Prawn Nurseries; their role in improving efficiencies and yields for prawn farms in Australia

A focus on quality outcomes for hatchery and pond production of black tiger prawns

A report for

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2017 Nuffield Scholar

October 2018

Nuffield Australia Project No 1708

Supported by:

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Executive Summary

Nursery systems are additional phases in the culture of prawns between larval production at the hatchery and final grow out in the pond.

Introducing nursery phases to Australian prawn production offers greater control over the crop for longer periods of time. Greater control affords the farmer the ability to manipulate growing environments and to more effectively assess production by way of efficiencies.

Post larval care in nursery tanks or raceways can improve the quality of the stock that is put into the ponds by benefiting from:

Access to the post larvae (PL) for assessment of health and development: PL raised in higher densities in tanks can be simply collected for visual observations and laboratory testing. The behaviour of PL in the nursery environment is easy to assess.

High quality commercial nursery diets: The nursery environment allows farmers to easily manage feeding by monitoring waste and gut contents. Efficiency in feeding means that the farmer can benefit from more expensive, higher quality feeds that are available for nurseries but inefficient in the ponds.

Reducing water management costs: Smaller water volumes in nurseries can easily be affected by water exchange, probiotics and siphoning of wastes, requiring less water than pond rearing of PL. Smaller volumes of water are cheaper and easier to move and can be treated to remove pathogens and pollutants.

Maintaining optimal water conditions: Nurseries can be housed in greenhouses to reduce temperature variability and provide warmer conditions in cooler production periods. Water parameters in nurseries are more easily manipulated due to controlled conditions and smaller volumes of water.

Improving biosecurity: Housing nurseries in greenhouses, treating incoming water and ease of disease monitoring provide greater biosecurity than pond rearing of PL. Controlled nursery systems also allow for effective quarantine of infected stock to prevent the disease spreading to the ponds.

Protecting stock from predation: The biosecurity benefits of nurseries also protect stock from predation by fish and birds that could otherwise gain access to ponds.

Growing PL to be bigger and stronger in nursery environments means that the animal gets a head start in the pond. Bigger, stronger PL are more tolerant of the stresses of the pond environment and stocking these improved PL can result in improved pond production.

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Foreword

From my experiences of over a decade of growing black tiger prawns (*Peneus monodon*) in Queensland, it became apparent that the variability of the quality of post larvae (juvenile prawns stocked into farm ponds) was a difficult to manage in the grow out stage. Good quality PL typically gave good results and were easily managed, while poor quality PL required greater investment of time and resources, often still resulting in poor yields from these ponds. The quality of post larvae from the hatchery is often identified as the reason for poor growth and survival of larvae in the farm pond, so I took up a position at Pacific Reef Fisheries hatchery to take on the challenges of larval rearing about five years ago. It quickly became apparent to me that larval quality is directly related to the quality of the parent prawns (brood stock).

Brood stock quality is one of the most important factors relating to PL quality and will continue to be an important issue for Australian prawn farmers to overcome. Australian prawn farmers are dependent on brood stock that is sourced from the wild and much effort and investment is directed towards domestication and genetic improvement of black tiger prawns to supply a consistent and sustainable source of quality brood stock to the industry.

However, while faced with increasing demand for quality PL to stock the expanding farm, the challenge is how to reduce variability in pond yields and increase farm production from wild sourced brood stock.

The Australian method of prawn production is to stock PL at 15 days old (PL15) directly into the farm ponds.

Experience shows that larger, older PL are stronger and more tolerant of environmental stresses to perform better in the ponds, but it is not as simple as holding the PL in the hatchery for longer. Larger PL need to be grown at lower densities and take up space in the hatchery that could potentially be used to rear more larvae. Stocking older PL at the beginning of the season also requires the hatchery to begin producing larvae earlier in the winter months when it is too cold to stock them into the ponds.

With more space and more time, PL can be grown to a larger size to improve PL quality, but control of water quality, temperature and nutrition is required for an animal that is too big to be reared in the hatchery and not yet ready to grow efficiently in the farm ponds.

An intermediate phase of rearing, or nursery, that can be used to improve PL, can reduce variability of PL quality and improve production on the farm.

The nursery phase is not typical of Australian prawn farms, and the development of a nursery at the Pacific Reef Hatchery site at Guthalungra in north Queensland was the motivation for me to apply my Nuffield Scholarship to explore the principles and practices of nurseries overseas.

With the generous support of my investor, the Fisheries Research and Development Corporation (FRDC), my employer, Pacific Reef Fisheries, Nuffield Australia and my friends at Epicor Bionetworks and Charoen Pokphand Foods (CP), I have visited prawn producers in Ecuador, Honduras, Nicaragua, USA, Canada, Vietnam and Thailand to learn about the benefits of prawn nurseries that can be applied to prawn farms in Australia.

I was surprised at the variety of prawn farming methods I saw and was inspired by the challenges that producers had overcome. The scope of prawn farming operations is marvellous.

I have seen prawn growing systems stacked under a ceiling, storeys high, during a frozen Canadian winter and hatcheries scattered uncovered under the equatorial sun. Super intensive farms that manage densities of many hundreds of prawns per square metre on less than ten acres and those that are many hundreds of hectares stocked at ten per square metre. Some scale up to multinational enterprises and others chose to scale down to produce prawns in the back shed.

The vision and collaboration of motivated farmers and stakeholders is pushing the limits of production possibilities overseas.

Acknowledgments

With great appreciation I would like to thank Nuffield Australia for sharing my enthusiasm for the Australian prawn farming industry and for the opportunity to travel, learn and meet people all over the world.

I would also like to thank:

The Fisheries Research and Development Corporation (FRDC) for their continued investment in the Nuffield Australia Farming Scholarship program for fisheries and aquaculture.

Pacific Reef Fisheries, who have generously invested in my travels by affording me the time away from the hatchery. Also, to the Pacific Reef larval rearing team that carried some extra load while I couldn't be there.

Nick Kempe at Proaqua for steering me in the right direction to source prawn farm contacts overseas.

Fernando Garcia at Epicor Bionetworks and the network of technical and sales staff and distributors in central America and Asia who facilitated farm and hatchery visits. Special thanks to Lorena Vanoni, Roberto Chavez and Fabrizzio Vanoni in Ecuador, Jorge Ullauri and Diego Reyes in Honduras, Fernando Castro Talero in Vietnam and Teerasak Kingshansilp in Thailand. I would have been lost without translation and help accessing bio secure production sites and it was great to make new friends along the way.

Also, thanks to David Garriques from CP in Thailand.

Travelling was a new experience for me and it was a great comfort to have such good people around me while I was learning to be tolerant of mini vans, hotel rooms and airports so I must thank my mates from the 2017 Brazil global focus group, Georgie Cartanza, Cameron Kruckow, Daniel Kahl, Brendan Hehir, Ryan O'Sullivan, Roland Van Asten and Kristina Polziehn.

The rewards of my Nuffield Scholarship are many, but none would have been possible without the cooperation of the many prawn producers that took time out of their busy day to talk with me and introduce me to their nursery systems – to these people I am forever grateful.

Abbreviations

ABARES – Australian Bureau of Agricultural and Resource Economics and Sciences

APFA – Australian Prawn Farmers Association

CP – Charoen Pokphand Foods public company limited

DO – Dissolved Oxygen

FCR – Feed Conversion Ratio

FRDC – Fisheries Research and Development Corporation

PL – Post Larvae

SPF – Specific Pathogen Free

SPR – Specific Pathogen Resistant

TAN – Total ammonia nitrogen

WSSV – White Spot Syndrome Virus

Objectives

- To understand the form and function of Phase 2 nursery stage.
- To understand the form and function of Phase 3 nursery stage.
- To understand what the benefits of nursery phases are.
- To understand what the potential benefits of nurseries are for Australian prawn farmers now and in the future.

Chapter 1: Introduction

Commercial prawn farms have been in operation in Australia since the late 1980s and production has since shown a steady increase in economic value, which follows the global growth of aquaculture. The global growth in aquaculture (7%/year) is exceeding both population growth (0.5%/year) and terrestrial farming production (2%/year) (CSIRO, 2017).

Prawns require high water temperatures to grow, therefore 95% of Australian prawn farms are in Queensland where optimum water temperatures in the ponds (greater than 25°C) is easily maintained for most of the year. Prawn farming is Queensland's largest aquaculture sector (APFA, 2018). Nationally, 25 farms with approximately 600Ha of total production area (ponds) are producing around 5000t ($80-90M) of the black tiger prawn (*Penaeus monodon*) (Figures 1 and 2). This contributes 15-20% of Australian prawn production, the remainder is fished from the wild (APFA, 2018).

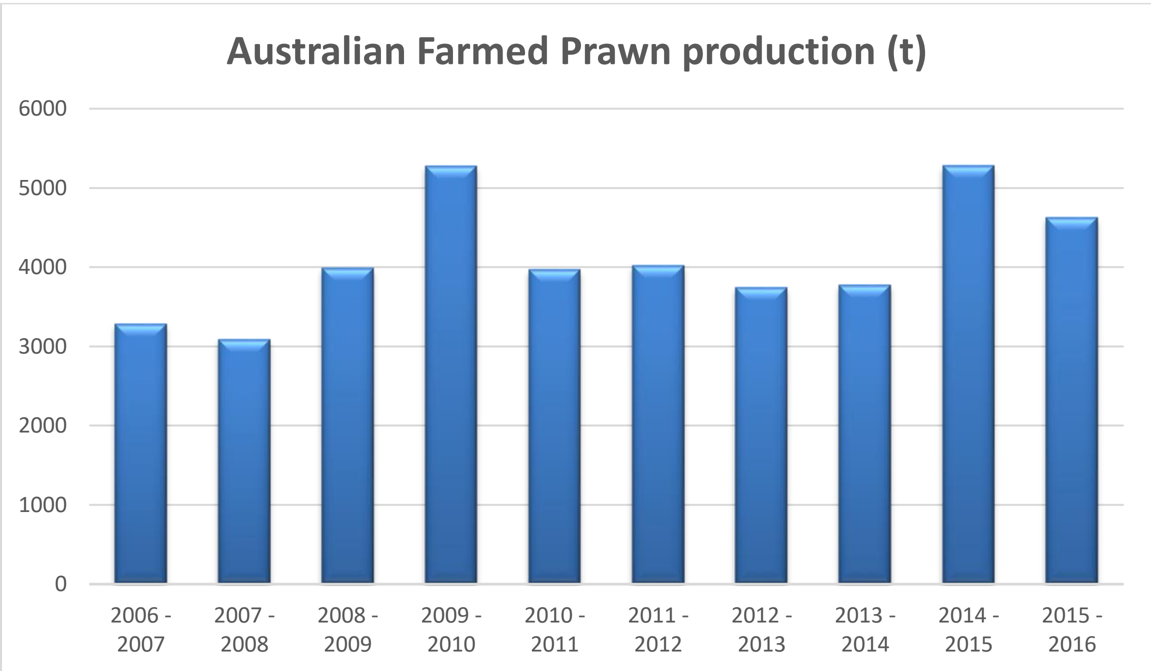

Figure 1: Australian Farmed Prawn Production (t) (ABARES, 2016)

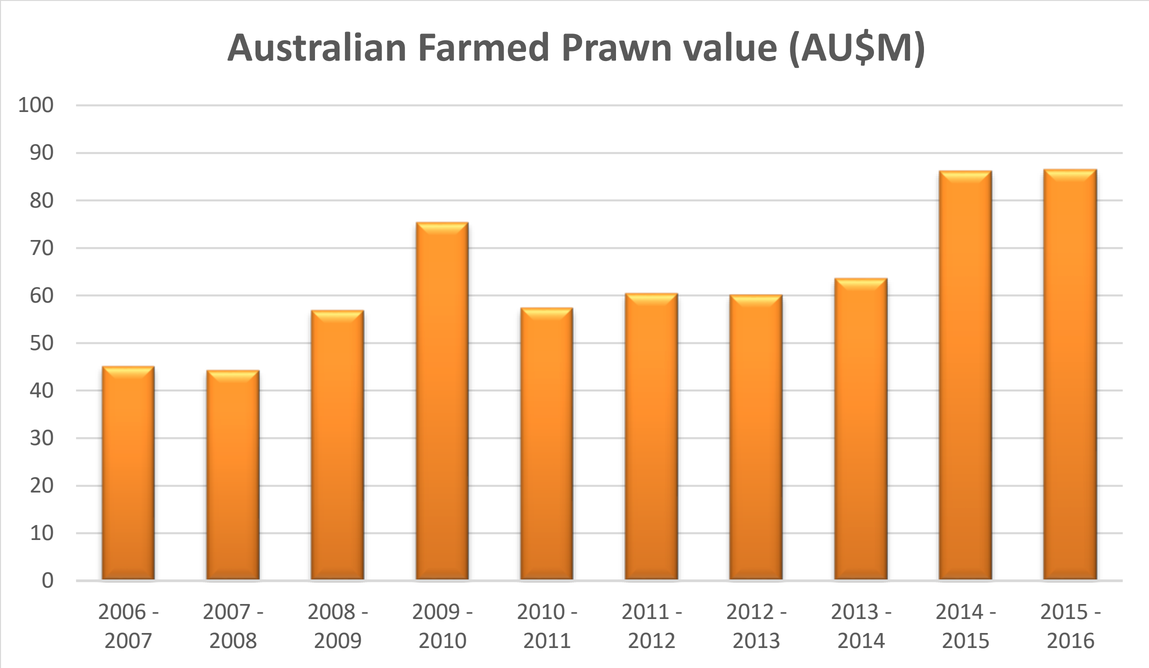

Figure 2: Australian Farmed Prawn Value (AU$M) (ABARES, 2016)

The CSIRO reports "that pond based marine aquaculture represents a huge potential for economic and environmental expansion of a drought proof industry around our northern coast line". However, the industry faces some challenges that may prevent further development of new and existing farms (CSIRO, 2017).

The greatest of these challenges are biological. Currently the industry is dependent on breeding stock that is sourced from the wild. This wild brood stock is proving to exhibit unreliable and irregular productivity in hatcheries, resulting in variable crop performance on the farm. The dependence upon wild brood stock also presents a biosecurity risk to Australian farms.

Australia is yet to have a commercially available domesticated black tiger prawn. A domesticated line of black tiger prawns would allow for continual supply of quality brood stock year-round and for development of the domesticated stock to be free of pathogens that are found in the wild and to genetically improve the stock to be tolerant, even resistant, to pathogens in the culture environment.

Domesticated strains of the pacific white shrimp (*Penaeus vannamei*) are available to farmers overseas and the development of this prawn has increased growth rates, production and production efficiency, as well as reduced the risks of stress and disease in the ponds.

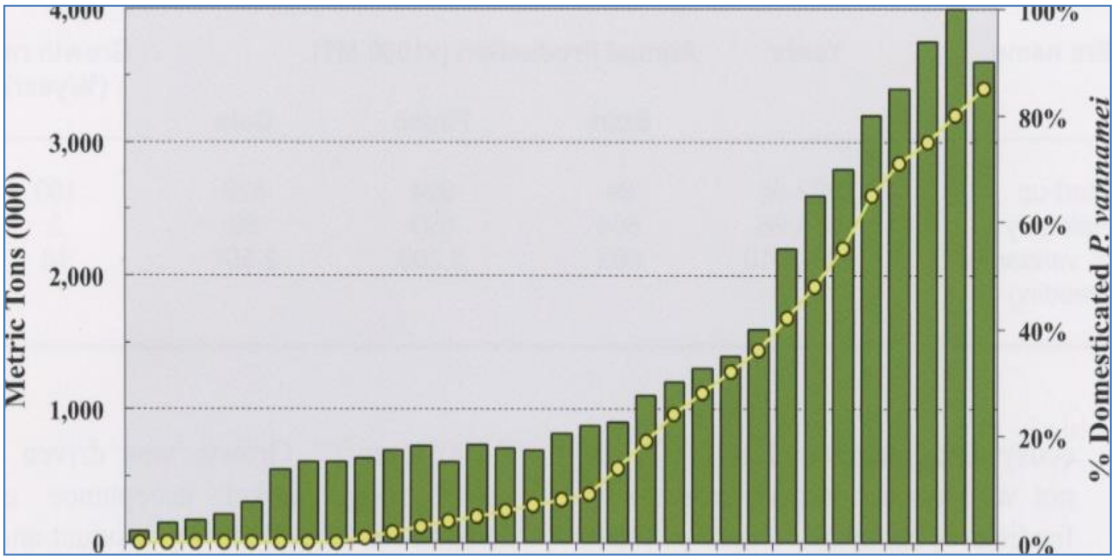

Figure 3: 1982 - 2012 world prawn farming annual production (primary y-axis, green bars) and percent contribution by domesticated Penaeus vannamei to total of world total (secondary y-axis, yellow line) (Wyban, J., 2016).

While domestication and biosecurity are very important, domestication is a costly and timely exercise and may take many years to achieve commercially available specific pathogen free (SPF) brood stock results in Australia. There is no real practical alternative to domestication but typical Australian prawn production systems, using wild brood stock, can be adapted to suit the production of larger, older, more robust PL for stocking into ponds.

An intermediate stage of rearing, or 'nursery stage', is a technology that is available to Australian farmers and can improve production efficiency in the ponds by reducing the risks associated with variable quality hatchery reared PL in the short term. A nursery can be defined as a controlled tank or raceway environment to nurture young PL to a larger size, allowing for healthy growth and development. Nurseries should be managed by trained technicians with a focus on PL quality and preparing the PL for the transition to the pond and grow out. The nursery stage is conducted between the larval rearing stage and stocking the PL into farm ponds.

Several stages of nurseries are in use throughout the world. Nurseries are being used by hatcheries after the larval rearing phase (considered to be stage 1) to improve PL quality (phase 2) and at the grow out site, to further increase the size of the PL prior to pond stocking (phase 3).

Nursery operations have proven to improve production efficiency by:

- Shortening larval rearing production times in the hatchery
- Extending the growing season by reducing grow out times
- Increasing survival of PL stocked into the ponds
- Improving Feed Conversion Ratio (FCR) in the pond
- Strengthening PL against pathogens in the pond
- Increasing pond yields

Chapter 2: What is a Nursery Production Phase?

Nurseries for the hatchery and the farm

Nursery rearing is the rearing of PL or juvenile prawns once harvested after the larval rearing phase (considered as stage 1) and prior to stocking into the final grow out ponds. Nursery systems, typically being much smaller than grow out systems, offer greater control over growing conditions through biosecurity and ease of management. Water can be treated and disinfected prior to use in the nursery, artificial environments can be provided to the animals by way of heating and shading, and pests and predators can be easily excluded. General observations of animal health and behaviour are easier in these smaller more intensive systems.

Hatchery nurseries (Phase 2)

Nursery rearing PL at the hatchery typically means to continue to provide control over water quality, health monitoring and diets of PL in larger volume tanks at high densities. Incoming water is disinfected to eliminate the risk of transfer of disease and contaminants from the surrounding environment and stored for use in the nursery.

Where conditions allow, such as in Central America, the nursery can be outdoors to take advantage of the optimal environmental temperatures, and tanks are covered with plastic to stabilise water temperatures (Figure 4). Where daily and/or annual temperatures may drop to become sub optimal for nursery rearing in exposed situations, the nurseries are housed in greenhouses to maintain optimal temperatures. In some cases, it may be necessary to use artificial heating such as submerged electrical heaters or gas fuelled heat exchangers to maintain constant growth temperatures.

Figure 4: Outdoor hatchery, Salinas, Ecuador (Source: Author)

Phase 2 nursery tanks can be round poly or concrete tanks (Figures 5 and 6) or rectangular concrete larval rearing tanks. Site and financial budgets are the determining factor for phase 2 nursery designs with round poly tanks being cheaper in construction but less efficient in their use of area.

High densities and optimal growth conditions are maintained by using strong diffused aeration from mechanical blowers to provide sufficient dissolved oxygen and to keep feed, PL and wastes in suspension. Water quality and animal health is managed and treated with probiotics, so water exchanges are kept to a minimum. Specific probiotics are targeted at controlling vibrio infection, organic wastes and ammonia concentration. Nurseries are prepared three days prior to stocking with daily applications of probiotics to ensure a healthy environment for the PL after the stress of transfer from larval rearing conditions.

Figure 5: outdoor concrete nursery tank, Salinas, Ecuador (Source: Author)

Figure 6: Indoor nursery tank, note the strong aeration, Salinas, Ecuador (Source: Author)

The Central American style pacific white shrimp phase 2 nursery reduces densities from over a hundred PL per litre in larval rearing conditions, to stock at densities averaging sixty PL per litre in 20,000 – 40,000 litre nurseries for 7 to 10 days. Their objective is to grow PL4-6 to PL14-15 for transfer to raceways on the farm.

PL quality assessments are conducted every other day, if not daily, in on site microbiology laboratories. Bacterial communities are monitored, visual assessments (microscopy) recorded and polymerase chain reaction tests conducted to monitor for disease. The view of many Central American prawn farmers is that each time the animals experience stress or disease it ‘changes the game’ and prawn producers must adapt practices and technologies to overcome stress and disease to avoid mortality in the pond.

Phase 2 nurseries contribute to farm biosecurity by containing the PL in a quarantine situation where problems are easily identified, diagnosed and treated by hatchery or laboratory trained staff. Probiotics and effective incoming water disinfection strategies are key biosecurity practices used to prevent infection of PL and transference of disease to the farm. These nurseries, managed well, return a survival rate of 80-85% but have been observed to range from 60-90% in the hatcheries visited for the purpose of this report. Management of the nursery crop is quite typical of larval rearing protocols. PL are monitored and fed every 2-3 hours and water parameters are measured 2-3 times daily by hatchery technicians.

Harvesting PL 4-6 from the larval rearing tanks in the hatchery allows for a higher turnover of larvae in the hatchery, increasing output of PL and utilising larval rearing infrastructure with greater efficiency. With a view to greater biosecurity in Australian prawn production, phase 2 nurseries may accommodate more frequent dry out and disinfection of the hatchery and improve the results of larval rearing practices.

A successful nursery at a CP hatchery in Thailand operates differently in that wastes and ammonia are managed with up to 100 percent water exchange daily and higher PL densities of 100 per litre in 30,000 litre larval rearing tanks (Figure 7). The major difference here was the CP 'turbo' domesticated SPF pacific white shrimp, which is very robust and has a high rate of growth and development.

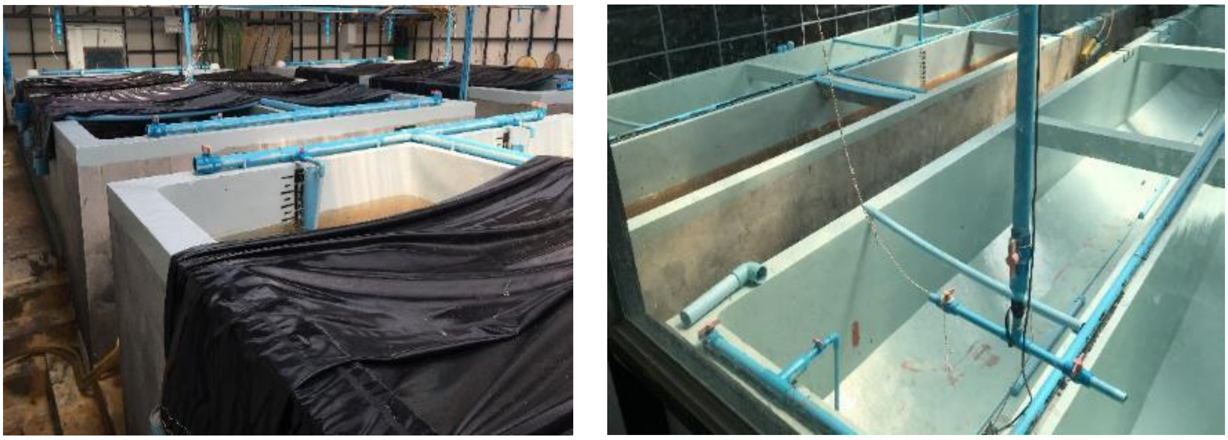

Figure 7: Two stage larval rearing / nursery tanks, larvae are reared 225/L in 15t tanks to PL4, water and PL are then drained into lower 30t tanks and grown to PL14 at 100/L, CP, Ranot, Thailand (Source: Author)

Another interesting addition to nursery rearing here, was the culture of a condensed marine ecosystem of naturally occurring organisms, that when added to the nursery tank, supplemented PL nutrition through live feed and helped to maintain water quality in the tank (David Garriques, personal communication). This demonstrates the function of a nursery to perform as an intermediate between controlled hatchery systems and more natural pond grow out ecosystems. Another example of the flexibility that is provided by nurseries is the concept of independent nursery operators (figure 8) purchasing young PL from hatcheries to value add by investing in improving size and quality of the PL for sale to farms.

Temperature controlled phase 2 nurseries operating at hatcheries may allow Australian hatchery operators to begin their season earlier in the year to produce PL that are larger and stronger and more tolerant of cooler pond conditions at the end of winter when Australian farmers are stocking ponds for the Christmas harvest in December. Longer growing periods for the Christmas crop, resulting in larger prawns and greater yields, could let farmers capitalise on the high price and demand that the holiday season presents to Australian prawn producers.

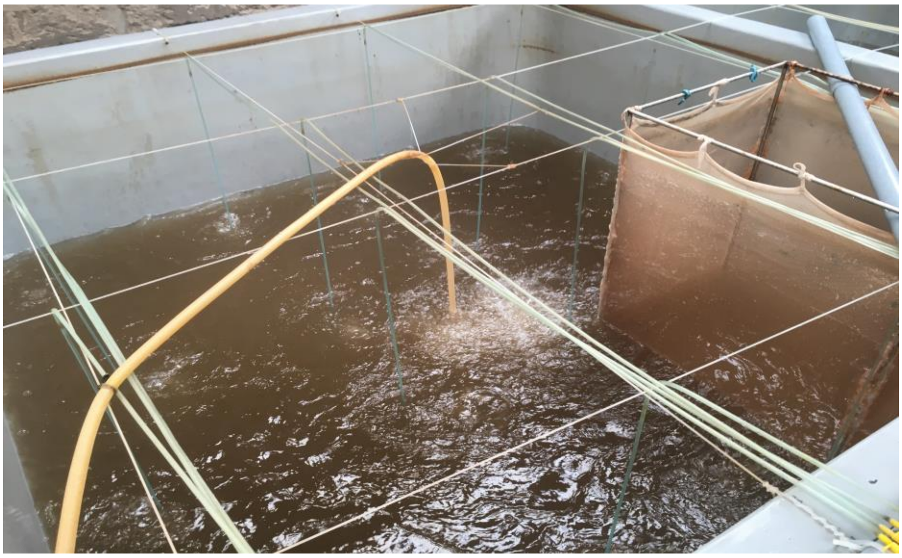

Figure 8: Near Phan Rang-Thap Cham in Vietnam, a small nursery operated independent of a farm and hatchery and improved small batches of PL from small independent hatcheries for market to small farms (Source: Author)

Phase 2 nurseries may only affect pond survival by promoting the development of the strong PL that would typically survive pond stocking at P12-15, while the weaker PL that may typically not survive the transition to the pond environment will perish at the nursery stage. Considering the higher turnover of larvae from the hatchery that is facilitated by the nursery, allowances can be made to correct lower than average survivals prior to stocking into the ponds where improvements in prawn survival cannot be affected by the farmer. This method is preferable to increasing stocking densities in the pond that can result in slower growth and reduced productivity due to stress in the prawns and overcrowding in ponds that show high survivals.

If Australian prawn farms are to continue to experience losses due to variable quality PL, hatcheries with nurseries are better equipped to recover from and account for these losses to ensure that only the best PL make it to the farm ponds for the long and costly grow out period. Losses in the pond cannot be compensated.

Pacific Reef Fisheries, a large black tiger prawn farming company in north Queensland, has invested in a nursery at their hatchery site at Guthalungra (Figure 9). Pacific Reef sees the potential of nursery systems as a way to increase PL production from their hatchery and to stock older PL onto their farm site at Ayr. After several years experimenting with quality improvement of PL at an outdoor trial nursery on the farm, which demonstrated the need for applied technical expertise and greater control over the growth and development of the animals, the nursery operations were moved to the hatchery where the knowledge gained from their farm trials resulted in the development of eight climate controlled concrete nursery tanks. The nursery, built in two stages of four tanks each, was developed over three years with support from the Coles Supermarket Nurture Fund. The completed nursery houses eight 100,000 litre tanks housed in two greenhouses and has independent water and air supply and a small laboratory for feed preparation and water testing.

Figure 9: Stage 1 of Pacific Reef Fisheries nursery at the hatchery at Guthalungra, Queensland, Australia (Source: Author)

After a period of nursery trials and protocol development at the hatchery, Pacific Reef have managed to increase the average age of PL stocked into their ponds by five to seven days and to increase hatchery production to satisfy the stocking of their 104Ha farm at Ayr. This has been achieved by nursery rearing PL from PL8-12 to PL18-22. In the past, PL were reared to PL14 in the hatchery and stocked directly into farm ponds. PL quality improvements have been gauged by rostral development, which has increased by an average of 30%, and by stress testing, which has improved by 50%.

Assessing the impact of improved nursed PL on grow out results shows that survival between 10 grams and final average harvest weight of 25 grams is improved and is more consistent than directly stocked hatchery PL. It may be that this regularity of pond survival rates in the latter part of the crop has contributed to the improved feed conversion ratios that show a 6% improvement in nursery stocked ponds.

The challenge is to adapt nursery management protocols to suit black tiger prawns which are not as tolerant of high stocking densities as are the domesticated strains of pacific white shrimp that are cultured overseas. The black tiger prawn's sensitivity to high densities must also be considered as the PL develop. Transportation methods and densities of nursed PL must be adapted by reducing densities and diligently assessing transport tanks for changes in water quality and for the availability of feed.

Farm Nurseries (Phase 3)

The objective of the nursery on the farm is to improve on the age, size and weight of the PL before being released into the final grow out ponds. There is great variation in form and function of phase 3 nurseries as there is great variation in the grow out methods of pacific white shrimp. Phase 3 farm nurseries can take the form of tanks (Figure 10), raceways (Figure 11 and 12) or ponds (Figure 13) and represent a much bigger cost to the farmer due to their size and the requirement for investment in construction and earthworks. They are larger than Phase 2 to accommodate larger PL at average densities of up to 4 PL per litre and to give the PL room to grow over longer culture periods. Due to their size, phase 3 nurseries are not typically artificially heated but are often in greenhouse structures to not only reduce temperature fluctuations but to keep the nursery contained as a biosecurity measure.

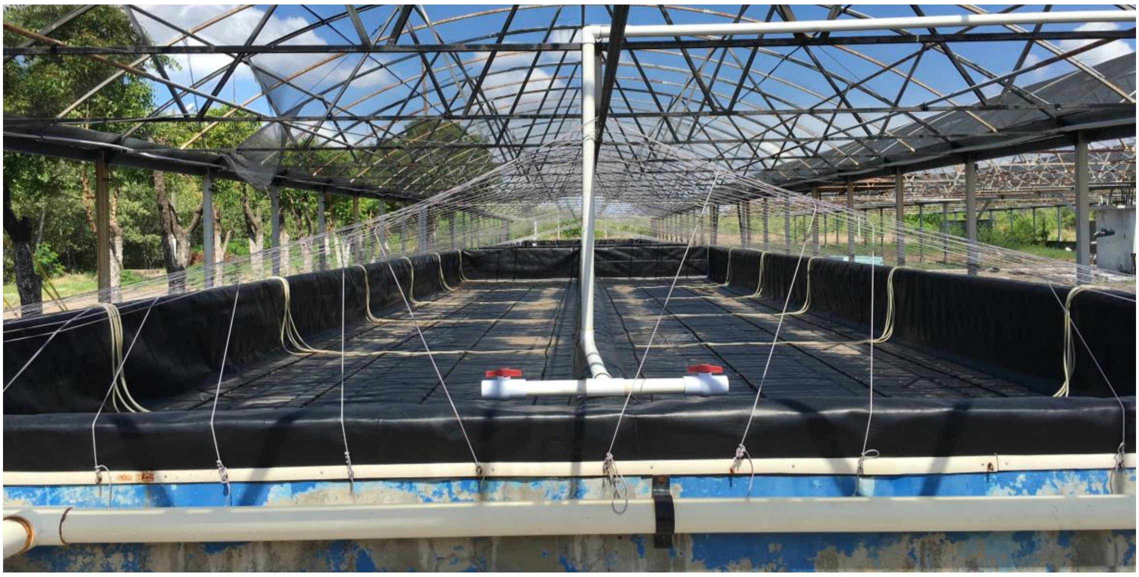

Figure 10: Phase 3 nursery tank near Choluteca, Honduras (Source: Author)

Figure 11: A phase 3 nursery in a greenhouse, Camanica farm, Nicaragua (Source: Author)

Figure 12: Large outdoor raceway nursery, Seajoy Biomar farm, Honduras (Source: Author)

Figure 13: 0.1 Ha nursery pond, Anh Khoa farm, Vietnam (Source: Author)

In Central America where the challenge is with disease such as Early Mortality Syndrome and in the past, White Spot disease, phase 3 nurseries serve to strengthen SPR pacific white shrimp. PL are grown in the nursery to PL30-35 before being stocked at very low densities into large four to five-hectare extensive ponds. Nursery survival here can be between 45 and 90% and is highly dependent on diligent management. The technical staff that are required for the intensive management of phase 3 nurseries on the farm are making extensive farms in Central America more labour intensive and increasing the cost of production but the view of the farmers is that the increased level of expertise on the farm is helping to build better production teams and the nurseries are a benefit to biosecurity and farm yields.
In Vietnam and Thailand where ponds are smaller (0.1-0.4Ha), grow out water can be disinfected and commercial SPF SPR pacific white shrimp are available, phase 3 nursery rearing can improve the prawns to over 0.5 grams for stocking into the small lined bio secure ponds at densities of over 250/m².

Nursery survival here is often 100% and is due to biosecurity, SPF SPR domesticated pacific white shrimp, and well managed feeding and animal health. With the level of control and intensity of some of the developing grow out systems in Asia, they can easily be considered a continuation of the nursery phases.

Globally, the two most popular phase 3 nursery systems are small lined ponds (Figure 13) and raceways (Figure 12). Ponds are typically 0.1 – 0.4Ha lined ponds with a central drain. Aeration is an important part of rearing the PL at high densities of up to four PL per litre. Paddle wheel aerators provide the circulation to centre the wastes for removal during water exchanges of 10-20% daily, while diffused air and venturi type pumps maintain the high levels of DO required. Bio secure nursery ponds are enclosed by fences and bird netting, to exclude crabs and birds which may pose a threat as a disease vector, or predator. Some farmers have even housed their ponds inside concrete walls and shade cloth covers to reduce risks of predation, disease transmission and variability of water quality from algal blooms (Figure 14).

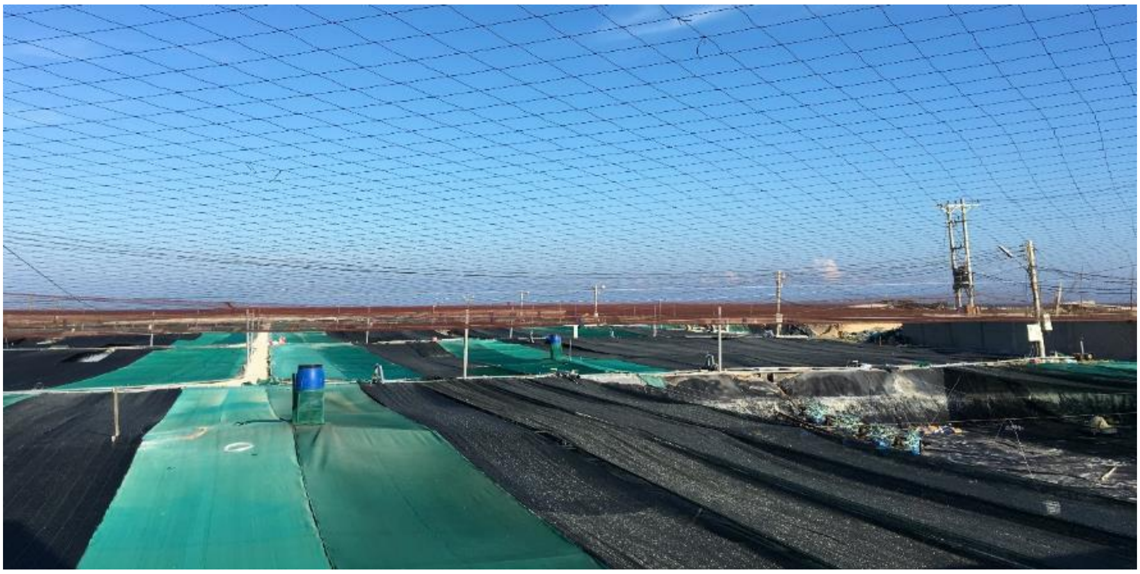

Figure 14: Controlled grow out conditions at Ahn Kho farm, Vietnam (Source: Author)

Raceway dynamics differ from the waste removal systems of intensive nursery ponds. Raceways use a central baffle to prevent wastes from settling while the aeration maintains strong circulation. Water exchanges of 20-30% per day and regular application of probiotics are used to help control the build-up of wastes. Paddle wheels are used for circulation in larger raceways along with diffused air to maintain DO. Air lifts, using diffused air, are used in smaller systems.

Commercial probiotics for prawn aquaculture are increasing in quality and availability and are a typical management tool in nursery production. Where disease and production pressure (intensity) pose a threat to the growth and survival of the crop, probiotics play a role in maintaining healthy prawns and a healthy environment. This is most notable with farm nurseries and intensive farming where the investment in the crop is most at risk, biomass and feed inputs are increasing significantly, and the duration of the crop is much longer.

Indoor intensive farms are gaining popularity in the US and Canada. The development of water management technologies such as zero discharge recirculating water treatment systems and bio floc in tank systems allow farmers to reduce the density of the prawns as they grow from PL to market size, effectively 'nursing' the prawns through each phase of production (Figure 15).

Figure 15: Intensive indoor shrimp production in rural Kansas, USA (Source: Author)

Chapter 3: What are the benefits of prawn nurseries?

Phase 2 and 3 prawn rearing nurseries have the potential to add value to Australian black tiger prawn farming operations, as seen in Central America, Vietnam and Thailand by the achievement of outcomes that have proven to add value to vannamei farming systems. Nurseries may not be able to provide immediate results for farmers but once the management of the system is adapted to how black tiger prawns are farmed in Australia, they have a vast potential to be a benefit to farmers by adding value to the crop through efficiency and production outcomes.

Production

- **Increasing turnover of larvae at the hatchery:** This is the simplest benefit to the hatchery. PL can be harvested from the larval rearing tanks earlier, transferred from the hatchery and stocked into the nursery. The function of the nursery is to increase available production area, which frees up infrastructure in larval rearing that is specifically designed for the development of larvae. This reduces risks in larval rearing, helps in maintaining consistency of larval quality and increases dry out frequency and biosecurity.
- **Reducing grow out periods**: Caring for very young PL in a one-hectare earthen pond is probably the most stressful period of the crop for both the animals and the farmer. Monitoring animal health, activity, and feeding behaviour is difficult and time consuming. Holding PL to advanced ages and weaning the PL on to larger feeds in nursery conditions can decrease the time between stocking into the ponds and when assessments can be made from feed tray observations. Reducing grow out times by stocking nursed PL may help to eliminate the initial most fragile stage of the grow out crop.
- **Improving FCRs in the pond**: Assessment of feeding from feed trays earlier in the crop means that the farmer can manage feeding practices more effectively and reduce feed conversion ratios. Australian grow out trials of nursery reared monodon PL have shown to be encouraging, delivering an improvement of 6%.

- **Stocking larger PL into ponds at the beginning of the growing season**: The nursery rearing time at the end of winter for the first grow out crop can allow hatcheries to begin larval production earlier in the year to provide a more robust PL for stocking. Improvements in production results from this first grow out crop are especially important as this is the crop that targets the high prices and the high demands of the Christmas market.
- **Improving survival in the ponds:** Older, larger PL typically return better results from stress tests, proving a tolerance to the stress that comes with environmental changes such as acclimation to pond conditions upon stocking. Robust PL are more likely to experience the transition from nursery to the pond environment with the least disruption to feeding activity, resulting in less stress, retaining strength and resistance to disease.
- **Identification of, and compensation for poor survival and quality prior to pond stocking:** Nursery rearing may not always provide an improved PL. Poor larval quality, high stocking density or poor nursery management may lead to stress in the nursery rearing phase resulting in poor growth and development that is evident in quality assessments prior to pond stocking. Nurseries allow for PL quality issues to be managed quantitively. Suboptimal PL can be held in the nursery for longer to try to remedy quality issues, or pond managers can increase pond stocking densities to compensate for losses due to suboptimal quality PL.

Biosecurity

- **Water treatment**: The quantities of water required for nursery rearing are relatively low when compared with pond production of black tiger prawns. The water requirements for nursery production can be treated and disinfected to provide a clean and safe culture medium. Probiotics and other inputs can be easily managed, in smaller more effective applications to provide a healthy growing environment.
- **Containment:** Nurseries can be designed to be fully contained systems with no direct contact with natural systems. Gates, doors, walls, netting, roofing and entire buildings can be used to exclude predators and disease vectors from nursery production areas. In designing nurseries to eliminate risks from the outside we can also more effectively maintain quarantine if an infection is present in nursery PL.

- **Management**: With effective water treatment and containment, bio secure management of nurseries is simplified. Probiotic health treatments, feed additives and medications are easily applied and more effective. The PL are easily accessed for monitoring and assessment to rapidly diagnose potential infectious health problems.

The Australian Prawn Farmers Association *5-year research and development strategic priorities for 2015-2019* state:

> "*The clear immediate and 5-year research priority area is 'Genetics and PL. This area had more than triple the support for research over the next 12 months compared to all other priority areas identified. Our R&D activities over the next 12 months and 5 years should include an appropriate level of research investment into this area. The more immediate need is increasing post larval quality and health, and consistent hatchery output. Domestication remains a high priority research area, and plans should be considered to ensure that R&D continues on this front for the benefit of the long-term future of the industry*".
>
> "*It should be noted that Disease & Biosecurity and Genetics & PL feature among the top 5 priorities for R&D as well as in the top 5 for Strategic Issues & Risks, further highlighting their importance*".

Prawn nurseries offer vast potential to improve Australian prawn production and will be able to improve production in priority areas that have been identified by industry.

Chapter 4: What needs to be considered when adapting nursery practices to black tiger prawn production in Australia?

Nursery phases add to production costs and the nature of improving PL quality by nursery rearing requires experienced technical staff and quality resources to manage a relatively fragile and intensive production phase.

- **Infrastructure**: Design, drainage, tanks/raceways/ponds, earthworks, buildings, and electrical and water supply must all be considered in the initial investment when adding nurseries for monodon production at Australian hatcheries and farms.
- **Staff**: The addition of nursery phases will increase the requirement for experienced technical staff in an industry that already is labour intensive and where labour costs are high. Nursery harvests are very hands on and it may take several hours to carefully harvest the nursed PL. The animals may be at risk if the appropriate number of people are not on hand to supervise, catch, count and transfer PL, as well as to assess and record counts, water quality data and feeding behaviour.
- **Biological**: Adding to the typical production phases creates risk by additional handling of the PL through transfer and harvest. Transport from the nursery to the farm present greater risk with larger PL over distance. Cannibalism is also a consideration as the PL age in the nursery, with stocking densities and feeding needing to be carefully managed to avoid losses due to cannibalism.

Conclusion

Nursery systems are a dynamic stage of prawn production that are enabling extensive and intensive pacific white shrimp farmers to overcome challenges and increase efficiencies at the hatchery and in the ponds. When assessing what a nursery is, what it looks like, and what it achieves, it is evident that nursery form and function is customised to overcome a problem, fit a budget, achieve improvement and manage risk. The value of investment in and development of effective nursery systems can reward producers in several ways:

Improving PL quality

- Increased control over PL growth and development prior to pond stocking
- High quality nursery diets
- Environmental stability
- Ease of access to the animals for observation and assessment

Improving Biosecurity

- Greater degree of PL care and health management
- Greater environmental control and management
- Exclusion of disease vectors

Australian black tiger prawn production is unique. No one overseas is investing in technologies that are directly applicable to improving the results of how we grow black tiger prawns here in Australia. Introduction and adaptation of prawn growing systems, such as nurseries, need to be adapted to Australian production and developed over time to be able to deliver more of the positive outcomes that they can provide. Nursery systems can be designed to a wide range of financial budgets, locations, levels of management and outcomes.

Development of nurseries can play a key role in Australian black tiger prawn farming practices moving forward and will allow farmers to fully capitalise on improved domesticated brood stock as it becomes available.

Recommendations

- A vigilant and defensive focus on biosecurity, both nationally through the regulator, and at the farm, to ensure sustainability and protect investment in the industry.
- Farmers to move quickly toward securing commercially available domesticated black tiger prawn brood stock to eliminate the challenges of disease and variability from the use of wild stocks and to encourage growth and investment in Australian prawn farms.
- Farmers to continually review their processes. For example: Is what is being done on the farm achieving the best outcomes? Are you becoming more efficient and more productive? Are you moving forward? Are you ready for the next challenge?
- Farmers to increase control over growing environments. Production phases such as nurseries represent only small changes from the previous phase. This gives more control over production to the farmer for longer. Phase 4 systems and intensive indoor systems are a result of the rewards of crop care and control.
- Australian prawn farmer investment in Australian prawn farms. It appears that growth in the industry is coming from expansion of existing operations, whereas overseas, production growth on the farm is coming from increasing efficiency, intensification, and new products. Prawn farmers in Australia shouldn't be hesitant to try new things and to share results of trials. Nurseries, centre draining lined ponds (shrimp toilet), total exclusion of predators, recirculating farm systems, probiotics, etc., can only be proven on the farm by farmers.
- Farmers to overcome rising production costs by improving efficiency on the farm through focused quality outcomes. Driving to be better before becoming bigger can help to build a better workforce and a stronger industry. A good example are the Central American farmers that were delighted to see that the interest by their farm staff, in the development of phase 3 nurseries on the farm. This promoted more constructive and productive discussion in the workforce to build stronger teams promoting better ideas to achieve greater outcomes. Research and development projects on the farm, conducted by farmers and supported by industry partners can improve the value of existing production systems and farm staff.
- Professional development of farm staff should be considered as the industry moves toward growing domesticated stock. As seen overseas in Figure 3, development of domesticated prawns has increased production and made prawn farming a more

attractive investment. While the Australian industry is also working to simplify the approval process for new farms and expansion of existing farms, it is important to know that Australia can provide a workforce to take on new management and technical roles to maintain what is expected to be an increase in production, development and investment. Experienced employees that can build production teams, train and evaluate staff, develop production protocols, and quickly overcome challenges represent a great asset to farms and investors. New production systems such as nurseries may act to encourage technicians to grow to meet the requirements of larger responsibilities and to develop professional skills and to further enhance ‘soft skills’ such as communication, accountability, teamwork and leadership to achieve goals.

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Plain English Compendium Summary

Project Title:	**Prawn nurseries; their role in improving efficiencies and yields for prawn farms in Australia** **A focus on quality outcomes for hatchery and pond production of black tiger prawns**
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Objectives	• To understand the form and function of Phase 2 nursery stage. • To understand the form and function of Phase 3 nursery stage. • To understand what the benefits of nursery phases are. • To understand what the potential benefits of nurseries are for Australian prawn farmers now and in the future.
Background	Nursery systems are additional phases in the culture of prawns between larval production at the hatchery and final grow out in the pond. Introducing nursery phases to Australian prawn production offers greater control over the crop for longer periods of time. Greater control affords the farmer the ability to manipulate growing environments and to more effectively assess production by way of efficiencies. Post Larval care in nursery tanks or raceways can improve the quality of the stock that is put into the ponds. Growing PL to be bigger and stronger in nursery environments means that the animal gets a head start in the pond. Bigger stronger PL are more tolerant of the stresses of the pond environment and stocking these improved PL can result in improved pond production.
Research	The author visited Ecuador, Honduras, Nicaragua, USA, Canada, Vietnam and Thailand. On these trips he visited prawn farmers that operate hatcheries and grow out ponds with nursery phases to learn about the role of nursery phases in their operations.
Outcomes	Prawn rearing nurseries have the potential to benefit Australian black tiger prawn farming operations, as seen in Central America, Vietnam and Thailand. By overcoming some of the challenges of prawn production, they have proven to add value to farming systems. Some of these challenges have been identified by Australian prawn farmers as priority areas that can be measured by key performance indicators.
Implications	Nursery phases in prawn farming operations add value through efficiency of production and provide an increase in animal quality and biosecurity management.
Publications	Verbal presentation, Nuffield Australia National Conference, Melbourne, 2018.