out of barramundi in the NT.

5.1 Pond culture

Earthen brackish water ponds are the traditional method used for barramundi culture in much of South-East Asia. Prior to the development of hatcheries, farmers used to collect wild fry and grow them in impoundments. There was little attempt made to regulate the numbers of fish grown and there was certainly no effort to grade them. The returns to the farmers were unpredictable using this method.

Following the development of hatchery technology the process of pond culture was made much more predictable. A known number of fish of a similar size could be stocked into a pond and the pond water conditions carefully regulated to achieve maximum return.

5.1.1 Design of grow-out ponds

Careful attention to design is the key to successful fish culture in ponds. Design of the ponds must take into consideration the following factors:

- Suitable soil type. The soil must be capable of retaining water. If it is not, then the pond may have to be lined either with compacted clay or with a synthetic liner. Both of these add to the cost of construction.
- The pond must be located near a water supply, either fresh, brackish or marine. The water should be available cheaply and not have to be pumped large distances or up too great a height.
- Location and size of the water inlet. Each pond must have its own water inlet (Fig. 5.1). It is poor management to have the discharge water for one pond being the inlet water of another. The water inlet must be of sufficient capacity to be able to exchange the water in the pond rapidly if needed.
- Location and size of the water outlet. Each pond must have its own water outlet, preferably on the opposite side to the water inlet. The outlet must be of sufficient size so that the pond can be drained quickly if needed. One type of pond outlet is the water gate or ‘monk’ design (Fig. 5.2).

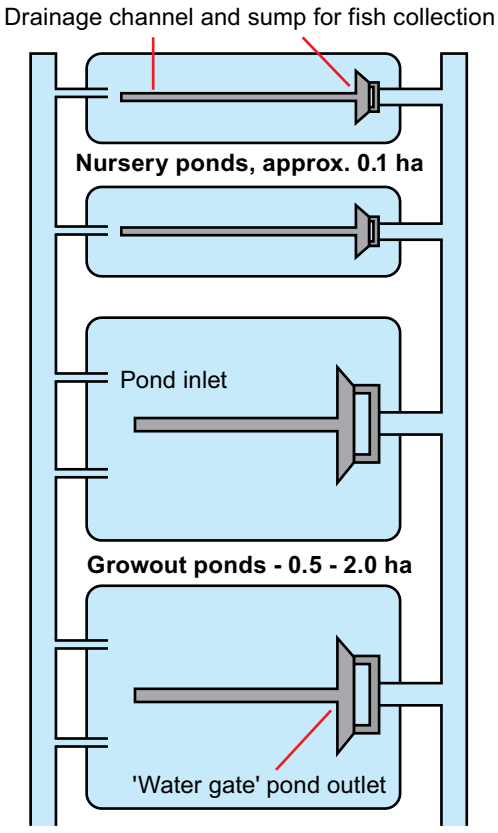


Figure 5.1. Simplified diagram of a small pond farm

- The pond must be designed for easy removal of the fish. The usual method is for the incorporation of a collection sump and drainage channel in the pond base or immediately outside the pond wall (Fig. 5.1).
- The pond walls must be designed to minimise the chances of erosion or collapse when subjected to heavy monsoonal rainfall or tidal wash.
- The pond base must be carefully sloped so that the pond can be drained totally and the fish concentrated in the harvest sump.
- The pond must be located near a source of electricity for the operation of aerators, pumps etc.
- If the pond is marine, then it is advisable (although rarely practical) to have a source of fresh water available which can be used to control salinity or treat the fish therapeutically.
- The pond may have to be protected from predators, e.g. birds.

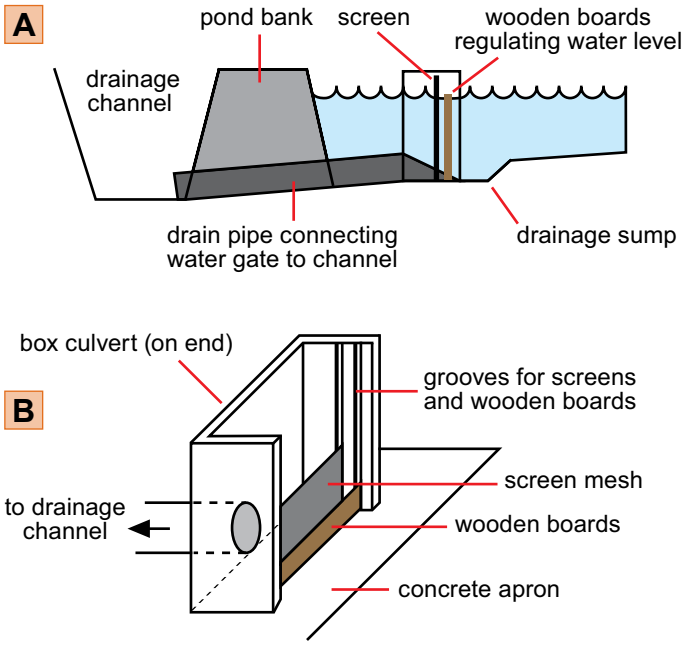


Figure 5.2. Typical water gate construction used for regulating the volume of water in a pond. A: cross sectional view of water gate and pond bank. B: more detailed view of a typical water gate

Photo 5.1. shows an example of a NT marine pond farm for barramundi.

5.1.2 Advantages of ponds for fish grow-out

- In areas where high tidal fluctuations and strong water currents make the placement of floating cages difficult, pump ashore, land based farms are a viable alternative.
- Large volume ponds may also help reduce the incidence of cannibalism because they offer the smaller fish an improved chance of escape.
- To a large extent, earthen ponds are also able to be serviced, irrespective of the weather. Conditions of high wave action caused by storms or strong winds, which can make servicing cage farms impractical or dangerous, do not generally apply to pond farms.
- Chances of fish escapes are much reduced in ponds compared to cages.
- Usually better control over water quality compared to cages.
- Less labour required than for cages, particularly true in areas that require regular cage cleaning.
- Disease management can be easier than for cages.

5.1.3 Disadvantages of grow-out ponds

- It may be difficult to monitor the fish because of turbid pond conditions. The farmer may be in doubt as to the actual number of fish surviving and their health status.
- Capture of the fish for grading, moving or slaughter may be more difficult than in cages. In the ponds the fish are spread over a wide area and, unless the pond is very well designed, the efficient capture of the fish can be problematic.
- Ponds can be more expensive to construct than cages.

- There may be a high cost of operation, especially with regard to aeration and water pumping.
- Uneaten feeds and fish wastes may accumulate and if the ponds are not managed carefully, toxic conditions can develop quickly.
- Large ponds are difficult to screen from predators such as birds.
- Marine ponds in the NT may need a large supply of fresh water to balance salinities during the dry months of the year.
- Water quality in ponds may change suddenly (e.g. the algal bloom in the ponds may crash on days of high humidity or after heavy rain) causing oxygen problems for the fish.

Photo 5.1. Aerial photograph of one of the NT's pond-based barramundi farms. This farm uses a unique 'race track' design for each of the ponds. Total pond surface area is approximately 12 hectares

5.2 Cage culture

Photo 5.2 Typical example of a South-East Asian floating cage farm. The walkways and nets are supported by floating plastic drums

Cage culture is the preferred culture method of barramundi in Thailand, Hong Kong, Malaysia, Singapore and Indonesia. In South-East Asia, cage culture is usually simpler and more profitable than pond culture.

Traditional Asian cage farming uses either simple fixed or floating cages. Fixed cages are made by fastening a cage net to four wooden poles or stakes installed at its four corners. Fixed cages are usually set in shallow bays with narrow tidal fluctuation.

In South-East Asia floating cages are made from timber, bamboo or steel walkways mounted on some sort of floatation from which the small cage net is hung (Photo 5.2). Floating cages are normally used in relatively deep, sheltered areas that are subjected to moderate tidal flushing.

5.2.1 Cage farming in tropical Australia

A few Australian barramundi farms also use cages for grow-out. The cages are either directly placed in the sea or located inside constructed ponds. Materials used for cage construction in Australia include, black polyethylene, PVC and steel.

In 2001, Marine Harvest installed an industrial scale sea farm for barramundi in the waters of Port Hurd, Bathurst Island, approximately 80 km northwest of Darwin. The first cage system installed at Port Hurd consisted of a large steel floating platform supporting 10 cages, each with a capacity of 500 m^3 (Photo 5.3).

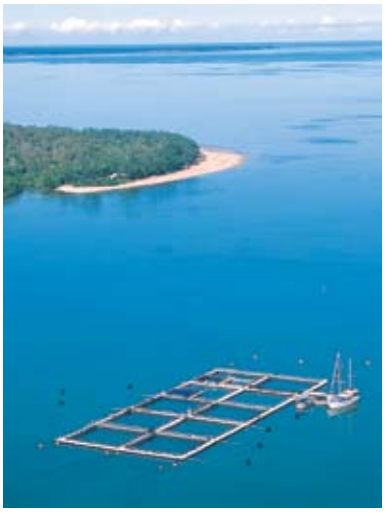


Photo 5.3 Marine Harvest's original barramundi cage farm at Port Hurd (courtesy of Marine Harvest)

In 2004, due to excessive corrosion, the company began to phase out the steel platform, moving instead to plastic polyethylene rings similar to those used widely in the salmon farming industry. Instead of fibre mesh nets, the company successfully pioneered the use of OneSteel® mesh (galvanised steel nets) to contain the fish and prevent predator intrusion (sharks, crocodiles). The extra heavy galvanising and the use of zinc anodes, gave the OneSteel nets an effective life of 18 months, which matched the production time for a batch of fish. The steel nets had the added benefit of not requiring cleaning and the cost savings in labour this represented meant the use of these nets was very cost effective.

5.2.2 Grow-out cages - site requirements

- Depending on the cage design, the site should usually be sheltered and not overly exposed to prevailing winds or large wave action. Exposed sites require special cages which are usually expensive to manufacture.
- Water depth depends on the depth of the cage, but there must be at least 2–-4 m clear between the bottom of the cage and the sea floor at low tide.
- Water current should be sufficient to flush away wastes from beneath the cage to prevent localised fouling. In areas of excessive current (over three knots) the cages may need to be specially designed and/ or specially anchored.

5.2.3 Advantages of grow-out cages

- Can be relatively economical and easy to construct, compared to excavation and plumbing for pond farms.
- Very economical to operate as there is usually no need for mechanical aeration.
- Fish can be held at much higher densities than pond farms.
- The fish can be readily caught for either grading or harvest.
- The system lends itself to automation of feeding, harvesting and grading.
- The cages can be protected to prevent theft of fish by birds.
- If the conditions become unfavourable at a particular site the cages can be towed to a new location.

5.2.4 Disadvantages of grow-out cages

- Fish totally rely on the addition of formulated feeds for survival and growth. During periods of inclement weather it can be very difficult to service cages.
- In areas where biofouling is severe, net changes on a weekly basis may be required. This is usually a labour intensive process and can add significantly to the operating costs of the farm. Solutions to the biofouling problem may include the use of rotating cages or 'net rocking' that allow net panels to be sun dried and cleaned *in situ*. The OneSteel® mesh nets used at Port Hurd proved to be resistant to fouling because of their zinc coating.
- Traditionally cage farms required areas of relatively deep, sheltered water. As cage farming technology has developed it is now possible to install cages in more exposed and remote locations but the cost of servicing the cages in these remote locations is high.
- Predators including sharks, crocodiles and man have to be controlled by specially designed nets / cages and security systems. The Port Hurd sea cage farm managed to reduce this problem by installing nets made of galvanised steel mesh.
- Fish cages may have a high on-going maintenance cost made up of replacement of damaged nets, net cleaning, purchase and maintenance of tender boats, etc.
- Damage to the cages caused by inclement weather other environmental factors (e.g. strong tides) can quickly lead to large losses of fish.
- Growth rates of fish may be slightly slower than in ponds due to extra exertion swimming against current.

5.3 Grading during grow-out

Once the fish are in grow-out ponds or pens it is not usually practical to grade them until harvesting commences. Generally the larger fish are removed for market and the smaller fish returned to the pond or to a neighbouring sea cage. The differential growth rate of barramundi means there can be an extended harvest period of a couple of months from one pond or cage.

5.3.1 Pond culture

Grading can be a difficult process for fish grown in ponds. It usually involves either totally draining the pond to collect and grade the fish, or if grading only a portion of the fish, dragging the pond with a suitable net. This is one reason why some pond farmers choose to grow their fish in cages inside the ponds.

If the fish are free-ranged within the pond the grading process can be made much easier by correct pond design. The inclusion of a capture zone or sump, can simplify the capture and return of fish to the pond.

5.3.2 Cage culture

Fish grown in cages can be easily graded if required. The netting on the cages is partially pulled out of the water or, if steel cage netting is used, an inner capture net is used to concentrate the fish. Once the fish are crowded into a small area they can then be scooped or pumped from the water into a mechanical grader.

Each farm has its own management practices that dictate if and when grading is required.

5.4 Stocking rates

It is recommended that inexperienced farmers should be conservative with their stocking rates in either cages or ponds. Stocking rates can be increased once the farmers become more experienced with fish husbandry and water quality control and when they gain a better understanding of the interaction of the fish with the farm environment.

5.4.1 Ponds

For new farmers the recommended stocking rate is 5–10,000 kg of harvest size fish per hectare. Actual stocking rates achieved by NT fish farms have been as high as 30,000 kg per hectare using supplementary aeration.

The actual stocking rate used in grow-out ponds depends on a number of factors. These include:

- Whether supplementary aeration is used and of what type. Most aerator manufacturers and suppliers will be able to advise on the correct level of aeration for the proposed stocking density. Aeration is recommended for stocking densities above 5,000 kg per hectare.
- The size, shape, depth and location of the pond.
- The amount of water exchange (new water added) in the pond and how much water is available for emergency exchange.
- The technical ability of the farm manager in animal husbandry and water quality control.
- Prevailing weather conditions.

5.4.2 Cages

The stocking rates used in cages also depend on a range of factors. There is no ‘one-rate-fits-all’ that can be used in cage farming and each farm must be individually assessed for its carrying capacity.

6. Nutrition

6.1 Larval nutrition

It is widely reported in the scientific literature that larval marine fish and crustaceans have a high requirement for highly unsaturated fatty acids (HUFA's). Three fatty acids in particular, eicosapentaenoic acid, (EPA or 20:5ω3), docosahexaenoic acid (DHA, 22:6ω3) and arachidonic acid (ARA or 20:4ω6) have been identified as being of special importance for the survival and growth of marine fish larvae. Diets that lack sufficient quantities of these fatty acids, or have them in the incorrect ratio, may decrease survival. Sub-lethal effects of dietary deficiencies may also be observed, such as malformation of the spine, missing gill opercular, jaw deformities and mal-pigmentation of the skin.

During larviculture care must be taken to ensure that the diet offered to the fish larvae contains sufficient nutrients to sustain healthy growth and is presented at a density that promotes efficient feeding and limits size variation (cannibalism) within the population of the same batch of fish.

6.1.1 Intensive production

In intensive hatchery production, (section 3.3.1), the larvae are usually only fed two types of live feed, rotifers and *Artemia*. In the intensive rotifer system described in 3.3.1.2 the chorella algal paste fed to the rotifers is supplemented by adding *Nannochloropsis oculata* and *Isochrysis sp.* (commonly called *T. iso*) algal pastes[3] into the larval rearing tanks. This ensures that the larvae receive rotifers with an optimal nutritional level and has been demonstrated to reduce deformity levels in the fish to an insignificant level.

Batch cultured rotifers and *Artemia* are generally nutritionally deficient and must be enriched by some means before they are fed to the fish larvae. A number of companies have developed a range of nutritional boosters for zooplankton which are extensively used in the marine aquaculture industry around the world.

At the DAC, *Artemia* are first hatched and then harvested, rinsed and added to a boosting tank along with an emulsion of DC DHA Selco® (INVE). The name of this product implies that it disinfects continuously (DC) and has high levels of the essential fatty acid DHA. The disinfecting nature of the booster means that it promotes lower bacterial growth during the boosting process compared to other oil-based boosters. The *Artemia* are enriched in the emulsion for twenty-four hours before being rinsed thoroughly and fed to the larvae.

Rotifers are fed to the larvae from first feeding (day two post-hatch) until day 14–16. *Artemia* feeding overlaps with rotifers from day 14. Traditionally, enriched *Artemia* have been fed to the larvae up to at least day 30–35 before weaning (the process of changing the fish from live food to a formulated diet) is completed. The emerging technology of new microdiets such as Skretting's Gemma Micro® have changed the way the larvae are reared. Today the usage of *Artemia* has been reduced by more than 95 per cent by commencing co-feeding Gemma Micro diet with rotifers from day eight which has also advanced weening to between days 16 and 20.

[3] Instant Algae®, Reed Mariculture, USA.

6.1.2 Semi-intensive production

The nutritional quality of live feeds in semi-intensive, large tank systems needs to be carefully managed. During the rotifer feeding phase the larvae are usually unable to graze rotifer numbers down to a point where more need to be added. This means that the rotifers are dependent on the algae in the larval rearing tanks for their nutritional quality. So for this reason the algal blooms need to be monitored carefully and it may be necessary to pump in more if algal densities drop. Ideally, two algal species are used in the semi-intensive system. *Nannochloropsis oculata* and *Isochrysis* sp. (T. iso). The algae complement each other with their fatty acid profiles. *N. oculata* is high in EPA and T. iso is high in DHA.

Once the larvae in the semi-extensive system have started to feed on *Artemia* then maintenance of the algal blooms become less important. The appetite of the larvae increases as they grow and they are capable of eating all the *Artemia* in the tanks. Each day, freshly boosted *Artemia* are added over three to four meals, ensuring that the larvae receive adequate nutrition.

Like the intensive method, the development of new micro-diets means that the amount of *Artemia* used for semi-intensive larval culture can be significantly reduced but weaning of the fish before 30 days remains difficult because of the low density of fish.

6.1.3 Extensive production

It is not possible to 'boost' the quality of the live feed in an extensive system in the same way as described above. Extensive systems usually contain copepods which are the primary food item for the fish larvae. It is well documented that because copepods usually contain optimal levels of the essential fatty acids they are a superior food item compared to rotifers and *Artemia*. Copepods are not normally used in intensive or semi-intensive systems because of their low productivity which makes it impossible to maintain sufficient prey density.

Maintaining the zooplankton bloom in extensive ponds can also be a problem although it is made somewhat easier by the lower density of fish larvae in the system. Generally the options to sustain the bloom are limited to increasing fertiliser rates and pumping in extra plankton from other ponds. Adding blended fish to sustain cyclopoid copepod blooms has been trialled with some success in the past, as has adding large quantities of *Artemia*. However, both these methods are not really practical on a large scale.

6.2 Juvenile nutrition

6.2.1 Weaning diets

As mentioned in 6.1.1 the development of new micro-diets has changed the way that barramundi are cultured at the DAC. Instead of starting the weaning process at day 20, the larvae are now being fed formulated diets as early as day 8 and are fully weaned by day 16–20.

Fish weaned in this way do not show any evidence of a weaning induced mortality which can happen using the previous method. This type of mortality occurred when a percentage of the fish failed to wean on to the formulated diet by day 30–35 and when *Artemia* feeding ceased these fish quickly starved to death.

Using Gemma Micro® the majority of the fish wean quickly and easily.

6.2.2 Nursery diets

Nursery diets for barramundi are fed to the fish from a size of 20 mm through to 100–120 mm. The diets that are normally used are slightly higher in protein and lipid content than the grower diets and they may also contain immuno-stimulants such as beta glucans which have been shown to help the fish resist disease.

The feeds for the nursery stage come in a wide range of pellet sizes and they are carefully matched to the size of the fish to maximise feeding efficiency.

6.3 Grow-out nutrition

In South-East Asia, barramundi grown out in ponds or cages may be fed two feed types, bait trash fish or formulated pellets.

6.3.1 Bait fish feeds

Bait fish is still one of the main feed sources for fish cultured in South-East Asia. The requirements for the bait fish are that it must be fresh, clean and cheap. Preferably the feed has been snap frozen immediately after capture and does not exhibit any sign of disease. Types of bait fish commonly fed to barramundi are: mullet, squid, sardines, anchovies, pilchards and other small marine fish.

Even though the tropical waters are rich in small fish, northern Australia has not developed a bait fishing industry, and because of this and logistical and health management reasons it is not considered a practical feeding method for barramundi farming in Australia.

Feed Conversion Ratios or FCRs (number of kilograms of feed used per kilogram of fish produced) for bait fish diets vary from 6:1 up to 10:1, depending on the moisture content and nutritional value. Bait fish diets usually record higher food conversion rates than pelleted diets because of their higher water content (usually 80–90 per cent compared to less than 10 per cent for pelleted artificial feeds) and a higher indigestible fraction, such as scales and bones.

All barramundi farms currently operating in Australia use formulated pellets for growing their fish.

6.3.2 Formulated pellet feeds

These are usually dry pellets consisting of fish meal, cereals, vitamins, minerals and binders. The actual configuration of the pellets varies with the manufacturer and the specific recipes are usually kept confidential.

In Australia there are two main companies manufacturing barramundi diets. They are Skretting in Tasmania and Ridley Aquafeed in Brisbane. Diet formulations offered by the companies are continually being improved as they strive to obtain better FCRs and make the feeds more cost effective. There is also a considerable amount of research being undertaken looking at replacing expensive fish meal with other, cheaper, protein sources (cereals, blood meal, feather meal … etc).

Farmers exclusively using a pelleted diet in Australia can expect a food conversion ratio of between 1.2:1 and 2:1. That is, it takes between 1.2 and 2.0 kilograms of feed to produce 1 kilogram of fish. The variation in feed conversion rates is due to variations in management practices, methods of feed application and feed formulation.

In Denmark fish feed manufacturers are required by law to ensure that salmon fed their products obtain a FCR of less than 1:1. They must also reduce the amount of phosphorous in the feed to lower nutrient inputs from fish wastes. There are no such requirements in Australia at the moment.

6.3.3 Advantages of pellets

Apart from availability, pelleted diets have a number of significant advantages over fresh diets.

- Consistency of supply. The pellets can be bought in bulk, and if stored correctly, can last many months with little drop in food quality.
- Consistency of quality. The nutritional quality and standard of the pellet are batch tested in the factory before the pellets are shipped to the farmers. This minimises, but does not totally eliminate, the problems of poor feed quality.
- Easy to feed. There is no preparation of the pellets required before they are fed to the fish.
- Pellets can be fed to the fish by automatic machines, reducing labour costs.
- Because the feed has been heat treated during the manufacturing process the risk of transmitting disease through the feed has been virtually eliminated.
- The bags of feed are easily stacked for storage.
- The formulation of the diet can be tailored to the species of fish being fed giving consistently high growth rates.

6.3.4 Disadvantages of pelleted diets

- Relatively expensive. One of the main ingredients in pellets is fish meal. Currently most of the fish meal used in pellets is imported from overseas at a high price and the price is rising rapidly as the supply of fishmeal has remained relatively constant as demand increases.
- There are no manufacturers in the NT. Transport from interstate adds significantly to the cost of the feed.
- The diets could still be considered to be in the developmental stage. It may be some years before the feed conversion rates achieved for barramundi come down to levels already being achieved overseas on salmon.
- In the wet season the pellets should be stored in air conditioning or refrigeration or used soon after delivery to prevent formation of toxic moulds in the bags of feed.
- There has been some debate about the effect of pelleted feeds on the final taste quality of the fish. Trials have indicated that this was a perceived rather than a real problem.

6.3.5 Moist pellets

Moist pellets are usually manufactured on site by the fish farmer. Moist fish meal is mixed with a vitamin and mineral pre-mix, animal protein and cereals. Moist pellets are unlikely to ever be used to grow barramundi in Australia but they may be useful for broodstock diets or for some reef fish species. Moist pellets have not been trialled in the NT.

6.3.6 Growth rates

Observed growth rates for barramundi grown under farm conditions are shown in Figure 6.1.

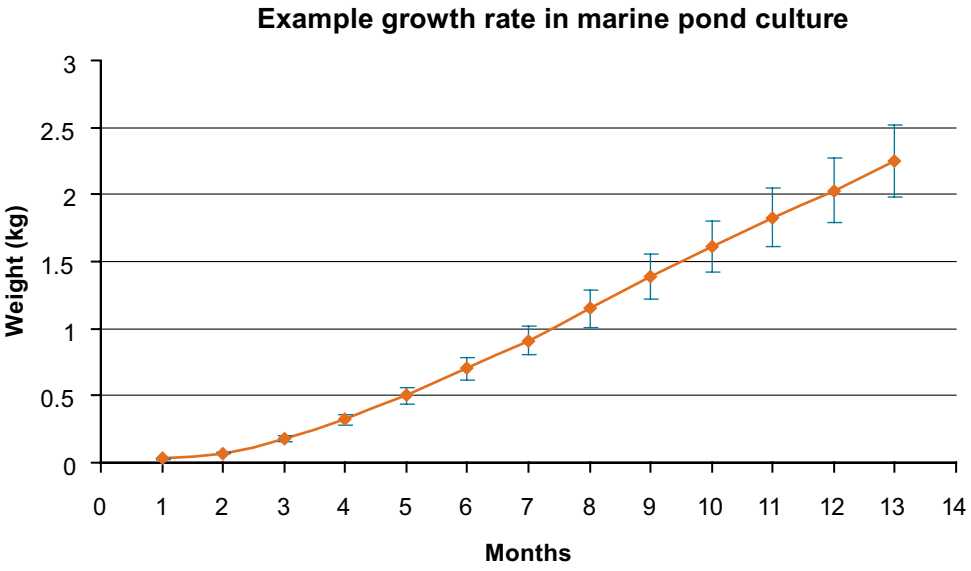


Figure 6.1. Example growth rate of marine pond raised barramundi in the NT. The plot shows the mean weight in grams (♦). The vertical bars show the standard deviation

6.4 Feeding methods

Farmers in the NT either use hand feeding or mechanised feeding hoppers and blowers to distribute the feed to the fish.

6.4.1 Hand feeding

Hand feeding is usually done once or twice per day. Once in the early morning and, if required, again later in the afternoon. The amount of feed given is dictated by the feeding activity of the fish. Once the fish cease a vigorous feeding 'frenzy' the feeding is stopped. Apart from preventing wasted feed, hand feeding gives the farmers a chance to interact with the fish and monitor their progress. A sudden cessation in feeding response from one day to the next is an indication that something may be wrong with the fish or the water quality.

The amount of feed given to the fish will depend on water temperature, time of day, size of fish being fed, amount of natural feed in with the fish and whether or not the fish have been partially harvested or disturbed recently.

The amount of food given to the fish also depends on the skill and experience of the farmer. Under-feeding or over-feeding will result in either a slow down in the growth rate of the fish or feed wastage. In both cases the FCR of the fish will suffer which will affect the economics of the farm.

6.4.2 Mechanised feeders

There are a number of mechanised feeders available. A popular type of feeder is the 'blow' feeder that consists of a hopper attached to a tube (or cannon) through which air (or water) and feed is blown out into the cage or ponds. The shape of the pellet spread and the distance the pellets are blown can be regulated by air volume and the length and profile of the cannon. The hopper and blower may be fixed in place or be transportable on the back of a quad bike or trailer. One advantage of this type of mechanised feeder is that it is similar to hand feeding in that the farmer is able to directly witness the feeding activity of the fish and can therefore gain information about the health of the stock.

Another type of mechanised feeder is the automated feeder that can be programmed to distribute feed to the fish on a pre-determined schedule. The feed is again held in a hopper and is usually distributed by a spinning disk. The main problem using automated feeders of this type is that the feeding habits of barramundi vary greatly from day to day and it is inevitable that feed will be wasted if a set program is used. The feed will continue to fall into the pond regardless of whether the fish are hungry or not.

In 1994 the DAC trialled a new feed controller produced in Tasmania. Called the Aqua Smart Adaptive Fish Feeding System, the machine was computer driven and regulated the amount of feed distributed to the pond by monitoring any uneaten feed that passed through a sensor suspended below the feed hopper. If the fish were not feeding, the automatic feeder was turned off. If the fish were feeding, the time of feeder operation was extended. The Aqua Smart computer also recorded the feeding activity of the fish and this information was later downloaded to a personal computer for analysis. The activity of fish could then be expressed graphically and several hours, days or months of information was able to easily be compared.

The results of the trial showed that during July and August the barramundi in the pond had a preference for feeding from late morning up until midnight. Problems with the system included, insufficient water depth below the feed hopper for the siting of the sensor and the lack of a feed pellet with a consistent sinking rate. Most of the pellets tried either sank too quickly or floated.

The system was demonstrated to have potential but so far none of the NT barramundi farmers have installed the system.

6.5 Feeding rates

The quantity of feed consumed each day by barramundi changes with time. When the fish are small they can consume an amount of feed up to 20 per cent of their own body weight per day. By the time they are 4–500 grams the amount consumed drops to 1–2 per cent of their body weight per day.

The quantities of various sized pellets needed to grow 1 tonne of barramundi are indicated in Table 6.1. It is assumed that the feed conversion ratio is 1.4:1. The figures in the table should be used as a guide only. Factors discussed in section 6.4 will influence the amounts of feed needed.

Table 6.1. Approximate quantities of pelleted feed needed to raise 1 tonne of barramundi. (= 2,000 fish x 500 g). Starting size of fish is 0.5 g

PELLET SIZE (mm)	QUANTITY (kg)
0.7	2
1.4	8
1.8	8
2.2	60
3.2	80
4.0	100
6.2	360
9.0	800
Total	**1418 kg**

7. Disease

A spectrum of diseases, pathogens and parasites are known to infect barramundi, some of which are of major biological and economic importance in the production of farmed fish and some of which occur incidentally.

A recent review of diseases of barramundi in aquaculture concluded that '*As our knowledge of barramundi disease increases and we understand more of the biology of the pathogens and the optimal rearing conditions for barramundi, improved management strategies will be developed to help avoid diseases and maximise productivity*.' Thus, it is important to have a detailed knowledge of the diseases, pathogens and parasites that infect, or are likely to infect barramundi as a basis for developing control strategies.

This chapter identifies those diseases which have occurred in, and which may impact adversely on, the production of barramundi. It is recognised that the continued intensive production of barramundi will likely result in further occurrences of known or previously undescribed diseases. A brief description of each condition is given, together with possible treatment and/or control mechanisms that may be applied.

7.1 Disease prevention

From an economic and management viewpoint, prevention is better than cure when it comes to disease in fish. This is especially important under large scale systems of production whereby treatment or control of disease outbreaks may be difficult if not impossible.

In discussing disease prevention it is helpful to understand the nature of disease and how diseases may be introduced into production systems. Diseases may be infectious, i.e., caused by living microbial (viral, fungal, bacterial) or parasitic organisms, or non-infectious, i.e., caused by non-living factors, e.g. , nutritional deficiencies, behavioural problems and hostile environment or toxins. Diseases may also be primary, i.e., caused by an infectious or non-infectious agent acting alone, or they may be secondary, i.e., they may occur following or resulting from some other initiating cause. There are numerous examples of both primary and secondary diseases.

The main ways through which primary diseases may be introduced into fish farms are through the addition of infected water, the use of infected feed materials or exposure to other infected fish. As such, primary diseases can be avoided by excluding the microbial organism or parasite from the culture system through the use of clean water, uninfected feedstuffs and avoidance of fish from uncertified sources. Secondary diseases commonly accompany poor environmental conditions and/ or stress and a poor aquatic environment and poor farm management encourages such diseases.

7.1.1 Water quality

High water quality standards are paramount to good fish health. An important way to prevent fish diseases is to ensure that the environment is kept as clean as possible. Some important measures that can be taken are highlighted on the next page.

- The water in which the fish are kept must be exchanged regularly or otherwise treated to remove wastes and pollutants.
- The culture area (tank, pond or cage) must be kept free from a build up of fish wastes and uneaten feed.
- If necessary, some form of aeration device should be employed to maintain high dissolved oxygen levels. Stress resulting from low dissolved oxygen concentrations is responsible for many cases of mass mortality.
- Indicators of water quality should be measured on a regular basis. These should include ammonia, nitrite, salinity, pH, water temperature and oxygen.

7.1.2 Feed quality

Feed must be stored correctly to prevent the introduction of infectious agents and to ensure that the nutritional value does not deteriorate. The use of whole or filleted fish from outside the local area is to be discouraged as this may readily introduce microbial organisms into the culture system. If whole fish, squid and/ or prawns are used, these should be snap frozen while fresh and stored at -18 to -30° C for at least 10–21 days before use. This will minimise the transmission of certain parasites but will not necessarily inactivate infectious agents.

Pelleted feed should also be kept cool, ideally at less than 20° C. In the dry season it is usually sufficient to keep the feed in a shaded building. In warm humid conditions such as experienced in the wet season in Darwin it is necessary to, at a minimum, store the feed in an air conditioned room. If this is not done, pelleted feed can quickly deteriorate. Fats become rancid, vitamins break down and mould can grow on the feed releasing toxins. Feed should not be stored for extended periods and good feed store management should be employed to keep track of stock and ensure that the feed fed to the fish is of the highest quality.

7.1.3 Quarantine

Unless previously tested and certified any new fish brought onto the farm should be quarantined for a minimum of two weeks to identify any diseases, pathogens or parasites they may be carrying. Treatment in quarantine may be necessary to eliminate microbial organisms and parasites and testing of fish for specific agents may be undertaken during this period.

7.1.4 Non-infectious diseases

7.1.4.1 Deformities

A range of deformities have been recognised in barramundi. These include missing dorsal fins, missing opercula and jaw abnormalities. Although the cause is uncertain, there is strong evidence that nutritional deficiencies or imbalances including minerals, vitamins, essential fatty acids, may be involved in rapidly growing fish.

7.1.4.2 Cannibalism

Photo 7.1. Cannibalism in barramundi with excoriation and necrosis of the integument (skin damage) (inset-arrow)

Cannibalism is a behavioural trait that may directly cause the death of the targeted fish by it being eaten or, in the case of a fish that is too large to be eaten it may result in skin damage with secondary bacterial infection and death (Photo 7.1). Cannibalism may be a major cause of losses in farmed barramundi, especially at the fry or fingerling stage. Cannibalism may be controlled by regular grading of fish ensuring similar sizes of fish in any one tank.

7.2 Viral diseases

7.2.1 Nodavirus (viral encephalopathy & retinopathy)

Nodaviruses infect the central nervous system of the fish resulting in vacuolation and degeneration causing a disease known as viral encephalopathy and retinopathy (VER) or viral nervous necrosis (VNN). The disease has been recorded in more then 30 marine fish species worldwide, including both cold and warm water species.

VNN was first identified in farmed barramundi in Australia in the mid 1980s as a major cause of losses in juvenile fish. Today VNN periodically causes significant mortalities of larval and juvenile barramundi in hatcheries. The virus may also infect a range of other native Australian fish species.

Although the exact source of nodavirus infection is uncertain it appears likely that virus is shed in the reproductive fluids of the male and female fish and is present in or on fertilised eggs. Infection from broodstock to progeny via the reproductive fluids or eggs is known as vertical transmission. Although vertical transmission from carrier broodstock appears to be a major means of spreading the disease, VNN can readily be transferred from fish to fish through virus shed into the water column. This is known as horizontal transmission. Once horizontal transmission is initiated by infectious levels of virus in the water, an explosive outbreak of VNN can be expected, including spread between tanks or culture systems due to aerosol transmission, i.e., the spread of virus in water droplets generated by aeration systems.

7.2.1.1 Signs of infection

Evidence of nodavirus infection is usually most prevalent in larval barramundi between 15 to 24 days of age although fish up to 7 weeks have been seen with the disease. Infected fish are generally pale or show generalised dark colouration with redness of the head area. Affected fish usually swim with an erratic spiraling action. These signs are followed by death. Losses can be severe and dramatic. Microscopically, affected fish show characteristic severe vacuolation in the grey matter areas of the brain and in the neuronal layers of the retina (Photo 7.2).

The presence of virus in the fish may be detected by molecular diagnostic techniques including Polymerase Chain Reaction or PCR and this does not necessarily mean that observable signs and death are inevitable. This latent or inapparent carrier state in which fish may carry the virus without showing disease is well recognized. Under certain circumstances, it appears that external stressors such as sudden change in temperature, low environmental temperatures, handling shock or nutritional deficiency may initiate a disease outbreak in fish carrying the virus.

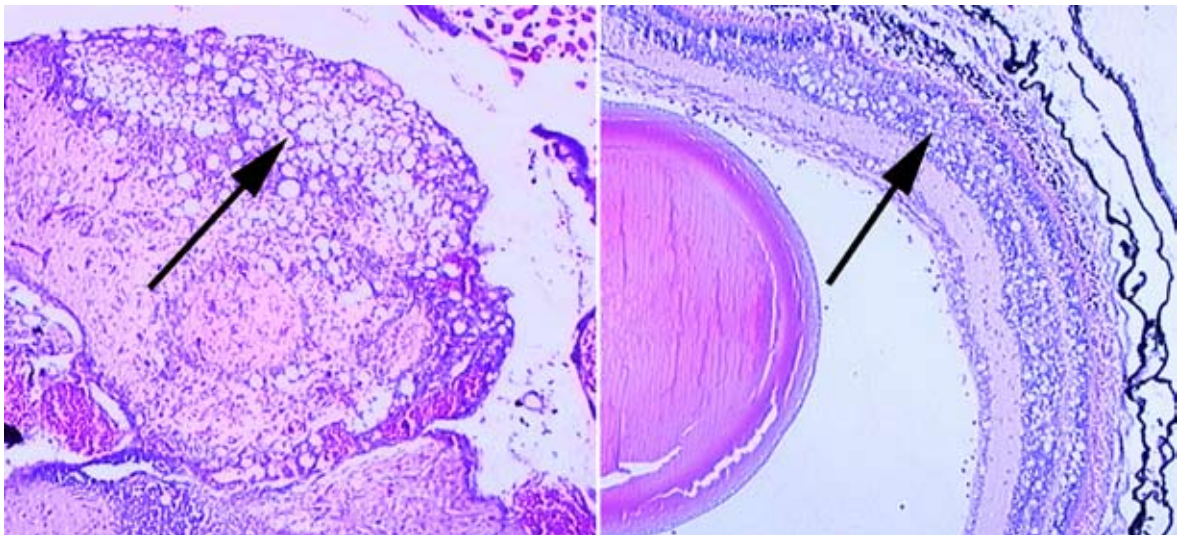


Photo 7.2. Brain (left) and retina (right) of barramundi with viral nervous necrosis showing massive vacuolation in nerve tissues (arrows)

7.2.1.2 Treatment and control

There is no known treatment for VNN.

If the disease occurs in a region in which the virus has not occurred previously destruction of all infected stock and decontamination of the rearing facility may be required to prevent spread to fish in the local environment.

In the face of a diagnosed outbreak of VNN in an endemic area, i.e., a region in which the virus is known to occur, there are a number of strategies which may be employed to reduce losses:

- All dead or diseased fish should be removed regularly from the culture vessel.
- Water flow rates should be maximized in an attempt to reduce viral loading in the vessel.
- Salinity may be reduced to 12–15 ppt to reduce osmotic stress.
- Water quality parameters should be optimized.

7.2.1.3 Prevention

VNN is a highly infectious disease which may cause significant losses in infected populations. Under no circumstances should fish known or suspected to have originated from populations infected with nodavirus be translocated to regions considered free of the disease. Imports of barramundi from endemic areas should only be conducted following exhaustive test and health certification procedures.

Strategies that can help prevent VNN episodes include:

- Broodstock can possibly be identified as 'carrier' fish through PCR analysis of their blood and/or reproductive fluids. All carrier fish should be removed from the hatchery. This technique has been used with some success to control VNN in European sea bass hatcheries in Greece. Broodstock of progeny incurring VNN can also be eliminated from the broodstock pool.
- Although not fully proven, the use of ozone to disinfect egg batches prior to larval rearing is strongly recommended. Ozone disinfection of fertilised eggs has been claimed to be effective in preventing VNN in halibut although VNN in European sea bass is found within the egg after spawning and therefore not amenable to external treatment by ozone.
- Following each larval rearing run, the hatchery should be thoroughly disinfected and dried to prevent any virus particles from one run carrying over to the next. Disinfection should apply to all pipes, filters and apparatus used in the hatchery.
- Larval nutrition and water quality should be maintained at optimal levels to help the larvae resist infection.
- The fish should be raised in a 'minimum stress' environment.

7.2.2 Lymphocystis

Lymphocystis is a disease of the skin caused by an iridovirus and is a common disease of fish worldwide. Lymphocystis is reported rarely in barramundi. Infections in other marine species, especially juvenile fish, are reported to cause high mortalities. Infection may be self-limiting. Affected fish may be unsuitable for market.

7.2.2.1 Signs of infection

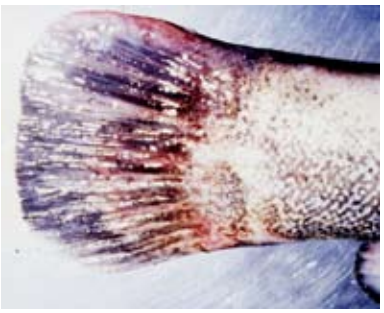


Photo 7.3. Tail fin of mature barramundi showing multiple pale nodular growths typical of lymphocystis

Lymphocystis is mainly a skin infection found in a wide variety of bony fish. It is found in fish from both freshwater and saltwater environments and is more likely to affect young fish than old. Lymphocystis has been recorded once in barramundi in the NT in fish introduced to an aquarium with other species. Although infection is generally not fatal, the nodules may cause severe disfigurement and render the infected fish unsuitable for market.

The disease is characterised by the development of single or multiple nodular lesions in the skin, particularly on the fins (Photo 7.3).

7.2.2.2 Treatment and control

At present there is no known treatment for lymphocystis disease. Providing fish are kept in a clean environment they stand a good chance of recovery. Lowering stocking density of diseased fish in cages is also considered to aid their recovery.

7.3 Bacterial diseases

7.3.1 Streptococcosis

Streptococcosis is a severe, generalised infection caused by the gram positive coccoid bacterium *Streptococcus iniae*. The disease may occur in both freshwater and marine environments and may result in high mortalities. Although streptococcosis has been recognized in barramundi in Australia for some years, it has only recently (2005) been described in barramundi from sea cages in the NT.

7.3.1.1 Signs of infection

Signs of infection vary. In acute cases, fish may be seen moribund or found dead with few external or internal signs. In less acute cases, affected fish may swim near the surface in an uncoordinated manner, may appear blind and be unresponsive to external stimuli. Focal or diffuse haemorrhages may be seen in the skin and especially at the base of the fins. Exophthalmos or protrusion of the eyeball, accompanied by intra-ocular haemorrhage may be a feature (Photo 7.4). Gills appear congested. Internally, multiple haemorrhages may be seen on the surface of the visceral organs. Often, the skeletal muscle has a pink-red colouration.

Photo 7.4. Barramundi showing focal and diffuse haemorrhages in skin and a base of fins and severe exophthalmos (eye protrusion) with intra-ocular haemorrhage caused by Streptococcus iniae

7.3.1.2 Treatment and control

Streptococcosis may respond to the administration of oral or injectable antibiotic to which the organism is shown to be susceptible and as prescribed by a registered Veterinary Surgeon.

7.3.1.3 Prevention

In areas where the disease is not endemic, stocking of farms with seedstock certified free of *S. iniae* is a sound strategy to prevent infection and contamination of the farm environment.

In endemic areas vaccination of seedstock before entry to the farm appears to be effective in preventing infection. Vaccination is undertaken using a killed, autogenous strain of the organisms, i.e., a strain obtained from diseased fish from the infected farm or region. Fish are vaccinated by a single intraperitoneal injection when they are approximately 7–10 g body weight. Alternatively, vaccination may be done using an immersion technique but immunity may not persist as long, compared with injection of the vaccine.

7.3.2 Vibriosis

Vibriosis is a severe, economically important bacterial infection caused by members of the genus *Vibrio* and other related genera. Vibriosis affects a diverse range of marine and estuarine fish species and is frequently secondary to other inciting causes, e.g., poor water quality, stress, poor nutrition.

7.3.2.1 Signs of infection

Vibriosis is characterised by extensive cutaneous (skin) and systemic haemorrhages and localised cutaneous ulceration may occur. In barramundi the clinical signs have been abnormal swimming behaviour, opaque eyes, and reddening of the abdomen. Internally, areas of necrosis and haemorrhage in kidney, liver and spleen may be seen.

7.3.2.2 Treatment and control

Vibriosis may be treated by administration of antibiotics including oxytetracycline. These must be prescribed by a registered Veterinarian.

7.3.2.3 Prevention

Vibriosis is stress related and avoidance of stress through good husbandry and optimal water quality is paramount in preventing the disease.

7.3.3 Necrotic enteritis and peritonitis (‘bloat’)

A syndrome of necrotic enteritis and suppurative (pus forming) peritonitis, commonly referred to as ‘bloat’, occurs periodically in farmed barramundi. The syndrome affects fish of fingerling size to mature individuals and is seen in both freshwater and marine environments. Bacteriological culture of cases from marine environments invariably results in the isolation of *Vibrio harveyi* and *Photobacterium damsela* subspecies *damselae*. In fish from freshwater environments, the isolates are typically *Aeromonas hydrophila*. On occasions, anaerobic bacteria are also isolated. These organisms are found in the intestine of healthy fish.

The syndrome appears associated with consumption of excess feed, and/or larger feed pellets and/or pellets of certain composition. It is postulated that the ingested feed may exceed the enzymatic digestive capacity of the alimentary tract and hepatopancreas, with subsequent

Photo 7.5. A 500 g barramundi with 'bloat' showing extreme liquefactive necrosis of visceral organs and abdominal fat with associated peritonitis

bacterial proliferation, toxin production, tissue necrosis, loss of integrity of the intestinal wall, massive peritonitis and bacterial proliferation and liquifactive necrosis of the visceral mass and abdominal fat. The condition usually affects individual fish or low numbers of fish and may result in rejection if fish with 'bloat' gain access to the market undetected.

7.3.3.1 Signs of infection

Typically, affected fish have swollen abdomens, become lethargic and die. Characteristically, the smell of moribund or recently dead fish resembles that of fish which have been dead for days. The abdominal cavities are distended by copious amounts of putrid fluid. In cases showing early pathology of the disease extensive fibrinous adhesions are present, binding visceral organs and tissues. In later cases, liquifactive necrosis of the visceral organs and intestine is seen. In advanced cases, the extent of necrosis is such that only remnants of visceral organs and tissues are discernible (Photo 7.5).

7.3.3.2 Treatment and control

Fish that have 'bloat' do not respond to antibiotic treatment because once signs appear too much damage has already been done to the intestinal tract and abdominal organs. Reducing pellet size and frequency of feeding are strategies employed to reduce the prevalence of 'bloat'.

7.3.3.3 Prevention

Immunisation by immersion in a killed vaccine containing *V. harveyi* and *P. damselae ss damselae* of fingerling fish leaving the nursery has been tried, however, the effectiveness of this vaccination in preventing 'bloat' remains uncertain.

7.3.4 Bacterial gill disease

Bacterial gill disease (BGD) commonly affects fry/fingerlings, especially those that are subject to environmental stress. As the name implies, the gills become covered with bacteria, predominantly from the Flexibacterial group, which effectively smother the gills. Rapid death and high mortalities may ensue.

7.3.4.1 Signs of infection

Infected fish may be found dead and typically, gills are flared out. Examination of fresh gills under the microscope shows vast numbers of elongate large bacterial rods over the gill epithelium.

7.3.4.2 Treatment and control

BGD may be responsive to salinity change and decreasing salinity in early cases may reduce the severity of infection. Surfactant agents, i.e., agents which remove the mucous from the gill may be used to treat the fish. The quaternary ammonium compound, benzalkonium chloride, may be used to treat, however, strict attention to correct dose is necessary as the toxicity of these compounds is increased at lower water temperatures and in lower salinity water.

7.3.4.3 Prevention

Maintenance of water quality parameters, avoidance of sudden changes in water temperature and avoidance of stress assist in preventing the disease.

7.3.5 Epitheliocystis

Epitheliocystis is a disease caused by infection of the gills by chlamydial organisms. Heavy infections in juvenile fish cause severe gill disease and may result in high mortalities. The disease has been seen on one occasion in nursery reared fingerlings in the NT. Solitary chlamydial cysts may occur in the gill epithelium in the absence of clinical disease.

7.3.5.1 Signs of infection

Infected fish may show no obvious signs. Gills may appear reddened and fish may swim near the surface of the water. Mortalities may be high. Microscopically, large numbers of cysts may be seen within the epithelium of the gill.

7.3.5.2 Treatment and control

There is no treatment for epitheliocystis once the fish are infected. Control may be exercised through minimising stressing infected fish. Disinfection of the eggs with formalin, prior to larval rearing has been demonstrated to be effective in preventing epithelocystis in greater amberjack, *Seriola dumerili*.

7.3.5.3 Prevention

The disease may be prevented by ensuring that juvenile stocks introduced onto the farm are not carrying the disease.

7.4 Fungal diseases

7.4.1 Red spot

Red spot or Epizootic Ulcerative Syndrome (EUS) has been periodically reported to infect a variety of fish species in the wild, including barramundi, in the NT. The disease occurs in freshwater and estuarine conditions and is generally not seen in marine environments and has not been reported from any farms. The cause is a fungal organism *Aphanomyces invadens*, motile spores of which invade the skin of the fish initiating infection. The fungus then proliferates within the skin and muscles of the fish resulting in the severe ulcers commonly known as ‘red spot’. Secondary infection with a variety of bacteria may also occur. In the NT, environmental

conditions are also important in red spot infections, with outbreaks of the disease mainly reported during the dry season.

7.4.1.1 Signs of infection

Typically affected fish have deep red or haemorrhagic ulcers on the skin of the bodies. The ulceration may extend to and involve the eyes. Fish may become lethargic and readily fall prey to other species.

7.4.1.2 Treatment and control

Red spot outbreaks have been treated successfully by raising the salinity of freshwater ponds.

7.4.1.3 Prevention

Although the disease is endemic throughout the coastal rivers of the NT, infection in fish farmed in saline waters is unlikely.

7.5 Parasitic diseases

7.5.1 Cryptocaryonosis

Cryptocaryonosis or Marine Ich is caused by infection of the skin and gills with *Cryptocaryon. irritans. C. irritans* is a ciliated protozoan parasite which is not host specific and which may cause serious disease in cultured marine fish, especially in the tropics. Most fish will harbour low numbers of organisms. This is one of the major parasitic diseases that affect barramundi kept in tanks for breeding. It is most likely to occur when fish are stressed and their resistance to disease is lowered, especially following capture of fish from the wild.

7.5.1.1 Signs of infection

The first clinical signs of the disease appear when the fish begin scratching or ‘flashing’ against the tank bottom or walls. As the disease progresses the fish suffer a loss of appetite and become listless. If left untreated the fish’s eyes become opaque and white spots or small ulcers may develop on their scales. Progression of the disease is rapid and if the fish are left untreated they may die within two to three days.

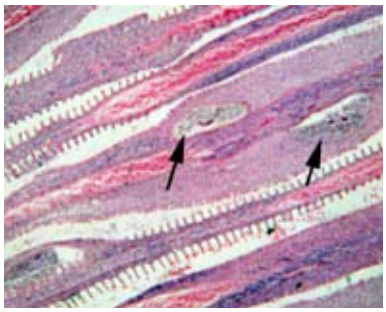


Photo 7.6. Cryptocaryon irritans (arrows) in the epithelium of the gill. Note severe thickening of the epithelium

Microscopic examination reveals large numbers of *C. irritans* cells on the gills and skin of infected fish (Photo 7.6).

7.5.1.2 Treatment and control

Although treatment of Marine Ich in barramundi may be effectively implemented in tanks and small ponds if detected early, treatment in large ponds or open water environments may be difficult or impossible. *C. irritans* requires high salinity water to survive. Treatment is effected by lowering the salinity from the usual level of 30–35 ppt down to at least 15 ppt or lower. This change in salinity can be performed rapidly if

necessary, although the recommended changeover period is 24 hours. Recovery should be evident from the first day of treatment and it is normal for the fish to start feeding in three to five days. The salinity must be kept low for at least nine days to break the life cycle of the organism. Heavily infected fish, especially juveniles, may continue to die despite treatment.

If lowering the salinity of the water is impractical, the disease can also be treated by administration of copper sulphate at no greater than 0.2 parts per million available copper as a long term bath.

Caution during treatment is warranted as there is little difference between the therapeutic dose and toxic dose of copper in fish. High mortalities may be incurred as a result of the treatment, especially if the fish have gill damage due to parasitism.

7.5.1.3 Prevention

Routinely lowering the salinity of the water in the broodstock tanks reduces the occurrence of cryptocaryonosis. This should be done regularly, at least twice per year, and the salinity should remain below 10 ppt, for nine days. All broodstock entering a facility should be subject to a quarantine period and freshwater treatment to eliminate *C. irritans*. There is some evidence that fish can build up immunity to cryptocaryonosis.

7.5.2 Trypanosomosis

Trypanosomosis is a disease caused by infection with the blood protozoan *Trypanosoma sp*. Trypanosomosis has been diagnosed once in the NT (July 2005) in sea-caged barramundi which experienced high mortalities. The disease appeared to be transmissible between cages but the means of transmission remains uncertain.

7.5.2.1 Signs of infection

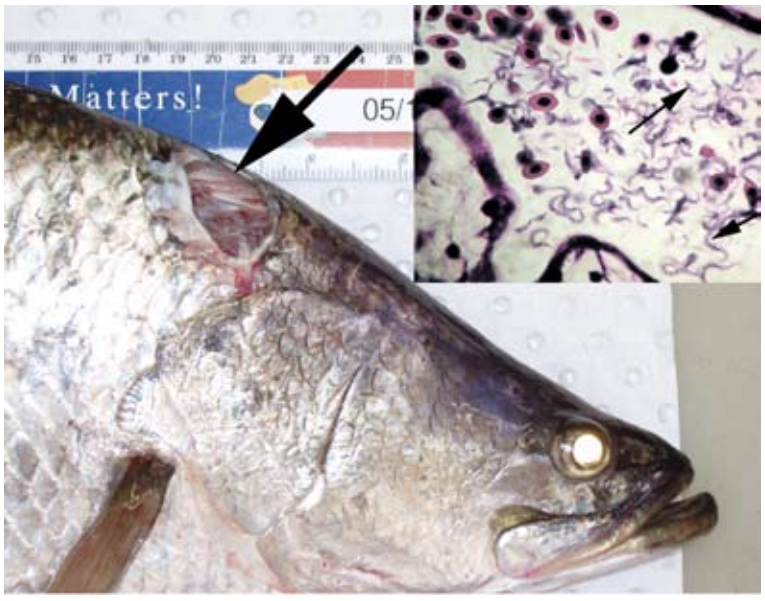


Photo 7.7. Trypanosomosis showing deep ulcer (arrow). Inset: trypanosomes in a blood vessel (arrows)

Affected fish show lethargy, incoordination, apparent blindness and death. Exophthalmos with intra-ocular haemorrhage, together with large haemorrhagic ulcers and smaller haemorrhagic erosions of the skin are seen (Photo 7.7). Internally a massively enlarged spleen (splenomegaly) and anaemia characterised by pale watery blood are conspicuous in most cases. Infection resulted in a high mortality. Massive numbers of Trypanosoma sp. are present in blood and tissues and these are readily observed on microscopic examination.

7.5.2.2 Treatment and control

There are no practical treatments for Trypanosomosis. Infection may be derived from infected fish, therefore the intakes of ponds should be screened to prevent entry of potentially infected fish.

7.5.2.3 Prevention

Infection is presumed to occur from non-captive fish so contact with wild fish should be avoided if possible.

7.5.3 Oodiniosis

Infection of the gills and skin with the protozoan *Oodinium sp*. has resulted in low grade mortalities in fish in marine or estuarine waters.

7.5.3.1 Signs of infection

The signs of the disease are similar to cryptocaryonosis where the fish begin scratching or 'flashing'. In heavy infections, fish may be found dead with mucoid, congested gills.

7.5.3.2 Treatment and control

As for *C. irritans*, treatment may be effected by lowering the salinity and/or using copper sulphate.

7.5.3.3 Prevention

As for *C. irritans*, plus thorough drying of pond bottom between crops may assist preventing subsequent outbreaks.

7.6 General quarantine and health requirements

It is important that once fish are observed to be sick or even if they have suddenly changed their behaviour, professional opinion is sought. After a problem has been observed and before a diagnosis has been obtained, the farm must place itself under a voluntary quarantine with restrictions of all movements of fish onto and off the farm. Failure to do so could jeopardise other farming operations, risk contamination of the surrounding aquatic environment and spread of infection to neighbouring farms.

7.6.1 Compliance with aquaculture licence

The aquaculture licence issued by the Department of Primary Industry, Fisheries and Mines contains a number of conditions that the operator must adhere to, particularly in instances of disease outbreaks. These include prompt notification of a disease event.

7.6.2 Barramundi disease control zones

Zoning is an internationally accepted means of restricting the spread of disease between different regions. Barramundi disease control zones have been defined in the Northern Territory to mitigate against spread of disease accompanying translocations of living barramundi within and/or into the NT for aquaculture or restocking purposes. Currently, there are eight NT disease control zones, with each other State and Territory constituting a further seven separate zones (Fig. 7.1).

Barramundi disease control zones are based on zoogeographic, historic, genetic and epidemiological data. Specifically, barramundi occur naturally in the rivers, estuaries and offshore environment across the northern coastline of Australia. Defined river basins and marine and coastal regions provide a fundamental geographic basis for zoning. Historically, there has been limited but significant movement of barramundi both within and into the NT in defined areas.

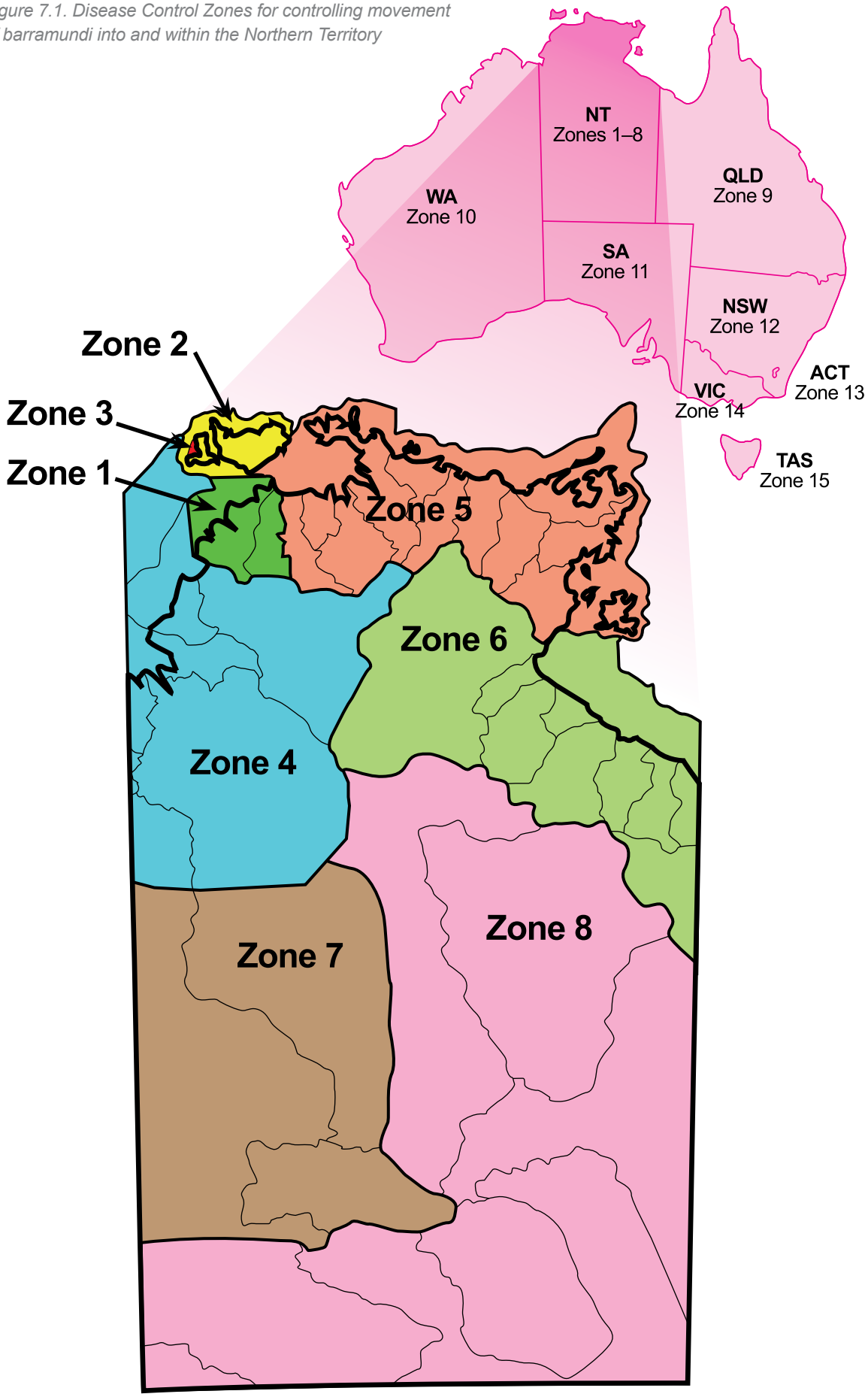
The occurrence and distribution of diseases of barramundi is not uniform across the natural range and significant diseases appear restricted to certain regions. Conversely, the disease status of extensive areas of the NT is not known and zoning is implemented on the basis of protecting these areas from incursions of disease until the true status is known.

Although there are conflicting arguments for the existence, and the importance, of genetically distinct populations of barramundi within the NT, the zoning strategy has also been designed to be precautionary and to protect, as much as possible, the genetic integrity of populations from the different regions.

All translocations of barramundi either within, or into, the NT require a *Permit to Translocate or Import Aquatic Life*. Exports into other States or Territories are subject to the requirements of the importing jurisdiction. Movements of living barramundi within zones, between zones of equivalent health status or into zones of inferior health status may, with specific exceptions, occur without quarantine and health certification procedures. Translocations between zones of non-equivalent or superior health status and importations from other jurisdictions may be permitted subject to specific conditions of quarantine, disease testing and health certification.

Details of zone boundaries and movement restrictions can be found in the Fisheries Policy Document, '*Transboundary Movements of Living Aquatic Animals: A zoning strategy for disease control in the Northern Territory*'. It should be noted that zone boundaries may change in response to new disease information. The most recent information on zoning and translocation should be obtained from NT Fisheries prior to moving any live barramundi.

Figure 7.1. Disease Control Zones for controlling movement of barramundi into and within the Northern Territory



8. Licensing and environmental impact

The increasing environmental awareness of the general public is being reflected by tighter government regulation of any activities that may impact on the environment. Government agencies in the Northern Territory are working together to ensure sustainable development of aquaculture.

To control and manage the impact of barramundi farming on the environment all aquaculture operations in the NT must obtain a licence to operate from the Department of Primary Industry Fisheries and Mines (DPIFM).

8.1 Aquaculture licence

The start of the licensing process for a new aquaculture business in the NT is the preparation of a Notice of Intent or NoI. This basically spells out who they are, what they want to do, how they want to do it and where they want to do it.

The NOI is lodged with Fisheries, and is circulated to the Department of Planning and Infrastructure, and the Department of Natural Resources, Environment and the Arts (NRETA). These Departments, together with advice from Fisheries, assess the merits of the proposal and decide the level of environmental assessment and a range of conditions that may be placed on the development, if it proceeds.

As part of the licensing process all prospective aquaculture ventures must pass environmental assessment, which is usually requested at the level of a Public Environmental Report (PER) or, for large scale operations, an Environmental Impact Statement (EIS).

There are a number of other approvals that need to be obtained by any aquaculture proponent (native title approval or agreement with traditional owners, marine leases etc), but the environmental approval is among the most important and is the one that usually controls or influences all the others.

It is the responsibility of the assessors and the proponent to ensure that the development of fish farms will have a minimal impact on the environment and that development proceeds in an orderly and planned fashion. It is important that the venture must be environmentally as well as economically sustainable.

8.2 Ecological Sustainable Development (ESD)

Firstly it should be acknowledged that all farming activities, including aquaculture, may have some environmental impacts. The farmers and the regulators must ensure that the impacts of the activity are socially and environmentally acceptable. It is the interaction between economic, ecological and social impacts that is at the basis of Ecological Sustainable Development or ESD.

ESD has arisen from the idea of integrating economic development and environmental protection. The concept is based on the recognition that the earth's resources are finite and through a better understanding of the global environment, steps should be taken to halt and perhaps even reverse the negative impacts of human development.

In Australia, the concept has embraced an ecological focus and the Australian National Strategy for Ecologically Sustainable Development defines ESD as:

> *'Development that improves the quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends'*

One mechanism that is being used by the NT Government to assist environmental sustainability is the Environmental Management Plan (EMP) that must be developed for each farm as part of the licensing process.

8.3 Environmental Management Plans

Part of the aquaculture licence conditions stipulates that the farm must develop an EMP to the satisfaction of Fisheries and NRETA. The EMP contains information on the daily operation of the farm, including disease management, waste management, risk minimisation and environmental remediation in the event of problems arising on the farm.

8.4 Environmental impacts of barramundi farming

Impacts of barramundi farming can be broadly categorised into five main areas of concern and they are (in no particular order):

1. Nutrient and waste discharge
2. Escapes
3. Fish meal in aquaculture feeds
4. Disease and parasites
5. Chemical usage

8.4.1 Nutrient and waste discharge

Nutrients

All fish excrete waste nutrients. The fish ingest food and excrete nutrients, especially nitrogen, in the form of faeces, urine and ammonia (via the gills). In a tropical environment one of the important factors to consider is the fate of the nutrients excreted by the fish and the assimilation rate of the nutrients into natural systems. All areas where marine aquaculture is undertaken in the NT are bounded by extensive mangrove forests. The mangroves, together with surface microalgae in the harbours and rivers, have a very large assimilative capacity for nutrients. The assimilation rate of the surface waters of Darwin Harbour has been estimated to be in the region of 0.6 grams of nitrogen per square metre (this does not include the nutrients absorbed by the mangroves). This assimilative capacity, coupled with enormous water flows through the farms has a dramatic effect on nutrient removal and dispersal. On-farm monitoring at the Port Hurd barramundi farm showed

that nutrients released from the sea cages returned to background levels (normal nutrient levels) within 50-100 metres of the cages. Monitoring undertaken at the discharge points of the Territory's marine pond farms has also shown that nutrient build-up is not occurring.

Cumulative impacts

It is important however to consider cumulative impacts on the marine system and while one or two farms on an estuary or harbour arm may not present a problem, each subsequent farm must be assessed for its impact together with all existing nutrient sources. This is one of the reasons why the NT Government has developed a farm site location matrix which helps guide the proximity of one farm to another. Refer to NT Fisheries Policy number: 04/06.

Waste accumulation

Another potential impact of fish farming is the risk of accumulation in the environment of solid matter (uneaten feed pellets and faeces) from the farms. In the case of sea cages these may accumulate under or near the cages and for pond culture they could build up within the pond creating water quality problems.

Waste build-up is really only a problem if the farm site has been poorly chosen. The locations chosen for sea cages in the Northern Territory have a very high water current flow which means there was no detectable waste build-up under the cages. The cages also acted as a fish attraction device and the few pellets that escaped the cages were eaten within seconds. For fish ponds, accumulated wastes can be manually removed at the end of the production cycle and recycled as fertiliser on the land as part of regular pond maintenance.

Farmers also have an economic obligation to themselves to ensure that very few pellets either leave the cage or are uneaten in the pond otherwise they are throwing money away. On-farm feed management is an extremely important aspect of barramundi farming.

During environmental assessment, the hydrodynamics and nutrient assimilation capacity of the area must be examined.

8.4.2 Escapes

Unfortunately it is a fact of life with fish farming that the fish will escape … or at least some of them will. Cyclones, sharks, crocodiles, corrosion, human error are all contributors to this problem. Escapes are more likely from cage farms than they are from pond farms.

As reported in previous Section 5.2.6, the NT's large sea cage farm invested heavily in preventing escapes, especially by installing steel mesh nets which helped overcome the problem of crocodile and shark attacks and also removed the need for an external, large mesh, predator net.

Damage to the cage systems from cyclones and storm surge is much more difficult to manage than the problems caused by predators. Between 2001 and 2006 considerable advances were made to the mooring structures and engineering of the cages themselves in an attempt to minimise losses due to environmental factors. Even with these improvements, losses from the cage system could not be ruled out and it is therefore important to ensure that if the fish do escape there are no long-lasting environmental consequences.

Possible effects of escaped fish include interactions with wild fish and either breeding with them, and potentially altering the genetic makeup of the local population, or by predation and competition for resources with wild fish.

There is a wide divergence of opinion on the effect of released fish on natural genetic variance. Some geneticists say that for the wild gene pool to be compromised the release rate would have to be enormous and that even then it would be debatable as to whether it would cause a problem.

The risk of escapes from marine pond farms, although still present, is much reduced compared to cage farms. The main escape risks from pond farms are due to birds picking up the fish and dropping them off site and from flooding of the ponds or failure of pond screens.

In the NT potential genetic impacts of barramundi farming are managed by only culturing fish from the local population and also by using a large number of different parents, maximising genetic variation in the farmed fish as much as possible. It is also known that escaped fish from cage farms tend to stay in the immediate area and in the future it is likely to become a requirement that farms have an escaped fish response plan in order to retrieve as many escaped fish as possible and minimise any adverse impacts.

8.4.3 Fish meal in aquaculture feeds

All formulated fish feeds contain a variable level of dry fish meal and fish oil. The actual percentages depend on the species of fish being fed.

According to the Food and Agricultural Organisation (FAO), annual world fish meal production is reasonably constant at 6 million metric tonnes and has been about this level for the last twenty years. Fish meal is manufactured from industrial fisheries, principally located in South America and Europe. Small, bony and generally inedible (to humans) fish such as anchovetta, capelin and sand eels are pressed and dried into a brown meal. Fish oil is a by-product of this process.

Fish meal has traditionally been used in pig and poultry feeds. Since the increase in aquaculture production over the last twenty years the proportion of fish meal used in pig and poultry feeds has declined dramatically and much of the fish meal previously used by these sectors is being diverted to fish feed manufacture. Some argue that aquaculture has put increased pressure on wild fish stocks, but so far this isn't necessarily the case, rather it has been a diversion from one end user to another.

The sustainability of using fish meal in aquaculture diets

The majority of the fish meal and fish oil fisheries around the world are carefully managed to be sustainable, with strict quotas, gear restrictions and closed seasons commonly implemented. Many of the fisheries are monitored on a daily basis and this monitoring is closely linked to the implementation of the management measures.

The relative constant level of fish meal production over the last twenty years is used by the feed industry to support the argument that the fishery is being managed for sustainability.

Conversion ratios of wild fish to farmed fish

Another criticism levelled at the aquaculture sector is that it does not make sense to harvest wild fish to turn them into feed for farmed fish. The argument against feeding fish to fish is based on the rate of conversion of wild fish into farmed fish – the so called 'fish meal trap'. For the carnivorous fish species that are farmed, such as salmon, snapper, barramundi, bream etc, it can take between 1.5 and 6 kg of wild fish to produce one kilogram of farmed fish and the argument is made that feeding 'fish to fish' wastes protein and therefore that aquaculture is not necessarily a net contributor to world seafood supplies.

Using barramundi as an example to explain this further:

- It takes about 5–6 kg (wet weight) of whole bait fish species to make 1 kg of dried fish meal.
- One kilogram of barramundi fish feed contains approximately 25 per cent fish meal.
- A well-fed farmed barramundi (assuming it is fed at the correct rate) will convert between 1.2 to 1.6 kg of pellets into 1 kg of body weight. Some farms do better, some worse, but this is an average figure.
- Doing the maths backwards, a farmed barramundi, on a well run farm, converts between 300 and 400 g of fish meal into each kg of body weight.
- This in turn translates to somewhere between 1.5 and 2.4 kg of wild fish used to make the fish meal.

The counter arguments to the wastefulness of using fish meal in aquaculture feeds make reference to the sustainability of the wild fishery and its strict management regime; the fact that largely inedible wild fish are turned into premium fish; and that the fish meal fishery existed before the rise of aquaculture and even if aquaculture stopped using fish meal today the fishery would continue at its present production level and the meal would once again be used for land based animals, which have a worse (higher) food conversion ratio than farmed fish.

The future of fish meal and fish oil in aquaculture diets

Whoever is right, those that say using fish meal in aquaculture is wasteful or those that say its use is justified, the fact of the matter is that aquaculture production around the world is growing exponentially and fish meal and fish oil supplies are finite. Fish oil supplies are supposed to reach full utilisation by 2010.

Everyone in the industry knows this and there are many projects underway around the world looking at fish meal and fish oil replacements and/ or supplements in fish diets. Some of these solutions may create more problems than they solve (e.g. genetically modifying crops to produce fish oil) whereas others are relatively simple, practical and achievable such as harnessing the omega-3 fatty acid (one of the key components in fish oil) production capacity of marine bacteria, fungi and microalgae.

Fish meal replacements based on plant and animal protein are also being thoroughly researched and the implementation of these replacements is well advanced. Recently the price of fish meal has risen rapidly which has had the effect of suddenly making the use of many sources of replacement protein more cost effective.

The guiding principle for all this research is that the products must remain acceptable to the consumer and not compromise fish health or public food safety. Basically the fish still need to taste like fish and to retain the health giving benefits of eating fish.

8.4.4 Diseases and parasites

Diseases, and the threat they pose to barramundi culture, were discussed in detail in Chapter 7. The key points for the NT are:

Stock produced from the DAC is thoroughly checked for disease prior to delivery to the farms. The NT also has very strict translocation protocols to control the movement of fish stocks onto and between the fish farms.

Despite these controls it is still possible for disease to develop on the farms and to become magnified, leading to loss of stock. It is also possible at other times for the fish to resist the pathogens. The key here is 'stress'. A stressed farm fish is more likely to be diseased or susceptible to disease than an un-stressed fish. A good fish farmer takes every effort to ensure their fish are not stressed, but despite this, events such as cyclones, spring tides, movement or grading of fish etc can lead to stress and outbreaks of disease. Whatever happens on-farm, the fish outside the farm are less likely to be 'stressed' and are therefore more resistant to disease. They are instead a reservoir for disease organisms but usually at a sub-lethal level. This means that the fish outside the farm are more of a threat to the farm than the farm is a threat to them.

The NT aquaculture industry is VERY concerned about disease and takes every effort to keep it out of the farms.

8.4.5 Chemical usage

It is a common misbelief that fish farms in Australia are major sources of chemical pollutants such as antibiotics, anti-fouling, anti-parasitics etc.

Whilst it is true that some fish farms do on occasions use antibiotics, so does every other form of primary production when it is appropriate to do so. When a fish farm is confronted by a disease there are three courses of action available, 1). Do nothing and hope it goes away, 2). Have the fish already vaccinated so that they are immune to the problem in the first place or 3). Use appropriate antibiotic or chemical treatment.

Usually option 1 is not an option as problems can escalate and losses can become significant very quickly.

Option 2 is the preferred option, but because of the newness of the industry, the fact that many diseases are still emerging, and that vaccine development is expensive and slow, means that this is often not a viable option. The DAC now has the ability to routinely vaccinate barramundi against three known bacteria and is the first hatchery in the country to do so. Vaccine development will continue to be strongly supported in the NT.

Although antibiotic and chemical use is actively discouraged in the industry, the current lack of vaccine development means that option 3 is often the only available course to take. The only antibiotic recommended for use on-farm at the moment is oxytetracycline. It is normally administered in the feed and must be prescribed by a veterinarian. One of the problems with in-feed antibiotic treatment is the fact that the fish are sick in the first place and sick fish may have reduced appetites which interferes with the effectiveness of the treatment. Luckily barramundi are usually great eaters and it takes a lot to put them off their feed! Nevertheless it is still possible for antibiotics to enter the environment by leaching from the feed or by excretion from the fish.

Accumulation of antibiotics in the environment can lead to the development of resistant bacterial strains and end up causing more problems than it solves. This is why they must be used judiciously. One of the advantages of using oxyetracycline for bacterial disease treatment is that it breaks down rapidly in water and has a relatively short retention time in marine or freshwater sediments.

The use of antibiotics must also be accompanied by a 'withholding period' following treatment. This is the period of time necessary for all traces of antibiotic to be eliminated from the fish. Failure to implement a with-holding period and the subsequent detection of antibiotic residues in the fish would result in the loss of markets which could impact on the whole industry.

The other chemicals often mentioned as emanating from sea cages are anti-parasitics and anti-fouling.

Anti-parasitics are often used in salmon farming to control organisms such as sea lice. So far the farmed barramundi in the NT have not had any problems with sea lice but there have been problems with organisms such as *Oodinium* and *Crytocaryon*. Treatment for both these problems has been limited to either fresh water baths or low level treatment with copper sulphate.

Anti-fouling is not used on fish farms in the NT other than on the work boats. The use of galvanised steel nets on the sea cage farm prevented any fouling build up and eliminated the need for costly regular net cleaning or for anti-foulant usage.

All chemical usage and storage on NT aquaculture farms is governed by each farm's Environmental Management Plan.

8.4.6 Other impacts of barramundi farming

There may also be a number of other real and perceived effects of barramundi farming. Many of them, such as possible interaction with marine mammals, visual interference, interactions with recreational fishers, etc, are site specific and can be dealt with during the environmental assessment process. It is recommended that all aquaculture proponents undertake a very thorough consultative phase as they develop their proposal. It is through solid consultation that many of the issues surrounding farm development can be resolved. Basically everyone who has an interest in the area has a right to be consulted and if the consultation is handled correctly many of the arguments against the farm may be able to be effectively addressed and a strategy to manage impacts can be developed.

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