Australian Prawn Farming Manual

Health Management for Profit

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The Department of Primary Industries and Fisheries (DPI&F) seeks to maximise the economic potential of Queensland's primary industries on a sustainable basis.

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Acknowledgments

This publication is the product of considerable effort by a diverse range of people with extensive experience in both the Australian and international shrimp farming industry. The content of the *Australian Prawn Farming Manual* is drawn from their knowledge as prawn farmers, research scientists, consultants, government extension providers or trainers who assist in the development of the prawn farming sector. Contributors were invited to provide written sections on their specialised area of expertise, and the draft document was collated and edited according to a plan formulated by the Prawn Manual Steering Committee.

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Alistair Dick has spent most of his working life with Seafarm Pty Ltd, Australia's largest prawn farming company based in North Queensland. He started out as a Pond Technician and now manages Seafarm's Mossman 25 hectare prawn farm facility. Alistair has managed environmental monitoring & management for the company's operations and investigated new technologies such as zero water exchange and intensive growout methods for banana prawns. He has a Bachelor of Applied Science and a Diploma of Aquatic Resource Management, and completed disease pathology and diagnostics courses at the University of Arizona. Alistair is also a member of the Australian Prawn Farmers Association R&D Committee.

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Chris Robertson has been the Senior Aquaculture Development Officer with DPI&F in Cairns for the north Queensland region since 1995. He was a prawn farmer for 11 years, commencing in 1983 as the founding Manager of Seafarm Pty Ltd, now Australia's largest prawn farming company based in North Queensland. He then developed and operated his own prawn and barramundi farm near Cardwell. He has more than twenty years of experience in tropical aquaculture, research, development and extension, and in the facilitation of industry investment. He has a Bachelor of Science from University of Melbourne with an Honours Degree in Marine Biology from University of Tasmania, and has provided aquaculture consulting services in Australia and SE Asia. Awarded a Churchill Fellowship in 1999 to investigate recirculation technologies in shrimp farming, he successfully developed and trialled Australian prawn farm recirculation methods with industry.

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Serena Zipf has a Degree in Arts/Law and is co-owner of Rocky Point Prawn Farms near Brisbane and Bundaberg, as well as the Rocky Point prawn hatchery. She has extensive management experience in the Australian prawn farming industry and has worked hard to promote and highlight innovative environmental practices, seafood quality and marketing programs. Serena has been an active member of the Australian Prawn Farmers Association, is an independent director of Queensland Sea Scallops, and a member of the National Food Industry Strategy's Trade & Market Development Committee.

Using this manual

Throughout this manual the following coloured boxes contain:

Important facts

Useful information

Handy hints

Part 1

Establishing a prawn farm – what you need to know

Prawn farming in Australia

Overview of the prawn farming industry

The Australian prawn farming industry produces more than 3500 tonnes of prawns a year, valued at over $47 million, and is based on approximately 900 hectares of ponds and 12 hatcheries (Lobegeiger and Wingfield 2004) (see Figure 1.1). The industry is based primarily in Queensland, the bulk of production being in north Queensland between Ayr and Port Douglas. Other significant prawn farming areas in Queensland include Mackay, Bundaberg and the Sunshine Coast and Gold Coast regions. Prawn farms in New South Wales are located in the Northern Rivers region from Ballina south to Coffs Harbour. Prawn farming is also conducted in the Northern Territory near Darwin and is under development on the northern coastline of Western Australia.

Figure 1.1 Prawn farming areas in Australia

The industry is mostly based on the farming of three endemic species:

- the black tiger prawn *Penaeus monodon* (Figure 1.2)
- the banana prawn *Fenneropenaeus merguiensis*) (Figure 1.3)
- the kuruma prawn *Penaeus japonicus*.

Figure 1.2
The black tiger prawn
Penaeus monodon

Figure 1.3
The banana prawn
Fenneropenaeus merguiensis

Other species such as the brown tiger prawn *P. esculentus*, the school prawn *Metapenaeus* spp. and the eastern king prawn *P. plebejus* were trialled or grown in the pioneering stages of the industry but did not provide significant production results or commercial success. Various other endemic species that are commercially farmed in other countries, including the grooved tiger prawn *P. semisulcatus* and the indicus prawn *P. indicus*, have also been trialled in Australia without any significant uptake in the industry. The three main species listed above have been adopted in the industry primarily due to a combination of their strong market value and successful hatchery/growing technology that is suited to Australian conditions.

Prawn farming is well established as an industry in many other tropical and subtropical regions of the world, although it is more generally known as shrimp farming in the Americas, Asia and the Middle East. The world prawn farming industry grew dramatically from the early 1980s and by 2004 farmed prawns accounted for approximately 2 million tonnes, or 50 per cent of world production. Because of the enormous demand, over-extended fisheries were unable to supply their markets, and shrimp farmers doubled the world's supply of shrimp in 30 years (Rosenberry 2004).

During the pioneering stages of industry development, Australian prawn farmers trialled farming methods used in other countries such as Taiwan, Thailand, Indonesia and the USA, but then modified the techniques to suit the Australian environment and workplace. Considerable industry and government investment in research and development (in genetics, growout technology, environmental and health management) has also provided a steady stimulus for the industry to expand. Despite its current small size in terms of gross production, the Australian prawn farming industry is now considered internationally as a leader in best practice management and product quality.

Using an international scale of classification (Table 1.1), virtually all Australian prawn farms are managed as intensive farms.

Table 1.1 Levels of intensification in international prawn farming

Level	Feeding	Aeration	Yields in kg/ha
Extensive	no	no	less than 500
Semi-intensive	yes	no	500–2500
Intensive	yes	yes	2500–10 000
Super-intensive	yes	yes	10 000+

In Australia, the seasonal staging of crops on different farms varies depending on location, marketing strategy, hatchery supply and other issues. Farms south of Mackay tend to produce one crop a year during the summer (because it is too cold in the winter months), whereas farms in the tropical north have the potential to produce two crops. However, many farms in the north stock one crop per year to capitalise on the higher fresh prawn prices around the Christmas period.

What is being a prawn farmer *really* like?

Prawn farming is a high-risk, capital-intensive industry that is site-specific and requires technical expertise. It is clearly more difficult to be financially successful in prawn farming than in conventional farming of livestock or horticulture. If you want to become a prawn farmer, you need to do a great deal of planning and consider financial and lifestyle issues.

Be prepared to work long hours, and forget about the idea of public holidays and weekends — prawns must be fed and looked after! On the positive side, the work is varied and done outdoors, and tasks change throughout the season, although every farmer is glad to see the last day of harvest. Due to the dynamic environment in which the prawns are raised, however, farmers must understand and manage the sudden changes in conditions that can occur at any hour of the day or night.

Prawn farmers must be aware that they are in an agribusiness industry; they should not just concentrate on production, but must also have a firm hand on risk management, marketing and liaison with various government bodies. And it helps if they have a healthy risk threshold!

The success of any aquaculture venture depends on sound initial planning. This is especially important in prawn farming, and should involve the development of a comprehensive business plan that identifies the enterprise goals, market feasibility and the requirements for production. Once these forecasts have been made, it is then possible to predict the financial feasibility and make cash flow projections.

Effective business planning will also assist in the selection of an appropriate site, generally the most critical step in establishing an aquaculture facility and a successful aquaculture business (see Chapter 2). In general, the business plan will dictate the design and size of the farm and specify the equipment and infrastructure required.

Four factors determine the success of any aquaculture venture:

- the production economics, which determines the profits of the venture
- the marketing of the product, which boils down to what price you can get, based on quality and quantity
- the comparative advantages that your product possesses
- the economic opportunity cost of undertaking aquaculture compared with other available activities.

Commercial aquaculture is driven by profit. By choosing to grow prawns for a living, you will be guided primarily by economics. However, technology can be a limiting factor, for example, in the availability of seed stock from hatcheries. Without considering risk, a high-value species would be chosen over a lower-value species. Purely commercial ventures require significant investment and are inherently risky, whereas family or small-scale aquaculture ventures have lower capital and technical requirements, are more easily managed and can provide a relatively stable return.

A wide range of commercial, regulatory, environmental and technical issues involved in establishing a new prawn farm need to be considered. Appendix 1 has more information on these factors, including *PrawnProfit* software that enables financial decision making for new and existing prawn farming ventures.

At a glance

- Prawn farming is a high-risk industry with a strong reliance on technology.
- It is imperative to find a good site. Many aspects of site selection are important, but good water quality and suitable soils for pond construction are vital.
- An important part of establishing a prawn farm is financial analysis of the business model you are considering, depending on the size of the farm, stocking densities etc. Before you commit to significant investment, economic analysis models such as *PrawnProfit* (see appendix 1) can help you in the assessment of business viability.
- State and Commonwealth governments have a wide range of information (technical, legislative and economic) to help you decide whether to invest in prawn farming.

Chapter 2

Site selection and farm establishment

Farm location and topography

The ideal site for a prawn farm is difficult to find and often just as difficult to establish when concerns about conservation and coastal development are taken into consideration. Most of the coastal areas suitable for prawn farming are popular residential locations. Conflicts with local stakeholders during the approvals process often delay the development of new farms, and sites located in more isolated (but not remote) areas are often preferred. Researchers at the Department of Primary Industries and Fisheries (DPI&F) in Queensland have also looked at the feasibility of inland prawn farming, using saline groundwater to farm black tiger prawns in low salinity systems. This may open up many more areas for prawn farming in Australia.

The regions suitable for coastal pond-based prawn farming in Australia stretch from Coffs Harbour in northern New South Wales along the northern coast of Australia to Geraldton in Western Australia. Prawn farms in arid coastal areas usually experience freshwater shortages and/or high salinity problems due to high evaporation, while those in high rainfall zones (for example, estuarine sites in the wet tropics in north Queensland) can have problems with low salinity or extended periods of freshwater during wet seasons.

The optimum topography for prawn farming is flat land that is less than one kilometre from access to estuarine or marine water, with elevations of more than 1 metre but not more than 10 metres above the highest astronomical tide (HAT) level. Ponds constructed in land less than 1 metre above HAT cannot be drain harvested during high tides, while very elevated sites require more energy for pumping and hence impose higher costs. The farm site should also have access to mains electricity (three-phase), roads and, at the very least, a regional business community that provides accommodation, shops and recreational facilities for staff. Travelling time from a hatchery to a farm site should also be less than 12 hours (preferably less than 3 hours), including air freight or road travel times.

Water supply — quality and quantity

Water quality at the intake point is a vital consideration in successful prawn farming. The site should have access to an unpolluted estuarine or marine water supply, with an optimum salinity range of 15 to 25 parts per thousand (ppt). Seasonal effects of rainfall and evaporation can cause fluctuations, but salinity should not be less than 1 ppt or greater than 35 ppt (average salinity level for seawater). Areas of tropical coasts that experience extended dry seasons will be particularly prone to high salinity in ponds, which can slow growth rates and subsequently increase production costs.

The optimum range for pH of the water source is 7.5 to 8.5. The pH of estuarine waters can be affected by acid sulfate soils and other local soil factors. Water sources affected by significant coastal pollution from industry, urban areas, agriculture and water treatment facilities should be avoided.

> The unit of measurement of salinity used in prawn farming is 'parts per thousand' or 'ppt' — essentially 1 part of salt to 1000 parts of water.

A very important aspect of the intake requirements for a successful prawn farm is access to sufficient quantities of seawater. Before choosing a location as a pump station site, you may need to determine whether sufficient daily volumes will be available for the design and size of the farm you are considering. The volumes available may be determined by the position of the intake point in a tidal estuary, where you can pump water to fill ponds only at high tide. Your site investigations will have to include calculations to determine whether a pump station can provide enough water for your farm.

Site and soil conditions

When choosing a potential aquaculture site it is essential to consider the soil properties. Some prawn farms have failed or faced difficult environmental management issues (such as seepage into groundwater) because of the use of soils with poor construction characteristics. By selecting sites with good soil properties, prawn farmers can increase profitability by reducing:

- pond maintenance, repair and potential environmental costs
- the need to correct for water leakages and excessive erosion within ponds
- pumping costs
- the potential for negative impacts on surrounding groundwater.

Soils suitable for pond construction and the farming of prawns must possess properties that allow for:

- economic construction of pond embankments
- growth of beneficial algal blooms
- water-holding and load-carrying capacity with a post-construction seepage rating of less than 1×10^{-8} metres/second
- favourable chemical growing conditions.

Both physical and chemical properties of the soil must be assessed when determining whether a site is suitable for the development of a prawn farm. The procedure consists of taking soil samples for analysis of various geotechnical parameters (such as percentage clay content and elasticity) to determine the suitability for pond construction. Soil sampling and field/laboratory testing can be used to evaluate:

- soil classification
- load-bearing capacity
- erosive potential
- potential for dispersion when water is added
- permeability
- soil pH
- presence of potential contaminants
- presence of acid sulfate soils
- soil organic matter content.

Earthworks for construction of ponds will account for the largest capital cost in a new prawn farm and can therefore have a significant bearing on the overall financial viability of the business. The earthworks cost can be highly variable if the soils are inconsistent and additional clay material has to be transported to the site to seal pond floors to ensure minimal seepage. An estimate of the construction cost, derived by conducting a rigorous sampling of the soils on a grid over the site, should be incorporated in the overall cost of ponds.

In general, soils for earthen pond construction should have:

- adequate clay content to eliminate or reduce loss of water by seepage
- low organic matter content
- pH of 5.5 to 8.5.

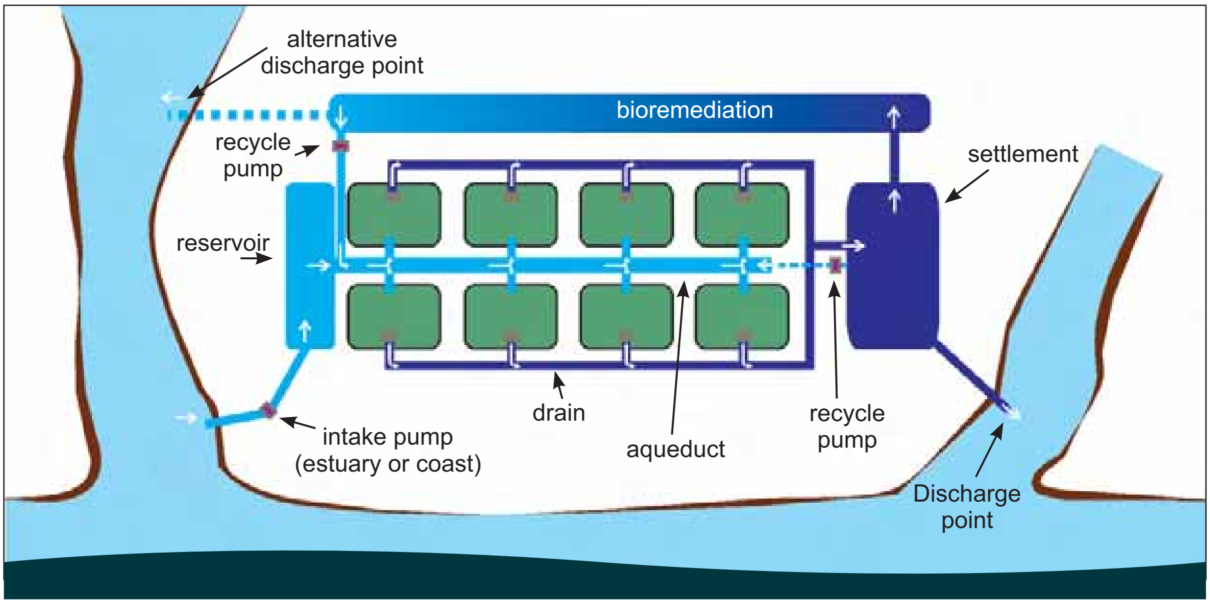
The Queensland Department of Primary Industries & Fisheries publication *Guidelines for the Construction and Operation of Earthen Containment Structure for Aquaculture* provides detailed guidelines for undertaking soil surveys, as well as discussion of both field and laboratory methods for testing soil engineering and chemical properties.

Problematic soils with the potential to interfere with the construction and operations of pond systems, or with the potential to be toxic to cultured organisms, include:

- acid sulfate soils
- dispersive soils
- expansive clays
- organic soils
- structured (aggregated) soils
- soft/compressible soils.

Soil types can vary enormously within a single site. Where unfavourable soils have been identified in parts of a site, it is often advisable to avoid any disturbance of them. Sites dominated by these types of soils should be avoided. Ameliorative techniques can be used to improve the soil quality and/or water-holding capacity, but these treatments are often costly. Given the enormous volumes of earthmoving required when constructing a prawn farm, it is not

Figure 2.1 A typical prawn farm layout



advisable to attempt to correct geotechnical problems with soil amelioration, for example, by adding bentonite. Shifting clay from other locations to seal ponds may also be very expensive and must be considered in the overall capital expenditure budget.

Farm design

Australian prawn farms are typically based on earthen ponds that are constructed in a layout that allows distribution of intake water by gravity through an aqueduct system, as well as drainage to the licensed outlet point by gravity (see Figure 2.1).

Growout

Most growout ponds have the following characteristics:

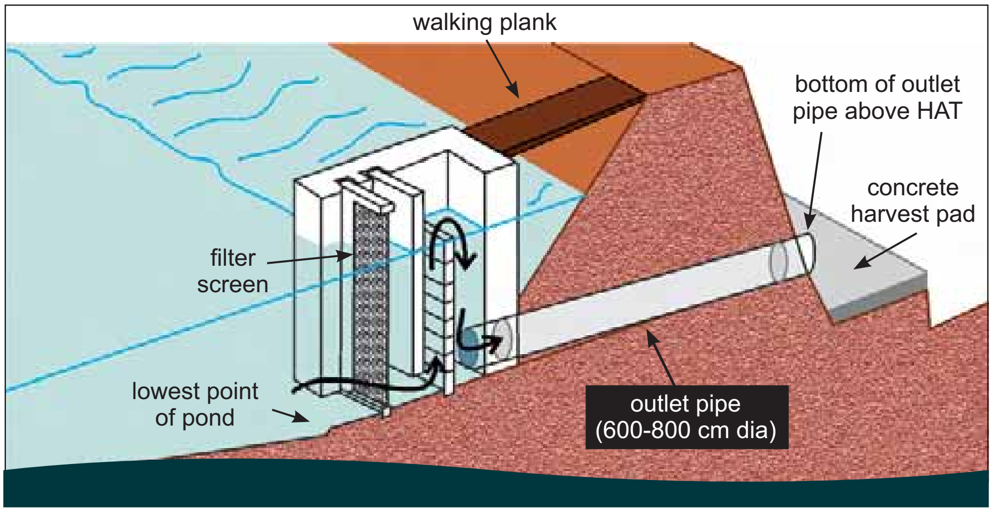
- they are approximately 1 hectare in area (some ponds are as small as 500 m^2 or as large as 2 hectares)
- they are roughly square with rounded corners, and one corner usually includes a concrete or gravel ramp for vehicle access. Tight corners or 'dead end' areas should be avoided to maximise water movement within the pond
- pond walls are usually sloped at 2 to 2.5:1 and can be lined with high density polyethylene black liner to protect against erosion (see Figure 2.2)
- three-phase electricity outlets (with approved safety switches) are located around the pond walls to enable pond aerators to be connected by cable
- four or more jetties are installed around the pond perimeter to provide access to monitor feed trays and water quality (see Figure 2.3)
- the pond floor is sloped at approximately 1:100 towards the deepest part where the outlet is situated

Figure 2.2
HDPE black plastic liner installed on a pond wall to minimise erosion from wind action and rain

Figure 2.3
Jetty for inspecting feed trays

Figure 2.4
A 'monk' water control and outlet structure

Figure 2.5 How a monk enables water screening, control and outlet for water exchange and harvesting of a prawn pond



- the outlet is constructed as a 'monk' that incorporates three slots for insertion of screening to keep the prawns in, rear level boards to hold the water in until harvest, and middle boards to channel water to drain from the floor of the pond (see Figures 2.4 and 2.5).

The intake pumping system (Figure 2.6) can be located directly on the bank of an estuary or coastal foreshore if there are no access problems caused by mangroves or other obstacles. Otherwise, an excavated channel or short submerged pipe system may be required to deliver water to a pump station that can pump water to the distribution system, such as an aqueduct. The intake pump should be located where it will enable the best possible water regime for the site in terms of:

- water quality — best salinity range, least influence of pollutants from upstream or downstream
- water quantity — the pump intake foot valve should be at the deepest site of the water source to avoid pumping dry at low tides and to be able to operate on all tide levels. Locating the pump so that it has the shortest possible distance for suction lift and overall distance from source to aqueduct or reservoir will improve the efficiency of pumping.

Figure 2.6 Typical prawn farm intake pump systems

Figure 2.7 An aqueduct channel delivering water to the growout ponds

Storage and water delivery

Distribution of water to the different ponds should be by an aqueduct system that is fed directly from a pump station or from a reservoir. An aqueduct is best built as an earthen canal or wide raceway system that is higher than the pond walls so water can flow freely in large volumes to any particular pond on the farm (Figure 2.7). Although you may think underground pipes would be cheaper and require less space than an aqueduct, they are generally found to be constrictive, use more energy (and therefore are more expensive in terms of power usage) and are unable to deliver sufficient water when you need it most.

It is recommended that the distribution system also include a reservoir (Figure 2.8) of significant volume (approximately 10 per cent of total farm pond volumes) so that intake water is stored and 'aged', and can be stabilised before delivery to a growout pond.

Figure 2.8 Pumping water into a reservoir

Figure 2.9 Harvest cage installed at the pond outlet

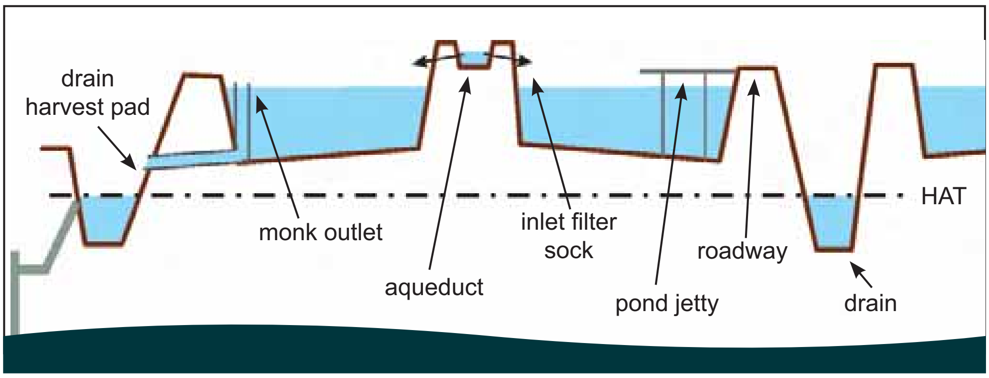
The inlet pipes from the aqueduct should be installed above the pond waterline to enable the use of 'filter sock' screens that can be kept dry when not in use (see Chapter 4). The inlet into each pond should have a delivery capacity of approximately 100 litres/hectare/second for rapid pond filling and water exchanges.

Drainage and roadways

A drainage system needs to have sufficient width and capacity to collect pond water discharged during water exchanges and from drain harvests, and deliver it to a settlement and/or bioremediation pond system for water treatment before release at the licensed discharge point. The drain point from each pond should have enough room for a harvest cage and access from the driveway above by steps and/or by crane to lift harvested prawns up to ice bins (Figure 2.9).

The majority of the roadways around the farm should be laid with gravel to minimise erosion and sediment runoff into the ponds during wet seasons (this

Figure 2.10 Cross-section of a prawn pond showing the water delivery and drainage system



can affect the algal blooms). It is imperative that gravel be laid on the main access roadways which carry heavy daily traffic (for feeding sessions, feed tray checks, water quality monitoring etc.).

The pond walls above the waterline should be grassed to protect the walls from erosion and make them durable. A layer of topsoil deposited on the walls during the construction phase and provision of initial irrigation will allow grass to grow quickly when the ponds are new.

If possible, the top levels of all pond walls and roadways should be the same (that is, the same distance below the aqueduct level). This will help in estimating the flow rates of water to each pond and make it easier to split the flows when more than one inlet is open (Figure 2.10).

For more information on effluent treatment and recirculation see *Wastewater remediation options for prawn farms*, P. Palmer (ed), 2005, DPI&F publication QO 04018, and *Recirculation Prawn Farming Project — Final Report*, C.H. Robertson et al, 2003, DPI&F publication QO03014

Effluent treatment, recirculation and bioremediation

An effluent treatment system can be used to reduce suspended solids (particulate matter, organic material, sediment) and dissolved nutrients in the effluent before release back into an estuary. This would take place at a licensed discharge point, which would preferably be a water body separate from the intake. A treatment system is required on a prawn farm in order to enable compliance with the conditions of environmental approvals and to achieve operational sustainability within the marine environment. Treatment technologies for prawn farming have been researched extensively. They range from the conventional flow-through settlement pond design to recirculation and bioremediation methods that recycle the pond water, and to the use of filtration equipment to reduce particulate matter in the effluent.

Research and development in the use of conventional settlement ponds has identified and improved efficiencies (Preston et al. 2003; Funge-Smith and Briggs 1998). These studies have provided the scientific knowledge to support

Figure 2.11 Recirculation trials conducted on a prawn farm in north Queensland (modified from Robertson et al. 2003)

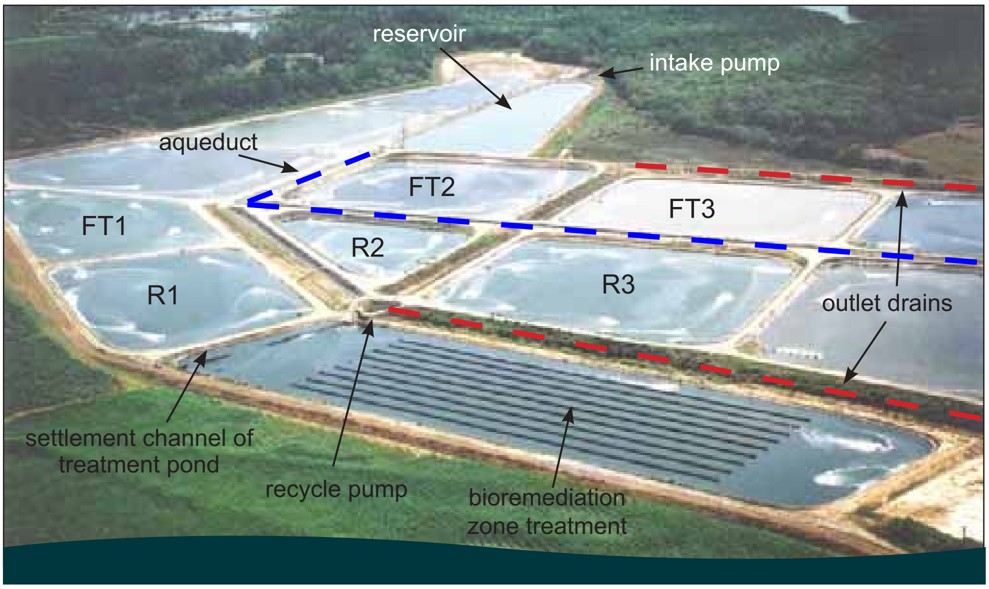


Figure 2.12 A bioremediation pond used in effluent treatment

investigations of recycling of the pond water within a farm where recirculation methods have been confirmed to be effective at commercial scale (Robertson et al. 2003) (Figure 2.11). Similar studies have investigated bioremediation that is aimed at capturing or using the excess nutrients in discharge effluents for additional production of other seafood species, such as mullet or milkfish, banana prawns, seaweed and oysters (Palmer et al. 2005).

Monitoring of discharge water quality and the environmental management requirements for a prawn farm are described in the Environmental Code of Practice for Australian Prawn Farmers, available from www.apfa.com.au.

Settlement ponds are typically required to be approximately 30 per cent of the overall growout area for the farm (for example, 3 hectares of settlement ponds for 10 hectares of growout ponds), and should have provision for the settlement of solids before the potential bioremediation of nutrient load by the culture of other species (see Figure 2.12). You should also consider a recirculation system in the farm pond design so that you can adopt one of the various options of reusing valuable 'green water' for:

- starting new blooms in newly prepared ponds (see Chapter 4)
- improving environmental performance by reducing the nutrient load in the discharge effluent
- reusing water that has already stabilised within the farm (see Figure 2.13)
- recycling when the intake water supply is not available or not suitable (for example, when there is zero salinity)
- quarantining a pond in the event of disease.

Figure 2.13 Using recycled water to fill new ponds (note the green algae colour)

The Australian prawn farming industry has adopted recirculation technology, whereby more than 35 per cent of the total industry growout area has the capacity to recirculate pond water within a farm, either as a 'cocktail' mix with new intake water or for the earlier stages of a crop when salinities are lower.

Essential equipment and resources for prawn farming

Prawn farmers in Australia use a range of equipment that can come from commercial suppliers or be manufactured on site to meet particular farm requirements. The types of equipment generally used are now well established across the industry, but some essential items need to be included in the operation of a typical intensive prawn farm.

For effective and consistent management of a prawn farm it is important to invest in reliable equipment. This can represent a sizeable component of overall capital investment, but it is necessary in order to maintain healthy stock and to ensure that the product delivered to the market is of highest quality possible.

The essential requirements are listed in Table 2.1.

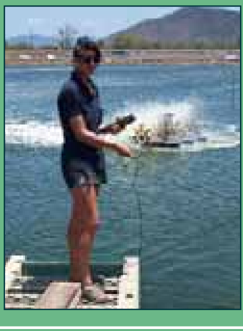
> Prawn farming is a capital-intensive industry and you need good-quality equipment and infrastructure to grow healthy prawns and a quality product for the market.

At a glance

- If you are considering starting a prawn farm it is vital that you make a thorough analysis of the site before you commit to the investment.
- Water quality and quantity, soil types and topography, and many other physical site features are very important factors in determining the potential for overall financial success of a prawn farming venture.
- When thinking about farm design, you should consider many of the proven technologies used in the Australian prawn farming industry, such as reservoir ponds, treatment and bioremediation systems, as well as the wide range of equipment that is necessary in a typical prawn farm.

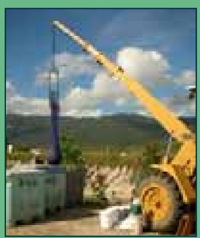
Table 2.1. Essential infrastructure and equipment used on a prawn farm

Infrastructure and equipment	What it may be used for	Important Points to remember
Pond production equipment		
Aerators 	Aeration and water movement in the pond	• Eg. paddlewheel or aspirator type • Aerators can increase dissolved oxygen, concentrate wastes to the centre, maintain a clean pond bottom around the edges, reduce ammonia and hydrogen sulphides, and mix pond water and plankton.
Intake Pumps 	To fill ponds and reservoirs; replace evaporation and maintain optimum water quality during the grow-out cycle	• Eg. "Chinese" mixed or axial flow, single stage, volume pumps; typically 400 mm diameter (see Fig. 3); usually low head and high volume. • Farm design should incorporate pumping capacity of at least 100 litres/second/hectare eg. up to 30% of a pond may need to be replaced within a 4-hr period when tidal water is optimal.
Generators	To generate power in case of "mains" failure,	• Must have capacity to run all of the farm aerators and preferably the pumping system as well. • phase to be compatible with electric Mains • May need more than one placed around the farm to meet standby requirements of all aerators and pumps
Inlet Screens ('filter socks'), with 120 micron fine mesh 	Prevent entry of predators and competitors (larval fish, other prawn species, crabs etc)	• Keep them protected from damage by sticks or other material pumped in • Use a coarse grade net (eg shadecloth) as a primary net upstream of the fine mesh screen • Keep them dry when not in use, out of the pond water to avoid algae growth that will clog the mesh

Pond monitoring (field) equipment		
Dissolved Oxygen meter 	Probe meter that records concentration of dissolved oxygen in the water (mg/L or ppm)	• Most dissolved Oxygen meters operate by a probe with a fragile permeable membrane that is immersed in the water. • The probe membrane must be kept moist and checked regularly. The meters also need to be calibrated regularly to be accurate
pH meter	Probe meter that records the pH of the water	• Most pH meters operate by a probe with a fragile permeable membrane that is immersed in the water. • The probe membrane must be kept moist and checked regularly. The meters also need to be calibrated regularly to be accurate
Temperature		Temperature function is usually included on pH and DO meters
Salinity 		Hand held refractometer (similar to a Brix meter that measures sugar content) or Conductivity function on pH meter
Secchi	To record algae bloom densities and water turbidity	Simple black and white panel on a stick or string, used to measure a depth where the turbidity causes the black and the white sections to appear the same See Chapter 3 on how to use a secchi
Feed trays 	To monitor feed consumption rate, the biomass of the crop and general health of the prawns;	See Feed Management

Office and Laboratory equipment		
Record keeping and data analysis equipment	• Computer • Photocopier • Fax • Software programs	Software you can use : • PrawnProfit (see appendix 1) for financial monitoring • Data spreadsheets for Water Quality and Biomass Monitoring
Sampling equipment	Desk top meter and probe to monitor dissolved nutrients	Ammonia, nitrites, phosphate
	Microscope to monitor prawn health and plankton	Slide microscope with upto X100 objective
	Disease test kits	See 7.5 Health Checks and Disease Testing Kits
Farm Machinery		
Tractor and implements	Pond preparation using blade and discs Slasher for grass slashing Front hoist for lifting equipment eg.shifting aerators Spreader for distribution of lime	A 4WD tractor will have more traction in mud but can leave deep wheel ruts in if used in ponds before they dry properly

Forklift	• Truck loading/ unloading • Shifting insulated bins during harvesting & processing • General lifting of pallets, feed and fertilizer storage	Driver requires formal training certification
4WD Motorbike	General farm access; monitoring of pond water quality	Good for quick access around the farm with less impact on the roadways
Utility and/or small truck	Transport of equipment & supplies, transport of harvest bins to processing building	Corrosion of vehicles on prawn farms is a constant problem
Feed vehicle 	Utility or 4wd motorbike fitted out with hopper and blower to feed prawns	Designed to carry quantities of the different feed grades so different ponds can be fed in one trip
Backhoe	Reshaping of pond walls, batters, drains, surfaces	Multipurpose – can scoop, dig, level and fill
Excavator	Reshaping pond walls, batters, drains, surfaces, lifting of heavy equipment and harvesting cages	Long reach, can be slow moving

Harvesting & Processing Equipment		
Trap and drain harvest nets, scoop nets 	Harvesting	See Harvesting the Crop. You should establish steps for easy access to the cage from the pond wall
Insulated bins for prawns	For chilling prawns in ice as they are harvested at the pond	• Plastic palletised seafood storage bins • One 1000l bin per 500kg of product to be harvested
Insulated bins for ice	For storage of ice pondside	Enough for 500kg of ice per insulated bin
Hoist, excavator or crane system 	To lift prawns from pond level into insulated bins on a utility on pond roadway	• May need lightweight system for lifting prawns from trapnets • Need heavy duty hoist to lift drain harvest nets or cages
Prawn grader		As required for a HAACP approved facility.
Gas prawn cookers	Cooking prawns	(60 – 80 kg capacity);
Ice maker		• > 5 t per day or capacity to match harvest quantity • Alternative is access to local ice supplier
IQF facility	Individual Quick Freezing of prawns	
Cooler and freezer storage rooms		
Scales		Small, medium and large weighing capacities);
Plastic pallets, scoop nets, tubs		

Chapter 3

Key issues for a healthy crop

Biology of black tiger prawns

Prawn morphology

Marine prawns belong to the family Penaeidae. While the morphologies and natural life histories of the various species are broadly similar, the differences between species can often be used to decide on the most appropriate husbandry practices (that is, the farming methods that best approximate conditions in the wild). A prawn farmer can, therefore, benefit from a better understanding of the animals' biology and natural life habits.

Figure 3.1 shows some of the main morphological features of the black tiger prawn *Penaeus monodon*. The sexes in prawns are separate, although the female carries a sperm package (spermatophore) under the plates of the thelycum after mating. Females generally grow faster and larger than males. They are considered to be sexually mature as broodstock 'spawners' in hatcheries (Fig. 3.2) when spermatozoa can be found in the terminal ampoule of the male, or in the thelycum of the female. Size and age are important factors governing their functional maturity. Wild black tiger prawns are reported to mature from an age of 5 to 12 months and at body weights of 35–50 g for males and 68–75 g for females when they can be used as broodstock breeders or 'spawners').

In Australia, trawl fishers usually supply hatcheries with large spawners with total lengths (tip of rostrum to tip of telson) of more than 19 cm for males and more than 24 cm for females. Males and females of this species are thought to live for one and a half and two years respectively. While younger and smaller black tiger prawns can develop immature gametes and mate in culture ponds, their fecundity (number of offspring) has often been found to be too low for commercial use.

The prawn life cycle

In the wild, juvenile to mature prawns typically make seasonal migrations into coastal and offshore waters where they can later spawn planktonic eggs (see Figure 3.3). After these hatch, there are several stages of planktonic larvae lasting

Figure 3.1 The morphology and body parts of a prawn (modified from Motoh 1981 and SEAFDEC 1988)

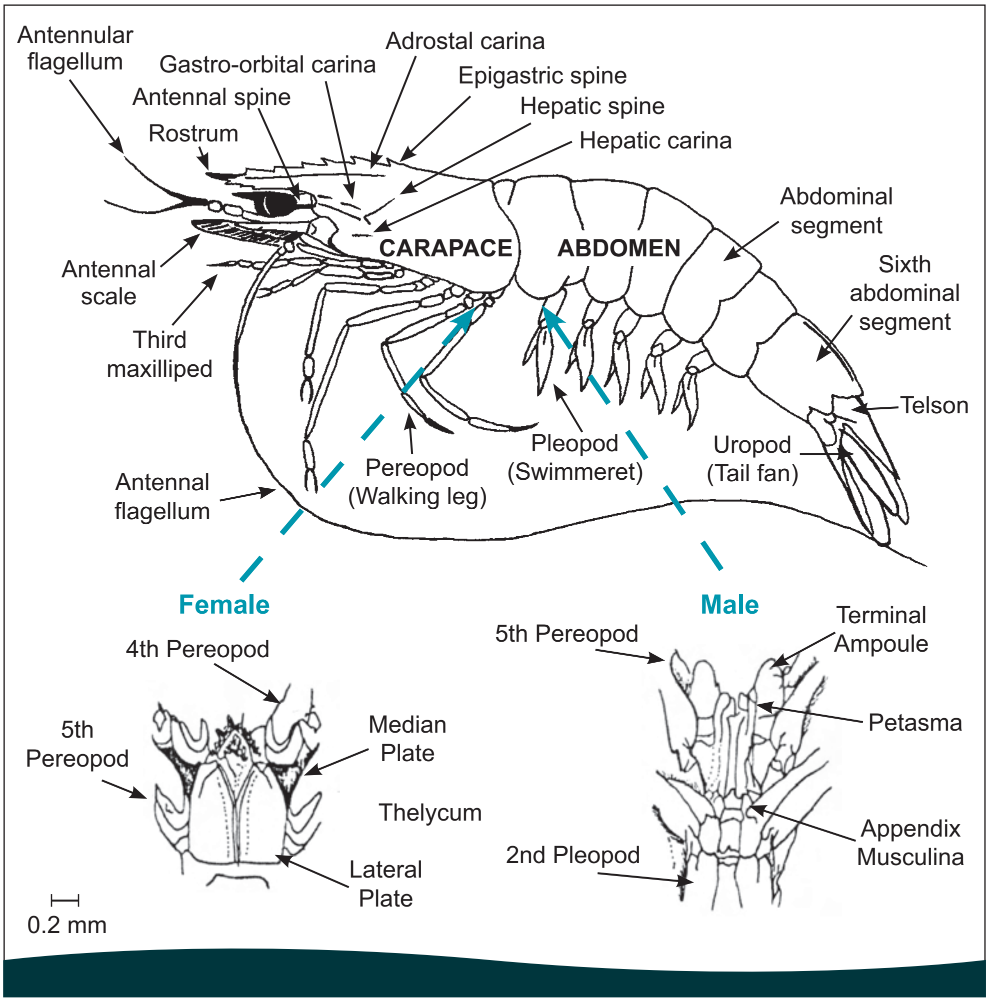


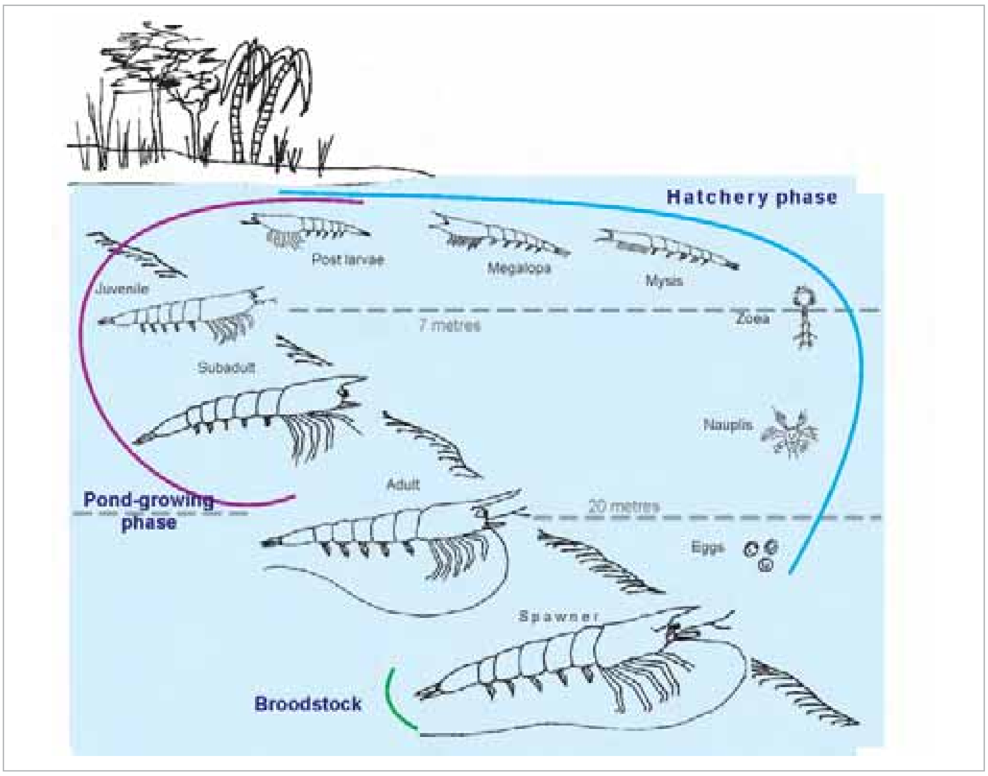
Figure 3.2 Broodstock size female Black Tiger Prawn suitable as a 'spawner' in a hatchery

for about three weeks before settlement on the bottom as postlarvae which then migrate towards inshore nursery areas (such as seagrass and mangroves). To encourage the prawns to mate and spawn in captivity, hatchery operators try to recreate the environmental conditions that are present when the adults move into deeper waters — very low light levels, oceanic salinities and stable temperatures. These environmental manipulations approximate conditions in the species' natural spawning grounds, and assist in reducing stress. In captivity, well-balanced nutrition and artificial stimulation of the endocrine system through techniques such as eyestalk ablation (destruction of a gland at the base of an eyestalk, causing gonad development) can initiate final maturation and spawning. The phases of the moon are also taken into consideration when planning husbandry practices due to their effect on the breeding cycle (for example, moulting and subsequent mating peak in adults around the full moon).

Since the black tiger prawn and the banana prawn are the two most commonly farmed species in Australia, it is worth comparing their natural life cycles (Figure 3.3). While black tiger prawns are known to migrate to relatively deep waters (10–70 m) to spawn, banana prawns are known to spawn in comparatively shallow waters (10–30 m deep), and even within river systems. The black tiger prawn is a much larger and more robust species, whereas the banana prawn matures at about half the size and is more successfully matured in shallow ponds and more easily domesticated for closed cycle breeding in captivity.

Baby prawns or postlarvae (PLs) hatch out of semi-floating eggs and live as part of the sea plankton before settling in the nursery areas of estuaries.

Figure 3.3 The life cycles of the black tiger prawn and the banana prawn (modified from Motoh 1981)



Juvenile black tiger prawns most commonly inhabit muddy creeks and seagrass flats, whereas juvenile banana prawns predominate in mud-mangrove habitats. Both species are known to move into rivers and travel well upstream into areas of occasional low salinity. Their ability to regulate the ionic concentration of their body tissues in variable salinities (by osmoregulation) is particularly well developed in early juveniles, as both species can survive in 3 ppt salinity or less. As they grow, they need to change their external skin (exoskeleton) and go through a moulting process. This is a difficult and stressful event for a young prawn and in an aquaculture situation can lead to disease.

In the wild, juvenile and adult prawns seek higher salinities that are necessary for spawning and larval development, which may explain their reduced low-salinity tolerance at larger sizes. During normal farming practices, where prawns are grown from advanced postlarvae or juveniles through to subadults, they are tolerant of a wide range of salinities. Nevertheless, rapid salinity changes which can exert osmotic stresses should be avoided if possible. Consistent high salinities caused by dry-season evaporation causes prawns to increase the amount of energy allocated to osmoregulation and will result in poor food conversion ratios and slower growth.

Stress is recognised as a precursor to disease. In prawn farming stress can be caused by many environmental variables including unstable or unsuitable water qualities, high densities, handling and inappropriate management regimes. Prawns' reactions to localised events are controlled by eyesight and by chemical 'taste' by sensory organs on the antennae and setae and their simple nervous systems, but many of their important longer-term physiological processes (such as moulting, maturation, metabolism, osmoregulation) are controlled by their

Brine shrimp are crustaceans that are used extensively in hatcheries and many aquaculture industries around the world as a live feed for larval fish and prawns. Also known as 'sea monkeys' or Artemia (most of the species are classified in the genus *Artemia)*, they are easy to cultivate on demand because they can be purchased 'off the shelf' and stored for long periods in vacuum tins while in their cyst stage. Hatching takes 24 hours and in prawn hatcheries they are used in the later stage of the rearing cycle. They are considered an ideal larval feed because of their high nutritional value and can be used as an overlapping feed in the transition of postlarvae from the hatchery tank to the pond (see Chapter 5).

endocrine system through the release and activity of hormones in the circulation system. For example, moult-inhibiting hormone is active during inter-moult periods and final maturation. The frequency of moulting is closely linked with growth and can be affected by pond salinity and water quality changes, but generally it slows as the animals get larger (for example, from once a day in postlarvae to once a month in adults).

Prawns' nutritional requirements also change with their physical development. During the hatchery phase, newly hatched nauplii do not feed, but the next three zoeal stages will feed on phytoplankton and/or fine suspended organic matter. Small zooplankton (such as rotifers and brine shrimp) become increasingly important in the following three mysis stages and subsequent postlarval stages. Postlarvae stocked in well-prepared ponds can feed on a range of naturally occurring planktonic food organisms (such as copepods) and detritus, which remain important until artificial feeds can replace the majority of the stocks' nutritional requirements.

By comparison, juveniles and subadults in the wild are opportunistic omnivores. When they locate food, they pick it up with the first three pairs of pereiopods and pass it to the mouth or to maxillipeds for sorting. Heavily chitinised mandibles surrounding the mouth help to tear and grind food before ingestion. In mangrove swamps prawns derive a large proportion of their nutrition from organic detritus (such as rotting vegetable matter), but as they grow and move into deeper waters they are able to gather an increasing variety of foods (for example, molluscs, small crustaceans and fish, other benthic invertebrates and organic debris). This provides the rich and balanced nutrition that is essential for high growth and quality gamete development (and their later use as broodstock).

Food can be observed in the gut in small prawns because they are semi-transparent; observation can be used to monitor their feed consumption in ponds (see Chapter 6, Figure 6.4).

Pond monitoring for effective management

Collecting and recording information about your crop is a vital part of your day-to-day work and can help you in:

- monitoring water quality and prawn health to pre-empt losses
- predicting water quality trends that may lead towards stress events for the prawns
- determining prawn growth, survival and feed consumption to maximise profitability
- progressive learning about your ponds, the local climate and water quality to make future improvements to your management.

Dissolved oxygen and pH can be tested regularly (usually twice daily) with field sampling equipment designed for use in aquaculture. Various other parameters can be analysed by using laboratory equipment (see Chapter 2) and can be done in conjunction with the monitoring of feed consumption and prawn health. A good monitoring program will give you additional tools to manage growth, survival, health and productivity of the crop as well as financial

A good water quality monitoring program is:

systematic

— it is done at the same place, same time each day or month
— it is conducted repeatedly and consistently

responsive

— information is available at any time
— it is user-friendly so that others can understand it

interactive

— it gives feedback on crop progress
— it enables analysis of disease problems caused by previous 'events'
— it can provide ability for rapid response to situations

predictive

— it can be used for future planning and decision making.

See Appendix 2: 'Water Quality in Aquaculture' DPI Notes, for the ranges of optimum water quality for other aquaculture species.

considerations. Monitoring the overall feed consumption of crops (see Chapter 6) in different ponds is an obvious example of the importance of monitoring for financial analysis.

On a large prawn farm with many ponds or crops at different stages, a monitoring program should be the responsibility of one staff member to maintain consistency. The information should be recorded on field data sheets used for water quality, feed usage and biomass estimates/harvest schedules and transferred daily to a spreadsheet in the office so the information can be analysed and stored safely. A lot of this information can be recorded electronically using a hand-held probe and data logger system, and then downloaded to a computer database each day for rapid interpretation and response (Fig 3.5). Automatic monitoring equipment with cable connections to an office computer data logging system has been trialled in the prawn industry, but was found to be unreliable and inappropriate.

Automated monitoring equipment will never be able to replace the crucial daily observations that you can make with an effective pond monitoring program. By learning more about the dynamics of pond ecology and prawn behaviour, a successful prawn farmer develops an understanding of water quality, prawn health and indicators of factors that can lead to poor water quality and prawn stress. Simply looking at the ponds a few times each day during the monitoring checks is part of that learning process.

Like all farmed animals, prawns will grow and survive well when they are maintained in optimum conditions that are as close as possible to those in their natural environment (see Chapter 4). Appropriate water parameters for the black tiger prawn are listed in Table 3.2. Anything outside these parameters will compromise growth and feed conversion.

Pond water quality management

Prawn farming is intensive animal husbandry, and like any animal, prawns need a stress-free environment for optimal growth. Many environmental factors can induce

Figure 3.5 A hand held water quality data logger and probe system, with secchi attached below the probe.

stress, but stable conditions within an acceptable range of parameters is one of the keys to success. Poor water quality, occurring either as a sudden event (or 'spike') or extended over time, will usually lead to disease problems and/or poor growth.

Australian prawn farmers have found that to maximise growth and minimise the risk of disease, it is best to exchange water in the ponds only when necessary and to provide it as slowly as possible. Most prawn farmers average less than 3 per cent a day over the entire crop. As described in Chapter 5, the first exchange may not be until day 50, but it is also important to ensure that the timing and amount of exchange are related to the quality of the incoming water, the amount of aeration in the pond and the skill of the manager.

Many of the water quality parameters are interlinked. For example, the amount of oxygen that can be dissolved in water is lower at high temperatures

Table 3.1 Solubility of oxygen in water at various temperatures and salinities *Modified from Boyd 1990*

Temperature	**Solubility of oxygen at various salinities (ppt)**				
Degrees C	0.00	5.00	15.00	25.00	35.00
12	10.77	10.43	9.80	9.21	8.65
16	9.86	9.56	9.00	8.47	7.97
20	9.08	8.81	7.71	7.28	6.87
24	8.40	8.16	7.71	7.28	6.87
28	7.81	7.59	7.18	6.79	6.42
32	7.29	7.09	6.72	6.36	6.03
36	6.82	6.65	6.31	5.98	5.68

The unit of measurement used in this table for chemicals and dissolved nutrients is parts per million, or ppm. This has the same value as milligrams per litre, or mg/L, which is often used in scientific literature and textbooks.

and salinities. This has an important bearing on how you manage the crop towards the end of the summer: if the biomass has increased significantly and temperatures and salinities are high, the risk of a sudden drop in dissolved oxygen (a 'crash') is higher because the margin for error is less. Table 3.1 shows the variation in oxygen level in water at different temperatures and salinities.

Oxygen levels fluctuate diurnally (twice daily) because:

- during the day, algae produce oxygen through photosynthesis and consume carbon dioxide, which causes an increase in pH; and

Table 3.2 Water quality parameters for optimum pond management

Parameter	Optimal range	Sampling frequency	How it is done
Dissolved oxygen	>4 ppm; >5 ppm preferably for optimal growth and survival	Twice daily	Field probe
pH	7.5–9.0; <0.5 variation diurnally; optimal is approx. 7.8	Twice daily	Field probe
Temperature	Above 24ºC and below 34ºC	Maximum and minimum weekly	Field probe
Salinity	10–28 ppt (optimal for growth is 15–25 ppt)	Weekly	Field probe
Total ammonia nitrogen (TAN)	<3 ppm (toxicity is pH dependent)	Daily if necessary	Laboratory analysis
Un-ionised ammonia (NH_3)	<0.25 ppm (percentage of TAN increases with pH)	Daily if necessary	Laboratory analysis
Nitrite (NO_2)	<10 ppm at salinities >15 ppt; <5 ppm at salinities <15 ppt	Daily if necessary	Laboratory analysis
Alkalinity	>80 ppm (ideally 120 ppm)	Daily if necessary	Laboratory analysis
Hardness	>2000 ppm	Daily if necessary	Laboratory analysis
Hydrogen sulfide	<0.1 ppm (pH dependent)	Weekly	Laboratory analysis
Secchi disk (turbidity)	20–30 cm	Daily	Field test (see below)

How to use a Secchi to determine pond turbidity

Figure 3.6 (left) Monitoring water quality from a pond jetty

Figure 3.7 (right) A secchi attached to a water quality monitoring probe for daily pond monitoring

Figure 3.8 (left) The secchi lowered into the water column until it disappears from view

Figure 3.9 (right) The secchi in the water column at the transition depth. This is the depth for the secchi reading

- during the night, algae and all other organisms (such as bacteria, prawns etc.) consume oxygen through respiration and produce carbon dioxide, which causes a decrease in pH.

Recent studies have shown that black tiger prawns respond to available feed more quickly when dissolved oxygen levels are above 3.5 ppm. Although they are known to survive at lower oxygen levels, repeated low oxygen events that can occur in the early morning (because of the diurnal fluctuations described above) should be preempted with close observations of daily water quality trends and avoided with proactive management strategies such as reduction in feed input and increase in pond water exchange.

Figure 3.10 shows how low dissolved oxygen events may occur due to weather changes. If several days of hot sunny conditions are followed by overcast weather, the dynamics of dissolved oxygen in the water column can change suddenly as well. Cloudy weather slows down photosynthesis and hence oxygen production; when this is combined with the lower oxygen-holding capacity of warmer saline water, dissolved oxygen levels can plummet during the night, and can potentially kill the whole crop before sunrise! This potential for disaster highlights the vigilance that prawn farmers require to understand the daily dynamics of water chemistry and prawn health.

As described earlier in this chapter, prawns grind up their feed with mouth mandibles and when crushing pellets can lose some to the pond detritus. In

Figure 3.10 How dissolved oxygen concentrations can change with the weather (modified from Boyd 1990)

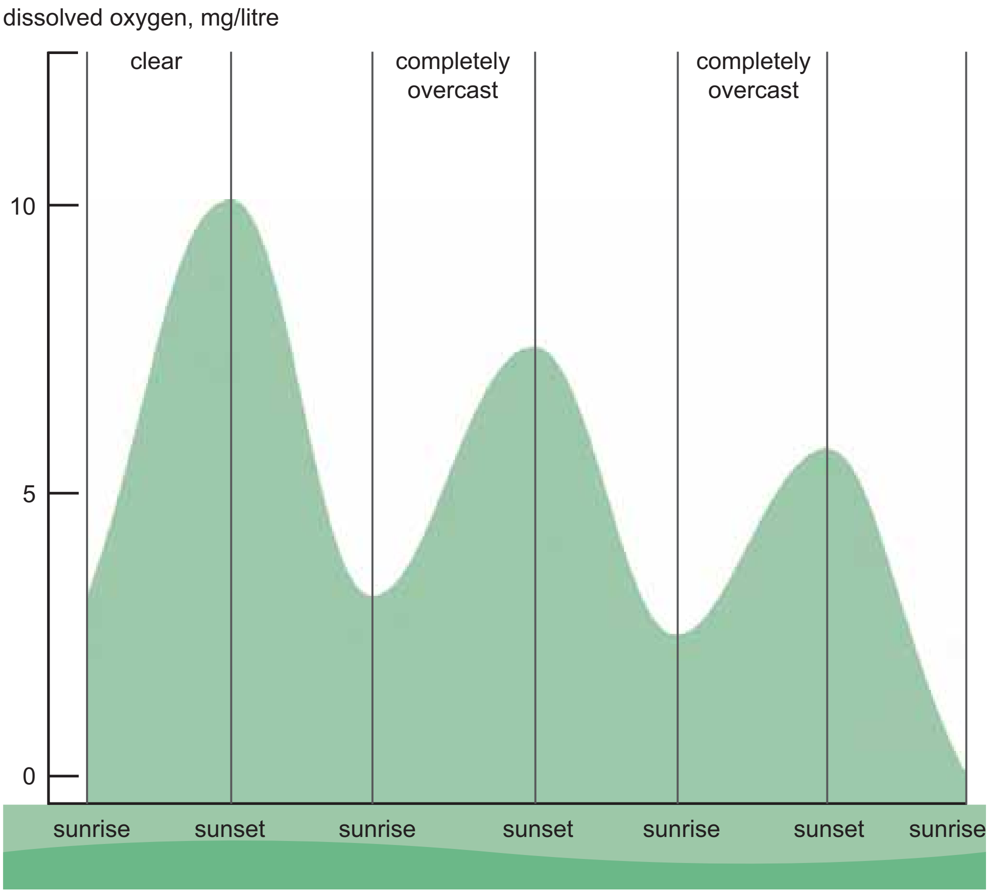
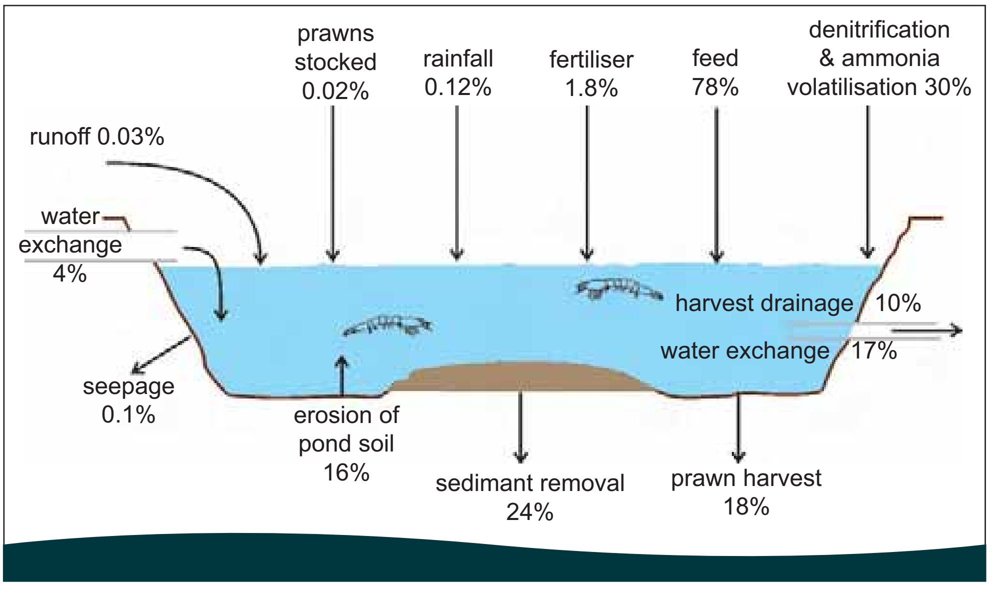


Figure 3.11 Typical nitrogen budget for an intensive prawn pond (modified from Funge-Smith and Briggs, 1998)



intensive prawn farming systems accumulation of feed residues, faeces, organic matter and toxic inorganic nitrogen is inevitable. Excretions released into the water become entrained in complex water chemistry processes which can result in excessive levels of dissolved and particulate nutrients (nitrogen and phosphorus are the most important). This in turn can exacerbate algal and bacterial blooms in the pond and lead to unstable water chemistry, with subsequent stress on the prawns.

The overall budget for nitrogen (as well as other important nutrients such as phosphorus) as a component in the feed and its release within the pond has been well documented (Fig. 3.11). Such information highlights the need for monitoring and management of such inputs and outputs, because it shows how a large input of nutrient (predominantly from feed) into a complex aquatic ecosystem is finely balanced with its output from the system by biological processes, such as denitrification by bacteria and physical processes such as water exchange. Note that the percentage of nitrogen leaving the pond in the prawns harvested is actually quite minor (18 per cent); the majority of it accumulates in the water column in unstable chemical processes that will continue to create stress situations for prawn health unless managed appropriately. For example, overfeeding can lead to production of excessive ammonia (which is toxic at very low concentrations) unless it is compensated for by increased water exchange in the pond.

Why monitor the health of prawns?

You need to be able to detect the early stages of disease problems and to respond before an outbreak becomes uncontrollable. In most ponds, changes in the prawns' health will only become apparent over time — based on a combination of observations on their general appearance, feed consumption, growth, the pond's water quality and so on. The importance of accurate, consistent record keeping in this process is obvious.

In most cases the external signs of ill health are non-specific. Even if a particular disease can be identified by the external appearance of the prawns, this is unlikely to provide any direct information about the environmental problem that predisposed the animals to the disease. This can only be found in the pond's environmental records. In the majority of cases on Australian prawn farms, environmental deterioration is a key underlying cause of whatever disease is emerging in the crop.

The environment in any prawn pond is not uniform and is constantly changing, sometimes in ways you cannot fully understand or control. Even though you may make every effort to maintain an optimal pond environment, you need to confirm regularly that conditions in the pond are suitable for the prawns — that is, that they are surviving, healthy and growing at acceptable rates. This is your 'early warning system', and it comes via regular examinations of prawns at the pond-side, on feed trays and particularly in samples of prawns collected by cast net. Any significant deterioration in the pond environment will result in an overall deterioration in the pond population's health. Note that this deterioration may not be uniform across all prawns in the pond. For example, the stronger individuals may not be affected in the early stages of a disease outbreak. This is why a representative and sufficiently large sample needs to be examined.

The edges of all ponds should be inspected each morning, beginning with ponds where birds are actively feeding or where unusual mortalities have been recorded. The purpose is to examine and count sick or dead prawns and thereby identify the early signs, or monitor the progression, of any disease outbreak (see definition of a disease outbreak in Chapter 3). At the same time, to reduce the risk of disease transmission within and beyond the pond, any prawn carcasses should be removed and disposed of safely.

When inspecting prawns on feed trays, you need to remember that different classes of prawns may occupy the trays at different times after feeding. If feed is cast over the pond bottom before the trays are filled, the stronger prawns will feed first on the pond bottom, displacing weaker individuals that then feed from the trays. After the feed on the pond bottom is consumed (usually after one hour or so), the stronger prawns may move to the trays, again displacing the weaker animals. You will need to understand how these changes operate under your feeding program to avoid making incorrect assumptions regarding the health of populations based on a single, post-feeding observation of prawns in the feed trays.

Prawns seen from the pond edges or on feed trays may not be representative of the general population in the pond. When you do your weekly check of the prawns' health, it is essential that the range of prawns examined is as close to representative as you can reasonably get. This is best done using a cast net in representative parts of the pond, including the central area where weaker (possibly sicker) prawns may be forced to congregate (see Chapter 6). The sample for these weekly general health checks should contain around 30 prawns (see below for more discussion on sample sizes for other types of examinations).

The following features should be assessed for each prawn and results recorded:

- external appearance (body and gill colour, missing appendages, signs of fouling on body or gills)
- gut condition (full, empty, appearance of contents)
- size (weight or length).

This regular, direct examination of a representative sample of prawns in each pond will give you an important indication of the health of the pond population as a whole and, by extension, of the suitability of the pond environment.

Biosecurity and health management

This manual is about managing prawn health and the pond environment to produce quality crops consistently and profitably. A biosecurity program should be part of your overall health management program, with the aim of protecting your prawns and your farm investment from the real threat of diseases. You will need to decide on the level of protection you want for your farm and then allocate sufficient financial resources, staff and farm infrastructure to support your program. This section introduces general principles of prawn farm biosecurity and health management. Chapter 9 presents specific details for each disease.

Effective biosecurity relies on a secure farm design, hygiene and quarantine, regular health testing, record keeping, and control of disease vectors.

What is biosecurity?

Biosecurity literally means 'life protection', but in practice it means preventing the introduction, establishment and spread of unwanted biological organisms or agents. In the context of prawn farming, biosecurity is about managing dangerous disease risks. Biosecurity programs can be applied at several levels, including pond, farm, locality and so on, up to national levels. Biosecurity measures should be part of every Australian prawn farm's health management program.

Prawn farm biosecurity involves applying sets of targeted, science-based procedures to eliminate or reduce the risk of a particular pathogen — that is, a disease-causing infectious agent such as a virus — (a) entering the farm, and (b) spreading within a pond, between ponds, to other farms, or to the wider environment.

Because of the costs (in time and money), many farmers generally implement biosecurity programs to reduce the risks associated only with dangerous pathogens. In an ideal world, they might aim for zero risk, but in reality they will need to balance the costs of any biosecurity program against the uncertain costs of future disease outbreaks. Development and implementation of a biosecurity program therefore requires a clear appreciation of the technical issues and involves compromises in which costs and benefits must be carefully considered. For these reasons, you will probably need to work with a health professional to develop a program to suit your particular situation. Effective implementation then requires long-term commitment from the farmer as well as discipline from the farm workers.

Farm-level biosecurity programs in many overseas countries typically target very serious pathogens such as White Spot Syndrome Virus (WSSV), Yellowhead Virus (YHD), Taura Syndrome Virus (TSV) or Infectious Hypodermal and Haematopoietic Necrosis Virus (IHHNV). These viruses are dangerous because they are highly contagious to prawns, are lethal and untreatable and have a diverse host range. The viruses and the diseases associated with them are relatively well studied and understood. In particular, important epidemiological information about each pathogen — its carriers, its routes of entry and modes of transmission — is generally available. This means that quite focused biosecurity programs can be developed for each pathogen. In those countries where domesticated, 'specific pathogen free' (SPF) or 'specific pathogen resistant' (SPR) shrimp species such as *Litopenaeus vannamei* or *L. stylirostris* are available and affordable, using such stocks is an important first step in reducing risk.

Exotic diseases and their clinical signs are described in Chapter 9.

The current situation in Australia is, in some ways, more problematic. There is arguably only one disease, Mid Crop Mortality Syndrome (MCMS), that at present warrants attention under a farm's biosecurity program. While there are uncertainties about the causal roles of various viruses associated with MCMS, available evidence strongly suggests Gill Associated Virus (GAV) is important. This virus is present in lesions in affected prawns and levels of infection correlate with crop losses. The roles of other viruses (see the sections on MCMS in Chapters 8 and 9 for further information) are yet to be established. To compound these uncertainties, SPF black tiger prawn stocks are not yet commercially available in Australia. Farmers should therefore consider developing and implementing biosecurity programs to manage MCMS, because they currently have no option but to stock black tiger prawns infected with GAV and perhaps other suspect viruses. In most cases, farmers should seek professional advice when developing such a program. Specific program components are discussed in the sections on GAV in Chapters 8 and 9. However, because the epidemiology of this virus, as well as that of other viruses thought to be associated with MCMS, is incompletely understood, the biosecurity program needs to be built around some general principles as well as specific measures. These principles are discussed below and they can be used for biosecurity programs targeting any pathogen.

Basic principles of biosecurity programs

Pathogens can be introduced to, or transmitted between, ponds or farms in several ways. These include the introduction of diseased or apparently normal, but infected, 'carrier' prawns, entry of wild carrier animals such as shrimp or crabs, improper disposal of dead prawns, contact with contaminated objects, contaminated water such as drainage water from other farms, contaminated feeds, or aerosols from infected ponds.

It is also important to recognise that not all potential causes of disease on prawn farms can be excluded by the application of a biosecurity program. For example, many *Vibrio* species occur naturally on farms as part of the prawns' normal microbial fauna and in the pond environment. Under certain stressful conditions, these bacteria can cause significant losses. Because they cannot be excluded, farmers must use a health management approach to minimise such losses.

An effective biosecurity strategy will use the following approaches to reduce risks of dangerous pathogens entering the farm to acceptable levels.

1. *Stock only postlarvae that have acceptable test results in terms of pathogen prevalence and load.*

   Pre-stocking tests to establish specific infection status are essential wherever postlarvae are derived from wild-caught spawners. In some cases, it may also be worth testing stock at selected times during growout to keep track of infection status.

   For any pathogen, the infection status of an individual prawn (such as a spawner) or a population of prawns (such as a batch of postlarvae) can be established only by sophisticated laboratory testing (usually involving PCR test of a sample taken from the prawn or the population). Ideally, a sample of 150 postlarvae is recommended for pre-stocking PCR testing. If possible, select the weakest animals (for example, when doing the activity test, chapter 5); the assumption is that these are most likely to be infected with the target pathogen. The sample is then divided into five pools (each of 30 postlarvae), and the pools are tested separately.

   You will probably need to discuss the test results with a qualified professional. In particular, you need to recognise the limitations of tests and test results. And even if the test result is negative, there will always be inherent uncertainties because of the possibility of sampling error (only a part of the individual prawn or a fraction of the population is actually tested) and because of imperfections in the test (no tests are absolutely perfect; they can sometimes produce false positive or false negative results).

2. *Do not exceed optimal stocking densities.*

   Excessively high stocking densities can stress prawns, and increase opportunities for cross-infections, making disease-related losses more likely.

3. *Eliminate or reduce risk from potential 'vectors' (infection-carrying agents) on the farm.*

   In general, vectors are living or non-living agents that can carry a disease agent from one susceptible host animal to another. Some living vectors, such as crabs, may not become sick themselves; others, such as birds carrying infected carcasses between ponds, may not even become infected. Inanimate vectors are vehicles, nets and feed utensils, harvesting equipment, packaging and waste water. Remember also that some prawn viruses can survive for some time in the environment (say, in the damp soil of an empty pond) and remain infectious to healthy prawns.

   Many of the dangerous prawn viruses, particularly WSSV, can infect vectors such as crabs, which can then serve as sources of infection for farmed prawns. Overseas, crusticides (including chlorine compounds and organophosphates) are often used to remove these animals from reservoirs

Contact your state Parks and Wildlife Service about bird management plans.

In Queensland contact the Queensland Parks and Wildlife Service.
www.epa.qld.gov.au.

Table 3.3 Managing vectors and biosecurity risk

Vector	Biosecurity risk	Possible remedies
Birds feeding on dead prawns	Viruses if present may be brought on to the farm from outside (other farms) or spread from infected ponds within the farm	Contact your state Parks and Wildlife Service about bird management plans www.epa.qov.au. Bird netting or bird control management plan
Crabs feeding on dead prawns	Viruses if present may be brought on to the farm from outside (other farms or the wild)	Mesh covers for inflow and discharge pipes. Consider removing crabs from canals and reservoir
Packaging and wastewater of new postlarvae arrivals from hatchery	If there is disease infection in the new arrivals you do not want to spread it to other ponds through contaminated water and packaging	Discard. Do not reuse on farm
Vehicles	A vehicle that has visited another farm may carry dirt and moisture onto your farm	Restrict external vehicle movement within the farm and have regular wash-down disinfection for all vehicles on the farm. Have a disinfectant sump at the entrance for all vehicles arriving and departing the pond area
Harvesting and feed equipment, such as feed trays	If there is a diseased pond, transfer to clean ponds may occur	Disinfect after use in the diseased pond, or have separate set for a diseased pond
Wastewater	Infectious water flowing into the environment or to other ponds (if it is a waterborne disease)	Disinfect or treat before discharge

before filling ponds. During pond filling and water exchange, water is filtered through twin bag filters (300 micron mesh size) to reduce the chance of other crustaceans entering the pond. There is currently no information about GAV infection in wild, non-penaeid crustaceans and whether these animals are important sources of infection for farmed prawns in Australia.

4. *Use water management practices that prevent or reduce contamination by the pathogen.*

In many overseas countries, the high densities and close proximity of shrimp farms can increase the frequency of dangerous disease outbreaks. Farmers have been forced to adopt careful water management practices such as minimal or even zero water exchange, together with mandatory use of reservoirs that combine storage and treatment of intake water. In very high risk areas, farmers with disease problems notify their neighbours to ensure that neighbours do not pump water while infected water from diseased crops is discharged.

Here, the situation is different. Given the generally large distances between Australian prawn farms, the large dilution factors in our rivers and the absence of significant exotic pathogens such as WSSV, introducing another farm's disease problems during pumping is less likely. However, farmers should pay careful attention to movements of water within the farm to ensure that it does not carry disease between ponds via pathogens suspended in the water, via infected prawns or via other carrier crustaceans. In particular, they should ensure that, if their outlet and intake points are relatively close, they are not pumping water onto the farm while water is being released from other ponds, particularly diseased, or even suspect, ponds.

5. *Reduce the risk of spreading infection between ponds by restricting movements of people, equipment and other possible agents.*

   Movement control entails controlling movement on to your farm, and movement within the farm, of people, vehicles, equipment, water and other vectors. Control of movement within the farm is aimed at stopping or minimising contamination of prawns, feed, water and equipment used. If there are concerns about a disease on the farm you may need separate equipment in each different production unit (for example, cast nets used for sampling prawns). Feed trays that are used for monitoring feed consumption (see Chapter 6) should be kept in the same pond throughout a crop. Visitors' vehicles should be restricted to the perimeter of the property. It is also advisable that a hatchery be established on a location separate from a farm.

6. *Implement a health management program that aims to minimise stress to prawns by optimising the pond environment.*

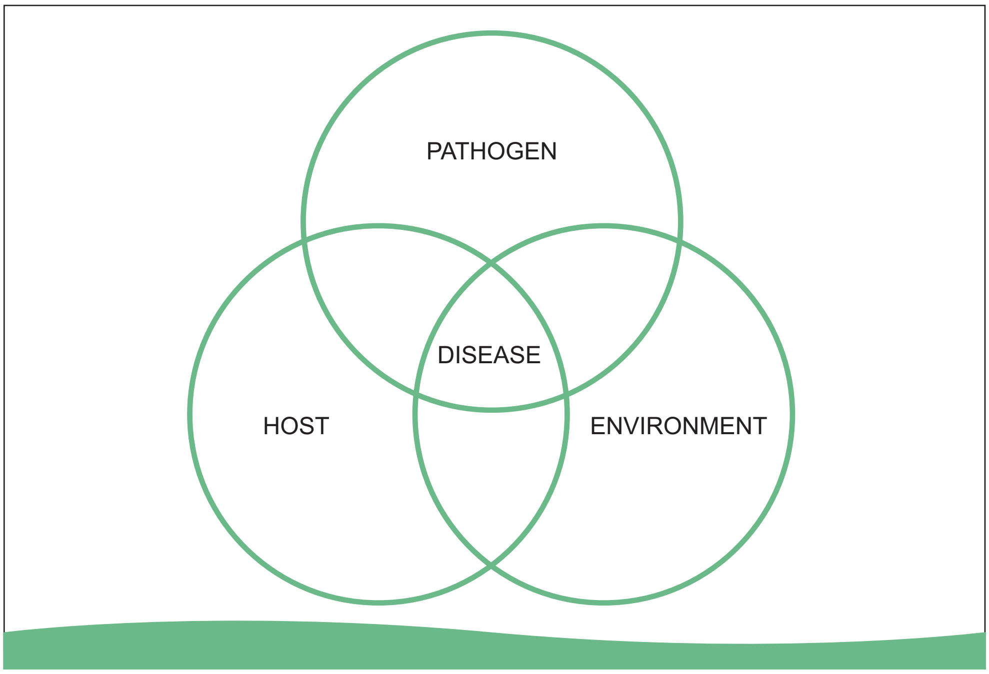
   Minimising stress to the prawns is a primary aim in pond and water quality management (see Chapters 5 and 6).

Biosecurity checklist

The biosecurity checklist should enable you to make sure that your prawn farm is adequately protected from disease risks:

- Start with health certified postlarvae or juveniles.
- Monitor and manage the hygiene of new arrivals.
- Identify and keep batches of postlarvae/juveniles separate.
- Record survival rates and production.
- Record mortality and disease events.

Figure 3.12 The epidemiological triad of Sniezko, indicating the pond factors that can lead to disease



- Regularly test prawns' health in the early, mid and later stages of the growout cycle.
- Cull poorly performing or diseased animals if possible.
- Check and manage pond-to-pond and carrier factors.
- Maintain pond hygiene and disinfection between production runs or prawn batches, or in a mortality event.
- Recycle or disinfect and treat discharge water in a mortality event.
- Manage movements of people.
- Report diseases or unusual mortalities to your state authority.

What is health management and how does it differ from biosecurity?

A health management program (HMP) and a disease emergency plan (DEP) are essential documents on prawn farms. These plans or programs are written specifically for and by each farm and incorporate the principles of biosecurity described above.

As many farmers have recognised, the frequency and severity of disease outbreaks in ponds seem to depend on a number factors, not all of them well understood. The first point to appreciate is that not all prawn diseases are infectious. For example, some are caused by toxins, others by nutritional imbalances. The following section focuses on infectious diseases because their causes are usually complex and control and prevention can be more challenging.

Infectious disease outbreaks in ponds depend on particular interactions between the host (prawns), the pathogen and the pond environment; these interactions can be represented in the 'epidemiological triad' of Sniezko (Figure 3.12).

In any pond, host characteristics (such as prawn age, nutritional status, stocking density), pathogen characteristics (such as its ability to infect, cause disease in, and kill the host) and environmental factors (such as water temperature or salinity) are constantly changing and interacting, usually without disease occurring. Sometimes, however, the three factors combine in such a way that a disease outbreak results.

The critical point is this: the presence of the pathogen, on its own, is usually not enough to cause a disease outbreak. That is, finding a pathogen in a single prawn, or even in most prawns in a pond, does not necessarily mean that a disease outbreak will occur. Other causal factors, related to the host and the environment, usually must also come into play to trigger an outbreak. This fact allows the astute manager to maintain the health of the pond, even though the prawns are infected with, or exposed to, a number of pathogens, including dangerous ones.

You can now see that the farm's biosecurity program is an integral part of the health management program. The biosecurity component reduces (but usually does not eliminate) the risk of dangerous pathogens entering and spreading on the farm. As well, many opportunist pathogens, such as *Vibrio* bacteria, are already ubiquitous in the ponds; they will cause disease if the prawns' general health and/or pond conditions deteriorate. So, having taken care of biosecurity to the extent that it is possible and desirable, farmers then need to manage prawn health and the environment in each pond to maximise the chance of a profitable crop. Note again that this will involve compromises between what is optimal and what is affordable. One of the main aims of this manual is to present enough information to enable you to choose the components of your farm's health management plan and determine the resources you will commit to it.

On-farm health management is vital to successful prawn farming. Your management of the crop for good growth and survival should focus on disease prevention rather than disease treatment.

A health management program focuses on all the critical control points along the production pathway where there are cost-effective opportunities to reduce risk of disease-related losses. The health management program comprises steps and control measures that are done daily, weekly, monthly and annually by staff, to reduce to acceptable levels the risks of disease-related losses on the farm. Note that risks are not eliminated; in most cases some disease losses will still occur but the cost of these losses will not justify increased expenditure on the program.

The key focus areas of a health management program are listed below. All of them are discussed in other parts of this manual. Particular disease-related issues are also discussed in sections dealing with individual diseases.

Health management programs comprise 'packages' of sound (that is, science-based) management procedures and approaches covering each of the areas listed below:

- seasonal factors and crop planning
- pond preparation

- pond filling and water preparation
- postlarvae selection and stocking process
- water quality management
- pond bottom management
- feed management
- prawn health monitoring
- farm record keeping
- dealing with disease outbreaks
- treatments and use of chemicals.

To develop a health management program for your farm, you will need to identify procedures and approaches that suit your operation; that is, the procedures should be tailored to your operation, both as a production facility and as a business.

Targeted health testing

You can use targeted health testing to check and monitor for infectious diseases by submitting samples of prawns to DPI&F or a veterinary laboratory. Knowing the exact health status of each new batch of prawn larvae coming on to the farm will improve disease management and you may want to discuss it with the hatchery before purchase. Arrivals of new stock should have accompanying paperwork to show:

- where the animals came from
- previous health testing reports or health certificates.

> Without such documentation and management based on the biosecurity principles described above, you will not be able to 'back track' any disease events if they occur.

Disease reporting and your obligations

If any disease outbreak occurs on your farm, whether you believe it to be serious or not, it is a condition of your Aquaculture Licence that you report it to state authorities so that rapid, accurate diagnosis and effective control measures can be implemented to protect the prawn farm, the prawn industry and Australia's export markets. Other unusual mortalities or production losses, even if you believe they are not due to disease, should also be reported so that appropriate samples can be examined to identify the cause(s), which may or may not be infectious in nature.

In Australia, each State and Territory has operational responsibility for the surveillance, monitoring, control and eradication of aquatic animal diseases, whether the diseases are endemic or exotic. In addition, Australia has international obligations, including reporting to the global organisation for animal health *Office International des Epizooties* (OIE), and each State/Territory government is responsible for gathering the information regarding notifiable aquatic animal diseases.

Definition of an 'outbreak'

Outbreaks of disease can be described in many ways. In this manual, any disease occurrence will be considered an outbreak when an additional 10 dead or sick prawns a day (assessed at first light in the morning) are seen around the edges of a pond on five consecutive days: for example, at least 10, 20, 30, 40, 50 prawns.

Table 3.4 **Health management documentation**

Health paperwork	Why is it important?
Batch of postlarvae with information about broodstock and survival data	Improves productivity of batches of prawns by identifying health risk factors
Any previous health testing reports or health certificates	Minimises the risk of disease introduction or dissemination through accurate tracking of problem prawn batches and ponds
Destination of growout farm	

Australia, mainly due to its geographic isolation, has maintained freedom from important, infectious diseases. The surveillance and reporting program focuses on the fact that Australia will increasingly be called upon — for example, by the World Trade Organization (WTO) — to substantiate freedom from major diseases in order to support export certification and quarantine import policy. Our scientific knowledge regarding aquatic animal diseases (distribution, causes, treatments, control and prevention) is often incomplete. Cooperation between industry and government agencies will enable a better understanding of diseases and their management.

Emergency disease events

An emergency disease event exists when a population of aquatic animals succumbs to significant mortality or there exist large numbers of moribund stock. This is in contrast to the relatively low mortality event defined for an outbreak above, or to high mortality as a result of an adverse environmental change (such as low dissolved oxygen) or a management error. If you think significant mortalities are disease-related, you must contact a government representative; this could be an aquatic health laboratory officer, a veterinarian, a field or extension officer, or fisheries and aquaculture management personnel (Table 3.5).

What happens after you report a disease emergency event?

In the event of a suspected infectious disease outbreak, the farm manager should reduce the potential for the disease to spread by restricting stock, vehicle and staff movement, on and off the farm.

A government aquatic health officer will initially contact the farm to collate contact numbers and location details and get an overview of the problem. Some immediate recommendations may be provided to help prevent spread of the disease. The process will then move through the investigative stage (sample collection, diagnosis, definition of restricted or quarantine areas etc.), alert stage (contacting all key personnel including interstate industry and government officials), operational stage (setting up of state/territory disease control headquarters and local disease control centres) and stand-down stage (debriefing, collating of records etc.). Progression from one stage to the next depends on the nature of the emergency and how much is

Table 3.5 State and Territory contacts to report aquatic animal disease

State or Territory	Government department	Contact
Queensland	Primary Industries and Fisheries	(07) 3830 8550 or 13 25 23
New South Wales	Primary Industries	1800 043 536 or 1300 550 474
Northern Territory	Business, Industry and Resource Development	1800 720 002
Western Australia	Fisheries	1800 815 507
South Australia	Primary Industries and Resources	1800 065 522
Tasmania	Primary Industries, Water and Environment	1800 005 555
Victoria	Primary Industries	(03) 9412 5710 or 136186
Australian Capital Territory	Environment ACT	(02) 6207 9777

known. A serious outbreak of an infectious disease may require the involvement of several government departments (such as environment, police and health) and the establishment of state and local disease control centres. Fortunately, the Australian prawn farming industry has not required an investigation of this magnitude, although preparedness is the key to management of an infectious disease if an outbreak occurs.

Disease emergency plan

A disease emergency plan (DEP) outlines steps and actions to be taken by all farm staff in the event of a disease emergency in accordance with responsibilities and conditions set out in your aquaculture approvals and permits (see Chapter 9). A disease emergency may be described as an unusual or virulent outbreak of a disease affecting prawns or other stock on your farm, or even an outbreak of an exotic disease not seen previously in Australia (see Chapter 9). While such events have not yet occurred in Australia, there is always a risk and it is vital that farm and industry plans are in place to avoid losses that have occurred in other countries.

A disease emergency plan should include specific written protocols to be followed by staff for use in the event of a disease emergency. It should also incorporate planning and implementation procedures to deal with the outbreak and prevent its spread throughout the farm. Veterinary officers at the departments of primary industries and fisheries in each state can provide assistance in formulating these plans.

DPI&F laboratories can test postlarvae or adult prawns and assist in overall farm health assessments. See the documents *Department of Primary Industries and Fisheries, Aquaculture Guideline* and *Guidelines on Aquatic Animal Specimens Accepted for Testing at QDPI&F Veterinary Laboratories and Service Fee Exemptions*

Responding to extreme disease events

The Australian prawn farming industry remains free of many serious prawn diseases such as yellow head virus (YHV) and white spot syndrome virus (WSSV). Over the past decade these diseases have caused major losses on prawn farms in the Asia-Pacific and Latin America regions. In some countries, the failure of prawn farms has resulted in economic hardship, increasing debt, abandonment of farms and unemployment.

It is important that Australia maintains a high level of surveillance for disease episodes and has strategies in place to manage an outbreak of an exotic disease. Control of an exotic disease is primarily the responsibility of the farmer and farm technicians, in collaboration with Commonwealth and State Government officials, veterinary officers, aquatic health personnel and diagnostic laboratories.

For a description of the known exotic diseases in shrimp in other countries, see Chapter 9.

The 'Aquavetplan'

Australian Commonwealth, State and Territory governments together with the private sector have developed strategies that define the methods and protocols to manage emergency, aquatic animal disease outbreaks. 'Aquavetplan' will ensure that a coordinated and efficient approach is taken to assist in disease management and eradication. The plan is a series of manuals (Table 3.6) that describe the proposed approach to an aquatic animal disease emergency event. The manuals are working documents that will be updated regularly as required, taking into account research findings, field trials and emerging disease threats.

At a glance

- Understanding the biology of prawns and how they live in their natural environment will give you a stronger appreciation of what they need and how to care for them in the artificial environment of a prawn farm. Maximising prawns' survival and growth depends greatly on minimising the stresses the animals encounter when pond conditions differ significantly from the conditions they are adapted to in the wild.
- Water quality monitoring is an important tool in reducing the variation in growing conditions such as dissolved oxygen, pH and salinity. A pond monitoring program is a strategic component in

If you are a prawn farmer in Queensland, it is a condition of your Aquaculture Development Approval that you notify state government agencies of any significant disease episodes that occur on your prawn farm.

Table 3.6 Aquavetplan manuals and their functions

Manual or publication	Function
Control Centres Management Manual	Description of procedures; management structures and duties to be implemented in terms of disease response, such as development of disease control centres; staffing; resources; movement permits and cost recovery
Enterprise Manual	Guides the response in terms of the type of rearing system, such as open, semi-open, semi-closed and closed
Destruction Manual	Guides the decision to destroy stock; choice and application of appropriate techniques; chemical use; risk of disease transmission to humans
Disposal Manual	Explains the safe transport of carcasses and waste; disposal site selection and their construction; incineration; plant equipment
Disease Strategy Manuals	Strategies for specific diseases, such as White Spot Syndrome Virus (WSSV), furunculosis etc.
Aquatic Animal Diseases Significant to Australia — Identification Field Guide (CD)	Emphasis on infectious diseases of commercially important fish; major exotic and endemic diseases; disease identification; contacts
Disease Watch — Play Your Part (CD)	Prevention; education; case studies

pond management, because it can provide predictive knowledge for stress events such as a dissolved oxygen crash as well as data for environmental management of the whole prawn farm.

- It is essential to keep good records of the pond environment, feeding regimes, prawn health and any other significant events for each pond during the growout period. These records can be used to identify and rectify problems in the pond environment or prawn health during the crop. Just as importantly, they can give farmers a clear picture of how a problem emerged and what the warning signs were. This can help farmers avoid the problem in subsequent crops.
- Biosecurity and the prevention or minimisation of disease are important for the prawn farming industry as well as your prawn farm. You can minimise disease impacts through good planning and management, for example by using on-farm risk reduction measures, reducing vectors that spread disease, controlling traffic into the farm, and using targeted disease testing.

Part 2

Getting started

Chapter 4

Pond preparation

Getting the pond ready for a crop

Correct pond preparation is an integral part of successful prawn farming. Prawn pond soils, like soils used to grow a plant crop, need to be prepared before the 'seed' is planted to get a good result at the end of the crop. Poor preparation can result in deterioration of the soils during the crop, with release of nutrients and toxic compounds to the water column, creating stress for the prawns and possible environmental problems with the discharge of effluent. Good pond preparation is also a proactive measure for disease control and should be a critical aspect of your disease management strategy. Pond sludges that accumulate on the pond floor may also need to be removed before the next crop; the on-farm disposal of sediments must be done responsibly.

Intensive prawn farming requires a considerable quantity of feed to be added to a pond over the course of a crop (approximately 10 tonnes for a 5 tonne crop). This massive input of organic material has the potential to overload the organic load in sediments and cause deterioration of the pond soils for your next crop. Pond sludge can accumulate in the centre of the pond because of the action of aerators and water currents during the crop and will appear as a mound in the centre of the pond when you drain it (Figure 4.1).

Sediment management guidelines are outlined in *The Environmental Code of Practice for Australian Prawn Farmers* (www.apfa.com.au) and the key factor is to minimise these wastes to promote environmental sustainability. The factors that determine how much sediment is deposited during a crop are primarily determined by farming practices and stocking densities.

Pond dry-out

The primary phase of pond preparation is pond dry-out, commencing immediately after the last harvest. Drying the floor of the pond is a proactive tool to minimise the risk of potential disease outbreaks and improve pond performance for the next crop. From here on, the aim is to create an optimum soil environment for your next crop by:

Figure 4.1 The sludge mound left in the centre of a pond after the crop is harvested

- the removal or reduction of a high organic load
- allowing the oxidisation of organic material
- allowing oxidisation of inorganic compounds such as hydrogen sulfide and ammonia
- decreasing the anaerobic bacterial load and increasing the aerobic load
- allowing benthic algal mats to die off
- allowing fish eggs, burrowing crustaceans and other potential predators to also die off.

Drying the pond floor will also enable:

- removal of accumulated sludge by front end loader or excavator (if necessary)
- removal of any obstacles such as aerators, electrical leads, anchor posts
- the use of machinery to till the pond bottom, reshape the pond bottom and slopes, and reseal the pond bottom and slopes.

Pond dry-out should begin once all stock are harvested from the pond, allowing enough time to remediate the soil before the next planned refill date (a minimum of two weeks).

Pond dry-out is done by removing all live and dead stock from any puddles or cavities, stopping the intrusion of any water leaking into the pond from the inlet pipes or other sources and allowing the clay sediments to dry and crack. This may take a minimum of five days, depending on the weather, sediment thickness, algal mats on top of the sediment, and the soil type.

Removing sludge

Removing a layer of pond sludge may be necessary if deposition has been excessive in a previous crop. A high organic load can tend to keep soils waterlogged and slow to dry out as well as encourage the proliferation of harmful anaerobic bacteria during the crop.

The decision on whether to remove the sludge should be based on the performance of the previous crop as well as the size of the mound created (Boyd 2003). A small mound can easily be dried and spread out using tilling so that the soil can be oxidised, whereas a large mound (say, higher than 10 cm when dried and wider than 40 metres in diameter) needs to be removed entirely from the pond and placed in a bunded area (in Queensland this must be done under the requirements of an EPA permit). Sludge that has been removed and cured for a couple of seasons may be returned to the pond walls as topsoil to encourage grass growth and reduce erosion.

The accumulation of sludge from the previous crop, which has been underwater four to six months, can cause an imbalance of the beneficial microbial populations in the soil, change soil chemistry and leave a nutrient load that will interact with pond water in the next crop (this can be beneficial if not excessive). If a significant amount of sediment has accumulated in the pond, it may affect the performance of internal slopes and spoon drains, affect water movement patterns, and result in a wider area of sediment in the next crop.

Allow enough time for the desired dry-out level and restocking program. You can work backwards from the stocking date: for example, seven to ten days to create a stable bloom, one to two days to fill the pond, one to three days for sediment removal and remediation, meaning a minimum nine to fifteen days before stocking). The thickest part of the sediment area should be cracked by the drying process and oxidised right through, so that if you break a piece off the colour will have changed from black to brown. If the sediment is not dry enough and the machinery used to remove it smears a black paste of sediment on to the good soil, it will need further drying time.

The machinery (such as front end loader or excavator) must be able to work efficiently and effectively on the pond bottom without leaving deep tyre marks or indentations on the surface (that is, the pond floor must be dry enough). The sediment should also be solid enough not to spill out when the truck is exiting the pond via the ramp.

Tilling the pond bottom

Tilling the pond bottom exposes more surface area of the soil, increases the effect of oxidation, and encourages more aerobic bacteria. Sunlight and dryness kill algal spores, benthic algal mats, fish eggs and any predators potentially remaining in the soil. The tilling process also generally assists in the breakdown of organic residues and nutrients that are locked up in the soil, making them more biologically available for the next crop.

Once all the sediment is removed, tilling can commence. Some farmers also add lime before tilling so it can be incorporated with the soil (see Chapter 3).

The soil must be dry enough to allow the implement used to work effectively. An indicator is to ensure that the soil is free-flowing past the tines of the implement and not clumping. If the first pass has exposed anaerobic soil (usually black), allow one or two days for it to oxidise and pass again.

Resealing the pond bottom

It is important to ensure that there is no pond seepage as this will increase pumping costs and can affect groundwater in local aquifers (see Chapter 2). Resealing also ensures that the final finish on the pond floor is smooth and that the pond drains well towards the outlet for the future harvest.

Resealing should be done last, after all other machinery has passed. This will ensure that the best seal is obtained and not disturbed before the pond is refilled.

An efficient method of resealing the pond bottom is by compaction of the pond floor with motorised rollers. There are also smaller versions of rollers (with and without motorised compaction) that can be towed behind a tractor. The method of resealing the pond bottom will be determined by how much it was disturbed during the remediation process and soil type.

Machinery needs

Choosing the appropriate type and size of machinery will be the key factor in determining the effectiveness of the pond preparation process (see Chapter 2). Time limitations could be caused by a narrow window of fine weather and an urgent need to restock (for example, because a hatchery has postlarvae available).

The three main options are to own or hire machinery or to engage contractors. In most cases, it is best to own the machinery you need, especially when it is needed on demand. This is all relative to the farm size and stocking frequency, taking into account whether the stock are harvested in a narrow time frame or whether the harvest is staggered over a long period.

Aeration set-up

Pond aerators and water movers play a critical role in setting up a desirable culture environment for prawns in large ponds. They are primarily used to maintain adequate oxygen levels and gaseous exchange. They also keep the pond water column well mixed and prevent stratification so that the water quality is consistent throughout the pond.

The circular flows that are generated by aerators will also concentrate slow-settling wastes (such as silt, algae and faeces) towards the centre of the pond, creating a mound of sludge that will be visible when you eventually drain the pond at harvest time (see Chapter 3). This mound should ideally be less than 40 m in diameter (1200 m^2) in a 1 hectare pond. The faster currents around the periphery of the pond sweep the pond bottom and keep this feeding area free of excessive organic debris.

Aerators can be installed in position with tall stakes hammered into the mud, or with long ropes to the bank. The layout of pond aerators should be designed to achieve the maximum flow of pond water with

> An optimum aeration regime would maintain dissolved oxygen levels above 5 ppm by adding aerators as the prawns grow and using up to 1 hp of aeration per 250 kg of stock. This is high and may require 16 to 24 aerators for each 1 hectare pond by the end of the crop, depending on the biomass of the crop.

the minimal energy input. Figures 4.2 and 4.3 provide some suggestions for appropriate layouts. In square ponds, the use of at least four aerators, each positioned 15–18 m from the sides at each corner, allows sufficient water supply to the aerator and minimises bank scouring.

One of the most common mistakes is placing paddlewheel aerators too close to the banks or corners where it is perceived that currents are tracking past in the generally circular pattern that develops. A general rule of thumb is to direct flows so they match and enhance flows from upstream aerators, assuming that a 2 hp aerator has

Poor layout of aerators in the pond can lead to erosion of the pond walls or floor and significantly increase the amount of sediment in the sludge mound by the end of the crop. This can decrease the life span of your ponds and increase maintenance costs (Preston et al. 2003).

Figure 4.2 Suggested layout of aerators for square ponds

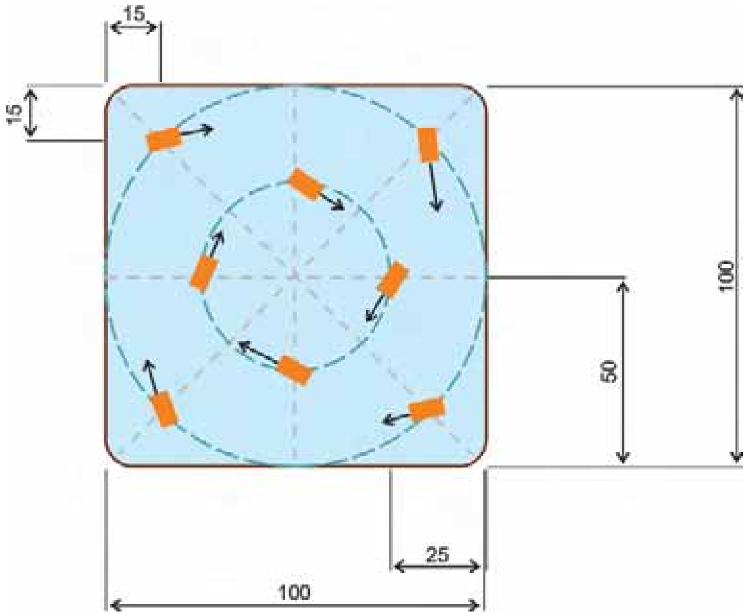
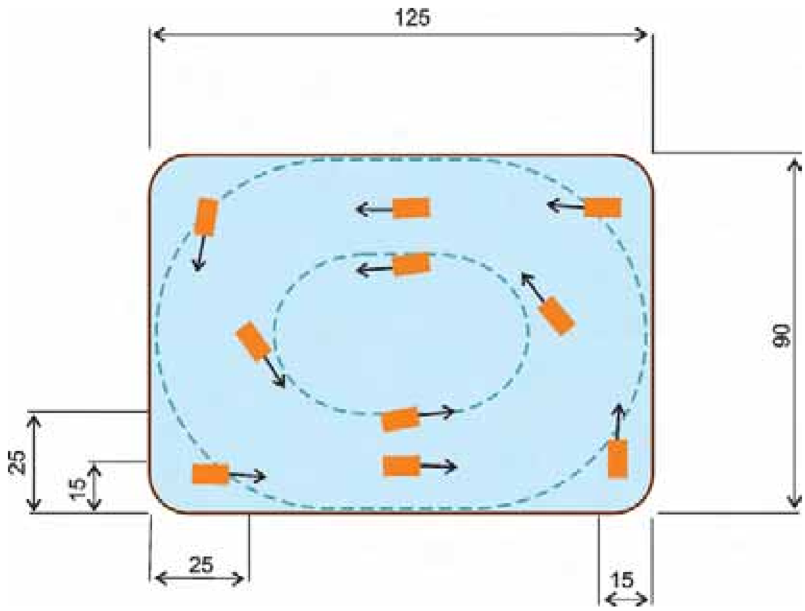


Figure 4.3 Suggested layout of aerators for rectangular ponds



a maximum effective push of 40 m. Directing flows across the path of another aerator should be avoided because this creates eddies and deposits wastes in places other than in the centre. Positioning in odd-shaped ponds needs to be undertaken on an individual basis, possibly by trial and error.

The use of lime in pond sediments and water

When and why do you need to use lime in prawn ponds? Liming is a general term that refers to the application of calcium and/or magnesium oxides or carbonates to ponds for management of the soils and the water column. They can be applied before and during the crop and can be effective in:

- increasing pH (alkalinity) and hardness in the water column
- guarding against extreme water pH fluctuations (acting as a buffer)
- improving the pH of pond sediments during dry-out periods to reduce disease in the next crop
- flocculating suspended or soluble organic materials in the water column to improve light penetration
- accelerating the decomposition of accumulated organic matter
- improving fertiliser response.

Several types of lime are commercially available, each varying in neutralising strength, solubility and, consequently, influence on pond chemistry. Liming materials vary in their ability to neutralise acidity. This ability is rated and described as their neutralising value (NV), which is determined by comparing the values to that of pure calcium carbonate. Table 4.1 shows lime types, their properties and recommendations on their use.

Agricultural lime is normally the best material for treating pond acidity, due to its cost effectiveness, availability and safety. As finer particles react faster and dissolve more rapidly in water than large particles, it is advised that finely ground lime be used. Agricultural lime is less reactive and less concentrated than hydrated or burnt lime, allowing changes to pH to be more easily controlled. While hydrated lime and burnt lime are not recommended for general use because of their high caustic properties, they can be used if the pH of the water column needs to be raised quickly or to reduce disease in drying ponds (pond disinfection). If used in the water column, the water should be monitored closely to ensure that the pH does not 'overshoot' and become too alkaline for the prawns. In order to allow sufficient time for these more caustic liming agents to react fully, they should be applied to empty ponds several weeks before refilling. As this material is extremely caustic, all handling must be undertaken in accordance with relevant occupational health and safety standards.

Although there are several published guidelines for determining lime requirements in ponds, due to the variability in soil properties between sites the most accurate way to determine liming doses is to have pond soil samples analysed for liming rate by a certified laboratory (this can also be done by most fertiliser companies). To obtain a value that is representative of pond conditions, a composite sample made up of samples collected from different areas of the pond should be analysed. A minimum of 10 samples/hectare of pond area

Table 4.1 Types and properties of liming agents

Type	Common names	Solubility	Neutralising value %	Recommendations
Calcium oxide (CaO)	Unslaked lime Burnt lime Quicklime	High	~179	Not recommended for general use as this material has the potential to rapidly raise pH to toxic levels with only short-term effectiveness
Calcium hydroxide ($Ca(OH)_2$)	Slaked lime Hydrated lime Builder's lime	High	~136	Not recommended for general use as this material has the potential to rapidly raise pH to toxic levels with only short-term effectiveness
Calcium carbonate ($CaCO_3$)	Calcitic limestone Calcite Agricultural lime	Moderate	85–100	Suitable for use
Calcium magnesium carbonate ($CaMg(CO_3)_2$)	Dolomite	Moderate	60–75	Suitable for use
Magnesium carbonate ($MgCO_3$)	Magnesite	Moderate	95–105	Suitable for use
Magnesium hydroxide ($Mg(OH_2)$)	Burnt magnesite	Moderate	180–220	Suitable for use

should be collected to form the composite. To determine the exact quantities of lime to be added to the pond, the laboratory recommended liming rates need to be adjusted to account for the neutralising efficiency of the lime selected for use. Methods for adjusting liming rates based on neutralising efficiency are explained in detail in Ahern et al. (1998).

To account for the slow dissolving rate of agricultural lime in seawater and the potential for insoluble coatings to form around lime particles, it is also advisable that lime be added at 1.5 times the recommended lime application rate. It is important to note that the maximum pH that can be obtained through the application of agricultural lime is 8.3, and the solubility of agricultural lime decreases as the pH rises. So the excess addition of agricultural lime is unlikely to have a negative impact on water pH; rather, it will simply last longer. However, excessive liming can decrease phosphorus availability in ponds through the precipitation of low solubility calcium and magnesium phosphate minerals. It is therefore important to leave sufficient time between lime application and pond fertilisation.

Liming pond sediments is an important part of pond preparation for the next crop. This can be done by broadcasting the lime as uniformly as possible over the complete surface of pond bottoms and embankments during the dry-out period. To prevent the loss of lime in windy conditions the lime can also be added to the soil as a slurry. To accelerate soil acidity neutralisation, lime should be harrowed into the soil to a depth of approximately 10 cm.

Filling the pond, water preparation and predator control

Unit of measurement
one micron =
one thousandth of a millimetre

With pond preparation complete and aerators in place, it is time to start filling ponds. Once you have a batch of postlarvae confirmed by the hatchery, agree on the supply dates and allow 21 days before stocking to start filling a pond.

Use 120 micron mesh screens or 'filter socks' on the pond inlet pipe. The mesh size of screens will vary between farms, depending on the types and amounts of organisms known to occur in the vicinity of your seawater intakes. Generally, a 120 micron mesh size is recommended to capture fish and crustacean larvae or eggs with diameters of 200–300 microns (Figure 4.4). If possible, the pond should be filled to a depth of 1 m with further water added gradually — say, 10 cm a week. Typically no water exchange is required for the first 30 to 50 days; that is, care should be taken with this approach. If the water is too clear, benthic algae will grow rapidly in the shallow water and could cause significant pond management problems (see Chapter 6). If you are inexperienced in bloom management, it may be best to fill the pond from the beginning. Allow the water to settle for one day then add fertiliser at the following 'starter' rate:

Urea	20 kg per hectare pond
MAP (mono ammonium phosphate)	10 kg per hectare pond

Figure 4.4 Filter screens or 'socks' installed on pond outlet pipes

The easiest way to do this is place the fertiliser in a hessian or fine mesh sack and suspend it in the flow of the incoming water (like a giant teabag). When you see some colour in the pond water (that is, an algal bloom is starting to grow) add 30 kg of an organic mixture such as pelletised chicken manure to the ponds. This mixture helps provide a good carbon source and will slowly release additional nutrients to stimulate a bloom.

Start the four corner aerators (see Chapter 3) when you add the first dose of fertiliser and continue to run them for 24 hours a day. This will ensure a gentle current around the pond and help keep the pond bottom swept clean along the feeding lanes (edges of the pond).

Establishing a good algal bloom

A primary aim in the initial weeks of preparing a pond is to establish and maintain a healthy and stable bloom of algae and other plankton in the water column ('green water') to provide the best growing conditions for the postlarvae. The plankton in a healthy bloom can provide a large proportion, if not 100 per cent, of the diet for postlarvae, as happens in the wild (see Chapter 3 and Chapter 6). High natural productivity in the pond also helps maintain water quality, mostly from the production of dissolved oxygen by photosynthesis and the removal of ammonia (Boyd 2003).

Generally, a brown algal bloom made up of planktonic diatoms will develop first. These are good nutritious algae but can be unstable. Diatom blooms support a good population of zooplankton. These algae require the addition of fertiliser at a rate of 10 kg of urea and 5 kg of mono ammonium phosphate every three or four days, depending on the secchi disk readings, which should be maintained below 50 cm. If the secchi reading drops below 30 cm you can then add 5–10 per cent more water to the pond to enhance the bloom further. The addition of 30 kg of pelletised chicken manure every three days for the first three weeks helps maintain stability and prepare the pond for the arrival of the postlarvae.

Fertilising rates and water use will be site-specific, depending on pond soil types and the quality of the incoming water, and you will need to trial various regimes over several crops to get the balance right. After growing a few crops you will have a better understanding of how to get the best result in your ponds because algal blooms tend to behave differently on each farm and there will always be significant variation in colour and algae species within a farm. Often you find every pond is a different colour on any given day (see Figures 4.5–4.10).

If you can recycle some of your wastewater this can also be useful in maintaining stability by pumping in a constant supply of the dominating algae (see Chapter 2 and Chapter 6). This is especially useful for those ponds that struggle to keep a stable bloom and for starting a bloom in a newly filled pond. If a bloom still does not develop, vegetable dyes can be used to provide shade on the pond floor and limit the growth of filamentous algae. This helps the postlarvae in their early stages until a phytoplankton bloom eventually takes over.

Figure 4.5 A green bloom, typical of the early stage in a crop, often dominated by diatoms

Figure 4.6 A milky green bloom, may be due to algae die-off

Figure 4.7 Light brown bloom

Figure 4.8 Brown bloom, dominated by dinoflagellates

Figure 4.9 Dark brown bloom

Figure 4.10 Dark bloom, dominated by blue-green algae, such as *Oscillatoria* spp.

At a glance

- Appropriate pond floor preparation and correct setting up of the aeration system before pond filling can both help provide a good healthy start for the postlarval prawns and form the basis of a successful crop through to harvest time.
- Adding lime to the pond soils is important in pond preparation, and lime can also be added directly to the water during the crop to help maintain optimum water quality conditions for maximum prawn growth.
- Establishing a good algal bloom is vital to encourage the growth of the postlarvae and provide the basis for a good yield at harvest.

Part 3

Growing the crop

CHAPTER 5

Starting a healthy crop

Assessing the quality of postlarvae

A critical 'make or break' stage in the prawn farming cycle is the selection of good-quality postlarvae and their subsequent stocking in growout ponds. Postlarvae are often called 'PLs' and are usually stocked in ponds at around PL15 (15 days after metamorphosis from megalopa) (Fig 5.1).

Failure to achieve good post-stocking survival of your postlarvae can reduce your harvest potential from the start of the crop, thereby reducing profitability. If post-stocking survival is low you may be forced to decide whether to restock (if additional postlarvae are in fact available) or continue with a sub-optimal stocking. The decision is made more difficult by the fact that by this time in the year the growing season is usually well advanced, and, as many farmers have found from bitter experience, shorter growout time resulting from late season stocking typically results in smaller prawns at harvest. With the influx of Asian imported farmed shrimp into Australia, undersize prawns are harder to sell profitably on the domestic market.

The first step towards optimising stocking success is selection of high-quality postlarvae. However, it is not always a realistic option for Australian farmers, who are often forced to take what they can get, given the relatively small output from our hatcheries (often due to lack of wild broodstock availability),

Fig. 5.1 Postlarvae at PL15 age ready for stocking in a pond

especially during peak demand in spring. Not surprisingly, farmers with their own hatcheries are in a better position to implement quality control than those who rely on an external supply of postlarvae. Farmers who depend on outside supplies need to develop strong relationships with hatchery operators to ensure access to good-quality postlarvae.

The Australian prawn farming industry will also benefit from future research outcomes of the *Penaeus monodon* Domestication Project jointly funded by the industry and the Fisheries Research and Development Corporation. This project is aimed at improving the reproductive performance of domesticated broodstock (bred in captivity), so that the industry can use captive breeders selected for optimum growth and survival, as well as the capacity to provide postlarvae all year round.

You can use a wide range of assessment criteria to measure the quality of postlarvae:

- Visible features include minimal size variation (large variation can indicate mixing of different aged batches or problems during the hatchery run), length to age ratio greater than 0.8 (use PL15s greater than 12mm length to avoid stocking runts), number of rostral spines (PL15s should have 6–7), open uropods, muscle to gut ratio in last segment of 4:1 (at least 80 per cent of postlarvae) and light colouration (fig. 5.1 to 5.4).
- Health assessments include no redness, no necrosis or fouling and minimal ectoparasites.
- Activity tests include vigorous feeding test — postlarvae placed in a bowl with brine shrimp (see Chapter 3) should have full guts in 10–15 minutes — or the commonly used 'swirl test' where postlarvae, when swirled in a shallow container of seawater, should realign and start swimming into the current.
- Some farmers also use a salinity or formalin stress test. In the latter, a small number of postlarvae are placed in a bucket of water used in the shipment with 100 ppm formalin for two hours. Survival should be more than 80 per cent in good-quality batches.

Most farmers now recognise that these assessments have some limitations. Two of these are particularly important:

1. Larval rearing tanks are stocked with multiple batches of nauplii to achieve the desired stocking density. Given that spawning and hatching times can vary by up to six hours or more, this means that there will always be some size variation within batches at any point during the larval rearing run.
2. Assessments of larval quality can never be standardised for moult stage. This means that activity and stress tests will give different results, within and between batches, based on where postlarvae are in the moult cycle. Postlarvae that have just moulted are less physiologically tolerant and are more susceptible to stress. Even in the 'swirl test', newly moulted postlarvae are more lethargic and will not realign as well as those that are further advanced in the moult cycle.

Despite widespread application of these assessments over a long period, both in Australia and overseas, there appears to be a general consensus among

Australian scientists farmers that there is no strong correlation between any of these measures and subsequent survival and pond performance. In fact, some industry stalwarts consider that assessment of postlarvae quality is not a 'look and score' exercise when postlarvae arrive at the farm. They agree that if there are obvious adverse signs such as redness, high levels of fouling, bent rostrums, postlarvae swimming in circles, necrosis or empty guts, then the batch may be compromised. Even so, some farmers claim to have obtained excellent pond results from postlarvae that were given poor initial assessments.

Instead of relying on the gross assessment detailed above, some farmers now place more value on the history of the larval run in the hatchery, for a finer-scale measure of postlarvae quality. Here they are looking for the initial condition of broodstock, good hatch rates, overall good survival throughout the run, whether the batch was nursed along with antibiotics and if it had reasonable moult synchrony (that is, not having a wide spread of different-staged larvae in the same batch).

In terms of more detailed health assessments, many farmers request screen testing for Monodon Baculovirus (MBV), Spawner Mortality Virus (SMV) and Gill Associated Virus (GAV). As with the gross assessments listed above, the

Figure 5.2 Postlarva tail section with gut visible

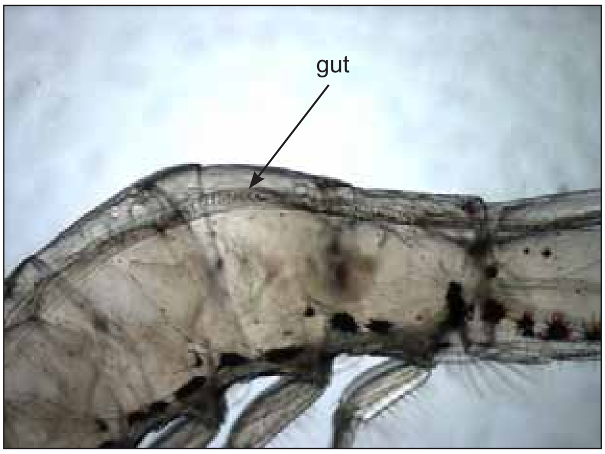


Figure 5.3 Postlarva last tail segment with gut visible

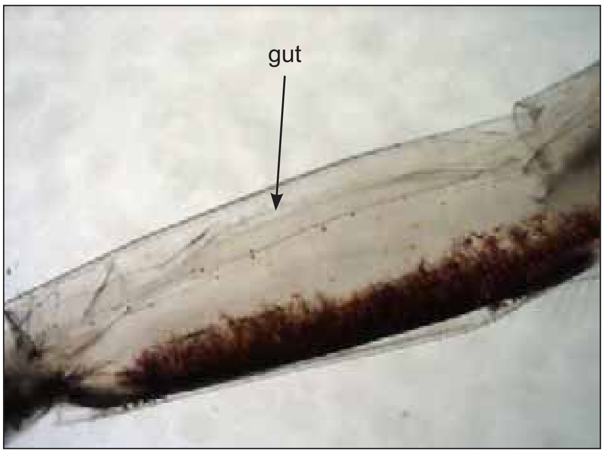


Figure 5.4 Postlarva with broken rostrum

Figure 5.5 Postlarva head and rostrum

industry consensus, particularly with regard to our most significant pathogen, GAV, has been that although these assessments may provide an indication of the condition of larvae leaving the hatchery, they have not been shown to be directly correlated with prawn survival in ponds. However, recent work by Munro et al. (unpublished) has shown that GAV prevalence in postlarvae does influence crop outcomes.

Timing of purchase of postlarvae

Australian prawn farms below the latitude of Townsville (19°15′S) are usually limited to one crop a year, with stocking occurring between September and November. Farms at higher latitudes may produce multiple crops by stocking ponds in winter, typically aiming for a harvest around Christmas. East coast hatcheries can produce postlarvae for winter crops, as wild broodstock (in the case of black tiger prawns) are generally available in reasonable numbers during May/early June. Experience has also shown that if postlarvae are stocked into ponds where the water temperature does not drop below 22°C good post-stocking survival can be achieved. Recent research has also shown that if broodstock are collected when sea temperatures are cooler than average, their subsequent offspring survival and yields in ponds can be lower (Lobegeiger et al. 2005).

If winter crops are established in the northern regions, the intention is often to follow them with a back-to-back summer crop for harvest in late autumn. Early monsoons may limit this opportunity, however, particularly if heavy rainfall prevents drying and preparation of ponds. Furthermore, for farms stocking black tiger prawns, postlarvae supplies cannot be guaranteed at this time of year (January/early February). To produce black tiger prawn postlarvae for a summer stocking hatcheries need to start stockpiling wild broodstock from as early as mid-October onwards, as supplies are generally unavailable from late November through into January. Reliable supplies of broodstock only become available again in late February/March, often associated with wet season flooding. By then, however, it is too late to produce and then stock postlarvae for a pre-winter growout crop.

Shrimp farmers in some other countries achieve multiple crops through the use of heated nursery ponds or raceways. Postlarvae are stocked at high densities in these nurseries for up to four weeks (during winter/spring) until temperatures in the growout pond are favourable or while growout ponds are dried and prepared for stocking during summer months.

Transporting the postlarvae to the farm

Post-stocking survival of good-quality postlarvae can be compromised through poor transportation and/or and acclimatisation procedures. To prevent losses, farmers need to develop a comprehensive stocking plan that includes:

- placing orders well in advance
- maintaining regular follow-up contact with the hatchery to ensure that production is on schedule (particularly as the stocking date draws near) and that health checks are undertaken

- advising the hatchery of pond water quality conditions
- adequate pond preparation well before stocking (see Chapter 4).

Farms sourcing postlarvae from hatcheries within six to eight hours' drive usually freight their postlarvae to the growout ponds in specialised transporter tanks. In the Australian industry there are a variety of protocols; some farms freight only at night to avoid daytime temperature extremes, while others feed brine shrimp to the postlarvae during transit. All transport protocols, however, should include emergency back-up procedures, especially for aeration (that is, spare aerators or oxygen cylinders), in case breakdowns occur.

For long-distance transport (say, from a hatchery near Brisbane to a farm near Townsville) postlarvae are usually packed in 20 L high-grade plastic bags filled with 9–10 L of water and pure oxygen and then air-freighted in approved styrofoam boxes. Stocking density depends on transit time, fewer animals being stocked for longer shipments, due to deteriorating water quality in the bags. For a shipment of six to nine hours (from the time of packing) a typical stocking density of PL15s is 8000–10 000/bag. For longer transits stocking density may be halved. Note that overseas work has shown that if transit time exceeds six hours, the loading of WSSV in the postlarvae increases significantly. It is therefore possible that long transit times (greater than six hours) for postlarvae in Australia could increase the load of pathogens such as GAV.

Before purchasing postlarvae you should make formal agreements with the hatchery owner about assessment of quality and when the ownership changes. This will minimise the potential for disputes if the quality or survival of the batch is compromised. In the Australian industry, ownership typically changes at the pond side for shipments sent in styrofoam boxes by air freight, if the purchaser opens the boxes and is happy with quality. Some prawn farmers send a utility with a live fish transporter to collect the postlarvae from the hatchery; ownership usually changes when the transporter departs from the hatchery. Any agreement on ownership changeover should include provisions for complicating factors, such as delays in airline flights.

Acclimatisation and stocking in the pond

If bags are used for transporting postlarvae, it is best to transfer them into an acclimatisation tank beside the growout pond, rather than stock directly into the pond from the bags, because as soon as the bags are untied the remaining oxygen escapes. This makes it difficult to maintain sufficient oxygen for the postlarvae during acclimatisation. Also, in terms of logistics, it is easier to control acclimatisation in a pond-side tank than to try to manage 30 to 40 floating bags in a growout pond. One advantage of transporting postlarvae in bags is that it is easier to verify the number sent by the hatchery.

Some hatcheries begin the acclimatisation process by adjusting water quality in the larval rearing tanks to match pond conditions (particularly salinity and temperature) before postlarvae are harvested and shipped. While this has obvious benefits, a major limitation is that water quality in the bags or transporter tank can change markedly during transit, especially in terms of temperature, pH and ammonia.

Preferences in the timing of stocking vary amongst farmers. Some have no choice if they are bound by air freight schedules. Some prefer to stock in the morning when pH and temperature are rising. Others base their stocking protocol primarily on pond temperature, while others prefer to stock in the afternoon or at night. The latter believe that postlarvae coming from dark conditions (in transporter tanks or bags) should not be suddenly exposed to direct sunlight, as this may cause stress. For black tiger prawn postlarvae, some farmers believe that the most critical water quality parameter is pH, given that postlarvae can tolerate wide fluctuations in salinity and, to a lesser degree, temperature. Irrespective of the time of stocking, many Australian farmers acclimatise their incoming postlarvae by slowly introducing pond water into the acclimatisation tank over a one-hour period. While this is occurring, many farmers add live brine shrimp to the tank to ensure that postlarvae enter the growout pond with a full stomach.

Brine shrimp are also known as *Artemia* or 'sea monkeys' and are important live feed used in the hatchery phase — see Chapter 3.

In the growout cycle most mortalities (some farmers estimate 70 per cent of all mortalities) occur during the first seven weeks after stocking. It is difficult to ascertain if these are independent of postlarvae quality and they are usually attributed to poor pond preparation, poor transportation or acclimatisation protocols and/or toxic blue-green algal blooms.

Water and feed management

The first 30 days of the cropping cycle are critical. As explained in Chapter 4, it is vitally important to encourage a strong bloom of plankton before stocking postlarvae. Algae are still an important food source for postlarvae when they arrive from the hatchery, and inorganic or organic fertilisers may be needed initially to feed the plankton bloom. As explained in this chapter, the need for additional fertilisers during start-up depends greatly on the nutrients present in water used to fill the ponds, and on the availability and levels of nutrients in pond bottom soils that were left by the last crop. To this end, naturally occurring copepods and other small zooplankton take the place of live brine shrimp that were previously fed in the hatchery. These desirable zooplankton species can pass through the 120 micron mesh socks/filters used to protect the pond ecosystem against the influx of competitors and predators (such as fish, crabs etc.).

Prawns can grow surprisingly quickly in ponds through their early juvenile stages when optimal conditions are established. This may be because they can feed on a number of sources in the pond at the same time (such as microalgae, benthic algae, various pelagic and benthic invertebrates, detritus, feed). A diversity of nutrition, as found in their natural environment, can encourage growth to the fullest potential (see Chapter 3). As the prawns grow, the crowding effects can soon become significant and the prawns' collective appetite will surpass the pond's natural productivity, but regular and careful feeding with pelletised feeds will alleviate this situation.

As discussed in Chapter 4, it is advisable to filter all incoming seawater through 'filter socks' or screens for as long as is practically possible during the crop to prevent pest species entering the culture environment. Occasional top-up water that may be needed during the first month or so to account for evaporation and seepage should also be filtered.

The common Taiwanese practice of applying minced or blended trash fish to encourage the zooplankton bloom and feed newly stocked prawns can be very successful, but this can be labour-intensive and is not widely recommended due to the potential for water fouling and disease risks. As mentioned above, some farmers also stock the pond with brine shrimp to initially provide feeds that the postlarvae are accustomed to, but this can be an expensive option if many ponds are being managed.

Good water quality and plankton stability during the days and weeks before and following stocking are among the most important factors for a successful crop.

Many farmers have concerns about overfeeding during the first month in terms of the amount of artificial feed offered to the low biomass of prawns that is present. However, feeding of fine-grade pellets is still recommended to ensure that the young prawns are presented regularly with fresh pellets during weaning. The amount of feed wasted during this time is minimal in the overall crop's feed inputs, and does not unduly affect water quality as long as enough aeration and circulation are maintained. At this early stage, feeds should be spread over as much pond area as possible, with some bias towards the edges where juvenile prawns tend to accumulate.

The feeding program Tables 1 and 2 provided in Appendix 3 are a guide to the amounts and types (size/grade) of feeds that should be fed to black tiger prawns. Table 1 is for the first 30 days for farms operating in the northern tropical climate zones. This feed chart provides amounts needed for 100 000 prawns of a given size, and so necessitates estimates of survival and average sizes of prawns in ponds. Survival and growth should be monitored weekly and feeding schedules should be amended to match the observed growth.

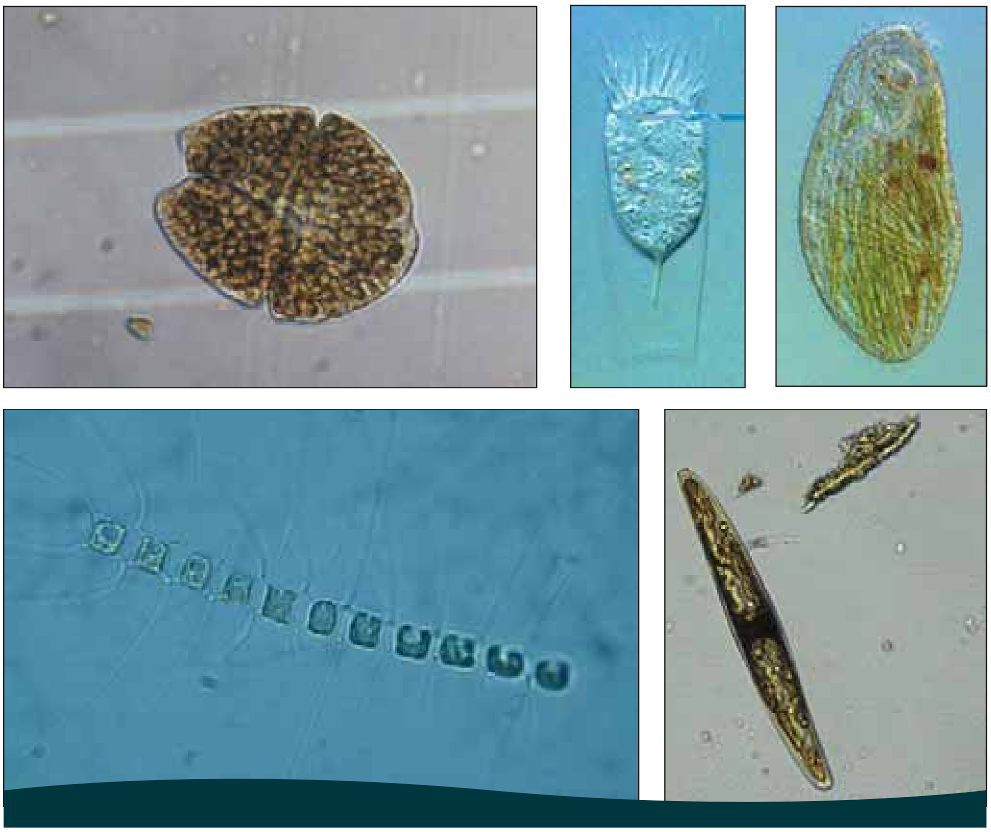
Table 2 is the subtropical region feeding chart, modified to account for lower growing temperatures (and slightly slower growth). As a rule of thumb, at temperatures below 24ºC, feeding amounts should be reduced by 50 per cent. Feeding should begin as soon as the postlarvae are stocked and frequency of feeding can be up to four times a day. Feed trays are usually used to guide feeding practices only after the prawns reach a size of 2 g. Before this, trays should be used occasionally to monitor the size and health of stock.

Plankton management

In a prawn pond the plankton community is loosely comprised of phytoplankton, zooplankton, protozoa and bacteria. The phytoplankton (also known as micro-algae) can include diatoms, dinoflagellates and other groups of unicellular algae species. The zooplankton will usually comprise copepods, amphipods, rotifers and other species groups (Figure 5.6). The establishment of a plankton bloom is a critical factor affecting the health and growth of prawns in ponds.

Pond plankton communities go through a succession of changes in the types of natural feed species that are available after the pond is first filled. Algal bloom changes are often caused by fluctuating population levels of particular zooplankton types (such as rotifers) grazing on the phytoplankton resource. When their grazing pressure exceeds the breeding rate of the dominant algal

Figure 5.6 Typical phytoplankton and zooplankton found in prawn ponds



species the algal bloom can fail, leaving room for other species that can take over and multiply by withstanding or avoiding this grazing pressure (for example, some blue-green algae species are not eaten by zooplankton). An important way to avoid this is to minimise water exchange and maintain a stable water quality regime. Ideally, water exchanges will not be necessary for the first month or so of the crop, limiting the potential for the introduction of organisms that can unbalance the ecosystem.

Figure 5.7 Floating mats of benthic algae that have lifted to the surface

Figure 5.8 Mats of dead algae deposited in a windward corner

Plankton blooms are promoted for a number of reasons, including shading the pond bottom and hence reducing the light available for the growth of benthic algae (algae that grow on sediment). Plankton blooms also provide the basis of a food source for newly stocked postlarvae, either directly as zooplankton or indirectly as phytoplankton, and play a role in the buffering of water quality in the pond. In benthic algae blooms, gases trapped in the mat may cause it to lift off the bottom, forming surface mats, then decomposing and fouling the pond bottom in windward corners (Figures 5.7 and 5.8). As prawns spend most of their time on the pond bottom, the dead algae can clog their gills, and create low oxygen conditions. Plankton blooms also play an important role in soaking up ammonia, a form of nitrogen toxic to prawns in high concentrations. Additionally they produce oxygen during the daytime, but this is counteracted by their consuming oxygen at night.

Establishing a plankton bloom can be a difficult process, depending on what organisms are in the water when the pond is being filled. Farmers have observed that establishing plankton blooms tends to be even more difficult in new ponds. If the water used to fill the ponds already contains a high number of plankton and plenty of nutrients — for example, if you recycle water from other ponds with a healthy bloom already established — a bloom should establish by itself. The addition of prawn feed and/or fertilisers containing urea, ammonium or nitrate as the nitrogen source and phosphate as the phosphorus source will ensure that the bloom, once established, continues to flourish over the first few weeks (see Chapter 4). Over fertilising should be avoided as it is a waste of money and, if ponds are flushed, increases the nutrient loads discharged from the farm. As prawns grow larger, and greater amounts of feed are added, the nutrients released from any waste feed and the metabolism of feed are sufficient to satisfy the needs of the plankton, and usually by mid crop it is no longer necessary to add fertiliser.

There are two excellent Australian guidebooks for identification of phytoplankton and protozoa in ponds: *A Guide to the Phytoplankton of Aquaculture Ponds*, C. Stafford, 1999, DPI&F Publishing, Brisbane, Queensland and *A Guide to the Protozoa of Marine Aquaculture Ponds*, D.J. Patterson and M.A. Burford, 2001, CSIRO Publishing, Melbourne.

At times, plankton blooms will not establish despite the addition of nutrients. It is not always clear why this happens — zooplankton grazing or algal virus attacks are two possible explanations. Benthic algae then begin to grow and may out-compete the phytoplankton, and the subsequent algal mats and sludge can create a serious threat to prawn health and the stable water quality conditions you are trying to manage. While you should be trying to avoid this situation, if algal mats do appear it is necessary to scoop them out manually. As a countermeasure, farmers may flush ponds in the hope that a new plankton inoculum will establish, although success with this strategy is highly variable. Alternatively, you can add commercially available vegetable dyes to the pond to reduce light penetration and hence benthic algal growth (usually as a preventative measure rather than a cure for the problem). This gives the plankton community longer to become established.

At a glance

- After you have filled the pond with water, establishing and maintaining a healthy algal bloom in the water column is one of the important procedures required before stocking postlarvae.
- You can use a range of tests to assess the quality of postlarvae before you stock them in the pond — healthy postlarvae are an essential requirement for a successful crop harvest.
- Developing a strong business relationship with the hatchery will assist you in getting good-quality postlarvae and help to reduce the risks involved in delivery and stocking.
- The transport and stocking process is a stressful time for the postlarvae when they are taken from a hatchery tank to the open water environment of a pond. Good planning and preparation can have a great influence on their survival and future growth, and therefore on the overall yield at harvest time.
- Young prawns can feed on the algae and zooplankton occurring naturally in a pond, and the management of a healthy and productive algal bloom is critical to the success of the crop at harvest time. The postlarvae will feed on the plankton until they overgraze it and can feed on the starter pellets.
- Pellet feeds are easy to use in intensive prawn farming and can help you achieve high yields, but are expensive and if overused can lead to deterioration in pond water quality. Maximising the effectiveness of feed management is a key determinant of overall profitability in your prawn crop.

Chapter 6

Mid-crop

Water management

As feed input increases, and organic material that has accumulated in the pond begins to break down through bacterial decomposition, the availability of inorganic nutrients that govern algal growth (such as ammonia, nitrate and orthophosphate) tends to increase as well. This can lead to thickening of phytoplankton blooms that will eventually need to be diluted to avoid unstable water quality.

While particularly turbid conditions are acceptable (secchi depth of 20–30 cm, see Chapter 3), the increasing biological demand for oxygen creates an increasing need for water exchange and vigilance in monitoring minimum oxygen levels and daily trends, even when aeration systems are in place. For example, all the dead algae from a bloom ‘die-off’ will be decomposed by bacteria that will consume a lot of oxygen, and without the contributions from photosynthesis will quickly depress the dissolved oxygen for the whole pond to dangerously low levels when an ‘oxygen crash’ occurs (see Chapter 3). This can typically occur after midnight when everyone is asleep, so can easily go to the full extent and kill all the prawns and other animals in the pond.

A daily water quality monitoring program is vital to avoid an oxygen crash or similar water quality events that can stress your prawns — remember the key to success in pond water management is stable water quality (see Chapter 4). Regular monitoring can help you predict such events before any stress occurs (see Chapter 3).

By midway through the crop, water exchange can be used to maintain optimum water quality conditions as well. Around 10 per cent in one day could be an appropriate level, but this may not be required every day. An exchange of 20 per cent every three days is also acceptable. A 30 per cent water exchange in one day is a large exchange and could disrupt any equilibrium of stable water quality conditions (if there is one) and in the pond.

'A lesson you will never want to experience'

An oxygen crash or similar unstable water quality event can be devastating for a first-time prawn farmer. If left to occur unchecked, the dissolved oxygen concentration can drop to zero and an entire crop of prawns can be lost in a single night. Cleaning up the mess can be a huge task (and 'emotionally draining') because the pond must be emptied and many thousands of kilograms of dead prawns must be removed from the pond floor and buried in an appropriate location on site, before they become an environmental hazard. This comes after the farmer has incurred all the financial costs and done the hard work of growing the crop. A partial mortality can be equally detrimental, because when a significant number of prawns die in the pond, water quality will deteriorate severely and the subsequent stress on survivors may mean that the crop never recovers.

Survival and biomass estimation

Estimating the biomass or standing stock of prawns in your pond is probably one of the most important field skills required in crop management. It is not only crucial for feed management, but also a useful tool for developing harvest strategies to optimise production levels. Many farm managers partially harvest their ponds to keep biomass below a certain, predetermined level (for example, no more than 5 tonnes/hectare), while others may commence partial harvests depending on water temperatures, dissolved oxygen levels and general health of the pond. Monitoring the biomass of the crop regularly is an important aid in improving the food conversion ratio (FCR) and maximising the growth rate, survival rate and yield. Keeping a close watch on the estimates of biomass weekly or even more frequently is also a critical tool for the management of growth problems or slow-acting disease. Knowing more about any health problems (and at what rate animals are dying off) allows farmers to decide whether to harvest early to optimise returns.

Methods commonly used to estimate biomass include diving the ponds with a mask to make visual estimations, using cast nets, or the feed tray/biomass method. All methods have their advantages and disadvantages and good management may include applying several (or all) methods to gain a more accurate estimation.

Sampling accurately each week in each pond and calculating the average body weight in grams is also a very important tool in monitoring biomass. Sampling is normally done at the same time each week, a minimum of 100 prawns being weighed.

At stocking and in the early stages of a crop

Early in the crop it is very difficult and not really necessary to estimate the body weight of the prawns because they are still too small to be caught in a cast net and may not yet be feeding on the feed trays. However, getting an assessment of

Figure 6.1 A postlarvae survival test cage moored on a monk

the initial survival (stocking can be a stressful time for the young prawns — see Chapter 5) and activity is critical in managing the early feeds (and possible re-stocking). Placing a small number of postlarvae (say, 100) in a large tub filled with pond water with aeration and placed in the shade or a survival test cage made from fine mesh (Figure 6.1) floating in the pond after acclimatisation may give an indication of early survival over the first few days. If mortality is observed in the first few days, it is highly likely that more prawns will die over the next few days — a good rule of thumb is to double the mortality estimates observed in the first two days. It is also worth noting that conditions in a cage or bucket are not the same as in a pond, so keeping the prawns for longer than a few days may give conflicting results.

Simply diving the bottom of a pond with a mask (especially near the stocking point in the first few days) to look for signs of mortality and activity can give an idea of early survival and health. An experienced person may even be able to estimate prawn densities by counting the number per square metre using this method. This can be repeated periodically until the prawns start feeding properly on the feed trays and are big enough to be sampled by netting.

Mid- to late crop

Usually by about week 6 the prawns are big enough to sample for biomass estimation. Cast netting is a commonly used way of estimating average size, density of prawns in a pond and the biomass. (Figure 6.2)

However, this method can be inaccurate as prawns may aggregate at different densities within a pond, each cast may cover a different total area, small prawns may get through the net and fast prawns may escape the net before it

Figure 6.2 Throwing a cast net to examine prawns

Typical calculations for cast net method to determine the density

Ten casts conducted on land show that the average cast area covered is 4 metres square.

Ten casts around the pond bank, plus 10 randomly allocated in the middle area of the pond, yield an average of 116 prawns per cast.

Density = 116/4 = 29 prawns per m^2.

gets to the bottom. If using this method, it is important to know the average cast area that you cover per cast and take a fixed number of samples from a variety of points around the pond and in the centre by using a rowboat. It is also important that you are consistently good at throwing a cast net — an experienced person can use this method to give a good idea of relative survival in each pond.

A more commonly used way to determine density and biomass is the feed tray method. This method is regarded as more accurate for different users (such as pond managers on different shifts) and assumes that prawns are of a certain size and that under good growing conditions (good pond temperatures, good pond health and between moults) they also consume a certain percentage of their body mass in feed per day. These percentages are feed type and site-specific and are also affected by growing conditions such as temperature etc., and should be adapted for each site and each feed management strategy.

Biomass (kilograms) = 10 000 × density (prawns/m^2) × average body weight (grams)

Approximate guide tables can be obtained from most feed suppliers and these should then be adapted for your farm and management practice. Here is where good historical data from pond record keeping (see Chapter 3) is useful, because you can calculate the actual survival and amount of feed used in crops as a percentage of the biomass to develop your own farm-specific, temperature-specific feed tables. This takes a few crops and a bit of time to fine tune, but has the added advantage of ensuring optimal feed rates and food conversion ratio. Feed trays should be checked continually and adjustments made as necessary to both feed rate and biomass/survival, i.e. it is a regular task that needs continual fine tuning. A 'feed consumption for body weight' table may look something like Table 6.1.

Table 6.1 Example of estimates of feed consumption for various prawn body weights determined for a prawn farm

Average prawn size (g)	Percentage of body weight eaten per day	
	26–28°C	28–30°C
5	4.5	5.0
10	4.1	4.4
15	3.6	3.8
20	3.2	3.3

Feed management

The feeding frequency should be increased to five times per day after the prawns have been in the pond for one month and feeding times should be spread evenly through the day with a dawn and a dusk feed.

Suggested daily feeding program:

6 a.m. or dawn
10 a.m.
2 p.m.
6 p.m. or dusk
11 p.m.

Prawns need regular feeding because they have small stomachs and rapid digestion. Although the manufactured feeds are designed to remain stable for about three hours, soluble compounds such as feeding attractants and essential nutrients can leach from the pellet very quickly. So feeding smaller amounts regularly is a more effective strategy to maximise the food conversion ratio over the entire crop. Spreading the feeding program over four to five times a day also minimises the effects of the high stocking density on growth caused by prawns fighting for food in the pond. Prawns generally feed and then rest periodically before returning to the water column in search of more food. This behaviour can enable you to use segregated feeding strategies for different size classes in the same crop, by applying feeds for the larger and more aggressive prawns first, and 20 minutes later feeding the smaller stock with a smaller pellet. This strategy requires that the biomass is theoretically split into two size classes, and therefore requires more detailed monitoring and feeding of stock.

Both survival and biomass may be estimated from Table 6.1:

Biomass (kg) = daily feed eaten (kg)/(% body weight eaten per day/100)

Number of prawns in pond = 1000 × biomass (kg)/average size (g)

Percentage survival rate = 100 × number of prawns in pond/original stocking number

Example: A pond initially stocked with 380 000 postlarvae is consuming 140 kg of feed a day and the average size of prawns is 10 g. The pond temperature is 28°C in the morning and 31°C in the evening and the pond is between moult cycles.

Biomass is 140/(4.4/100) ≈ 3181.8 kg

Number of prawns in pond ≈ 1000 × 3181.8/10 ≈ 318 182

and survival rate ≈ 100 × 318 182/380 000 ≈ 83.7%

Daily feeding requirements can be determined from Tables 3 and 4 in Appendix 3. After calculating the biomass of the standing crop in a pond, the feed tables can be used to decide which pellet grading to use, the amount to feed per day, and the amount to place on feed trays for effective monitoring of feed consumption.

Using feed trays for good food conversion ratios

Careful attention to feeding practices is necessary to achieve good food conversion ratios. This is achieved through:

1. weekly stock estimates (see above)
2. following feed charts to set a base rate
3. feed tray observations to determine when changes in ration size are needed.

Feed trays are an important tool to use so you can match the daily feed usage with the prawns' appetite (Figure 6.3). This will further improve feeding efficiencies on a daily basis, minimise underfeeding or wastage, and help maintain good water quality in the pond (leftover feed will leach nutrients). The general rule in monitoring appetite for an efficient feeding program is to increase by a little and decrease by a lot.

For example, if no feed is left on the tray, feed can be increased by 10 per cent, but if feed is left on the tray, decrease by 20–50 per cent and try to find out the cause of the prawns' lower appetite. If most of the feed is left, the next feed

How to calculate the daily feed requirement for a pond

Example:

Biomass estimate is 1000 kg @ 22 grams average body weight (ABW)

→ 3% to feed = 30 kg/day

This amount is then divided by the number of feeds being done each day.

Figure 6.3 Checking a feed tray to monitor feed consumption

can be skipped. The point to remember is that uneaten feed can leach nutrients and lower water quality in the pond as well as potentially increase the nutrient load in the farm effluent that is licensed under your EPA permit. Feed costs can account for more than 30 per cent of production costs so it is very important to manage the feeding program closely to get good food conversion ratios for overall farm profitability.

The general rule in monitoring appetite for an efficient feeding program is to increase by a little and decrease by a lot

Another important feed monitoring technique is to check how much feed is left in the gut of prawns after a feeding session (Figure 6.4). Catch a prawn with a cast net and hold it up to the sunlight or bend it gently and observe whether it has feed in its gut (see Chapter 3). You can then determine the percentage of prawns that are feeding.

Figure 6.4 Checking the amount of feed remaining in the prawn gut

For general enquiries about prawn health in Queensland you can contact a Veterinary Officer (Aquatic or Fish Health) at the DPI&F laboratories at Oonoonba, Townsville or Yeerongpilly, Brisbane by calling 13 25 23

Your feed blower (see Chapter 2) needs to be powerful enough to clear the bank and spread the feed evenly from the bottom of the pond bank to near the sludge pile, which could be 20 metres from the edge. Particular attention should be paid to the destination of feed from blowers on windy days, because the prawns (not surprisingly) cannot access feed if it is deposited on banks above the water line. The tendency to overfeed the corners of ponds with blowers mounted on vehicles should also be avoided, because this is where other organic matter can accumulate due to the settlement of wind-concentrated filamentous algae and other debris.

When changing diet sizes or brands it is recommended that you change over a three-day blending period. Feeds should be used within six months of manufacture and stored away from sunlight in cool, dry, vermin-free environments. If longer storage periods are necessary, air-conditioned rooms or refrigeration may be necessary, and good feedstock control should be practised to ensure a first-in first-out approach that provides the freshest feed possible. When ordering feeds you should consider the time taken to supply them, and you should also think about a buffer or reserve feed supply to account for any unforeseen delays (such as delays caused by floods).

Plankton management

By midway through the growth season, the plankton community is usually well established in the pond. It is generally not necessary to fertilise the water by this stage as the daily feed input and subsequent metabolites are sufficient to fuel plankton growth. The plankton community is loosely comprised of phytoplankton, zooplankton, protozoa and bacteria. Each of these groups has a cyclical pattern of growth, where there are periods of growth and death, and each group has impacts on the other: for example, bacteria release nutrients for phytoplankton growth, and zooplankton feed on phytoplankton. The most common method of managing the poor water quality that can result from a death phase is flushing of water through the ponds. However, this can be counterproductive as it introduces new colonising plankton species which may keep the system unstable. Increasingly, farmers are finding that reducing flushing rates and/or partial recycling of water can improve the stability of plankton blooms.

If possible, your weekly water quality checks (see Chapter 3) should include identification and quantification of the plankton. This can be done easily by collecting whole water samples and examining them under the microscope. It can provide an early warning of potential problems with prawn health and/or growth and gives a regular evaluation of general pond health.

At a glance

- Water quality monitoring and management are vital to achieve sustainable prawn growth and avoid a disaster such as a dissolved oxygen 'crash' where the entire crop of prawns can die during the night. Beware!
- Unlike cattle or sheep, your prawns are underwater and it is often hard to observe if any have died or are unwell. You can use a range of methods to monitor their survival as well as the overall biomass (standing crop) during the crop so you can estimate the overall crop yield before harvest.
- By mid-crop you need to keep a close watch on the amount of feed being used each day, to ensure that it is eaten as well as to avoid overfeeding, which can pollute the pond (and waste money). Feed trays can be used very effectively to monitor the efficiency of feed management.

Chapter 7

Final phase to harvest

Water and feed management

The final phase of the crop requires close management of the water quality in the pond and the environmental performance of the farm at the licensed outlet pipe. If your management of the crop so far has been effective, the prawns have grown significantly and they need a lot more feed per day! This is a good outcome but it can also increase the risk of deterioration of the water quality, essentially because of the major increase in nutrient loading added to the pond per day.

Feeding practices are similar to those in the mid-crop phase in terms of frequency and management, but the amount of feed per day has increased along with the amount added to the feed tray. Because even larger amounts of feed are needed, it is vital at this stage to monitor feed consumption and health of the stock to recognise quickly any reductions in survival (see Chapter 6 and feed tables in Appendix 3). While a pattern of continually increasing feed consumption should be expected, any variations in the appetite of the prawns should signal caution, a need for closer inspections and a probable adjustment of feed rates.

Some farmers do not provide the last one or two feeds before harvest to allow for purging of the digestive system (this empties the 'gut line'), but if left hungry for too long the prawns will start to consume bottom detritus, which lowers the quality of the final product. Increasing salinities to full-strength seawater (35–36 ppt) towards the time of the harvest can also improve the taste of the product.

Plankton management

The final phase of growing a crop is the most challenging in terms of managing the plankton bloom. By this time, the high nutrient loads from the metabolism of feed, coupled with the high temperatures and light availability occurring in late summer, can encourage high plankton growth. Typically, grazers of phytoplankton, such as zooplankton, are not present in high numbers and therefore there is little to control the volatility of phytoplankton growth. Crisis events can occur where algal blooms die off (a 'crash'), particularly when water temperatures become high. When this occurs, oxygen levels in the ponds can drop quickly. The most commonly used methods of dealing with this problem are increasing aeration, temporarily reducing feed inputs and flushing the problem pond with water (see Chapter 3).

When nutrient loads are high, prawn gills may become fouled with filamentous algae or blue-green algae such as *Oscillatoria* spp. Prawns can also suffer from Haemocytic Enteritis if they consume blue-green algae with the prawn pellets (see Chapter 8). Some phytoplankton species are considered toxic, and while there is no documented evidence of toxic phytoplankton killing prawns in Australian ponds, the chronic effects on prawn health should not be ignored.

The high nutrient and carbon loads resulting from the high feeding rates also promote bacterial growth. Protozoa that feed on bacteria also increase in numbers and some species — for example, peritrich ciliates such as *Epistylis*, which attach to prawn gills — can become a health problem for prawns. Again, temporarily reducing feed inputs and/or flushing are methods commonly used to reduce bacteria and protozoa numbers.

Continual vigilance on the part of pond managers is the best way to ensure that crisis events are averted. They should monitor pond water quality daily (Chapter 3) and look for warning signs of plankton bloom instability.

Preparing for a harvest

Simple planning and preparation for a harvest can make the work much easier and prevent costly mistakes that may result in wastage or deterioration of the product that you have worked so hard to produce. Make sure you have all the equipment on hand (see Chapter 2) and make sure you have arranged a buyer or market and have booked the transport to get the product there.

Essential items that must be ready for a drain harvest include:

- bins for storing chilled prawns pond-side or at the processing room — more than enough to hold the estimated quantity of prawns (see Chapter 6)
- bins for storing ice pond-side — more than enough required to chill the estimated quantity of prawns
- ice delivered or made on site in an ice-making machine
- scoops, hoist or lifting arrangement, pallets, chemicals, salt etc.

Harvesting the crop

Wing net harvesting

Wing or 'trap' nets are good for harvesting live prawns in small quantities (Figure 7.1). They also have the advantage of enabling a thinning of the crop (reducing the overall biomass) and taking out the larger prawns in each pond with minimal disturbance to the pond. Thinning can improve the eventual yield from the pond by providing the smaller prawns remaining with more room and access to feed. Unlike drain harvesting, the wing nets do not collect sludge and sticks from the pond floor. Using wing nets is an easy way to harvest live medium to large prawns, usually those with hard skins (because they are more active).

Generally the pond water level is lowered to one-third to half and 4–8 wing nets per pond are set at right angles to the pond sides in a strong current area

Figure 7.1 A wing or 'trap' net set in the pond for harvest of live prawns

2–4 hours before collection. Depending on density and conditions, wing net hole sizes are chosen according to the preferred prawn size to be harvested.

Lifting the prawns from the pond to the top of the pond wall and into a vehicle can be strenuous work and should be planned properly to avoid spillage and work-related injuries. Two methods used are:

1. placing prawns from the cod end in net-covered baskets while standing in the pond, then lifting the baskets up the side of the pond wall
2. using a crane to lift the cod ends and nets directly into the tubs or tanks on the back of a vehicle used to transport prawns to the processing area.

Collecting prawns regularly from the nets (approximately each hour) and transporting them quickly in small baskets to the processing area may mean that you will not need to use ice if it is a short distance to the processing room.

Drain harvesting

Drain harvesting can be used for either thinning out a crop (by partial drain) or harvesting an entire crop in one hit. It is generally a lot faster than using wing nets in terms of workload per kilogram of prawn harvested, but can often lead to a significant proportion of the product being harvested with a soft shell (if the prawns have moulted recently). Because all of the pond water and its contents have to pass through the harvest cod end, the drain method can also cause damage to your prawns in the very last stage of your farming work: broken prawns squashed in the net, and sludge or dirt deposited in the gills and around the appendages. You will also have to sort out various kinds of rubbish that may accumulate in the pond during the crop: sticks, filamentous algae and trash fish that may have entered the pond despite the use of filter socks. You need to have a good look at the prawns before the harvest to minimise the problems of soft shell and quality issues.

HACCP = where food safety is assessed according to a standard through the implementation of an effective Hazard Analysis Critical Control Point (HACCP) system. The HACCP system provides for an assessment of food hazards, acceptability limits, monitoring and the implementation of possible corrective action. Documentation is an important part of the HACCP process.

Drain the majority of the pond water through the screens on the monks to prevent escapees, before starting the actual harvest process. This is best done from the bottom of the pond (by setting monk boards to drain from the floor of the pond). When the pond water level has been lowered by approximately half, you can remove the screens and start collecting prawns in the cod end or cage set up in the harvest bay of the drain (Figure 7.2). A harvest box with a diverter to two cod ends will allow you to keep the water flowing out and enable uninterrupted collection of the prawns (it also will minimise the damage to prawns in each net). Given that quantities collected each time can be significant (50–150 kg per net), the lifting up to a pond-side bin or basket (usually on a vehicle) should be by hoist or crane (Figure 7.3).

Processing prawns after the harvest

Processing methods vary greatly within the Australian prawn farming industry as they depend on farm size and the infrastructure available on the farm. Processing of prawns requires Hazard Analysis Critical Control Point (HACCP) approved factory standards as a minimum, but for a small prawn farm processing of green prawns can be subcontracted out to a nearby approved factory, with only basic HACCP required up to harvest stage.

The quality of a prawn starts to deteriorate immediately after it dies. The digestive organ, or hepatopanceas (see Chapter 3), contains a range of enzymes that cause changes to the prawn's appearance and texture because they remain active after death. While not feeding the prawns for 24 hours before harvest may reduce the amount of digestive enzymes (mainly proteases) present in the stomach, the hepatopancreas still retains plenty of activity. Any longer than 24 hours may make them hungry enough to eat the bottom detritus and spoil the quality of the cooked product. These enzymes digest through the surrounding tissue and attack the ligaments that connect the head (cephalothorax) to the tail meat (abdomen). These weakened tissues will then result in a significant amount of weight loss and head loss during storage and cooking. Initially the only visible defect will be a discolouration of the organ, but this will spread through the head and into the tail meat.

A manual on the design and establishment of an on-farm HACCP approved processing facility can be purchased through the Australian Prawn Farmers Association: www.apfa.com.au.

Most of the farmed prawns produced in Australia are cooked immediately after harvest. If you want to sell them as green product (fresh chilled or frozen), you will need to handle them differently. As all enzymes operate faster in warmer conditions it is imperative that prawns be chilled immediately after capture. This can be in an ice slurry, in refrigerated seawater (RSW) or under ice.

Another enzyme, polyphenol oxidase, will cause the dark pigment known as black spot to develop on the gills, shell of the head and shell of the tail. Unfortunately, unless the prawns are frozen immediately, a chemical treatment will be required to prevent black spot. A range of chemicals are approved by Food

Figure 7.2 Drain harvesting with a harvest cage

Figure 7.3 Lifting the cod end with a crane

Figure 7.4 Releasing the harvested prawns from the cod end into an ice bin

Best Practice: Harvest, processing and transport of farmed prawns, QSIA (1997). You can purchase this easy-to-follow best practice manual online at: www.seafood.net.au.

See also the publication *Safe Seafood Australia Guide to Standard Primary Production and Processing Standard for Seafood*, 1st ed, 2005, Available from the FSANZ website: www.foodstandards.gov.au.

Standards Australia and New Zealand (FSANZ) for use on prawns, but the most commonly used is 4-hexylresorcinol. Citric acid can be used with green prawns in the ice brine to remove any algae fouling on the shell.

All chemicals can be applied as an initial quick dip, but if there is subsequent storage in chilled water some of these chemicals will wash off, leaving the prawns more vulnerable to developing black spot during processing and transport. It is often more convenient to apply chemicals during a holding period. This allows a reduction in the amount of chemical used and better penetration of the chemical into the flesh. If the prawns are really prone to black spot — say, because they have recently moulted — a combination of initial dip and soaking may be required. Remember, the presence of any chemical additives will need to be documented on packaging.

Prawns that are to be cooked should be processed as quickly as possible to minimise losses. The cooking method will affect the quality and amount of recovery. If the prawns are undercooked, the enzymes will remain active and cause damage. If the prawns are overcooked, they become tough and lose a lot of weight. Prawns should be cooked in boiling water. Salt can be added to the cooking water but the salinity should be no more than that of seawater (30 ppt). Cooking times should be related to the amount of time held in boiling water, not total time, as the basket will come off the boil after it is placed in the cooker. The float method, where the prawns are boiled until they start to float, will lead to slightly undercooked prawns with active enzymes. Larger prawns require a longer cooking time. Overall, it is better to conduct some trial cooking before the major harvest because cooking times will vary between sizes and even between ponds.

At a glance

- As the crop reaches the final stages the feed consumption and subsequent nutrient input per day will be significant and this can make it harder to maintain stable water quality and an algal bloom regime.
- The higher nutrient and organic loads in the water column can cause prawn health problems, such as biofouling of gills.
- Water exchange can be used to improve water quality in the pond but is best done in small quantities over time to minimise sudden changes that may stress the prawns.
- Partial harvesting can be done with live trap nets, or the pond can be drained to collect the entire crop. You can plan wisely for a crop harvest and avoid costly wastage of prawns that you have worked hard to grow. Processing of the product also must be pre-planned and completed according to standardised food processing procedures.