Prawn farming without the environmental drama:

A model suitable for remote or indigenous aquaculture

A practical farm design to assist the development of remote and indigenous aquaculture

By K Chang & A D McLennan
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Introduction

Despite issues of economic scale and the potential for adverse environmental impacts of land-based prawn farming in Australia, prawn farmers have developed an exclusively outdoor pond-based intensive farming approach. The systems required to grow prawns under these conditions are capital intensive needing a highly technically based infrastructure regime to support and sustain the production facilities. Increasingly overseas competition from low cost structure countries, such as the Indian sub-continent, Thailand, Vietnam and China, has led many to question the long-term sustainability of this still emergent aquaculture sector in Australia.

The purpose of this paper is to consider an alternative to the present intensive farming techniques used in the vast majority of Australian prawn farms. The model presented below is based on a working low intensity prawn farm established in the Roper River area of the Northern Territory by Ken Chang, co-author of this paper, during the 1990s.

In an report to the World Bank, KPMG Center for Aquaculture and Fisheries (Hempel, Winther and Hambrey) identified set a variety of conditions for the improved sustainability of prawn farming being;

- More rational and appropriate land and water use;
- More rational and equitable resource access or allocation;
- Conflict resolution;
- Protection of the environment;
- Improved monitoring and regulation related to disease incidence; and
- Improved water management, supply and wastewater disposal.

In addition to meeting these criteria, low intensity prawn farming has the potential to reduce the industry entry barriers in terms of capital and support infrastructure. Further, it is believed the application of the processes such as outlined in this paper will facilitate a more active participation in the industry by Australia's indigenous communities, creating new opportunities for equity, community growth and self-sufficiency.

Industry Background

Prawns, (or shrimp as they are known elsewhere around the world), are the most commonly and thus most important seafood product traded internationally (*SOFIA)*. Over the last 20 years prawns have accounted for around 20% by value of the seafood traded internationally, a level that has remained stable over this time, (*SOFIA)*. In the last decade world prawn production has expanded steadily, with over a quarter of the prawns traded internationally coming from aquaculture sources. (*SOFIA)*.

In 2000, Black Tiger prawns ranked twentieth (20^{th}) in global aquaculture production in terms of species by weight but ranked 1^{st} in value at US$4.05 billion (*SOFIA)*. In 1995 63% of all farmed prawns were Black Tiger prawns although this level has declined to 52% in 2000 with the increased cultivation of the easier to grow whiteleg shrimp (*penaeus vannamei)* and fleshy prawn (*penaeus chinensis*), the latter mainly grown in China (*SOFIA)*. Currently 30% of all seafood consumed worldwide derives from farmed sources *(SOFIA).*

In Australia the combined wild harvest and culture prawn production of Australia in 2002 was to the order of 29,000 tonnes (*Australian Prawn Farmers' Association).*

There are approximately 40 prawn farms operating in Australia, predominantly located in Queensland, (*Lodegeiger and Wingfield)*, which in 2001/2002 accounted for 3411 tonnes with the bulk of the balance grown in New South Wales (*ABARE 2004*). 95% of all farmed prawns in Australia are Black Tiger prawns (*penaeus monodon*) (*Love and Langenkamp, 2002*) and are grown intensively in ponds ranging from 0.4 hectares to 1.7 hectares in size stocked at an average density of 37 - 38 post larval prawns (PL) per square metre (*Lodegeiger and Wingfield).* This stocking rate delivers an average return of 4, 054 kilograms of grown prawns per hectare at harvest (*Lodegeiger and Wingfield).*

Following a period of steady growth the industry output has declined in the last documented season from the peak of 2001/2002, when farmed prawn volumes reached 3636 tonnes valued at $56.9 million at an average return of $15.65 per kilogram, down from the previous year at $15.88, (*Galeano et al*). The value of production in 2002/2003 remained static although the volume of production decreased by some 230 tonnes to 3.403 tonnes at an average price of $16.71 (*ABARE 2004*). 96% of all farmed Black Tiger prawn production in Queensland is marketed domestically (*Lodegeiger and Wingfield).*

Table 1

Black Tiger Prawn Farms in Australia

Number and Ponded Area of Commercial Black Tiger Prawn Farms [a]							
	1995-96	**1996-97**	**1997-98**	**1998-99**	**1999-00**	**2000-01**	**2001-02**
Commercial Farms							
New South Wales	4	4	4	na	5	na	na
Queensland	24	23	26	26	29	30	32
Northern Territory	na	na	na	na	na	3	3
Ponded Area	ha	ha	ha	ha	ha	ha	ha
New South Wales	60	53	72	116	112	110	128
Queensland	302	329	390	451	528	586	717
Northern Territory	na	na	na	na	na	13	na
Total	362	382	463	567	640	709	na

[a] *- some farms may also produce banana and brown tiger prawns*

Source – Love and LangenKamp, 2003

Table 2

Volume of Farmed Black Tiger Prawn in Australia

Australian Farmed Black Tiger Prawns *(Penaeus Monodon)*								
	95-96	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	**01-02**	**02-03**
Volume (tonnes)	1 336	1 278	1 902	2 174	2 705	2 683	3 636	3 403
Total Value ($m) [a]	17.7	17.9	28.2	31.6	41.1	42.6	56.9	56.9
Unit Value ($/kg)	13.25	14.00	14.83	14.54	15.19	15.88	15.65	16.71

[a] *2000-2001 figure includes 33 tonnes of banana prawns for NSW valued at $0.5m.*

Source – Galeano et al 2004, Lodegeiger and Wingfield

Research on behalf of the Australian Federal Government's Department of Agriculture, Fisheries and Forestry, shows there has been a massive shift in the buying habits of Australian consumers through the 1990s. Prawns became the preferred seafood for consumption both in restaurants and in the home. Supermarkets increased their overall seafood market share from 8% per annum of the frozen product sector to over 54% per annum with an increase in supermarket seafood sales from the early 1990 until 1999 of 368% per annum (*Ruello*). There is, however, no definitive research available on consumers'

preferences for Australian or imported product although anecdotal evidence indicates there is little price elasticity where the product size and quality is similar.

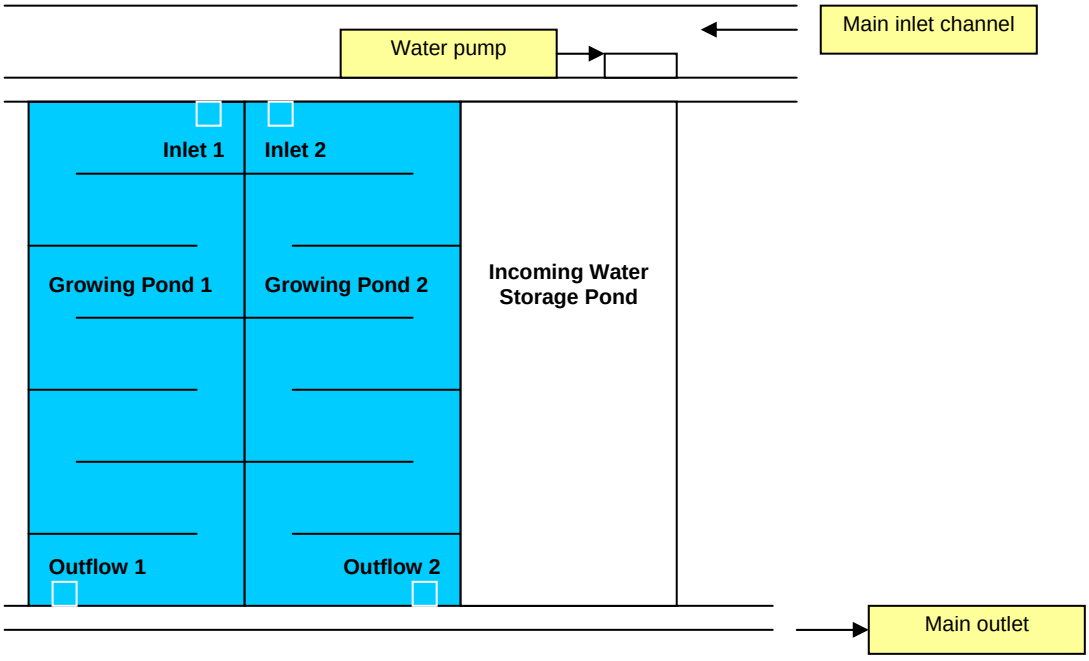
Basic Concept

The basic concept behind low intensity prawn farming is to reduce the number of animals being farmed per hectare (stocking density) to such a point as to minimise their husbandry needs and the environmental impact to such an extent as to be effectively negligible. Conventional prawn farming in Australia involves stocking densities averaging approximately 37 - 38 post-larval prawns (PL) per square metre in ponds of the scale detailed above (*Lodegeiger and Wingfield*). Low intensive prawn farming calls for a stocking density of 3 to 3½ PL per square metre in a much larger pond of 10 hectares rather than the smaller ponds used for more conventional intensive prawn farming.

The pond design as shown in Figure 1 below can be expanded dependent upon the size of land and resources available, without compromising the basic operational concept. The model under review is a two growing pond or twenty hectare production facility including a ten hectare water storage pond as laid out below. The model, as shown, can accommodate up to a total of six (6) 10-hectare growing ponds before an additional reservoir is required.

Figure 1

Single Module of Model Low Intensity Prawn Farm



As mentioned above, each growing pond is ten hectares in size and, when stocked at a density of 3 to 3½ PL per square metre will produce approximately 11,000 kilograms of prawns per pond per crop with minimal management input. As detailed above, conventional

prawn farming in Australia averages approximately four times this level of productivity for the equivalent pond area. . Labour productivity in the low intensity farm is 11 tonnes per labour unit where conventional far labour productivity stands at 12.3 tonnes per unit (*Lodegeiger and Wingfield*). Thus whilst the low intensity system is roughly only one quarter as productive per hectare of pond area as the intensive prawn farming model, the reduced labour requirement and reduced operating costs tends to offset this apparent disparity.

Dependent upon local conditions, the walls and partitions of the ponds are built up to a height of one and a half metres (1.5 m.) and five metres (5 m.) wide at the top by removing soil from within the ponds. This technique reduces the amount of soil required to be moved, with a subsequent reduction in costs associated with treatment of Acid Sulphate Soils where necessary, and therefore the overall capital cost. Whilst there are specific issues associated with the shaping of the interior of the ponds it is not necessary to consider those at this time.

A clay-based soil is most suitable for construction of the pond walls. Where the soil is more friable it may be necessary to line the ponds. In this instance the cost would have to be balanced with the other advantages of low intensity farming as detailed below.

As shown above in Figure 1, water is pumped directly into the growing ponds when the tidal conditions applying locally are most propitious. The storage reservoir is to provide back up water for those extended periods when the source water is not suitable for direct application to the growing system, for example during local floods when the source water may be predominantly freshwater. Wastewater from the growing ponds, due to its extremely low nutrient load, can be channelled straight back into the water source at the appropriate point. To reduce the number of pumps and the pumping cycle the layout of the system should be such as to allow it to gravity fed through the system and into the outlet channel. Construction of higher walls on the reservoir will enable this water to be also gravity fed into the system when required.

Concept Operational Considerations

Advantages

Lower Stress – higher growth rates – minimal environmental impact

Lower stocking densities more closely resembles natural growing environment and thus creates less stress in the stock. The lower the environmental stress the lower the mortality level and the higher is the growth rates of the animals, thus harvest can be earlier or animals can have the opportunity to grow to a larger size in the time allowed.

The lack of competition within the pond system enables the animals to grow to a larger size more quickly by comparison to the traditional intensive prawn farming systems. The benefits

available in the marketplace for those producers able to consistently offer a larger animal are clearly an advantage for low intensity prawn farms' bottom lines.

The truism for wastewater experts that "the solution to pollution is dilution" is never better applied than in low intensity prawn farming. The low stocking rates utilised in the low intensity model under consideration, coupled with the frequency of water exchange and lower FCR, and thus less surplus feeding, enables the water outflow quality to be close to that of the inflow. As there is prawn waste material in so minute amounts, by comparison to the volume of water, there is no need to pre-process the water before release into the general environment. The wastewater from the system will already meet the most stringent environmental standards imposed upon the industry, a massive savings in land utilisation, effort and overall cost.

Lower Operational Costs

The low stocking density, regular exchange of water, absence of algal oxygen depleting blooms all contribute to lower operational and energy costs. There is no requirement in the model for the use of aeration as there is sufficient natural aeration of the ponds to satisfy the needs of the animals. As there is no aeration required there is no need for extensive electrical installation to support it.

As the inlet pump and any refrigeration, required only during the harvest period, can be adequately supplied by the use of low cost diesel power, (Note: diesel energy used off-road in aquaculture production currently attracts a Federal Government rebate of approximately $0.39 per litre, more in proclaimed remote regions), the system is very suitable for areas where there is no access to the electrical grid whatsoever. The total absence of the need for external electrical supply means the areas capable of supporting the farm system are dramatically expanded over intensity prawn farming sites.

With traditional pond aquaculture a source of freshwater is required to control rising salinity during periods of high evaporation. As the water is being regularly exchanged with a new water supply directly from a known quality source, the low intensity model does not require a bulk freshwater source at all.

Conventional intensive prawn farming requires the animals be fed up to six (6) times daily. The low stock density level means the competition for feed within the ponds is reduced and the animals will grow very satisfactorily on only two daily feeds. Lower feeding frequency significantly reduces both labour and energy costs.

The low competition for food also has a dramatic impact on Feed Conversion Ratio (FCR). The typical bought feed FCR for the working farm this concept is modelled upon was close to 1.1:1, a significant feed cost savings per kilogram of product produced.

Selective harvest through static netting

The design of the ponds and the natural tendency of the animals to circulate within the system mean simple static nets can harvest animals of a specific size without the need to drain the ponds. Smaller animals than those of the target size simple pass through the mesh whilst target sized prawns are herded into collection pockets. As the process relies on the natural movement instincts of the animals, they are harvested with less stress and thus less damage than is experienced in conventional drainage or seining harvest systems.

In drainage systems, where a net is placed over the pond outlet and every animal is harvested regardless of size, the animal are collected under the force of the water flow and thus typically results in product damage and overall lower market prices. Seine netting systems use a weighted drag net pulled across the bottom of the pond with small electrical charges used to prevent the animals from remaining on the bottom of the pond. This system can cause significant benthic disturbance resulting in not only the harvested animals experiencing stress and damage from the electrodes and weight of the netted animals, but also the remaining animals have to cope with the subsequent increased turbidity and loss of growth profile.

A further consideration in low intensity prawn farming is that the animals can be left in the ponds beyond their usual harvest time to bring the product fresh to market at its price peak, for example Christmas, Chinese New Year and Easter, without an adverse impact on the smaller animals in the pond.

Lower disease risk

Endemic diseases carried by prawn broodstock, and thus seedstock, within Australia tend to display themselves when the animals are under greater stress. The lower stocking density employed in low intensity prawn farming reduces the prospects of animal stress thus improving growth rates and reducing the occurrence of disease outbreaks with the subsequent losses endured by prawn farmers through higher animal mortalities. Additionally, where disease does occur the spread and severity of the outbreak is reduced due to the lower stocking density.

Shorter pond down-time

Traditional intensive prawn farming requires the ponds to be dried off periodically to allow the build up detritus to be broken up and sterilised by the ultra-violet rays of the sun. The lower stocking density being proposed will significantly reduce the time required for this to occur in

the model farm. Continuous production can be further facilitated in the long term through the simple agency of having a third pond and allowing one of the ponds to lie fallow on a rotational basis.

The lower stocking densities utilised in low intensive prawn farming has an impact on the level of pond base built up detritus and thus on the degree of cleaning required between crops. The reduced levels of detritus mean that ponds can be dried, cleaned and recover within a two week changeover period.

Stable productivity

Those traditional intensive prawn farms that operate on a two crops per year cycle in Far North Queensland typically sacrifice the average size of the animals produced in the "off-season" crop. The animals tend to grow slower when the environmental conditions are less than optimal. With less competitive pressure, stemming from the lower stocking density the size of the animals, produced from crop to crop in a low intensity system will tend to be unchanged. Consistency of quality and supply, (often seen by consumers as size related), is essential if premium prices for product are to be achieved.

Simple System management

The low intensity farming system being proposed in this paper requires a minimum of day-to-day management input. Greater frequency of water exchange minimises water management skills required in low intensive prawn farming and the lower feeding regime also reduces the overall necessary skill levels by comparison to intensive farming systems. This is not to say there are not system management inputs required, simply that they are minimised.

Lower labour requirements

Where the low intensity prawn farm is to be used as a training facility or job creation purpose there is sufficient work which can be done on a manual basis to meet the basic requirements, however, the system can be operated with a minimum of labour if required or desired through utilisation of a more mechanically assisted approach. One qualified aquaculture technician can meet the basic needs of the system with one labourer to assist with the more general work, a level that approximates the productivity rate of more traditional prawn farms as shown above.

System transferability to Intensive Regime

Where it is desired the low intensity pond system can be easily modified for intensive farming procedures in the future. The normal intensive farming infrastructure, such as external power, smaller growing ponds, wastewater settling/treatment ponds, increased feed technology and the like, can be retrofitted as appropriate. Minor earthworks only are required to subdivide the

existing ponds, although more conventional wastewater treatment facilities will need to be designed and constructed on the site.

Higher average farm-gate prices

The capacity to harvest the ponds using sized mesh nets ensures the product being prepared for the market is consistent in size and quality. Larger animals are harvested leaving the smaller animals to grow further. Thus a higher percentage of the crop will meet the size requirement for premium prices in the market, generally around the 15-25 per kilogram size, by comparison to the product generally being offered to the market at 30-40 pieces per kilogram.

Disadvantages

Predation

The larger pond size of low intensity prawn farming tends to make the system more vulnerable to suffer predation, particularly from birds. The larger pond boundaries also make it more difficult to exclude land-based predators such as rats, or in built up areas, people. The sheer size of the ponds makes it impractical to fit bird netting as may be utilised with smaller ponds. This element of the system may, however, provide additional employment opportunities where the system operates as an employment generation vehicle.

A variety of techniques are available to the low intensity prawn farmer to reduce bird (and other) predation including dogs, noise makers, decoys or even the general workforce. Trapping and relocation can be effective against most nocturnal prawn pond predators.

Longer harvest period

The capture methods applied in low intensity prawn farming tend to yield lower volumes over a longer period requiring either on-site storage capacity or small shipments to markets that can adversely impact operating costs.

Larger farm footprint

The low intensity nature of the system naturally means a larger amount of land is required to produce a commercially viable crop by comparison to intensive prawn farming systems. The demands of capital usually require the maximum production from the resource available. Whilst this philosophy may be appropriate where the infrastructure is available to support it, in many instances under consideration in this paper, such an approach is not appropriate. The offsetting element for this feature is that despite the larger farm footprint there is a massive reduction in the overall environmental impact of the farm activities.

Operational Outcomes

A full sized single crop of 11 tonnes of prawns per ten-hectare pond at a size of 15-25 pieces per kilogram will take approximately 7 to 8 months to grow within the system. In monsoonal regions the pond salinity will drop, however, this variation will not interfere with the prawn production process and, in fact, will aid the overall growth rate of the animals.

System Requirements

Land – basic module requires approximately 35 hectares of land, preferably reasonable flat with access to suitable clean saline water, either directly on the coast or through tidal action.

Infrastructure – the facility is self-contained and requires only some form of road access, although where required it may be serviced by water-borne vessels.

Equipment – earthmoving equipment is desirable initially to set up the ponds and water channels. A water pump station and diesel engine pump plus nets, ice-making facilities for packing product and minor hardware and tools will be required. Where the system is to be run with minimal labour a vehicle and feed caster will also be needed. A building for housing feed, ice making, product packing and equipment storage are also mandated by the operating requirements or regulatory strictures.

Seed Stock – the basic module farm requires between 600,000 and 700,000 PL at 2 cents each, (average price 2002/2003 - 1.78 cents (*Lodegeiger and Wingfield*) approximately $14,000.

Major Operational Costs

Feed – approximately 12 tonnes of feed/10 hectare pond/crop – approximately $30,000 for a specialised feed.

Diesel – dependent on camp utilisation rate and number of ponds – approximately $8,000 per annum for basic module farm as shown above.

Labour – minimum requirement of system is I technician and 1 labourer. Where system is part of employment creation or operated other than as a strictly commercial venture this will vary dependent on local conditions and needs.

External Support – during the initial phases of farm design and operation, and future site development, it is expected that farmers new to the low intensive prawn farming system will require specialised external advisory support. How much support will be required will vary from farm to farm dependent upon local circumstances.

Revenue Generation

Farm-gate price of all farmed black tiger prawns in 2002/2003 in Australia averaged $16.71 per kilogram across all product of all sizes and quality (*Galeano et al*). Market price of black tiger prawns, at 15-25 pieces per kilograms size, varies from time to time but given the quality and consistency of size of the product that can be anticipated from a low intensity prawn farm, $20 per kilogram can be reasonable projected (*Sydney Fish Market Historical Data*). Thus the potential revenue from a single module as shown above is $220,000 per pond per crop.

Conclusion

The low intensity farming system outlined above is based on empirical results achieved in Australia by Ken Chang. Minimal environmental impact low intensity prawn farming has proven to be resource and capital effective, capable of operation with minimal management intervention and requires minimal skilled labour input. The system design is suitable for large and small-scale operations in remote regions, with what would be generally considered to be very low levels of industry support infrastructure.

The low intensity prawn farming system does meet those criteria set out by KPMG for the improved sustainability of the prawn farming industry, and at the same time offers a practical and commercially viable operational option for remote area prawn farming.

Application of low intensity prawn farming techniques is believed by the authors to be ideally suited to indigenous aquaculture projects in Far North Australia as well as low capital, general commercial ventures.

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About the Authors:

Ken Chang came to Australia as a business immigrant in 1990 under the technical expertise provisions following a successful career in aquaculture development in Taiwan. Mr Chang graduated with a degree in aquaculture from the National Taiwan College of Marine Science and Technology in 1982, one of the world's most advanced centres of aquaculture. He has had a distinguished academic and commercial business career over more than 20 years in a variety of aquaculture specialties and is regarded as one of Australia's leading experts in the technical and commercial management of prawn hatchery and farming. Since his arrival in Australia Mr Chang has built an enviable reputation for excellence in management within in the Australian prawn industry, both on his own behalf and as a consultant.

Contact Details: 61 401 225 698

Email: aquaculture@mail.com

Postal Address PO Box 507
Ashfield, 1800
New South Wales, Australia

Tony McLennan has an MBA specialising in international trade and a successful history in regional development and technical services business management. A long term resident of Gippsland, Mr McLennan is a founding member of the Gippsland Aquaculture Industry Network Inc. (GAIN), an aquaculture industry representative body with a national and international reputation in the field of aquaculture industry development. Among his recently roles has been the preparation of a Regional Investment Dossier for the aquaculture industry in the Latrobe Valley on behalf of the Victorian Department of Primary Industries and Manager Special-Projects with Oceanair Ltd. in Victoria.

Contact Details: 61 408 513 500

Email: tony.mclennan@growfish.com.au

Postal Address PO Box 186
Traralgon 3844
Victoria, Australia