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# Spiny lobster aquaculture development in Indonesia, Vietnam and Australia

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# 145

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# **Spiny lobster aquaculture development in Indonesia, Vietnam and Australia**

**Proceedings of the International  
Lobster Aquaculture Symposium held in  
Lombok, Indonesia, 22–25 April 2014**

*Editor:* Clive M. Jones



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Cover: Farmed juvenile lobster (*Panulirus homarus*) ready for stocking to grow out cages. (Photo: Dr Hoang Do Huu)

# Foreword

In April 2014, the Australian Centre for International Agricultural Research (ACIAR) co-sponsored, with the Indonesian Ministry of Marine Affairs and Fisheries, a Symposium in Lombok Indonesia, as a forum to present findings from the project SMAR/2008/021, to discuss constraints and opportunities for the developing Indonesian lobster aquaculture industry and to identify key issues that further research might help to resolve.

At the time of the Symposium, lobster aquaculture in Indonesia was experiencing unexpected constraints in the face of great opportunity. Catch of seed had rapidly increased over the preceding 12 months to an extent that the catch then exceeded that of Vietnam where a large and successful industry was already established. However, the volume of marketable lobsters produced in Indonesia from that seed had shrunk from an already low base, as the small-holders involved chose to catch and sell seed, and to avoid grow out of lobsters. The reasons why were not clear, but what was clear is that Indonesia had opportunity to establish successful grow out, adapting and adopting technology from Vietnam, and expanding production to match or exceed that of Vietnam where in excess of 1,500 tonnes are produced with a farm-gate value of around US\$100 million.

ACIAR's project SMAR/2008/021 involving collaboration between James Cook University, Queensland Department of Agriculture, Fisheries and Forestry, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Directorate General Aquaculture Indonesia (DGA), and Vietnam agencies; Institute of Oceanography and Nha Trang University, was commissioned to assist the establishment of a viable lobster aquaculture industry in Indonesia. Success was achieved across all aspects of the research and development activities, with the exception of increased production of marketable lobsters. In this instance, economic and social factors are playing as important a role as those of a biological nature. Further research and development will be necessary to understand and address these factors and to provide basis for efficient and viable lobster growout.

In order to rapidly and widely disseminate the research findings arising from the ACIAR lobster project, the International Lobster Aquaculture Symposium was held from April 22 to 25 in Lombok and provided opportunity to present all the research findings from the ACIAR project SMAR/2008/021. Two days of oral papers were delivered, a field trip was conducted to inspect lobster farming in Lombok, and an industry development workshop was held on the final day. Thirty-one oral papers were delivered representing all research conducted through the life of the project, and perspectives on industry development constraints and opportunities. There were 91 registered participants representing Indonesia, Vietnam, Australia, New Caledonia and USA, including the current and 2 past Directors General Aquaculture.



Nick Austin  
Chief Executive Officer  
ACIAR





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*Clive Jones*  
Editor

# 1. Introduction

Clive Jones<sup>1</sup>

Development of spiny lobster aquaculture is of increasing interest around the world, as demand increases and capture fisheries supply decreases. There have been two primary sectors of research and development activity: firstly utilizing natural settlement of lobster seed, and secondly developing hatchery technology. Ultimately the two sectors will merge when hatchery technology is fully commercialized and the price of hatchery-produced seed is equivalent to that of the natural supply.

This report provides a summary of information presented at a lobster aquaculture symposium held in Lombok, Indonesia, from 22–25 April 2014. The symposium represented the findings of the ACIAR project SMAR/2008/021: ‘Spiny lobster aquaculture development in Indonesia, Vietnam and Australia’, and identified knowledge gaps that require further research and development. The project had an industry development focus, and the Symposium provided an opportunity for input from research scientists, extension staff, government policy makers and managers, and lobster fishers and farmers to discuss industry development and identify key issues that further research could address to progress the lobster aquaculture industry’s expansion and improved productivity and viability.

To maximise the opportunity, the Symposium was structured to include formal oral presentations (presented in English), a field trip to a lobster seed fishing and farming village, an industry development workshop (presented in Indonesian) and social events to encourage the most comprehensive exchange of information and ideas possible.

Oral papers concerning project research and activities were presented by project collaborators from Indonesia, Australia and Vietnam. Additional oral papers were presented to provide regional and global perspectives on lobster aquaculture from associates from New Caledonia and the USA. The papers were scheduled within five sessions encompassing lobster seed (puerulus) fishing, nursery culture, grow-out, industry development and other perspectives. A synopsis of significant findings, key issues and knowledge gaps was prepared for each session. This publication presents synopses of each of the oral presentations in summarised form.

The Indonesian lobster farming industry began in the early 2000s on the south-east of the island of Lombok as a secondary activity to seaweed and grouper farming. Small lobsters were frequently seen by the seaweed and grouper farmers, settling on the seaweed or cages, and farmers began retaining them for culture in separate cages. By 2005, there were several farmers solely growing lobsters and devoting more time and effort to catching the seed. By 2009, when the ACIAR project began, there was a small but discrete lobster farming industry with targeted fishing for the seed (puerulus stage) lobsters and dedicated grow-out farms. The total production and productivity levels of lobster farming in Indonesia were low relative to the well-established lobster farming industry of Vietnam. ACIAR sought to increase production and improve productivity through the research project summarised in this document.

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## **2. Seed Supply**



# 2.1 Census of the lobster seed fishery of Lombok

Samsul Bahrawi<sup>1</sup>, Bayu Priyambodo<sup>1</sup> and Clive Jones<sup>2</sup>

## Introduction

Lobster aquaculture first began in Indonesia in the south-east of the island of Lombok, in West Nusa Tenggara Province (Figure 1). Here, lobster seed were first found and targeted fishing of them developed.

The objective of this research was to establish baseline lobster seed catch data for those areas around Lombok Island where seed were being routinely caught. The research intended to examine and collate data on total catch, localised catch, species composition, seed price and seasonality. The census was designed to be on-going to enable collation of long-term data to examine sector growth, inter-annual variability and trends that might assist in effective management of the resource.

In Lombok, lobster seed are typically fished by placing materials in the water column suspended

from floating frames that provide an attractive shelter for the pueruli. The shelter materials used varies, but most commonly it is either rice bag material cut into strips and tied in bundles or cement bag paper which is folded to create multiple crevices.

## Methods

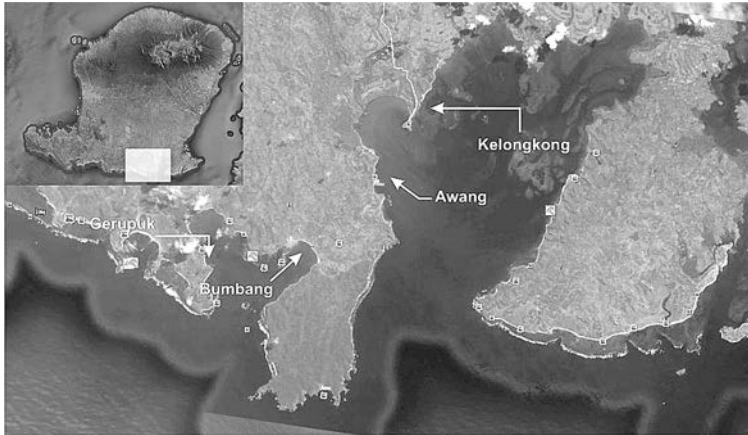
For each of the main villages close to where lobster seed are caught (Figure 2), a seed census officer (1 person per location) was recruited and trained in the data collection method. The census officer recorded data once a week from interviews with the lobster seed fishers in their location. Data was recorded on a standardised form, and once these forms were completed, they were photographed and the images sent to the census coordinator.



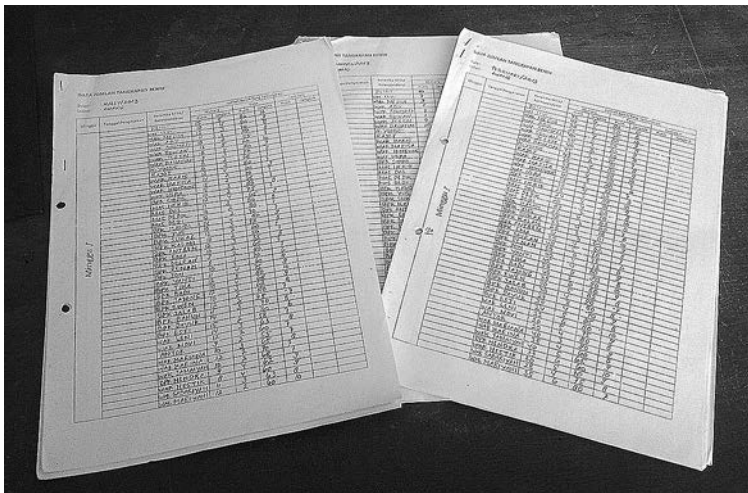
Figure 1. Map of Indonesia showing the location of Lombok

<sup>1</sup> Marine Fisheries and Aquaculture Development Centre, Lombok, Indonesia. Email: samsul.ntb@gmail.com

<sup>2</sup> James Cook University, Cairns, Australia



**Figure 2.** Locations in south-east Lombok for the seed census data collection. Gerupuk: 98 respondents, fishing began in 2004; Bumbang: 233 respondents, fishing began in 2003; Awang: 141 respondents, fishing began in 2000; Kelongkong: 47 respondents, fishing began in 2008



**Figure 3.** Examples of the census forms used by the census officers

## Results and discussion

Seed census data has been collected since 2007. The number of lobster seed fishers contacted to gather the data and the total number of seed fishers operating is shown in Table 1. Over the period 2007 to 2014, data has been gathered from a minimum of 78% of fishers and up to 96% in any given year; thus providing a good representation of actual catch.

Census data confirmed that there are six species of lobsters represented in the seed catch comprising *Panulirus homarus*, *P. ornatus*, *P. versicolour*, *P. longipes*, *P. penicillatus* and *P. polyphagus*.

Total catch of all seed, based on census data, is presented for each year from 2009 in Figure 4.

Between 2009 and 2012 the annual number of seeds was relatively stable at 600,000 per year, however in 2013 the number of seed caught increased

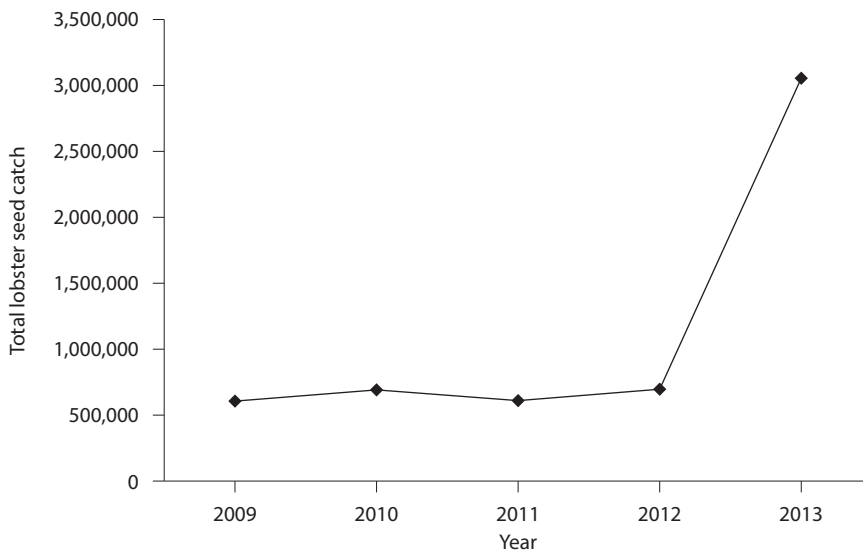
dramatically. This is attributed to: improved fishing techniques, including the use of lights to attract swimming pueruli; improved deployment of shelter materials; and improved positioning of catching frames within the bay. Increase in catch is also attributable to increased effort, with many more fishers engaged in lobster seed fishing since early 2013. The total seed catch for 2013 was in excess of three million pieces.

Figure 5 suggests a distinct peak in seed catch in the period May to July, with a possible secondary, but much weaker peak in November. By examining the catch data for 2009 to 2012 on a different scale (as shown in Figure 6) the same peaks are evident,

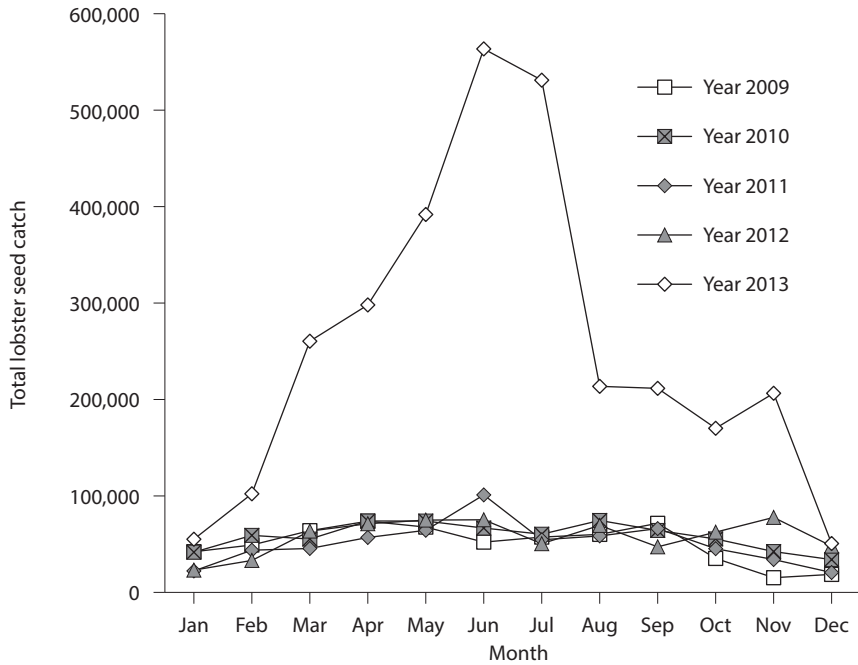
although there is considerable inter-annual variability. We suggest that the peak in puerulus abundance in May to July corresponds with early summer reproduction and release of newly hatched phyllosoma larvae in mid-summer, around November to January in the southern hemisphere. This accounts for the five to six month larval duration for the tropical species caught. The secondary peak of puerulus abundance around November and December may relate to reproduction occurring in northern hemisphere stock, where breeding and release of newly hatched phyllosomas would occur around May to July. This contrasts with a distinct single peak in puerulus abundance in Vietnam from November to March.

**Table 1.** Number of seed fishers interviewed and total number of seed fishers operating each year from 2007 to 2014

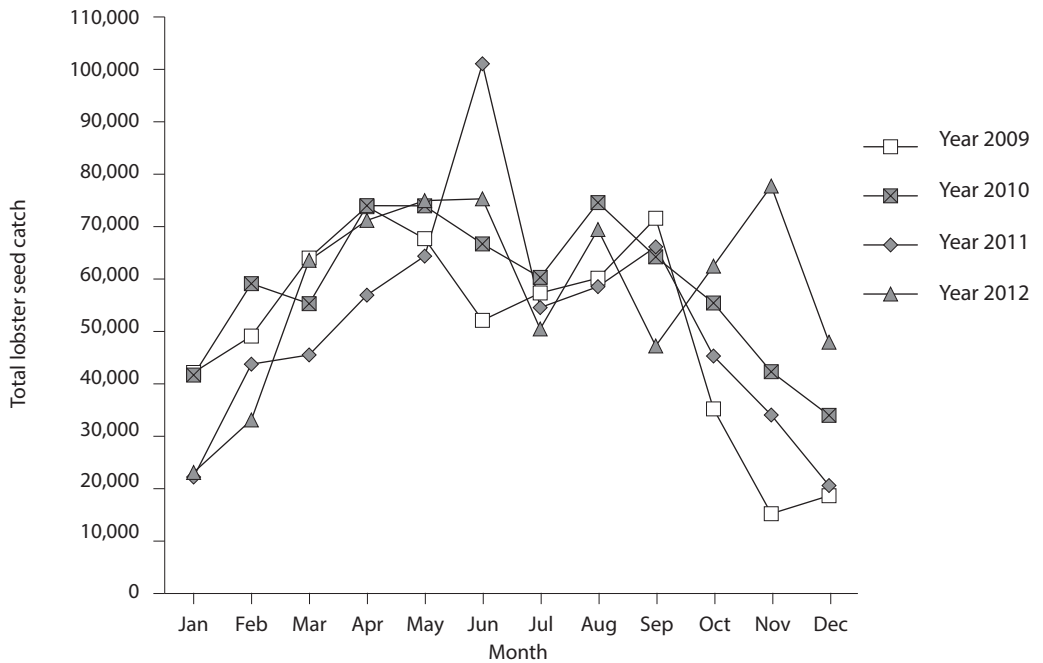
Period	Number of contacted seed fishers / total number of seed fishers	Percentage contacted
07/08	245/269	91.1
08/09	287/305	94.1
09/10	309/332	93.1
10/11	315/357	88.3
11/12	387/402	96.3
12/13	408/526	77.56
13/14	484/556	87



**Figure 4.** Annual total catch of lobster seed in Lombok 2009 to 2013



**Figure 5.** Total lobster seed catch by month for each year 2009 to 2013



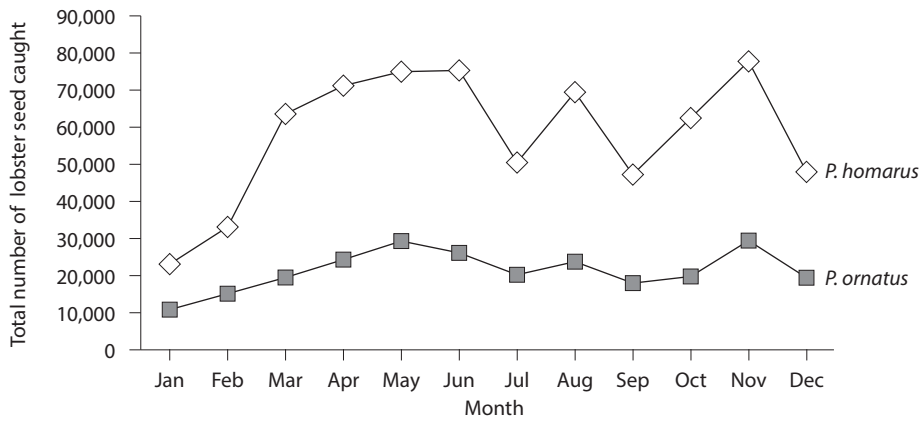
**Figure 6.** Total lobster seed catch by month for each year, 2009 to 2012 on a finer scale than in Figure 5

Within the lobster seed catch, there are two dominant species: *Panulirus homarus* and *P. ornatus* which account for more than 99% of seed caught. The species composition appears to fluctuate between years, and in 2012, 63.27% of seed were *P. homarus* and 36.73% *P. ornatus*, while in 2013 *P. homarus* represented 86.65%, and *P. ornatus* 13.35%.

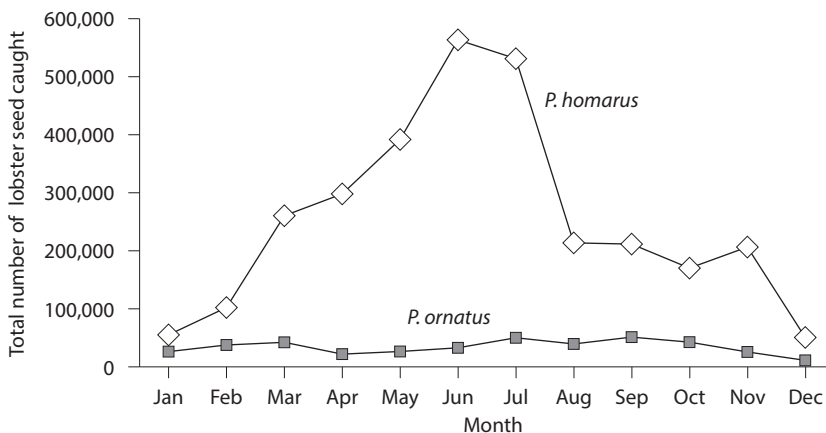
Although lobster seed of both *P. homarus* and *P. ornatus* were caught throughout the year, the data for 2012 indicated two peaks, from April to June and October to November (Figure 7). In 2013, when catch

rates were much higher, there was a more distinct peak in catch of *P. homarus* from May to July, and no discernable peak for *P. ornatus* (Figure 8).

Individual price for *P. homarus* seed in Lombok is illustrated in Figure 9 for each month of each year from January 2009 through to April 2014. The graph shows that the price from 2009 to 2012 was quite stable from IDR 2,500 to 5,500 (equivalent to US\$0.21 to \$0.50 each). In April to May 2013 the price decreased dramatically from IDR 5,500 to 2,000 due to the increasing supply of seed. However,



**Figure 7.** Lobster seed catch by month for *P. homarus* and *P. ornatus* in 2012



**Figure 8.** Lobster seed catch by month for *P. homarus* and *P. ornatus* in 2013

from June 2013 to April 2014, the price progressively increased to IDR 16,000 each (US\$1.34) as demand also increased. Similarly, the price for *P. ornatus* seed was quite stable from 2010 through to early 2013 (Figure 10) at IDR 4,000 to 8,000 each, but has trended upwards since, to IDR 18,000 in April 2014. Although *P. ornatus* represents a relatively small

proportion of the seed caught, and after grow-out is seldom distinguished from *P. homarus*, it fetches a small premium on *P. homarus* because it is perceived to be a more valuable species. Total revenue from both species in 2012 and 2013 is shown in Table 2.

In Vietnam, the relative price of seed for each species is much higher, and the price discrepancy

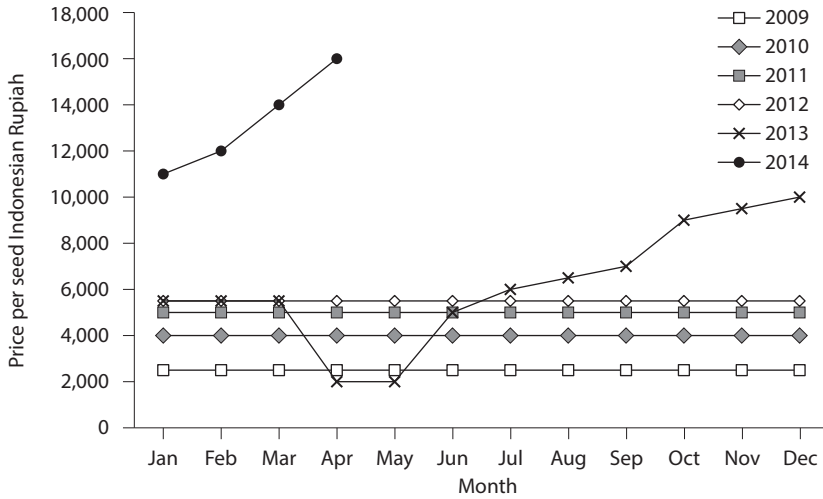


Figure 9. Monthly price for lobster seed for 2009 to 2014 for *P. homarus*

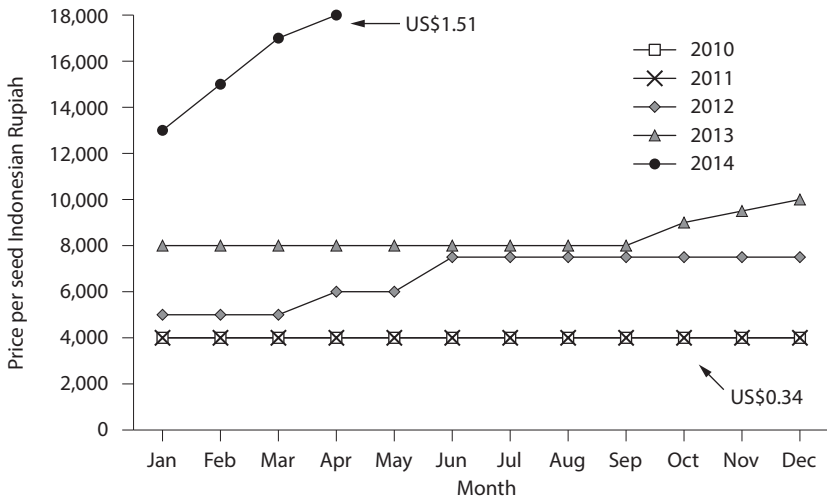


Figure 10. Monthly price for lobster seed for 2010 to 2014 for *P. ornatus*

between the two species is much greater, due to the more developed nature of the lobster farming industry in Vietnam and greater demand (see Chapter 2.2).

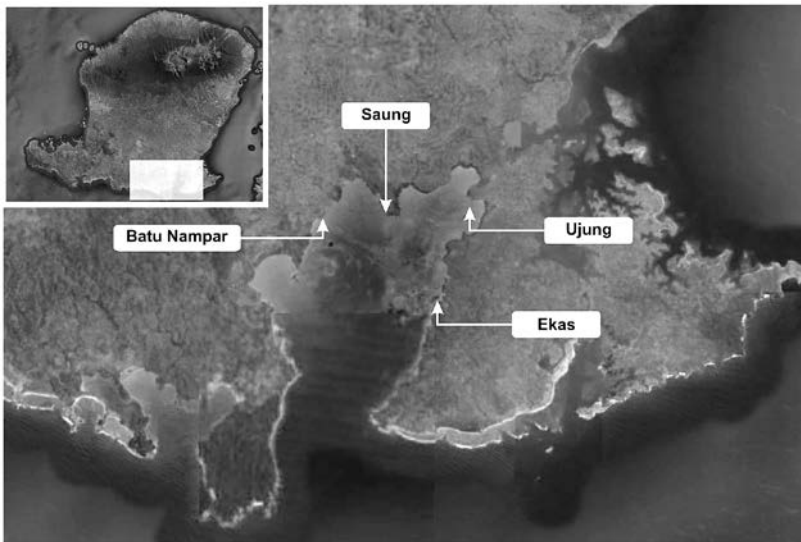
By the end of 2013 there were four new locations in south-east Lombok being fished for lobster seed; Batu Nampar, Saung, Ujung and Ekas, all within Ekas Bay where the pre-existing seed fishing areas of Awang and Kelongkong are located. Since late 2013, all these fishing areas use lights as part of their seed fishing method.

## Conclusions and recommendations

Through conducting a monthly census of seed catch in Lombok, valuable data is being collected on the development of the fishery since 2009 which will be useful in determining a management plan for sustainable exploitation of the resource. The census should continue indefinitely, and include other locations as lobster seed resources are confirmed there. Long-term monitoring of the seed resource will help

**Table 2.** Total revenue from lobster seed trade in Lombok for 2012 and 2013

Species	Year	Total seed caught	Price (IDR)	Total Revenue (IDR)
<i>P. homarus</i>	2012	440,684	5,500	2,423,762,000
	2013	2,646,886	2,000 to 10,000	14,049,720,000
<i>P. ornatus</i>	2012	255,861	5,000 to 7,500	1,724,842,000
	2013	407,783	2,000 to 10,000	3,365,768,000

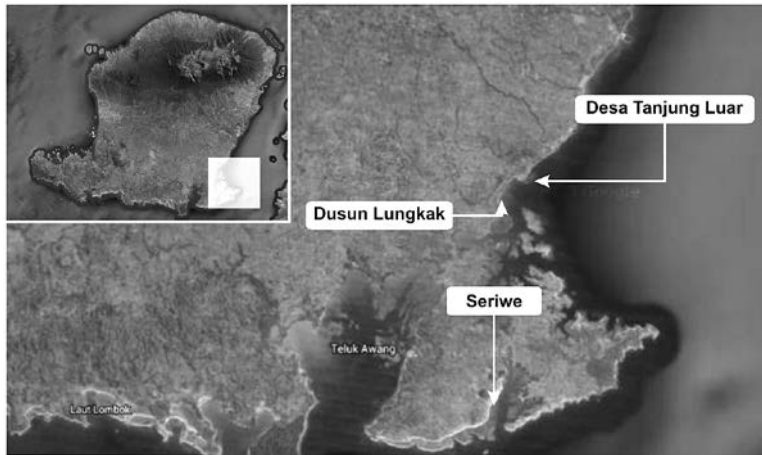


**Figure 11.** New areas of Lombok being fished in 2013. Batu Nampar: 80 fishers; Saung: 50 fishers; Ujung: 10 fishers; and Ekas: 80 fishers

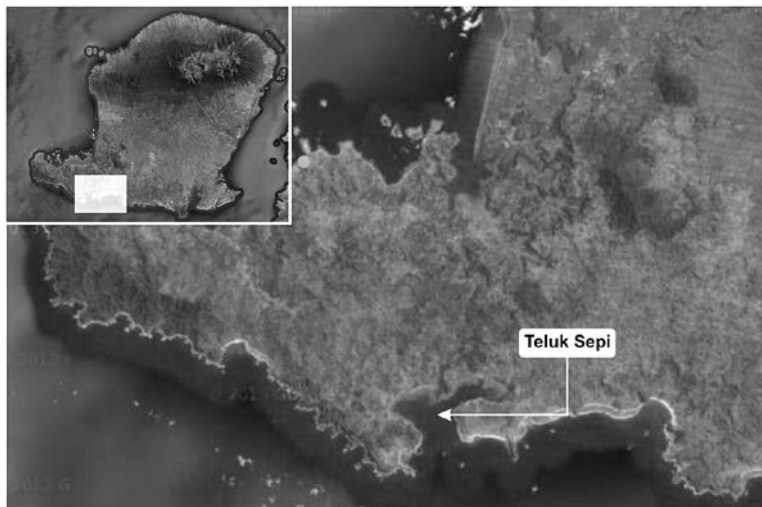
to identify inter-annual variability and trends in catch per unit effort, and may be correlated with large-scale data on climate, oceanography and breeding stocks.

Further improvements in the accuracy and precision of data collected should be sought by identifying all seed dealers and ensuring their cooperation.

Further research is warranted to investigate and clarify the effects of light, depth and catching equipment on seed fishing in order to maximise catch.



**Figure 12.** New areas of East Lombok being fished in 2014



**Figure 13.** New areas of West Lombok being fished in 2014



## 2.2 Census of the lobster seed fishery of Vietnam

Hoc Tan Dao<sup>1,2</sup> and Clive Jones<sup>3</sup>

### Introduction

Spiny lobsters are the world's most valuable crustaceans. Many countries have an interest in spiny lobster aquaculture but only a few have produced any farmed lobsters for the market due to difficulties in securing a supply of seed. The difficulty arises from challenges in culturing spiny lobster larvae from the eggs through to the puerulus, due to the protracted larval duration (from four months to more than one year) and technical difficulties in nurturing and sustaining them. At present, there is no commercial hatchery production of lobsters anywhere in the world.

Nevertheless, there is a significant lobster aquaculture industry in Vietnam, producing more than 1,500 tonnes of cage-raised lobsters annually. There is also a rapidly developing spiny lobster farming industry in Indonesia. Aquaculture in these countries is based on collection of naturally settling pueruli and juveniles.

Until a hatchery supply of seed can be established, the supply of naturally settling seed is very important for sustaining aquaculture production. Little is known about this supply, including the source and the impact of fishing. A first step in understanding the resource is to conduct a census to collect the catch data, with a view to establishing some form of fisheries management to ensure long-term sustainability.

This paper presents data from an annual census of lobster seed catch in Vietnam from 2005 to 2014.

### Methods

As lobster seed are most abundant in the period from October through to April, two surveys were

performed each lobster seed fishing season, the first in November and the second in April. These direct surveys were conducted each year from 2005/06 to 2010/11, after which data were collated by phone surveys with significant dealers.

Direct surveys involved a structured interview with dealers, i.e. operators who buy lobster seed from multiple fishers and on-sell it to lobster farmers. The interviews comprised examination of the dealers' logbooks. Photos were taken of the logbook pages and the data was later transcribed to a spreadsheet for collation and analysis. A typical logbook page is shown in Figure 1. The surveys also provided an opportunity to make qualitative assessments of the methods and equipment used by dealers for handling, storage and transport of lobster seed.

### Results and discussion

Seven species of *Panulirus* were recorded among the seed catch in Vietnam, including two that were the most abundant, and for which detailed catch data were available: *P. ornatus* and *P. homarus*, and five less-common species: *P. versicolor*, *P. longipes*, *P. penicillatus*, *P. polyphagus* and *P. stimpsoni*.

Lobster seed were caught in seven central to south coast provinces from Da Nang to Binh Thuan (Figure 2). The catch season extended over six to eight months, from September/October to the following March/April. The provinces from which most seed are captured comprise Binh Dinh, Phu Yen and Khanh Hoa (Figure 2).

Techniques used to catch the seed were primarily aimed at catching swimming pueruli, and secondly at catching settled juveniles. For the pueruli, the methods comprised: i) set seine nets, positioned to intercept the swimming pueruli; ii) netting supported by floating frames, on which pueruli would settle; and iii) various habitat traps made from a variety

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3/2 140/50			
Niên	10 + 1 X	gũy	6 + 1 X
Cho	5	ngô	17 + 1 X
Tue	25 + (3kêu)	Kinh	13 + 3 X
*	4	Chach	10 + 2 X
Táo	8 + 2 X	Chơng	22 + 3 X
Hĩ	17 + 1 X	nyhĩ	13 + 3 X
Biểu	18 + 1 X	vũ	7 + 2 X
Nam	5 + 2 X	Phân	31 + 2 X
Chinh	6	* Mĩ	29 + 1 X
ngiệp	9 + 2 X		5
Xuân	6 + 2 X	Hĩn Kĩ	8 + 2 X
			113
			162

**Figure 1.** Photo image of typical lobster seed dealers' logbook from Vietnam, showing date, price (for *P. ornatus* / *P. homarus*), boat / fisher and number of *P. ornatus* and *P. homarus* bought



**Figure 2.** Seven coastal provinces of Vietnam where lobster seed are caught

of materials suspended in the water from floating frames. The majority of pueruli in 2014 were captured using the seine net method.

For the juveniles (i.e. post-plerulus stage, with pigmented body and functional mouthparts), the catching method comprised various habitat traps, designed to provide an attractive habitat for the juvenile lobsters to occupy. The three most common were: i) timber posts with small holes drilled in them; ii) coral rocks with holes drilled in them; and iii) netting bundles with multiple folds, edges and crevices within which the juveniles conceal themselves.

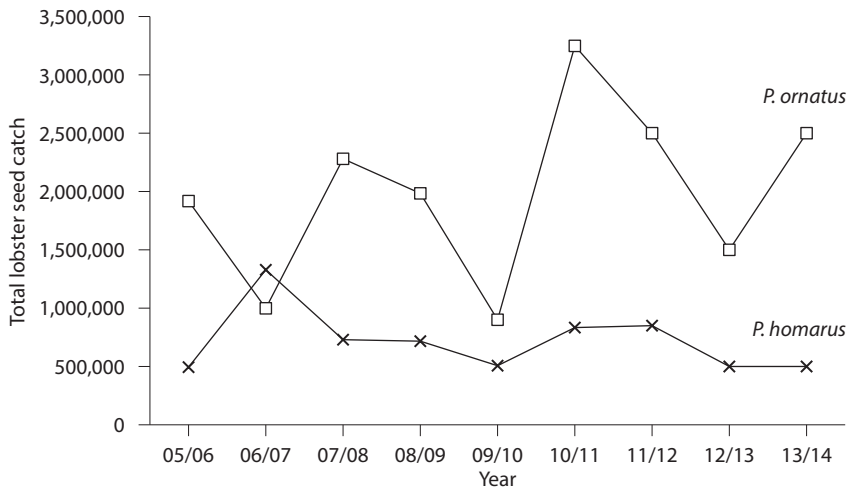
The surveys indicated that more than 95% of seed purchased by dealers were pueruli, and the remaining 5% were small (< 1 g) pigmented juveniles.

For the pueruli, the fishers would hold newly captured lobster seeds in small bottles filled with sea-water but with no aeration. These pueruli were then sold to middlemen (dealers) each day, normally in the morning after fishing through the night. The dealers would gather the purchased seed together, storing them for periods of <1 to 3 days in tanks or larger storage containers (buckets, plastic bins) typically at the dealer's house before selling them to farmers. In most instances, the dealers provided no aeration or water quality management (filtration, additives) to the storage containers. Nevertheless, survival of pueruli through this phase appeared to be consistently high.

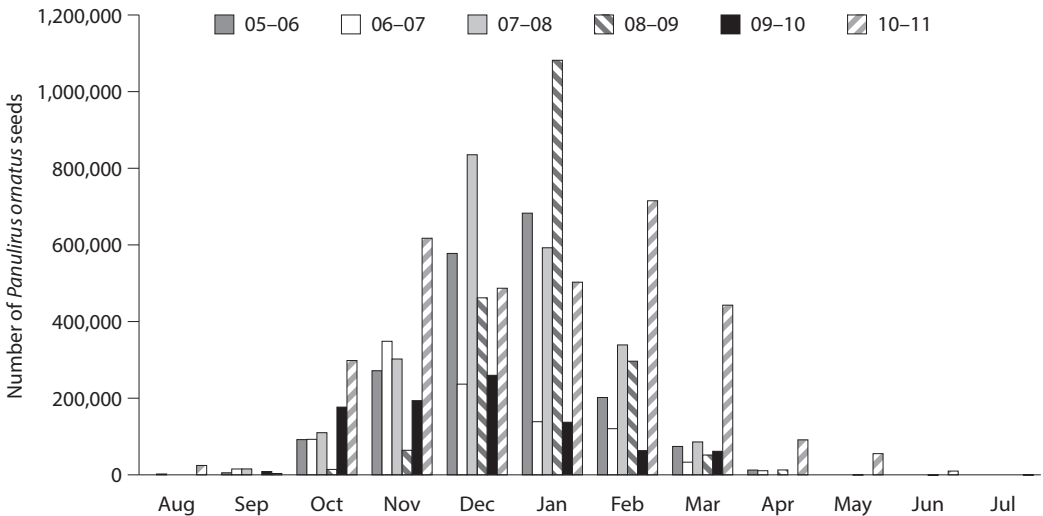
Analysis of the catch data over successive years showed large variation in total catch of lobster seed, especially for *P. ornatus* (Figure 3). The highest monthly catch was from November to February (Figures 4 and 5).

The price of *P. ornatus* seed between 2005/06 and 2010/11 ranged from US\$3.00 to \$9.00 each (Figure 6). The price per seed has continued to

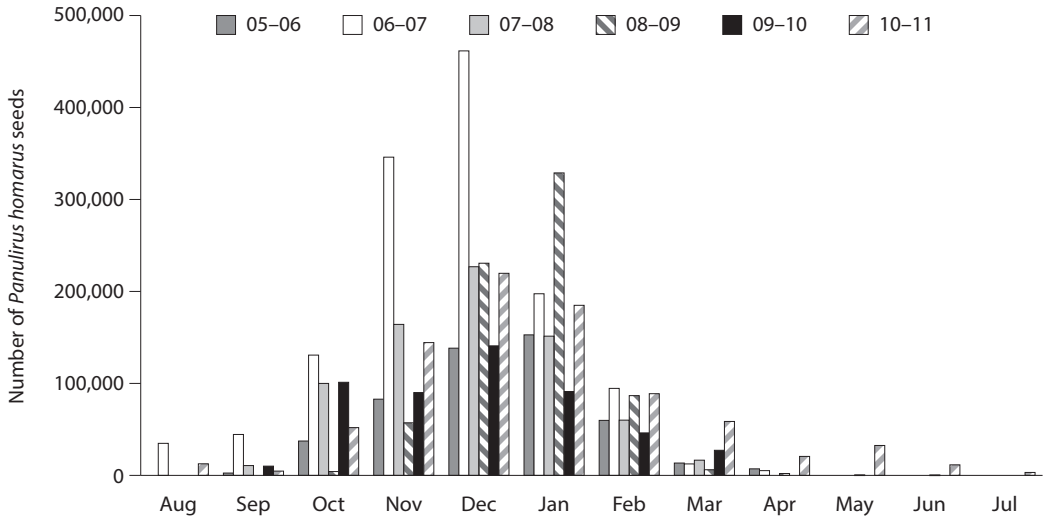
increase in more recent years with increasing demand, and in 2013/14 the price was US\$12.00 to \$14.00. The reduced catch of seed in 2006/07 and 2009/10 stimulated a higher price, and in 2007/08 a milky disease outbreak posed increased risk for farmers, coinciding with a large catch that year, which prompted a collapse in price.



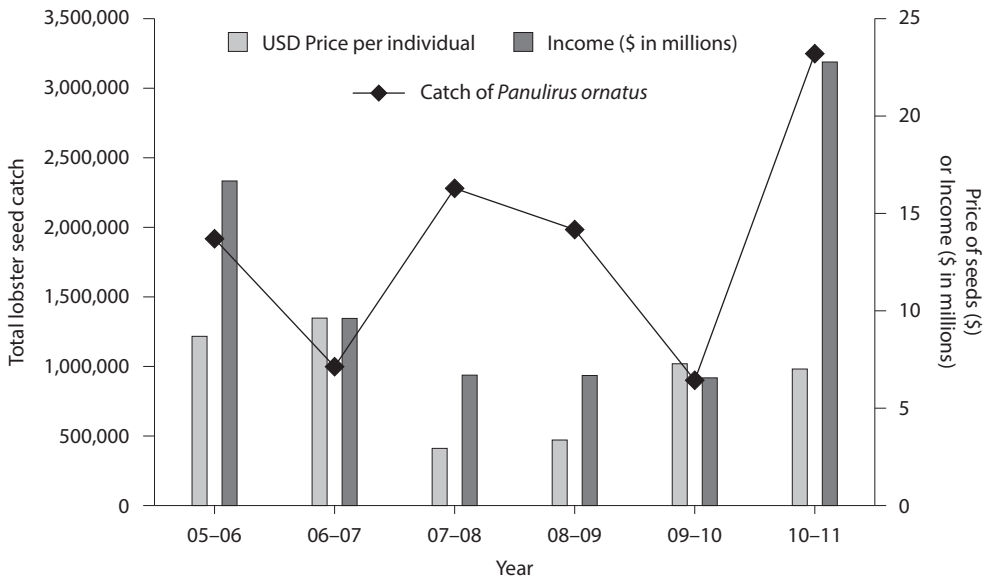
**Figure 3.** Annual catch of lobster seed in Vietnam 2005/06 to 2013/14



**Figure 4.** Monthly catch of lobster seed of *P. ornatus* in Vietnam 2005/06 to 2010/11



**Figure 5.** Monthly catch of lobster seed of *P. homarus* in Vietnam 2005/06 to 2010/11



**Figure 6.** Total catch, revenue and price per seed of *P. ornatus* from 2005/06 to 2010/11

For *P. homarus* seed, the price between 2005/06 and 2010/11 ranged from US\$0.60 to \$2.40 each (Figure 7). After the 2007/08 milky disease outbreak, the price of *P. homarus* seeds increased steadily as farmers reasoned *P. homarus* lobsters were more robust than *P. ornatus* and less susceptible to milky disease. Although the basis for this assumption has not yet been proven, a higher number of farmers now actively seek to farm *P. homarus*, as the market in China has increasingly accepted this species as a suitable substitute for *P. ornatus*, reflecting an increasing market price for 800 g+ lobsters. Further, *P. homarus* is thought to grow faster than *P. ornatus*, reaching a marketable size in less time.

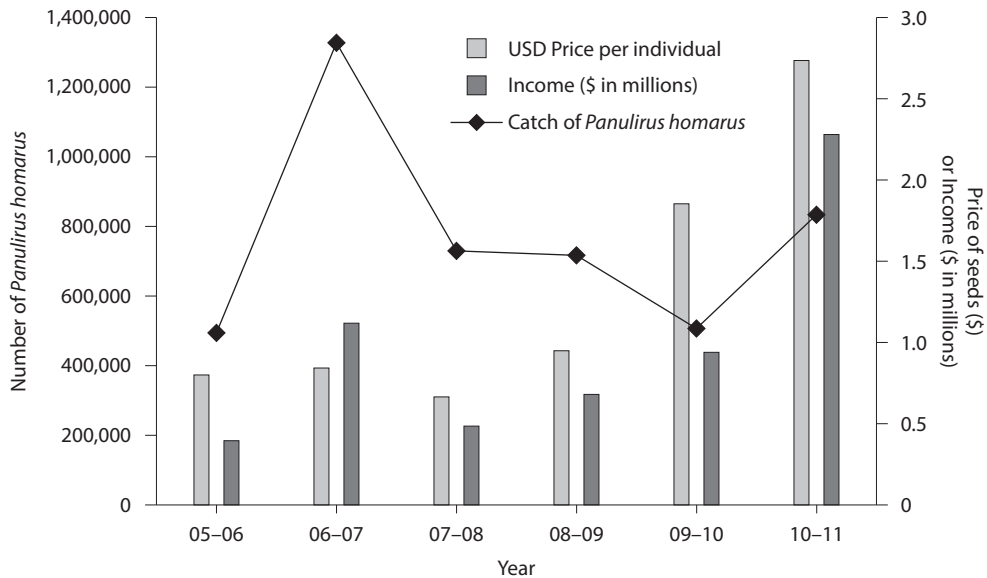
**Table 1.** Proportion of dealers interviewed to gather seed catch data

Period	Number of contacted dealers / total number of dealers	Percentage
05-06	71/81	87.7
06-07	94/97	96.9
07-08	97/97	100
08-09	99/99	100
09-10	101/102	99
10-11	114/114	100

## Conclusions and recommendations

The fishery for lobster seed in Vietnam to support lobster farming is now well established. Although catches vary from year to year, there is no indication that the exploitation of the resource is unsustainable. As the economics involved are very attractive to poor coastal villagers, i.e. low risk to high return, the sector is likely to be fully developed with no more capacity. Annual catch of *P. ornatus* seed appears to be steady at between one and three million pieces per year, while that for *P. homarus* is steady at between 0.5 and 1 million pieces per year.

The increasing trend in price per seed has applied to both primary species, although the increase has been sharper for *P. homarus* in recent years. The price reflects ongoing increase in demand for on-grown lobsters by the Chinese market. Wholesale price for 1 kg+ *P. ornatus* was up to US\$120 per kg in 2014 (see Chapter 5.9) and for *P. homarus* above 700 g, \$80.00 per kg. These high prices for consumption-size lobsters have driven demand for the seed, with corresponding increases in seed price. Recent significant increases in supply of seed, particularly for *P. homarus* caught in Indonesia (see Chapter 2.1) and exported to Vietnam and elsewhere, may impact on seed price in Vietnam.



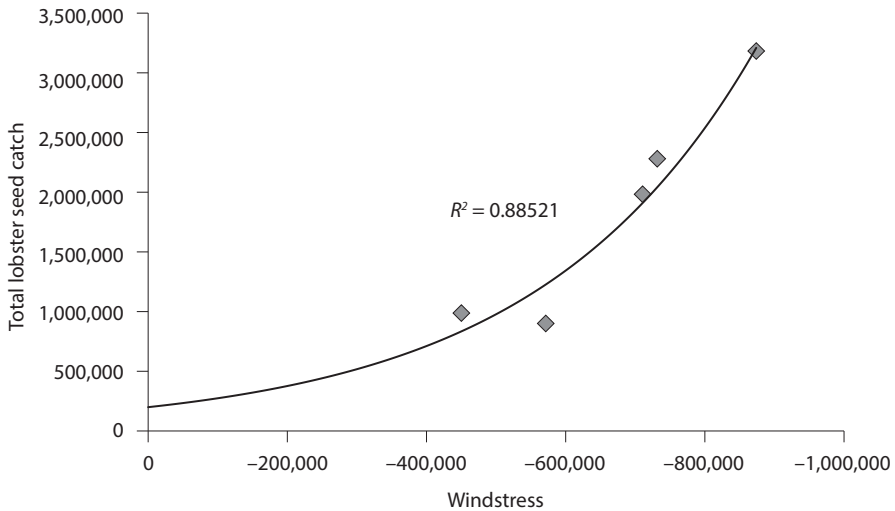
**Figure 7.** Total catch, revenue and price per seed of *P. homarus* from 2005/06 to 2010/11

Local fishers and dealers in Vietnam suggested there was a relationship between the variations in lobster seed catch and the pattern of seasonal winds, a proposition that is supported by the analysis of lobster seed catch and wind data from 2005 to 2011 (Dao et al. unpub. data). During this period, the number of lobster seeds of *P. ornatus* reaching Vietnam increased with increasing wind stress (Figure 9;  $r^2 = 0.885$ ). *P. ornatus* larvae are found mainly within the well-mixed surface layer, i.e. the layer above the thermocline, which in the tropics is typically about 100m deep (Phillips 2013; Pitcher et al. 2005). Winds blowing over the ocean surface exert a stress on the ocean's surface that drives the surface layer (Fischer 1979; Marschall and Plumb, 2008) which is carrying the lobster larvae. As a consequence, the pattern of seasonal winds has a strong effect on the lobster seed catch in Vietnam. The correlation between recruitment of lobster species and seasonal winds has been documented for other lobster species. Westerly winds positively correlated with the recruitment of *P. cygnus* in Western Australia (Caputi and Brown 1993; Caputi et al. 2003; Caputi et al. 2001; Griffin et al. 2001). Similarly, seasonal onshore winds were shown to be important in the local retention of recruits of *P. homarus* and *P. penicillatus* in Java, Indonesia (Milton et al. 2014).

Further research is warranted on factors affecting puerulus settlement both at regional level (oceanic and weather patterns) and at fine level (coastal hydrodynamics and hydrographic variables).



Middleman with lobster seed



**Figure 9.** Variation of total wind stress and total seed catch of *Panulirus ornatus* during six fishing seasons in Vietnam from 2005 to 2011





Lobster farmer purchasing seed



Middleman facility for holding lobster seed

## References

- Caputi N. and Brown R.S. 1993. The effect of environment on puerulus settlement of the western rock lobster (*Panulirus cygnus*) in Western Australia. *Fisheries Oceanography* 2(1): 1–10.
- Caputi N. Chubb C. Melville-Smith R. Pearce A. and Griffin D. 2003. Review of relationships between life history stages of the western rock lobster, *Panulirus cygnus*, in Western Australia. *Fisheries Research* 65(1): 47–61.
- Caputi N. Chubb C. and Pearce A. 2001. Environmental effects on recruitment of the western rock lobster, *Panulirus cygnus*. *Marine and Freshwater Research* 52(8): 1167–1174.
- Fischer H.B. 1979. *Mixing in inland and coastal waters*. Elsevier.
- Griffin D.A. Wilkin J.L. Chubb C.F. Pearce A.F. and Caputi N. 2001. Ocean currents and the larval phase of Australian western rock lobster, *Panulirus cygnus*. *Marine and Freshwater Research* 52(8): 1187–1199.
- Marschall J. & Plumb R. 2008. *Atmosphere, Ocean, and Climate Dynamics*: Elsevier Academic Press: USA.
- Milton D. A., Satria F., Proctor C. H., Prasetyo A. P., Utama A. A. & Fauzi M. 2014. Environmental factors influencing the recruitment and catch of tropical *Panulirus* lobsters in southern Java, Indonesia. *Continental Shelf Research* 91, 247–255.
- Phillips B. 2013. *Lobsters: Biology, management, aquaculture & fisheries*. Wiley. com.
- Pitcher C.R. Turnbull C. Atfield J. Griffin D. Dennis D. and Skewes T. 2005. *Biology, larval transport modelling and commercial logbook data analysis to support management of the NE Queensland rock lobster *Panulirus ornatus* fishery*. CSIRO Marine Research.

## 2.3 Assessment and development of the lobster seed fishery of Indonesia

Samsul Bahrawi<sup>1</sup>, Bayu Priyambodo<sup>1</sup> and Clive Jones<sup>2</sup>

### Introduction

In addition to investigations into the already established fishery of the lobster seed resource in Lombok Indonesia, research was conducted to assess the availability of lobster seed in other parts of Lombok and other Indonesian provinces. The objective was to provide a quantified assessment of lobster seed resources at a range of sites through the application of a standardised seed-collecting device that would enable:

- assessment of the presence of lobster puerulus settlement at each location
- identification of the species available
- estimation of the magnitude of the puerulus resource in each area
- continuous monitoring of the lobster settlement each year to detect seasonal patterns and annual variations.

The ultimate aim of the research was to identify localised lobster seed fisheries that could be developed to supply seed for lobster farming. This paper introduces the lobster seed assessment and development activities across all of Indonesia, but should be read in conjunction with Chapters 5.11 and 5.12 that provide additional details of associated activities in Southern Sulawesi and Aceh.

### Methods

From 2010 to 2013 an assessment of lobster seed availability was made at: Aceh Province (Simeulue Island and Breuh / Aceh Island); West Sumatra Province; West Nusa Tenggara Province; East Nusa

Tenggara Province; South Sulawesi Province; South-east Sulawesi Province; North Sulawesi Province and Maluku (Figure 1).

Sites were chosen based on the known presence / abundance of adult lobsters nearby (i.e. an established fishery) and in these areas, in bays where tripods would not be susceptible to strong wind and waves.

The method involved the use of a standardised collector, which was designed based on similar structures used in Vietnam. It is constructed from bamboo bound together with rope to form a rectangular frame with a tripod structure on top. The collector was designed as a sampling tool only and not for maximum catch or commercial purposes. This differs from the typical commercial lobster seed fishing equipment used in Lombok, which is described in Chapter 2.1.

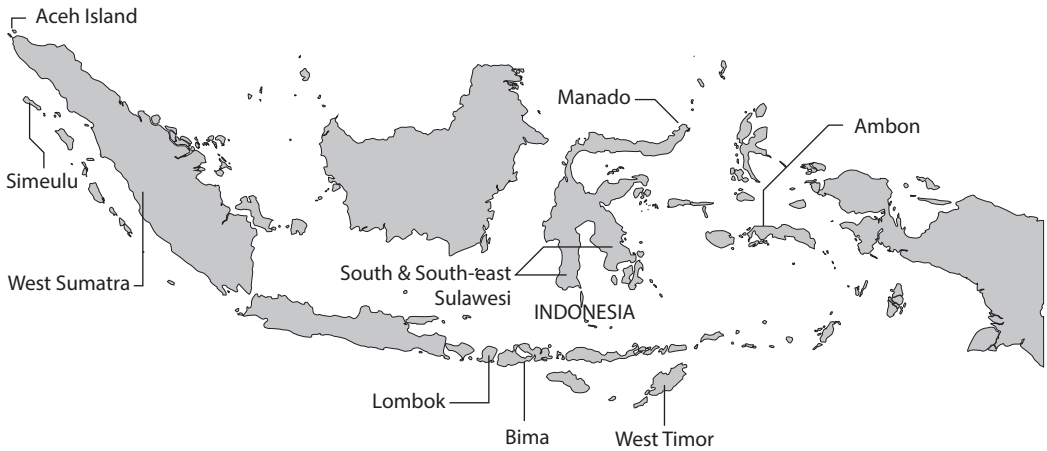
The tripod design facilitated the attachment of a light (powered by either battery, kerosene or electricity) hung from the apex to aid in attracting pueruli. The design is illustrated in Figures 2 and 3. Styrofoam floats were bound to the base of the frame to provide flotation. Tripods were anchored in position using rope tied to an anchor of either concrete, rock or rice bags filled with sand. Each tripod was 2 m long and 1.5 m wide.

At each of the four corners of the frame, shelter traps were suspended on rope lines. On each line, there were two bundles of trap material, the first at 2 m depth and the second at 4 m. For two of the lines, rice bag traps were used, and on the other two lines, bundles of cage netting material. A unit of shelter consisted of two rice bags, with two units of rice bag and two units of waring (cage mesh) per tripod. Therefore 16 rice bags and 16 units of waring (cage mesh) were used per tripod. Four tripod collectors were deployed at each location with spacing of at least 25 m between each tripod in any direction.

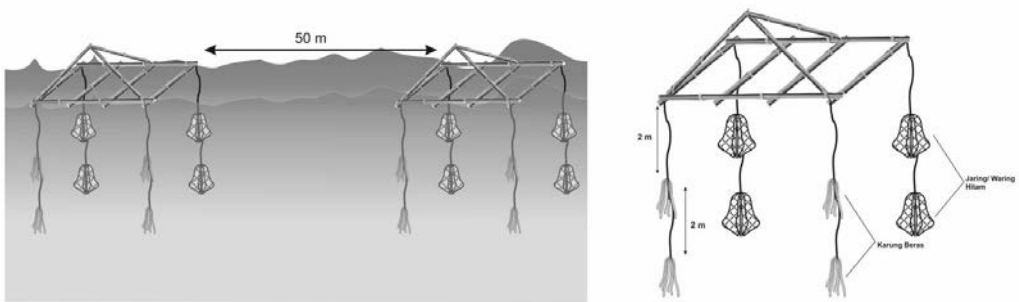
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<sup>2</sup> James Cook University, Cairns, Australia





**Figure 1.** Map of Indonesia showing locations where lobster seed assessment activities were undertaken



**Figure 2.** Illustration of the tripod collector for assessing puerulus availability

Once installed, the collectors were left for two weeks for conditioning before collection commenced. Seed collectors were then checked once every three days, and the number and species collected were recorded on a data sheet.

Tripods were left in place and monitored for a minimum of 12 months to account for any seasonal factors in settlement of pueruli.

## Results and discussion

The total catch of lobster seeds by the standardised tripod collectors at the various locations is summarized in Table 1. At West Sumatra Province, Ampenan NTB, Bima NTB and North Sulawesi, no lobster seeds were found over at least a 12 month period.



**Figure 3.** Photo of typical tripod collectors

On the island of Simeulue in Aceh Province, lobster seed assessment activity started in 2010, and although 19 tripods were deployed in three different bays (Teluk Dalam, Teluk Busung dan Teluk Sinabang, see Chapter 5.12), very few lobster seeds were found over two years. The area around Simeulue has well-established lobster fishing, with substantial catch of *P. penicillatus* and *P. versicolor* in particular. As in other locations, the presence of adult lobsters does not necessarily ensure presence of settling

pueruli. Furthermore, the tripod collector used which has been confirmed as suitable for catching *P. ornatus* and *P. homarus* may not be suitable for the pueruli of these other species due to behavioural differences and different habitat requirements. It was noted that the three bays sampled were characterised by clear water with live coral at the bottom. This contrasts with conditions at Ekas Bay in Lombok where seed catch is very high, which is turbid with a sandy mud bottom.

**Table 1.** Total number of lobster seed collected with tripod collectors at locations throughout Indonesia; listed from west to east

Location	No. of Tripods	Year	Lobster seeds	Species <i>Panulirus</i>
<i>Aceh Province</i>				
Breuh / Aceh Island 5°41'51.5"N 95°04'10.2"E	6	2012	536	<i>P. homarus</i> and <i>P. ornatus</i>
Breuh / Aceh Island	6	2013	396	
Simeulue Island 2°38'26.5"N 96°01'24.1"E				
Dalam Bay	5	2010	No seeds	–
Busung Bay	5			
Sinabang Bay	4			
Desa Latak Ayah	8	2011	4	<i>P. homarus</i> and <i>P. ornatus</i>
<i>West Sumatra Province</i>				
West Sumatra Kampung Sungai Nipah Kanagarian Painan Selatan, Kecamatan IV Jurai, Kabupaten Pesisir Selatan	12	2012	No seeds	–
<i>West Nusa Tenggara Province</i>				
Ampenan Lombok 8°34'26.3"S 116°04'16.7"E	16	2012	No seeds	–
Sekotong Lombok 8°44'07.0"S 115°58'39.3"E	8	2010	No seeds	–
Bima				
Sape Bay 8°26'34.4"S 118°42'13.2"E	16	2010–2011	No seeds	–
Waworada Bay 8°43'09.2"S 118°53'08.2"E	8	2010		
Sanggar Bay 8°21'25.7"S 118°16'50.8"E	8	2011		
<i>South Sulawesi Province</i>				
Laikang Bay 5°34'14.7"S 119°29'24.9"E	28	2010–2012	45	<i>P. homarus</i> <i>P. versicolor</i> <i>P. versicolor</i> <i>P. ornatus</i> <i>P. versicolor</i>
Bone Bay	16	2011–2012	23	
Polewali Mandar	8	2012–2014	35	
<i>South-east Sulawesi Province</i>				
Labengki Island	–	–	–	–
<i>North Sulawesi</i>				
Desa Tumbak	8	2012	No seeds	–
<i>East Nusa Tenggara Province</i>				
Timor Island	24	2010	No seeds	–
Tablong		2011	22	<i>P. ornatus</i>
Kupang 10°15'13.4"S 123°28'28.8"E	12	2012	0	
<i>Maluku Province</i>				
Seram Timur 2°48'23.9"S 130°23'17.3"E	12	2012	No seeds	–

## Conclusions and recommendations

This program was ambitious in its expectation of establishing lobster seed collectors in numerous locations across the country, and being checked every few days over at least a year. The arrangements made with local Dinas staff or other collaborators dissipated over time, leading to inconsistent data collection. In particular, when catch rates initially were low or zero, there was decreased enthusiasm. In hindsight, it is recommended to have paid staff to maintain and monitor such sampling equipment.

The seed assessment activities also highlighted that different methods and equipment may be required for different species. The method applied is suitable for *P. homarus* and *P. ornatus* but may be ineffective for other species. Further, the habitat preference of seed lobsters may also differ between species, such that

different habitat types may need to be explored to identify those that attract settlement. Further research is required to explore these knowledge gaps.

Despite some weaknesses in the program, seed resources that may be worth commercial exploitation were identified in Aceh and South-east Sulawesi. At the time of the Symposium, substantial exploitation of seed resources in both these locations had not occurred.

Overall, the seed availability in Lombok currently dwarves that from all other locations in Indonesia, and may in itself be sufficient to support a significant grow-out industry in the country. Further assessment of seed resources is of lower priority now, and emphasis must be placed on extracting maximum value from the confirmed and large seed resource at Lombok.



Figure 4. Photos of lobster seed collectors

## 2.4 Lobster seed fishing, handling and transport in Vietnam

Tuan Le Anh<sup>1</sup> and Clive Jones<sup>2</sup>

### Introduction

In Vietnam, the lobster farming industry comprises distinct sectors, the first of which is the seed supply sector which includes the fishery for the seed and the subsequent handling, storage and transport of the seed to lobster farmers.

This paper describes the methods and equipment applied to the fishing and catching of lobster seed in Vietnam. Lobster seed fishing in Vietnam is primarily focused on the puerulus stage, which is a free-swimming stage, with equipment and methods developed to intercept them as they swim towards suitable habitat for settlement. Secondly, there are fishers who fish for small, juvenile lobsters that have already settled, and are therefore fished using different methods. Handling and transport of the seed is also described in this paper.

### Lobster seed fishing

#### Seine nets in combination with electric light

The most common method for fishing of swimming pueruli involves the use of seine nets, typically 100 to 150 m in length with a depth of 4 to 6 m, and a mesh size of 5 mm. The nets are set from boats in a V-shaped deployment with an opening of around 25 m. The opening faces the direction from which pueruli are expected to swim (Figure 1). The direction of swimming has been determined by trial and error, and is typically in a southerly direction against a north-flowing current which eddies from

the predominant southern flow of the Vietnam coastal current. Exceptions to this occur in some locations, and deployment of the seine is thus specific to each location. Common factors correlating with the abundance and catch of pueruli appear to be geography that facilitates a narrowing of the sea within a bay or between mainland and islands, and turbid waters as influenced by river flows in the area.

The boat used in the setting of the net is equipped with strong fluorescent lights with an intensity of 1,000 to 2,000 W. The boat is positioned at the apex of the V-net setting, with lights directed along the set net towards the opening, on the premise that the swimming pueruli are attracted towards the light. This premise is supported by catch rates that are much higher during the dark phases of the moon.

The seine net is usually set at about 8pm, and the first retrieval is made at around 12pm to 1am. At this time, the net is pulled up into the boat to retrieve the lobster pueruli which become caught in the mesh. Shortly afterwards, the net is set again and at around 4am it is pulled in for the second and last time. The nets are not set during daylight hours as catches then are very low, in accordance with the nocturnal swimming activity of the puerulus stage. The collected lobster seeds are consistent in appearance with a transparent body, carapace length of 7 to 8 mm and a weight of 0.25 to 0.35 g.

As per the seed census information presented in Chapter 2.2, the great bulk of lobster seed in excess of 95% are captured as pueruli using this method. Smaller numbers of juvenile lobsters are caught using the methods described below.

#### Traps made from netting material

A net trap consists of a bundle of netting material made by tying several lengths of fine 5 mm mesh size

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net into a rosette with a diameter of approximately 40 cm.

These traps are submerged in depths of 4 to 5 m around December every year.

The fishers retrieve the net traps at intervals of three to five days, usually in the morning, removing the lobster juveniles by shaking the trap into a scoop net. Lobster seed caught with this trap type are typically pigmented juveniles that have moved past the puerulus stage and settled to a benthic existence. They have a carapace length of around 7.5 to 10 mm, and a weight of 0.3 to 1.0 g.

The season for this seed fishing method extends from December through to the end of June, after which the traps are collected and stored ashore in a cool place for next season.

### Traps made of perforated coral or timber

These traps are made from coral rocks and timber poles, into which holes are drilled to create habitat for juvenile lobsters. There is considerable variation in specifications, but typically the coral rock has a weight of between 2 and 5 kg and a diameter of 25 cm. Holes are drilled into the rock at 10 to 15 cm intervals, each hole is 5 to 10 cm in depth with a diameter of 1.0 to 2.5 cm. Timber pole traps are

created in an equivalent manner. The poles are usually 2 to 3 m in length with a diameter of 10 to 15 cm.

The coral rocks are placed on the sea floor and the timber poles are embedded vertically into the sediment in 3 to 5 m of water, as per the netting traps described above. Juvenile lobsters are retrieved by diving and manually removing them from the holes. In some instances, these traps are suspended from a fixed floating raft or from a long-line supported between floating tripod frames. The tripods facilitate use of electric lights which enhance catch rates. This method catches settled juveniles of the same size as the net traps.

### Diving and catching

This method is based on retrieval of juvenile lobsters from natural habitat, including coral and rocky reefs along the coastline. It typically results in the catching of somewhat larger juveniles compared with the methods described above. These juveniles normally have a carapace length of 12 to 15 mm and a weight of 7 to 9 g. The number of juveniles collected using this method is very limited, with approximately 100 to 150 animals caught by a crew of five people in a 10 day trip during the main seasonal months.

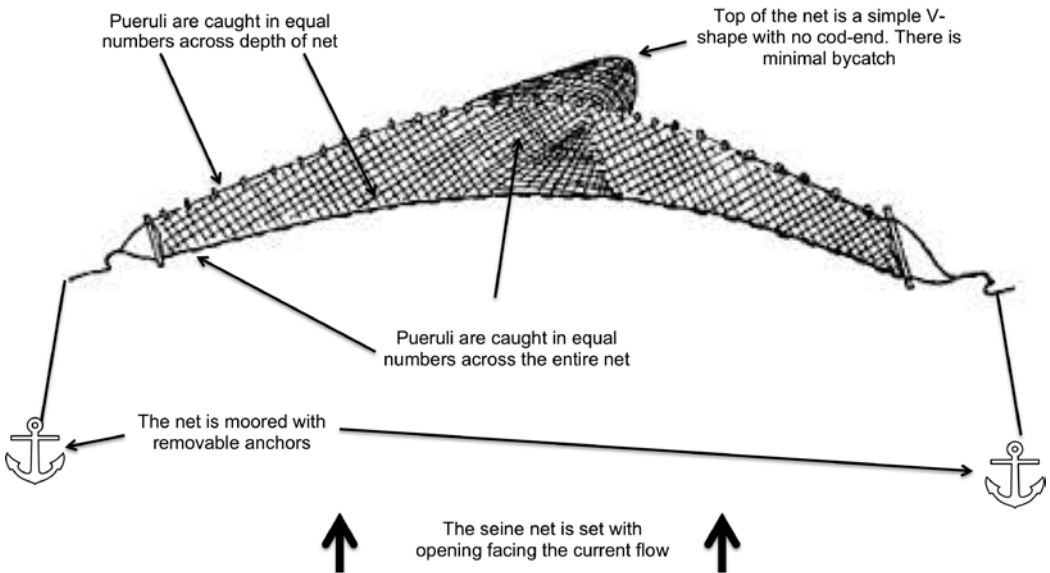


Figure 1. Illustration of seine net as used for capture of lobster pueruli in Vietnam



## Lobster seed handling and storage

Pueruli fished by seine net are immediately placed in plastic bottles with a capacity of 4 L. Approximately 100 to 150 lobster seeds are held in each bottle, which is aerated by a battery-operated aerator. Typically the time spent in these bottles is between 5 and 12 hours, after which the pueruli are purchased by the lobster seed dealer and removed for storage or packed for transportation.

The juveniles captured with the trap methods and diving are also normally stored in plastic bottles or small containers, often without aeration, for brief periods until sold to dealers.

Dealers are motivated to hold lobster seed for the minimum time possible to minimise mortality. The period between purchase from the fishers and sale to the farmer is normally one to two days. Consequently, most dealers have some form of holding tank system, usually at their home. In most instances, these systems are primitive with little or no biological filtration, minimal water replacement and only basic aeration. Nevertheless, the survival of pueruli and juveniles in these holding tanks appears to be very high, and thus there has been little incentive for the dealers to provide more sophisticated systems.

Once a sale of seed to a farmer has been secured, usually through mobile phone communication, the lobsters are packed into small Styrofoam boxes for transport. The environment for the holding and packing of lobsters should be well away from direct sunlight. First, the seed lobsters should be separated from any other organic materials and waste, and seed should be of an equivalent size for packing. The lobster seed are placed into a plastic bag which is filled to one third of its volume with clean seawater, and the remaining two thirds with oxygen. Some pieces of fine-mesh net, which have been cleaned and soaked in sea-water for a few days, should be placed in the bag for the lobsters to cling to. The bag is then tied tightly and placed in the Styrofoam box. If ice is to be used, it is made with seawater in a plastic drink bottle, filled 90% then frozen. The frozen bottle is placed on top of the plastic bag in the box. The box is then sealed tightly, ready for transport.

In some instances, oxygen is not used, and in this case an aeration tube is supplied into the bag, connected to a portable, battery operated aerator.

Seed are normally transported by motorbike to the farmer.

Evidence from recent years suggests the mortality of newly purchased seed is consistently greater than 30% within the first several weeks after purchase. This may be attributed to latent physiological stress from the environment provided during holding and transportation. Consequently, there has been a shift to keeping lobster seed in sea cages, rather than tanks, until the day of shipment. Although this adds considerable cost, it is offset by improved condition of the seed, as evidenced by better survival in subsequent weeks.

Common industry practice is for *P. homarus* lobsters to be kept unfed for the day before transportation, while *P. ornatus* lobsters are fed prior to transportation. First stage juvenile lobsters are usually fed on *Acetes* shrimp, small/chopped *Penaeid* shrimp or finely chopped trash fish.

## Conclusions and recommendations

The fishing of lobster seed in Vietnam is performed using four techniques: seine nets, net traps, coral/timber traps and diving. The seine net method captures swimming pueruli and accounts for more than 95% of seed captured. Seed are held by the fishers in plastic bottles of up to 4 L.

Lobster seed are purchased from the fishers within a few hours of capture, and then held in basic tank systems prior to being transported to farmers. Seed are transported in bags of seawater with oxygen or aeration, held in small Styrofoam boxes.

It is evident that mortality of lobster seed is low during the first few days after capture, but more than 30% die in the subsequent several weeks. To counter this, there is an increasing trend of holding seed in sea cages where the environment is more stable and conducive to better condition of the lobsters. Further research into lobster seed condition under various holding conditions is warranted to determine the optimal procedure.



**Figure 2.** Photos of lobster seed capture, handling and transport in Vietnam as described above (continued)



**Figure 2 (cont'd).** Photos of lobster seed capture, handling and transport in Vietnam as described above



## 2.5 Lobster seed fishing, handling and transport in Indonesia

Samsul Bahrawi<sup>1</sup>, Bayu Priyambodo<sup>1</sup> and Clive Jones<sup>2</sup>

### Introduction

The capture of lobster seed for the purposes of aquaculture has developed in Indonesia since the early 2000s, particularly since 2004 after the tsunami. The most well-developed area in Indonesia for lobster seed fishing is in the south-east of Lombok, particularly the villages of Teluk Awang, Kelongkong, Teluk Bumbang and Teluk Gerupuk where seed abundance is highest. These villages are characterised by fishing as the main enterprise, but are quite impoverished. The people, although poor, are innovative and have developed a wide variety of methods and equipment to catch the lobster seed.

This paper describes the equipment and procedures used by lobster seed fishers in Lombok for the capture, handling and transportation of the seed.

### Lobster seed fishing

In general, the fishers manufacture their equipment themselves, using bamboo to make rectangular frames that are then equipped with Styrofoam floats. These frames are then positioned at a depth of 5 to 20 m and typically located 100 to 500 m directly out from the beach adjacent to the village. From the frames, habitat traps are suspended, such that they provide a refuge for swimming pueruli. Each morning, the traps are retrieved from the water and lobster pueruli found hiding in the habitat are removed.

Typical frame size ranges from  $2.5 \times 2.5$  m to  $12 \times 12$  m, with around 20 to 30 trap lines suspended from each frame. The habitat material used for the

trap was initially (2005 to 2010) rice bags that had been cut into strips and bundled to create a rosette that contained multiple edges and crevices (Figure 1). These rice bag bundles are tied to a rope line at 1 m intervals, such that each line may have five to 20 bundles per line, depending on the depth. Thus, a typical frame may have 200 to 300 traps attached. The trap lines were typically set so that the terminal trap was 1 m above the sea bottom.

Since 2010, fishers have increasingly used recycled cement bag material to fashion habitat traps. Both rice bags and cement bags are very inexpensive, a necessary factor for the fishers involved, but the cement bags appear to support a better catch rate. In addition to a change of material, cement bags have been used to create a different style of trap. The bag, which consists of dual layers of plastic and paper, is folded concertina style and then tied across the middle to create a 'bow tie' like unit with multiple crevices. In this respect, the traps closely resemble the crevice collectors used in Australia and New Zealand for lobster stock assessment research (Booth and Tarring, 1986). The bow ties are attached to a rectangular piece of netting held taught by a timber frame, creating a wall of traps (Figure 2), that is then suspended from the floating frames.

### Handling

The fishers usually check the traps every day, or for some who have other jobs, every two to three days, typically in the morning between 7 and 10am. Pueruli retrieved are placed into a plastic bucket or bowl with seawater, sometimes with seaweed or netting material to provide shade and a substrate to cling to. Puerulus are aggregated in these containers until all traps have been checked. They are then returned to shore for

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**Figure 1.** Photos of typical rice bag bundle traps used for capture of lobster pueruli in Lombok



**Figure 2.** Photo of cement bag bow tie style habitat traps as used for capture of lobster pueruli in Lombok

selling, or in some cases transferred to a nursery cage if the fisher also farms lobster.

## Transportation

Prior to 2010, lobster seed were usually mixed with wet sand and then placed in a cardboard or Styrofoam box for transport. This dry method proved to be a poor approach that resulted in substantial mortality. In recent years, the typical practice has been to place the seed in a plastic drinking bottle or plastic bag that is then aerated with a battery-powered aquarium aerator, or into which oxygen gas is placed (Figure 3).



**Figure 3.** Photo of plastic bottle with battery aerator used for transport of lobster seed in Lombok

Transport to local grow-out farms in Lombok is typically very simple as the time required is relatively small. Increasing sales of lobster seed to dealers, who then export them to other countries, has seen the development of more sophisticated transport packing and handling methods, involving aeration or the use of compressed oxygen.

## Conclusions and recommendations

The catching methods for puerulus in Lombok vary and continue to develop. Most lobster seed are caught using habitat traps that are made from rice bag or cement bag material fashioned into traps that provide multiple crevices. Lights are increasingly used (as in Vietnam) to attract the swimming pueruli to the trap frames. Catch of lobster seed appears to be greatest in the traps deployed close to the sea floor.

It is considered better to transport puerulus rather than small juveniles, as the pueruli appear to be more robust. Portable aeration is recommended when transporting the seed and dry transportation (in sand) is no longer practiced.

There is increasing competition among fishers, resulting in the deployment of frames further away from the village towards to opening of the bay, where seed are likely to be swimming from.

Further research is needed into the effect of trap type and depth on the catch rate of puerulus collectors to improve catch efficiency. Research is also required to improve transport for long distances to maximise survival upon arrival.

## References

- Booth J.D. and Tarring S.C. 1986. Settlement of the red rock lobster, *Jasus edwardsii*, near Gisborne, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 20: 291–297.

### **3. Lobster Nursery Culture**

# 3.1 Tropical spiny lobster feed development: 2009–2013

Simon J. Irvin<sup>1</sup> and Scott Shanks<sup>2</sup>

## Introduction

The development of pellet feeds is a priority for the long-term sustainability and advancement of the spiny lobster (*Panulirus ornatus* and *Panulirus homarus*) aquaculture industry. This paper outlines research performed over several years in the testing and development of moist and dry pellet feeds for juvenile (<8 g) spiny lobsters. A goal of the project was to promote pellet feed use through establishing demonstration farms in Indonesia where formulated feeds were the sole source of nutrition. In a previous ACIAR project (FIS/2001/058) (Williams 2009) formulated feeds were developed which promoted growth and survival rates comparable to those achieved with fresh feed items and trash fish. Although feed development with sub-adult lobsters progressed rapidly, feed development with juvenile lobsters (<5 g) posed more of a challenge, with routine incidences of high mortality within experiments coupled with a requirement for fresh ingredients and high moisture content. Nevertheless, a moist formulated feed was developed that promoted high survival and growth of lobsters, and was superior to feeding a mixed diet of green-lipped mussel and fish (whiting) flesh. At the conclusion of the project, a commercial feed company specialising in extruded shrimp feed had produced a feed for spiny lobster grow-out. Preliminary studies suggested this feed may be suitable for production of juvenile and sub-adult lobster. Assessment of this feed in replicated trials and on

demonstration farms was the starting point for feed development work in the project research reported here.

Throughout Asian-Pacific aquaculture, trash fish (low value fishery product) is still the major source of nutrition for large marine crustaceans. This feeding practice typically originates in the infancy of an industry and becomes entrenched as the industry is established. The development of spiny lobster (*Panulirus spp.*) farming in Vietnam and more recently in Indonesia are prime examples of this reliance on trash fish (Figure 1). While trash fish is effective and economical in establishing an aquaculture industry, it is unsustainable. The nutritional profile of trash fish is variable and suboptimal. Its use as the feed source is likely to result in poor food conversion ratios and negative environmental impacts. High seasonal variability in the availability of trash fish reduces the ability to effectively vary feed rates and frequency. These are important factors in optimising growth and minimising waste. The progression from trash fish to dry feeds is a complex process, starting with the incorporation of trash fish with dry ingredients to produce a moist feed, and ultimately the total removal of fresh items to produce a dry feed. Dry feeds have many advantages, such as the ease and cost effectiveness of storage and conversion to marketable flesh, flexibility with feeding strategies and critically, better environmental sustainability.

In this project we focused on feed development with juvenile spiny lobster via the assessment of dry commercial feed and refinement of lab-produced moist formulated feeds. The culmination of this project was the development and testing of a practical farm feed using locally available ingredients and technology at the village level in Indonesia.

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**Figure 1.** Photo of typical trash fish used for lobster farming feed

## Methods

A total of 11 research trials and experiments were performed, referred to below as Experiments 1 through 11. Due to various constraints affecting the first four, they are summarised very briefly. The subsequent seven experiments are presented in full.

### Experimental animals, systems and duration

For all experiments, recently settled juvenile lobsters of either *P. ornatus* or *P. homarus* (0.5–8 g) were sourced from Awang Village, Lombok, Indonesia. Experimental tanks and cages were provided with individual air-stones and supplied with ambient ( $25 \pm 4.0^\circ\text{C}$ ) flow-through ( $60 \text{ Lh}^{-1}$ ) seawater (33–35 ‰) and sufficient mesh hides for all lobsters. Unless otherwise stated, the growth and survival data is reported for a trial duration of 42 days.

### Diet manufacture

The diets were made at the CSIRO Marine Research Laboratory at Bribie Island, Australia or at the Marine Aquaculture Development Centre (MADC), Lombok under the supervision of ACIAR staff (Figure 2).

### Moist feeds

Fresh ingredients, such as mussel, fish flesh and squid were placed at  $-20^\circ\text{C}$  until semi-frozen then extruded through a 3 mm die plate of a semi-commercial meat grinder to form a homogenous mince. The dry ingredients were finely ground

(<  $710 \mu\text{m}$ ) using a mortar and pestle for small constituents or by hammer mill (Mikro Pulverizer, Metals Disintegration Coy, Summit, NJ, USA) for bulk ingredients. The fresh ingredients and Pearl E™ binder were thoroughly mixed together using a domestic electric hand mixer before the oil and remaining dry ingredients were added, followed by a further 10 minutes of mixing to form a dough of approximately 40–50% moisture content. The dough was extruded through a 3 mm die plate of the meat grinder to form spaghetti-like strands. The strands were placed in an airtight bag and set overnight in a refrigerator at  $4^\circ\text{C}$ . The strands were stored at  $-20^\circ\text{C}$  until required for feeding.



**Figure 2.** Photo of pellet feed production at MADC, Lombok

## Experiment 1: Commercial diet evaluation—three lobster sizes

The first experiment compared the growth and survival response of juvenile lobsters fed either a commercial lobster feed (Lucky Star, Taiwan Hung Kuo Industrial Co., Ltd) or trash fish. In Lombok, Indonesia, trash fish consists primarily of a single species of sardine captured by seine net in the vicinity of the lobster farming areas. Three size classes of lobster were assessed: 0.5 g, 4 g and 8 g. The objective was to determine the size at which pellet feed promoted superior growth and survival performance over lobsters fed trash fish. At every examined size class, the growth of lobsters fed trash fish was superior to that of lobsters fed the commercial pellet diet. However, an inverse survival relationship was observed, with superior performance achieved by lobsters fed the commercial pellet.

## Experiment 2: Commercial diet evaluation—mixed diet

The second experiment compared the growth and survival response of juvenile lobsters fed either a commercial lobster feed (Lucky Star, Taiwan Hung Kuo Industrial Co., Ltd), trash fish or a 1:1 (commercial pellet: trash fish) mixed diet. The hypothesis was that lobsters fed a combined diet 1:1 would achieve superior growth and survival over lobsters fed a diet consisting of only the commercial diet or trash fish. The hypothesis proved accurate. Lobsters fed the mixed diet exhibited superior growth and survival performance over lobsters fed only the commercial diet or only trash fish. As in the first experiment, the growth of lobsters fed trash fish was superior to that of lobsters fed the commercial pellet diet and an inverse relationship was observed in relation to lobster survival.

## Experiment 3: Mixed diet evaluation—demonstration farm

At the demonstration farm at Awang Bay, lobsters were fed a mixed diet (1:1) of Lucky star and trash fish. Over a six month period it was reported by the farmer (Pak Pamit) that the lobster consumed little or none of the commercial pellet. The use of pellets in any form is a positive for the industry, however without rapid success, the uptake by the industry is

likely to be nil, particularly due to the high availability and low comparative cost of the trash fish diet.

## Experiment 4: Commercial diet and ACIAR moist diet evaluation

The fourth experiment compared the growth and survival response of juvenile lobster (*P. homarus* and *P. ornatus*) fed either a commercial lobster feed (Lucky Star) or a moist pellet (ACIAR basal, Table 1). The hypothesis was that lobsters fed the moist pellet would achieve superior growth and survival over lobsters fed the commercial diet. The hypothesis proved accurate in both species. Lobsters fed the moist pellet exhibited superior growth and survival performance over lobsters fed the commercial diet. The improved growth and survival performance was in part hypothesised to be due to increased feed intake of the moist pellet due to the increased palatability and attractiveness provided by the presence of fresh ingredients and high moisture content. *P. homarus* exhibited significantly higher growth and survival rates compared with *P. ornatus*.

These results suggest that fresh ingredients, and/or moisture content, are important components of feeds for juvenile lobsters, and that optimal dietary requirement may vary between lobster species. As protein is the major nutrient and incurs the greatest cost in lobster feed, an inter-species protein requirement study was undertaken.

**Table 1.** Diet formulations for experiment 4

	ACIAR
Fishmeal	40.00
Krillmeal	10.00
Wheat flour	5.00
Fish (fresh)	17.20
Mussel (fresh)	19.80
Squid (fresh)	1.00
Fish oil	2.00
Astaxanthin	0.80
Cholesterol	0.30
Lecithin	1.25
Mineral premix	0.50
Vitamin premix	0.80
Stay C	0.30
Binder	1.00
Total	100.00
DM (%)	65.9
CP (%)	40.6
Lipid (%)	8.1

## Experiment 5: Evaluation of the growth and survival of two spiny lobster species fed formulated feeds containing varying levels of protein

### Introduction

Spiny lobsters are opportunistic carnivores, typically consuming high protein invertebrates, such as molluscs, crustaceans and polychaetes (Williams 2007). A study by Smith et al. (2005) confirmed that dry feeds formulated for juvenile spiny lobster (*P. ornatus*) should contain high dietary protein, >60%. One of the challenges of formulating feeds for very small juvenile lobsters is to balance the requirement for high protein with the hypothesised necessity for fresh ingredients and/or high moisture inclusion. As the level of fresh ingredient and moisture increases, the level of protein on an as-used basis decreases. This is important to consider, as although fresh ingredients and high moisture may increase feed intake, total meal size (dry matter basis) already constrained by the presence of a small foregut may be restricted. In this experiment, response to dietary protein was assessed by comparing the growth and survival performance of spiny lobsters (*P. homarus* and *P. ornatus*) fed a moist reference diet or one of three dry feeds formulated to incrementally vary in protein from 33 to 54%.

### Methods

#### *Feed and animal preparation*

The four experimental feeds were produced by Indonesian University students and MADC staff under the supervision of ACIAR staff at MADC, Lombok (Figure 2.) The feeds were formulated to incrementally vary in protein from 33 to 54% and standard 10% fishery ingredient inclusion. The reference diet contained a protein level of 40% and 38% fishery ingredient inclusion (Table 2). At Awang Bay, 1,500 small juvenile (~1 g) spiny lobsters were transported from a nursery cage to the experimental system located at the MADC's research station at Sekotong. Prior to initiation of the experiment, 40 lobsters were weighed to define the mean  $\pm$  SD weight. Ten lobsters were then allocated to each cage based on all allocated individuals being within the mean  $1.01 \text{ g} \pm 0.23 \text{ SD}$  (Figure 3). Lobsters were

weighed to minimum of 0.01 g accuracy. Forty cages were used in the experiment, with each treatment replicated five times (Figure 4). The duration of the trial was 42 days. The experimental system was maintained by >100% daily water exchange with the intent of maintaining optimal water production conditions, monitored daily for temperature. The lobsters were fed to satiety twice daily, seven days a week, for the duration of the experiment. The lobsters' survival, final weights and weight gains were analysed as single ANOVA (Table 3).



**Figure 3.** Photo of small spiny lobsters housed in experimental unit



**Figure 4.** Photo of replicate cages in raceway system



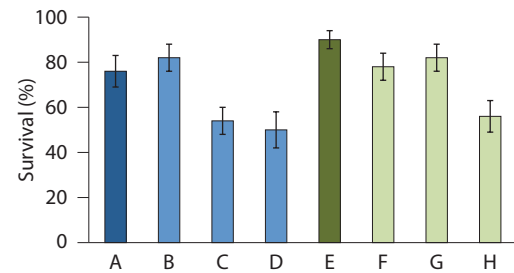
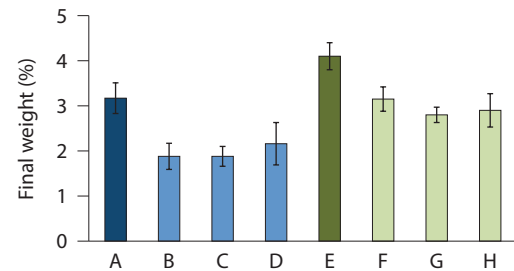
**Table 2.** Diet formulations

	A/E	B/F	C/G	D/H
Fishmeal	40.00	60.00	44.50	30.00
Krillmeal		10.00	10.00	10.00
Wheat flour	7.50	10.00	10.00	10.00
Casein	7.50	0.00	0.00	0.00
Fish (fresh)	17.20	10.00	10.00	10.00
Mussel (fresh)	19.80	0.00	0.00	0.00
Squid (fresh)	1.00	0.00	0.00	0.00
Fish oil	2.00	0.00	2.00	3.00
Astaxanthin	0.80	0.80	0.80	0.80
Cholesterol	0.30	0.30	0.30	0.30
Lecithin	1.25	1.25	1.25	1.25
Mineral premix	0.50	0.50	0.50	0.50
Vitamin premix	0.80	0.80	0.80	0.80
Stay C	0.30	0.30	0.30	0.30
Binder	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00
DM (%)	65.9	84.3	84.3	84.3
CP (%)	40.6	53.9	43.40	33.40
Lipid (%)	8.1	8.9	9.5	9.20

## Results and discussion

The average survival, final weight and weight gain of lobsters from each treatment is presented in Figures 5 and 6. The average weight gain and survival rate of Mutiara (*Panulirus ornatus*) lobster was 128% and 66% and for Pasir (*Panulirus homarus*) lobster, 214% and 77%. In both species, lobsters fed the basal diet (A) had significantly higher weight gain and survival rates than those fed the low-, medium- and high- protein diet. There was no significant difference in the weight gain or survival of lobsters fed the protein test diets in either species. As in the previous study, with all feeds it was observed that Pasir lobster have significantly higher growth and survival than Mutiara lobster. The two key differences between

the reference diet and protein diets were the fresh ingredient level and moisture content. In the reference feed, these characteristics are interrelated, as it is the inclusion of fresh ingredients which dictates the moisture content. It is unclear whether it is fresh ingredient, moisture content or a combination of both which promotes a positive growth response in small lobsters. At this small size (1 g) it appears that the inclusion level of fresh ingredient and high moisture inclusion outweighs the benefit of high protein inclusion. Future studies should assess the essentiality of fresh ingredients and moisture content, and assess the benefits of bioactive ingredients and protein concentrates in moist feeds.

**Figure 5.** Experiment 5: Survival of *P. ornatus* and *P. homarus* lobster fed different diets**Figure 6.** Experiment 5: Growth of *P. ornatus* and *P. homarus* lobster fed different diets**Table 3.** Performance attributes of lobsters fed the experimental diets

Lobster	A	B	C	D	E	F	G	H
	<i>P. ornatus</i>				<i>P. homarus</i>			
Initial weight (g)	1.00	0.98	0.99	1.00	1.03	1.03	1.03	1.03
Final weight (g)	3.17	1.88	1.88	2.16	4.10	3.15	2.80	2.90
Weight gain (%)	217 <sup>a</sup>	91 <sup>b</sup>	89 <sup>b</sup>	116 <sup>b</sup>	298 <sup>a</sup>	205 <sup>b</sup>	172 <sup>b</sup>	181 <sup>b</sup>
Final survival (%)	76 <sup>a</sup>	82 <sup>a</sup>	54 <sup>b</sup>	50 <sup>b</sup>	90 <sup>a</sup>	78 <sup>b</sup>	82 <sup>b</sup>	56 <sup>b</sup>

a,b,c: column mean without a common letter differ ( $P < 0.05$ )

## Experiment 6: Evaluation of the growth and survival of spiny lobsters fed formulated feeds containing potentially bioactive ingredients

### Introduction

Tropical spiny lobsters have a relatively long larval duration exceeding four months. At the completion of the larval phase, the swimming, pigmented post-juvenile settles in shallow, near-shore habitats. These habitats typically consist of seagrass and algae. The microflora and microfauna populations living in this habitat are diverse, consisting of algae, bacteria, fungi and invertebrates. Similar communities of post-juvenile populate near-shore on artificial structures, such as fish cages and pylons. The juvenile utilise these habitats for shelter and nutrition (Williams 2007). It is hypothesised that the addition of these types of flora and fauna to practical lobster feeds may improve lobster growth and survival. Ingredients such as krill and Novacq™ have been shown to promote high growth rates when added at 10% inclusion level in practical diets fed to shrimp. It is hypothesised that a similar result may be achieved when known or potential bioactive ingredients are included in practical diets and fed to very small juvenile lobsters. In this experiment, we evaluated the bioactivity of a range of ingredients (Table 4) by comparing the growth and survival performance of spiny lobster fed a single ingredient substituted basal diet.

### Methods

#### Feed and animal preparation

The seven experimental feeds were produced by Indonesian University students and MADC staff under the supervision of ACIAR staff at MADC, Lombok (Figure 2). The feeds were formulated to contain a 40% crude protein and 38% fishery ingredient inclusion (Table 5).

The commercial control (fresh fish—label H) was sourced locally in Lombok. From Awang Bay, 1,500 small juvenile (~1 g) spiny lobsters were transported from a nursery cage to the experimental system located at the MADC's research station at Sekotong. Prior to initiation of the experiment, 40 lobsters were weighed to define the mean  $\pm$  SD weight. Twelve lobsters were then allocated to each cage based on all allocated individuals being within the mean  $1.37 \text{ g} \pm 0.4 \text{ SD}$ . Lobsters were weighed to a minimum of 0.01 g accuracy. Forty cages were used in the experiment, with each treatment replicated five times. The duration of the trial was 70 days. The experimental system was maintained by >100% daily water exchange with the intent of maintaining optimal water production conditions, monitored daily for temperature. For the duration of the experiment, the lobsters were fed to satiety twice daily, seven days a week. The lobsters' survival, final weights and weight gains were analysed as single ANOVA (Table 6).

### Results and discussion

The average survival and weight gain of lobsters from each treatment is presented in Figures 7 and 8.

**Table 4.** Ingredients selected for testing

Ingredient	Description
Krill meal	A high protein and high value ingredient produced from small temperate crustaceans which feed on phytoplankton. It is commonly used as a feed additive at low inclusion levels in crustacean feeds.
Liquid algae	Mixed micro-algal species in liquid form, sourced in Indonesia.
Spirulina	Cyanobacteria, comprising two species: <i>Arthrospira platensis</i> and <i>A. maxima</i> , commonly used as a feed supplement in the aquaculture industry.
Novacq™	Shrimp growth factor developed by CSIRO.
Algamac™	New AlgaMac-ARA (arachidonic acid) is a spray-dried aquaculture nutrition additive. It is produced from cells of <i>Mortierella alpina</i> algae, source of phospholipid and Arachidonic acid.
Mixed ingredient	20% inclusion of the above ingredients.

The average final weight and survival rate of lobster was 3.6 g and 57% respectively. Lobsters fed the commercial equivalent of trash fish (H) had significantly lower survival than the average for lobsters fed formulated feeds; 27% and 61% respectively. Lobsters fed the basal diet (A), krill (B) liquid algae (C) and Novacq™ (D) diets had superior survival (>65%) over lobsters fed the mixed (E) spirulina (F) and Algamac™ (G) diets (<55%).

Lobsters fed the basal diet (A), liquid algae (C), spirulina (F) and fresh fishery control diet (H) had significantly higher growth rates than lobsters fed all other diets. The largest weight gain was achieved with lobsters fed the basal diet (A) and fresh fishery control diet (H); 252% and 285%, respectively. None of the ingredients tested produced a growth response typical of known crustacean bioactives. In fact, in all treatments a reduced growth performance was

**Table 5.** Diet formulations

	A	B	C	D	E	F	G
Fishmeal	40.75	40.75	40.75	40.75	40.75	40.75	40.75
Krillmeal		10.00			2.00		
Liquid algae			10.00		2.00		
Novacq™				10.00	2.00		
Spirulina					2.00	10.00	
Algamac™					2.00		10.00
Wheat flour	7.50	4.00	4.00			2.50	2.50
Casein	7.50	1.00	1.00	5.00	5.00	2.50	2.50
Fish (fresh)	17.20	17.20	17.20	17.20	17.20	17.20	17.20
Mussel (fresh)	19.80	19.80	19.80	19.80	19.80	19.80	19.80
Squid (fresh)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fish oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Astaxanthin	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Cholesterol	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Lecithin	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Mineral premix	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Stay C	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Binder	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
DM (%)	65.00	65.00	65.00	65.00	65.00	65.00	65.00
CP (%)	40.50	40.50	40.50	40.50	40.50	40.50	40.50
Lipid (%)	9.00	9.00	9.00	9.00	9.00	9.00	9.00

**Table 6.** Performance attributes of Lobsters fed the experimental diets

	A	B	C	D	E	F	G	H
Initial weight (g)	1.34	1.39	1.37	1.37	1.42	1.35	1.33	1.38
Final weight (g)	4.57	3.82	4.37	2.57	2.28	4.08	2.30	5.25
Weight gain (%)	251	141	219	86	71	192	75	285
Final Survival (%)	65	68	73	68	56	50	51	27

a,b,c: column mean without a common letter differ (P<0.05)

observed compared to the basal diet, with the level of reduction ranging from negligible to highly significant. The addition of liquid algae (C) and spirulina (F) had the least effect, with a 13% and 23% reduction in final weight observed. The inclusion of krill resulted in a growth reduction of 44%. The presence of Algamac™, Novacq™ or ingredient blend resulted in a dramatic reduction in growth rate, between 60% and 70% lower than achieved by lobsters fed the basal diet.

The high performing basal diet supported the best combination of growth and survival. The trash fish diet supported similar growth rates to the basal diet but lobsters fed this diet had very low survival (27%). This suggests that the trash fish diet lacks a critical nutrient affecting survival. The high growth rates of lobsters fed the trash fish diet could be partly attributed to cannibalism and density effects. The best performing test ingredient was the liquid algae treatment, which promoted a slightly higher survival rate than the basal diet, but a lower growth rate.

The addition of krill had an adverse effect on lobster growth. This is a surprising repeat result as growth experiments with larger lobsters have shown krill and krill hydrolysate to be a growth promoter.

## Experiment 7: Evaluation of the growth and survival of spiny lobsters fed formulated feeds containing varying levels of astaxanthin

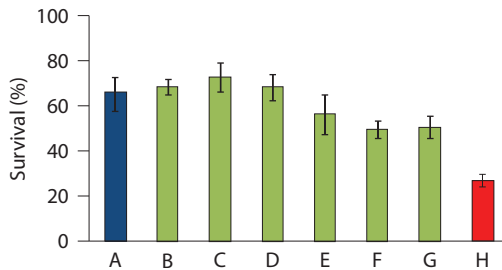
### Introduction

Astaxanthin is an expensive micronutrient known to be critical for lobster growth and health. Although astaxanthin requirement has not been evaluated for *P. homarus*, it has been assessed for the similar species *P. ornatus*. The study found that for juvenile lobsters (18 g) astaxanthin inclusion had no effect on growth or survival, and an inclusion of 50 mg/kg total carotenoid was recommended (Barclay et al. 2006). Preliminary studies suggested that with very small (<3 g) juvenile *P. homarus* lobsters, astaxanthin does have a significant effect on growth and survival. In this pilot study, we directly compared two feeds which only varied in carophyll pink (astaxanthin) level, low 100 mg/kg or high 800 mg/kg.

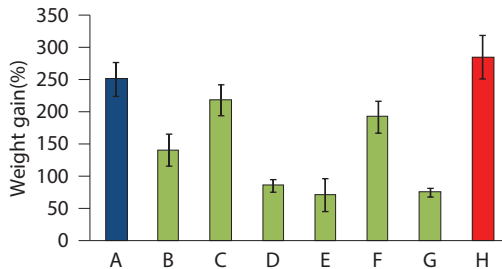
### Methods

#### Feed and animal preparation

The two experimental feeds were produced by CSIRO at the Aquaculture Feed Technology Laboratory on Bribie Island (Table 7). The feeds were formulated to contain 39% crude protein and two levels of carophyll pink, 100 mg/kg or 800 mg/kg. From Awang Bay, 1,500 small juvenile (~2 g) spiny lobsters were transported from a nursery cage to the experimental system located at the MADC's research station at Sekotong. Prior to the initiation of the experiment, 40 lobsters were weighed to define the mean  $\pm$  SD weight. Ten lobsters were then allocated to each cage based on all allocated individuals being within the mean  $2.30 \text{ g} \pm 0.76 \text{ SD}$ . Individual lobsters were weighed to a minimum of 0.01 g accuracy. Twenty cages were used in the experiment, with each treatment replicated five times. The duration of the trial was 42 days. The experimental system was maintained by >100% daily water exchange with the intent of maintaining optimal water production conditions, monitored daily for temperature. For the duration of the experiment, the lobsters were fed to satiety twice daily, seven days a week. The lobsters' survival, final weights and weight gains were analysed as single ANOVA (Table 8).



**Figure 7.** Experiment 6: Survival of *P. homarus* lobster fed different diets



**Figure 8.** Experiment 6: Growth of *P. homarus* lobster fed different diets

**Table 7.** Diet formulations

	A	B
Fishmeal	48.20	40.00
Soy concentrate	0.00	0.00
Casein	0.00	7.50
Wheat flour	7.50	7.50
Fish (fresh)	17.20	17.20
Mussel (fresh)	19.80	19.80
Squid (fresh)	1.00	1.00
Fish oil	2.00	2.00
Astaxanthin	0.10	0.80
Cholesterol	0.30	0.30
Lecithin	1.30	1.30
Mineral premix	0.50	0.50
Vitamin premix	0.90	0.90
Stay C	0.30	0.30
Binder	1.00	1.00
Total	100.00	100.00
DM (%)	65.00	65.00
CP (%)	39.70	39.70
Lipid (%)	8.80	8.80

**Table 8.** Performance attributes of Lobsters fed the experimental diets

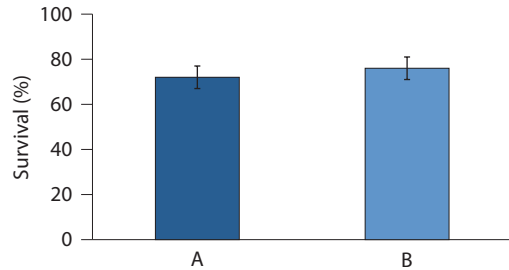
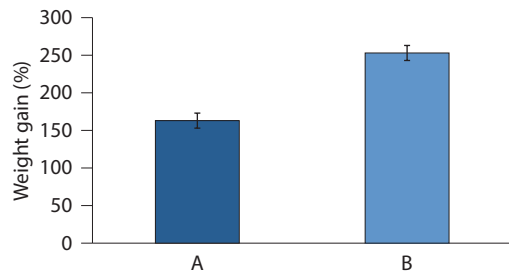
	A	B
Initial weight (g)	2.24	2.20
Final weight (g)	5.91	7.78
Weight gain (%)	163 <sup>a</sup>	253 <sup>b</sup>
Final Survival (%)	72 <sup>a</sup>	76 <sup>a</sup>

a,b,c: column mean without a common letter differ ( $P < 0.05$ )

## Results and discussion

The average weight gain and survival of lobsters from each treatment is presented in Figures 9 and 10. The average weight gain and survival of lobsters was 208% and 74% respectively. Lobsters fed the high astaxanthin feed (B) had significantly higher growth rates than lobsters fed the low astaxanthin diet (A). Survival was high, 72–76%, and not significantly different between treatments. A clear growth benefit was achieved with the addition of astaxanthin from 100 mg/kg to 800 mg/kg. Lobsters fed the high astaxanthin diet grew 55% faster than lobsters fed on the low astaxanthin diet. It is clear that very small *P. homarus* have a higher requirement for astaxanthin than juvenile *P. ornatus*. From these results, it is

recommended that feeds for juvenile lobsters contain > 800 mg/kg caropyhll pink and that a dose response evaluating the requirement of very small lobster *P. homarus* for astaxanthin should be an essential component of any future project.

**Figure 9.** Experiment 7: Survival of *P. homarus* lobster fed different diets**Figure 10.** Experiment 7: Growth of *P. homarus* lobster fed different diets

## Experiment 8: Evaluation of the growth and survival of spiny lobsters fed formulated feeds containing varying inclusions of fresh ingredients

### Introduction

Cage culture of tropical spiny lobster, *P. homarus* is a developing industry in Lombok, Indonesia. Wild harvested seed lobsters are fed solely on trash fish (fishery product) until reaching a market size of 150–250 g. The availability of trash fish varies seasonally, from highly abundant to none, and consists primarily of a single species of sardine. During the period of no availability, lobsters may be fed an alternative diet of

freshwater snails, vegetables or nothing. It is during such times that farmers become interested in using a pellet feed. However, when trash fish are abundant there is an opportunity to produce a basic solar-dried feed containing a mixture of minced trash fish and locally available shrimp feed. Little is understood about how essential fresh ingredients (such as fish) are in formulated feeds for survival and growth in juvenile spiny lobsters (<5 g). A study by Irvin and Williams (2009) reported that sub-adult lobsters (>600 g) had no requirement for fresh ingredients in formulated lobster feeds. However, results from preliminary studies suggest that juvenile lobsters do have a requirement for fresh ingredients. It is hypothesised that the presence of fresh ingredients in lobster feeds is beneficial for lobster survival and growth as it increases feed intake. This hypothesis is based on the theory that fresh ingredients contain chemo-attractants which promote a feeding response in crustaceans, and that these diets are texturally softer, which may suit the underdeveloped mouthparts of juvenile lobsters. However, the inclusion of fresh ingredients in feeds leads to an increase in complexity and cost with regard to pre and post storage and the production of the feed. In this study, we compare the growth and survival of juvenile spiny lobsters fed a series of moist feeds which vary only in fresh ingredient inclusion.

## Methods

### *Feed and animal preparation*

The four experimental feeds were produced by CSIRO at the Aquaculture Feed Technology Laboratory on Bribie Island. The feeds were formulated to contain 39% crude protein and four levels of fishery ingredient inclusion, incrementally ranging from 38 to 0% (Table 9).

At Awang Bay, 1,500 small juvenile (~2 g) spiny lobsters were transported from a nursery cage to the experimental system located at the MADC's research station at Sekotong. Prior to initiation of the experiment, 40 lobsters were weighed to define the mean  $\pm$  SD weight. Ten lobsters were then allocated to each cage based on all allocated individuals being within the mean  $2.30 \text{ g} \pm 0.76 \text{ SD}$ . Individual lobsters were weighed to a minimum of 0.01 g accuracy. Twenty cages were used in the experiment, with each treatment replicated five times. The duration of the trial was 42 days. The experimental system

was maintained by >100% daily water exchange with the intent of maintaining optimal water production conditions, monitored daily for temperature. For the duration of the experiment, the lobsters were fed to satiety twice daily, seven days a week. The lobsters' survival, final weights and weight gains were analysed as single ANOVA (Table 10).

**Table 9.** Diet formulations

	A	B	C	D
Fishmeal	48.20	51.10	53.70	54.50
Wheat flour	7.50	7.90	8.40	9.70
Fish (fresh)	17.20	12.20	6.50	0.00
Mussel (fresh)	19.80	14.00	7.40	0.00
Squid (fresh)	1.00	0.70	0.40	0.00
Fish oil	2.00	2.10	2.20	2.60
Astaxanthin	0.10	0.10	0.10	0.10
Cholesterol	0.30	0.30	0.30	0.40
Lecithin	1.30	1.30	1.40	1.60
Mineral premix	0.50	0.50	0.50	0.50
Vitamin premix	0.90	0.90	0.90	0.90
Stay C	0.30	0.30	0.30	0.40
Binder	1.00	1.00	1.10	1.30
Water	0.00	7.40	16.70	27.50
Total	100.00	100.00	100.00	100.00
DM (%)	65.00	65.00	65.00	65.00
CP (%)	39.70	39.90	39.80	38.40
Lipid (%)	8.80	8.80	8.80	9.00

**Table 10.** Performance attributes of Lobsters fed the experimental diets

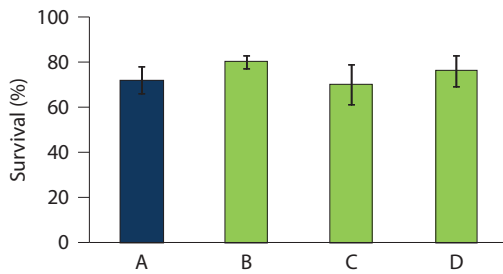
	A	B	C	D
Initial weight (g)	2.24	2.18	2.21	2.23
Final weight (g)	5.91 <sup>a</sup>	5.71 <sup>a</sup>	5.51 <sup>ab</sup>	4.36 <sup>b</sup>
Weight gain (%)	163 <sup>a</sup>	162 <sup>a</sup>	149 <sup>ab</sup>	97 <sup>b</sup>
Final Survival (%)	72	80	70	76

a,b,c: column mean without a common letter differ (P<0.05)

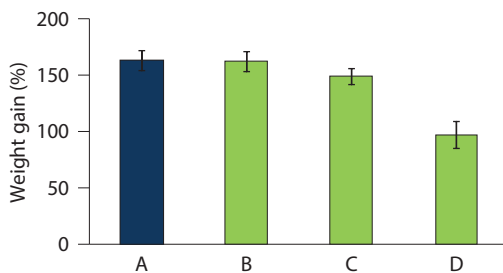
## Results and discussion

The average survival and weight gain of lobsters from each treatment is presented in Figures 11 and 12. The average weight gain and survival rate of lobster was 143% and 75% respectively. Survival was typical of lobsters of this starting size and not significantly different between treatments. There was no significant difference in the growth rate of lobsters

fed diets which had a fresh ingredient inclusion ranging from 38 to 14%. However, lobsters fed a diet containing no fresh ingredients exhibited growth rates significantly lower than all other treatments. This suggests that the inclusion of fresh ingredients does promote improved growth in juvenile spiny lobsters. This is hypothesised to be due to the fresh ingredients containing high levels of chemo-attractants which promote a feeding response in crustaceans, and that these diets are texturally softer which may suit the underdeveloped mouthparts of juvenile lobsters. From these results, it is recommended that feeds for juvenile lobsters contain 15 to 20% inclusion of fresh ingredients. In this study, water was added incrementally to each treatment so that each feed had the same dry matter content. What is equally important is to determine the optimal dry matter content of the feed. Feeds with a dry matter content of <85% have a short shelf life and require freezer storage or frequent production (every two days).



**Figure 11.** Experiment 8: Survival of *P. homarus* lobster fed different diets



**Figure 12.** Experiment 8: Growth of *P. homarus* lobster fed different diets

## Experiment 9: Evaluation of the growth and survival of spiny lobsters fed formulated feeds containing varying levels of moisture content

### Introduction

Feeds with a dry matter content of <85% have a short shelf life and they require either freezer storage or frequent production (every two days). Post-production storage issues can be resolved by oven or solar drying (>90% DM) the feed. However, it is hypothesised that the high moisture content (<85% DM) in lobster feeds is beneficial for lobster survival and growth by increasing feed intake. This is based on the theory that texturally softer feeds promote a feeding response in crustaceans and they may suit the underdeveloped mouthparts of juvenile lobsters. In this study, we compare the growth and survival of juvenile spiny lobsters fed a series of feeds which vary only in moisture content.

### Methods

#### *Feed and animal preparation*

The four experimental feeds were produced by CSIRO at the Aquaculture Feed Technology Laboratory on Bribie Island. The feeds were formulated to contain 39% crude protein and 38% fishery ingredient inclusion at four levels of feed dry matter, incrementally ranging from 65 to 90% (Table 11). From Awang Bay, 1,500 small juvenile (~2 g) spiny lobsters were transported from a nursery cage to the experimental system located at the MADC's research station at Sekotong. Prior to initiation of the experiment, 40 lobsters were weighed to define the mean  $\pm$  SD weight. Ten lobsters were then allocated to each cage based on all allocated individuals being within the mean  $2.30 \text{ g} \pm 0.76 \text{ SD}$ . Individual lobsters were weighed to minimum of 0.01 g accuracy. Twenty cages were used in the experiment, with each treatment replicated five times. The duration of the trial was 42 days. The experimental system was maintained by >100% daily water exchange with the intent of maintaining optimal water production conditions, monitored daily for temperature. For the duration of the experiment, the lobsters were fed to satiety twice daily, seven days a week. The lobsters' survival, final



weights and weight gains were analysed as single ANOVA (Table 12).

**Table 11.** Diet formulations

	A	B	C	D
Fishmeal	48.20	48.20	48.20	48.20
Wheat flour	7.50	7.50	7.50	7.50
Fish (fresh)	17.20	17.20	17.20	17.20
Mussel (fresh)	19.80	19.80	19.80	19.80
Squid (fresh)	1.00	1.00	1.00	1.00
Fish oil	2.00	2.00	2.00	2.00
Astaxanthin	0.10	0.10	0.10	0.10
Cholesterol	0.30	0.30	0.30	0.30
Lecithin	1.30	1.30	1.30	1.30
Mineral premix	0.50	0.50	0.50	0.50
Vitamin premix	0.90	0.90	0.90	0.90
Stay C	0.30	0.30	0.30	0.30
Binder	1.00	1.00	1.00	1.00
Oven time (hrs)	0.00	1.15	2.00	24.00
Total	100.00	100.00	100.00	100.00
DM (%)	65.00	74.00	82.00	90.00
CP (%)	39.70	39.90	39.80	38.40
Lipid (%)	8.80	8.80	8.80	9.00

**Table 12.** Performance attributes of Lobsters fed the experimental diets

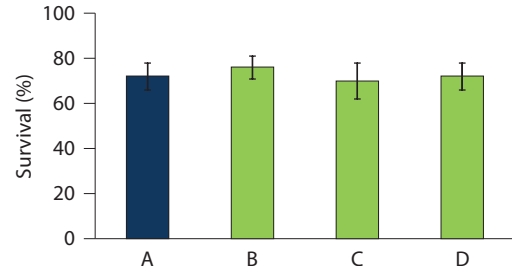
	A	B	C	D
Initial weight (g)	2.24	2.19	2.30	2.24
Final weight (g)	5.91	5.78	6.13	5.47
Weight gain (%)	163	164	166	144
Final Survival (%)	72	76	70	72

a,b,c: column mean without a common letter differ (P<0.05)

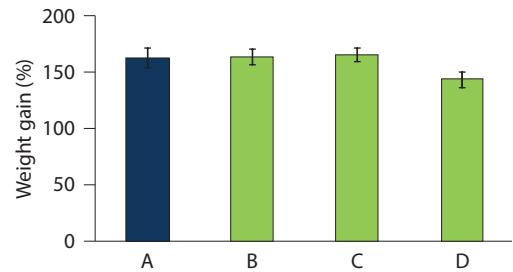
## Results and discussion

The average survival and weight gain of lobsters from each treatment is presented in Figures 13 and 14. The average weight gain and survival rate of lobster was 160% and 73% respectively. Survival was typical of lobsters of this starting size and not significantly different between treatments. There was no significant difference in the growth rate of lobsters fed diets which had a dry matter content ranging from 65 to 82%. However, lobsters fed a dry diet (<90% DM), exhibited growth rates significantly lower than all other treatments. This suggests that the presence of moisture in feeds does promote improved growth in juvenile spiny lobsters. This is

hypothesised to be due to moist feeds being texturally softer which may suit the underdeveloped mouthparts of juvenile lobsters and improve feed intake. From these results, it is recommended that feeds for juvenile lobsters contain >85% DM content. Feeds which contain a dry matter content of <85% have a short shelf life and they require freezer storage or frequent production (every two days).



**Figure 13.** Experiment 9: Survival of *P. homarus* lobster fed different diets.



**Figure 14.** Experiment 9: Growth of *P. homarus* lobster fed different diets.

## Experiment 10: Growth and survival of spiny lobsters fed a practical moist diet containing a known high quality fishmeal or local fishmeal of unknown quality

### Introduction

The development of a high-performing, pelleted lobster feed is a high priority for long-term sustainability of lobster farming in Indonesia. Fishmeal is the major protein source used in lobster feed, contributing up to 50% of the diet. It is well understood that feed can only be as good as its ingredients

(Glencross et al. 2007). The quality of the fishmeal will greatly impact the palatability and feed intake of the diet, and the growth and survival rate of the lobster. Fishmeal quality and protein level varies due to the species, origin, processing and storage. Feeds tested in previous lobster growth studies in this ACIAR project were reliant on the use of imported (high quality) ingredients, with the exception of fresh fishery products. In this experiment, fishmeal type was assessed by comparing the growth and survival performance of spiny lobster (*P. homarus*) fed a basal diet containing either local or imported fish meal.

## Methods

### Feed and animal preparation

The two experimental feeds were produced by Indonesian University students and MADC staff under the supervision of ACIAR at MADC, Lombok. The feeds were formulated to contain a crude protein of 44% and fishery ingredient inclusion of 39% (Table 13).

From Awang Bay, 1,500 juvenile (~1 g) spiny lobsters were transported from a nursery cage to the experimental system located at the MADC's research station at Sekotong. Prior to initiation of the experiment, 40 lobsters were weighed to define the mean  $\pm$  SD weight. Twelve lobsters were then allocated to each cage based on all allocated individuals being within the selected range, mean  $1.3 \pm 0.3$  SD weight. Lobsters were weighed to minimum of 0.01 g accuracy. Ten cages were used in the experiment, with each treatment replicated five times. The duration of the trial was 42 days. The experimental system was maintained by >100% daily water exchange with the intent of maintaining optimal water production conditions, monitored daily for temperature. For the duration of the experiment, the lobsters were fed to satiety twice daily, seven days a week. The lobsters' survival, final weights and weight gains were analysed as single ANOVA (Table 14).

## Results and discussion

The average survival, final weight and weight gain of lobsters from each treatment is presented in Figures 15 and 16. The final weight and survival of lobster was 2.68 g and 68% respectively. Lobsters fed the diet containing imported fishmeal had significantly higher weight gain and survival than those fed the diet containing the locally sourced fishmeal. This finding

supports the fact that feed ingredient types can vary in quality and are therefore likely to promote variable performance with regard to lobster growth and survival. It is clear that the development of effective formulated feeds for lobsters must be coupled with rigorous evaluation of local and imported ingredients.

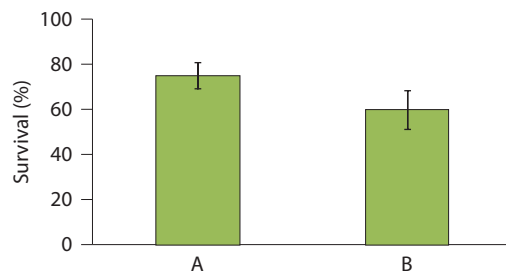
**Table 13.** Diet formulations

	A	B
Fishmeal (Peru)	40.0	0.00
Fishmeal (Indo)	0.00	40.0
Casein	7.50	7.50
Wheat flour	7.50	7.50
Fish (fresh)	17.20	17.20
Mussel (fresh)	19.80	19.80
Squid (fresh)	1.00	1.00
Fish oil	2.00	2.00
Astaxanthin	0.80	0.80
Cholesterol	0.30	0.30
Lecithin	1.30	1.30
Mineral premix	0.40	0.40
Vitamin premix	0.90	0.90
Stay C	0.30	0.30
Binder	1.00	1.00
Total	100.00	100.00
DM (%)	66.00	66.00
CP (%)	41.00	41.00
Lipid (%)	8.00	8.00

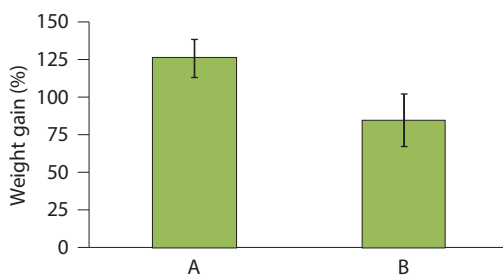
**Table 14.** Performance attributes of Lobsters fed the experimental diets

	A	B
Initial weight (g)	1.31	1.29
Final weight (g)	2.97 <sup>a</sup>	2.39 <sup>b</sup>
Weight gain (%)	126 <sup>a</sup>	85 <sup>b</sup>
Final Survival (%)	75	60

a,b: column mean without a common letter differ ( $P < 0.05$ )



**Figure 15.** Experiment 10: Survival of *P. homarus* lobster fed different diets



**Figure 16.** Experiment 10: Growth of *P. homarus* lobster fed different diets

## Experiment 11: Evaluation of practical farm feed using locally available ingredients and technology at the village level in Indonesia

### Introduction

An important objective of the project was to promote the use of pellet feeds by the lobster industry in Indonesia. Our first study involved co-feeding a commercial (Lucky Star, Taiwan Hung Kuo Industrial Co., Ltd) and trash fish diet. Experimental studies suggest that the feeding of a mixed diet would promote growth and survival superior to the feeding of trash fish alone. However, observations from farmers suggest that lobsters were not consuming pellets in the farm cage environment. The major difference between experimental cages and farm cages is the increased culture depth and water current in the farm environment. The reason for lobster not consuming pellets in farm cages could be partly explained by pellets rapidly losing attractiveness in the farm cage environment. These observations led to a series of studies refining a moist feed, and ultimately led to the development of a feed ready for on-farm testing.

### Methods

#### *Feed preparation*

The feed was produced by an Indonesian lobster farmer (Pak Werry) under the supervision of ACIAR staff in Lombok. As the quality of locally available ingredients is yet to be adequately assessed, a locally sourced high-quality shrimp feed was used as the base ingredient and major dry source of protein (Table 15).

**Table 15.** Diet formulations

	A
Shrimp mash	40.0
Fish (fresh)	17.20
Mussel (fresh)	19.80
Squid (fresh)	1.00
Fish oil	2.00
Mineral premix	0.40
Vitamin premix	0.90
Binder	1.00
Total	100.00
DM (%)	66.00
CP (%)	41.00
Lipid (%)	8.00

### Results and discussion

Observations from the farmer suggest that lobsters were not consuming pellets in the sea cage environment (Figure 17). However, the same batch of feed was readily consumed by lobsters stocked in land-based tanks. The major reported difference between land-based tanks and the sea cages was the increased culture depth and water current in the sea cage environment. In all environments, the pellets were found intact with high water stability after a 12 hour period. It is possible that lobsters in sea cages do not consume the pellet due to the pellets losing attractiveness. In the short term, the reason why the pellets are not being consumed should be evaluated. If it is due to a lack of attractiveness, then options which promote and prolong pellet attractiveness should be considered. Increasing the quantity of fresh ingredient and marine protein concentrates, and pre-dipping the pellet in squid mince are a few options which could be investigated. In the medium to long term, it is critical that the lobster feed base is replaced with ingredients of known origin and quality. This will require the assessment of a broad range of locally available ingredients and is more likely to involve a successful collaboration with a locally based feed company.

### Conclusions and recommendations

In this project, we focused on feed development with juvenile spiny lobster via the assessment of dry commercial feed and the refinement of moist formulated feeds. The culmination of this project has been the development and testing of a practical farm feed

using locally available ingredients and technology at the village level in Indonesia. The key opportunity for lobster farmers is to adopt the technology and produce and store a practical feed when trash fish is abundant, of high quality and low value.

Inclusion of astaxanthin (>0.75%) provided the largest growth benefit to small *P. homarus* lobster. The optimal dietary requirement is unknown and should be investigated. The developed practical farm



**Figure 17.** Photo of pellets produced on farm in Lombok Indonesia

feed requires refinement to gain acceptance by the lobster (and farmer). In the short term, reasons why pellets are not being consumed should be evaluated. If it is due to a lack of attractiveness to the lobster, then options which promote and prolong pellet attractiveness should be considered. Increasing the quantity of fresh ingredient and marine protein concentrates, and pre-dipping the pellet in squid mince are a few options which could be investigated. In the medium to long term, it is critical that the shrimp feed base is replaced with ingredients of known origin and quality. This will require the assessment of a broad range of locally available ingredients and collaboration with a locally based feed company.

## References

- Barclay M.C. Irvin S.J. Williams K.C. and Smith D.M. 2006. Comparison of diets for the tropical spiny lobster *Panulirus ornatus*: astaxanthin-supplemented feeds and mussel flesh. *Aquaculture Nutrition* 12: 117–125.
- Glencross B.D. Booth M. and Allan G.L. 2007. A feed is only as good as its ingredients—a review of ingredient evaluation strategies for aquaculture feeds. *Aquaculture Nutrition* 13: 17–34.
- Irvin S.J. and Williams K.C. 2009. *Panulirus ornatus* lobster feed development: from trash fish to formulated feeds. Pp 147–156 in 'Spiny lobster aquaculture in the Asia-Pacific region', ed. by K.C. Williams. Proceedings of an international symposium, Nha Trang, Vietnam 9–10 December 2008. Australian Centre for International Agricultural Research: Canberra.
- Smith D.M. Williams K.C. and Irvin S.J. 2005. Response of the tropical spiny lobster *Panulirus ornatus* to protein content of pelleted feed and to a diet of mussel flesh. *Aquaculture Nutrition* 11: 209–217.
- Williams K.C. 2007. Nutritional requirements and feeds development for post-larval spiny lobster: A review. *Aquaculture* 263: 1–14.
- Williams K.C. 2009. Spiny lobster aquaculture in the Asia-Pacific region. Proceedings of an international symposium, Nha Trang, Vietnam 9–10 December 2008. Australian Centre for International Agricultural Research: Canberra.

## 3.2 Transport and husbandry of post- puerulus tropical spiny lobsters

Scott Shanks<sup>1</sup>, Samsul Bahrawi<sup>2</sup>, Bayu Priyambodo<sup>2</sup> and Clive Jones<sup>3</sup>

### Introduction

This paper provides an overview of research conducted, and current industry practices, for the handling, packing and transport of lobster seed, and their initial nursery culture in Indonesia.

Aspects of nursery practices for tropical spiny lobsters are discussed, comprising standard operating procedures, knowledge gaps and research required to improve survival and growth of lobsters through the nursery phase.

For the Indonesian lobster farming industry, accurate statistics on survival of lobsters from point of capture as a puerulus to advanced juvenile of around 10 to 30 g, are not available. Anecdotal evidence suggests survival through this nursery phase may be as low as 20%. This compares poorly with Vietnam, where survival through the nursery phase is greater than 70%.

### Experimentation

A series of four experiments were performed to examine aspects of husbandry in the nursery culture of *Panulirus homarus*. These are referred to below as experiments one to four, and cover assessment of density in sea cages, density in tank culture, provision of shelter in tanks and tank colour.

### Experiment 1: Growth and survival of spiny lobsters cultured at three densities in sea cages

#### Introduction

This experiment set out to assess the effect of density on the growth and survival of *P. homarus* cultured under sea-cage conditions, and was performed in April 2010.

#### Methods

Traditionally lobster farmers in Vietnam and Indonesia use small fresh fish as lobster feed however this feed type is highly polluting and is unlikely to meet the lobsters' nutritional requirements. To maximise the likelihood of adequate nutrition, a combination of trash fish and a commercial lobster pellet (Lucky Star) was used in a 1:1 mix to feed the lobsters in this experiment.

Each cage was 75 cm wide × 75 cm long × 75 cm high, providing a floor area of 0.56 m<sup>2</sup>. Cages were suspended from a floating frame located approximately 200 m offshore of the MADC research facilities at Sekotong, Lombok (Figure 1).

From the village of Awang in south-east Lombok, 1,200 juvenile (<4 g) spiny lobsters (*P. homarus*) were transported from a nursery cage to the experimental system at the MADC's research station at Sekotong. Prior to initiation of the experiment, 40 lobsters were weighed to define the mean ± SD weight. All lobsters were then graded into 3 sizes: small (<0.8 g), medium (0.8–2.0 g) and large (>2.0 g). The medium size grade had the highest number of lobsters so these were used for the experiment. A total of 11, 28 or 45 lobsters were then allocated to each of three cages to achieve stocking densities of 20, 50 and 80 lobsters per square metre. There were four replicates of each of the three treatments.

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The duration of the trial was 84 days. Weight samples were taken every two weeks, and during this process all cages were thoroughly cleaned and reinstalled. For the duration of the experiment, the lobsters were fed to satiety three times daily, seven days a week. The lobsters' survival, final weights and weight gains were analysed as single ANOVA.

### Results and discussion

The average survival, final weight and weight gain of lobsters from each treatment is presented in

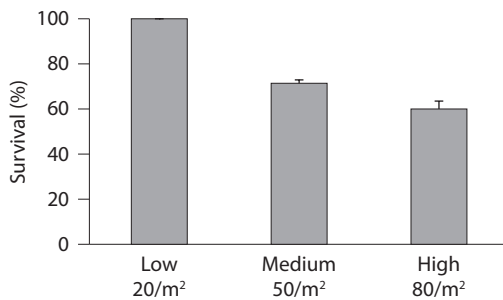
Figures 2 and 3. There were significant differences ( $p < 0.05$ ) in both survival and growth between treatments.

Lobsters cultured at the lowest density had significantly higher survival rates (100%) than those in the medium (71.4%) and high density (60%) treatments.

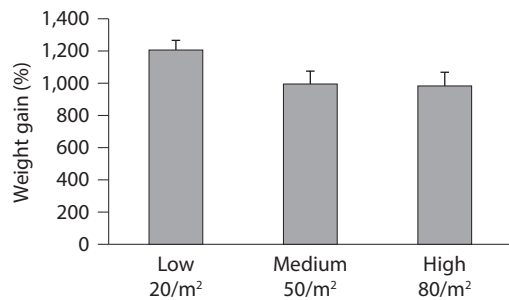
Lobsters cultured at the lowest density had a significantly higher growth rate than those in the medium and high density treatments, with 1.62 g/week, 1.28 g/week and 1.23 g/week respectively.



**Figure 1.** Experimental sea cages for nursery experiments at MADC Sekotong, Lombok



**Figure 2.** Survival of juvenile *P. homarus* grown at three densities in sea cages for 84 days



**Figure 3.** Percentage weight gain of juvenile *P. homarus* grown at three densities in sea cages for 84 days

## Experiment 2: Growth and survival of spiny lobsters cultured at three densities in tanks

### Introduction

After the MADC sea cage research facility was destroyed by a storm in June 2010, subsequent experiments were performed in a tank system onshore. The experiment summarised here set out to further assess the effect of density on the growth and survival of *P. homarus*.

### Methods

Forty small open-top cages (30 cm × 60 cm × 50 cm deep) with a floor surface area of 0.18 m<sup>2</sup> were fabricated from netting attached to a frame, and placed into large concrete tanks as depicted in Figure 4. Five density treatments were applied, comprising: 30, 60, 90, 120 and 150 m<sup>-2</sup> with eight replicates of each. The experiment was maintained for eight weeks, and was terminated on 4 October 2010.

The mean weight of lobsters stocked was 0.24 g. Feeding was performed twice each day with 35% of the daily ration fed in the morning and 65% in the evening. Lobsters were fed at a rate of 20% of biomass on a dry weight basis.

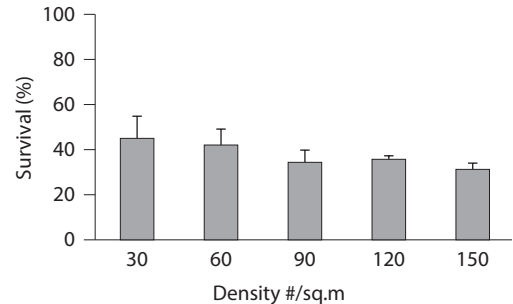


**Figure 4.** Experiment cages within tanks at MADC Sekotong as used for husbandry and nutrition experiments 2010 to 2012

### Results and discussion

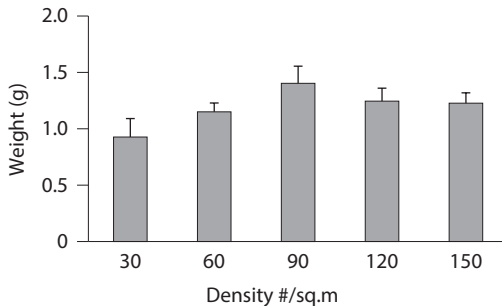
At the completion of the experiment after eight weeks, survival was quite low, with the mean for each density ranging from around 30 to 45% (Figure 5). There was no significant difference ( $P < 0.05$ ) in survival, although a negative correlation between density and survival was apparent.

The mean size at harvest ranged from around 0.9 to 2.2 grams (Figure 6) but there was no significant difference between densities.



**Figure 5.** Survival of juvenile *P. homarus* cultured over 56 days at five densities in tanks





**Figure 6.** Size of juvenile *P. homarus* cultured over 56 days at five densities in tanks

Survival at 14 days was high, above 95% for nearly all cages, but fell dramatically by day 28 when it was consistently less than 60%, falling further, although more slowly, to the experiment's conclusion at day 56. There was no apparent critical event or factor that the high mortality could be attributed to. Nevertheless, the poor survival is likely to have masked the effect of the density treatments, and no conclusion can be made about the density effect.

It is however possible that the diet provided was inadequate, leading to the poor survival by day 28 as a consequence of high cannibalism.

### Experiment 3: Growth and survival of spiny lobsters cultured with different shelters in tanks

#### Introduction

Previous research has indicated that providing shelter to lobsters cultured in tank-based conditions has a positive impact on survival. This experiment assessed the effect of four different forms of shelter.

#### Methods

The experiment system used was the same as that described above for Experiment 2, although with four treatments and six replicates. The experiment was initiated on 10 October 2011.

The four shelter treatments comprised: i) seaweed, using small bunches of fresh *Gracilaria*; ii) mesh bundle, made from a bundle of mono-filament netting; iii) hard shelter consisting of a series of PVC pipes bound together; and iv) no shelter control.

Twelve lobsters were stocked to each cage at a nominal density of 67 m<sup>-2</sup>. Mean size at stocking was 0.33 g. Lobsters were fed a commercial lobster pellet (Lucky Star) in 1.5 mm noodle form. Feeding was performed twice each day with 35% of the daily ration fed in the morning and 65% in the evening. Lobsters were fed at a rate of 20% of biomass on a dry weight basis.

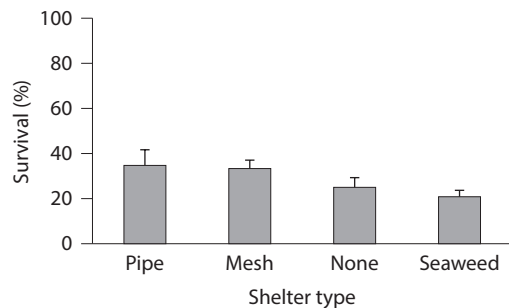
#### Results and discussion

Over the duration of the eight week experiment, survival was very low, with the mean for each shelter type ranging from around 20 to 35% (Figure 7). There was no significant difference (P. 0.05) for survival, although the pipe and mesh shelters had the highest survival.

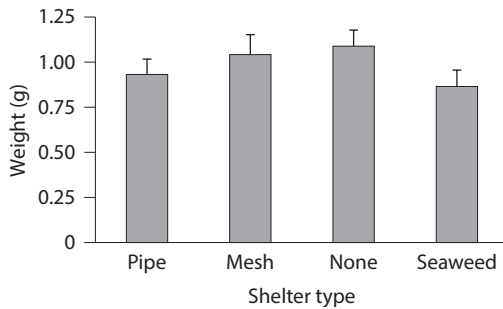
The mean size at harvest ranged from around 0.9 to 1.1 grams (Figure 8), but there was no significant difference between shelter types.

In this experiment, survival fell sharply from the outset, such that less than 50% of lobsters persisted to day 28. As for the previous experiment, there was no apparent critical event or factor that the high mortality could be attributed to. Again, the poor survival is likely to have masked the effect of the shelter treatments, so that no conclusion can be made about the shelter effect.

It is however likely that the diet provided was inadequate, leading to poor survival.



**Figure 7.** Survival of juvenile *P. homarus* provided with different shelter types and cultured over 56 days



**Figure 8.** Size of juvenile *P. homarus* provided with different shelter types and cultured over 56 days

#### Experiment 4: Growth and survival of spiny lobsters cultured in tanks of different wall colour and translucency

##### Introduction

Tank colour and light levels have both been proven to affect survival in a number of aquaculture species, including but not limited to *Scylla serrata* and *Perca fluviatilis*. Our interest in this factor was aroused by the contrasting results of similar lobster research between two laboratories where tanks of different colour and translucency were used. In Australia, experiments carried out in dark coloured tanks on tropical spiny lobsters resulted in very high survival, while equivalent experiments in Indonesia using white translucent tanks resulted in very poor survival. There could be a variety of reasons for the low survival in the Indonesian experiments, including stock health and water quality, but the differing characteristics of the tank colour and light penetration were also a factor. This experiment was conceived to assess the affect of tank colour / light penetration on survival and growth of juvenile *P. homarus*.

##### Methods

The experiment system used consisted of rectangular polyethylene tanks equipped with intake and outlet pipes to enable through-flow of seawater. Twenty tanks were set up in a block that was two tanks wide and 10 tanks long to provide for two treatments and 10 replicates. The experiment started on 21 April 2012 and ran for eight weeks.

Fifteen lobsters were stocked to each tank at a nominal density of 83 m<sup>-2</sup>. Mean size at stocking was 0.33 g. Lobsters were fed a laboratory-made

semi-moist lobster pellet, the formulation for which had previously been used with success in similar experiments. Feeding was performed twice each day with 35% of the daily ration fed in the morning and 65% in the evening. Lobsters were fed at a rate of 20% of biomass on a dry weight basis.

Shelter was provided in the form of 2 m<sup>2</sup> of 5 cm cage mesh bundled and weighted, then placed in each replicate cage to reduce stress and cannibalism. Unfiltered seawater was passed through each cage/tank at the rate of 160 Ls per hour or approximately two exchanges per hour.

The two treatments comprised: i) translucent, white-walled, polyethylene tanks; and ii) opaque, black-walled, polyethylene tanks.

##### Results and discussion

As for previous experiments in this series performed at the MADC research centre at Sekotong in Lombok, the survival of lobsters through the period of the experiment was very poor (Figure 9), with significant mortality occurring consistently from the outset to the completion. By day 56, survival was less than 20%.

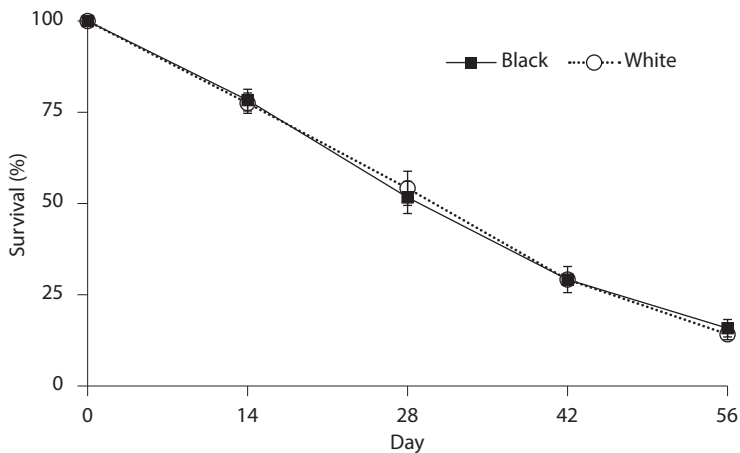
As diet in this experiment was considered to be a proven effective diet, and all other known factors were optimal, the high mortality was attributed to an unspecified water quality issue that may have similarly impacted the previous experiments. The poor survival again masked the treatment effect, such that no conclusion could be made about the efficacy of tank colour and translucency.

## Conclusions and recommendations

### Handling and transport

A variety of techniques have been used for transferring juvenile lobsters from one location to another over the years, with varying levels of success. These include:

- dry in Styrofoam box
- rolled in moist sand and packed in cardboard or Styrofoam box
- seawater-filled soft drink bottle with 5–10 puerulus (puerulus fishermen to middlemen)
- bag filled with seawater in Styrofoam box with/without battery aerator
- bag or bags partially filled with chilled seawater then filled and sealed with pure oxygen.



**Figure 9.** Survival of juvenile *P. homarus* cultured in opaque black and translucent white tanks for 84 days

Some of these techniques are suitable while others can lead to reduced survival during and post transport.

Current best practice for handling and transport comprises:

- juvenile lobsters are not fed for at least 12 hours prior to transport (this requirement is not necessary for translucent puerulus as they are non-feeding)
- lobsters are chilled to 22–25 °C for 30 minutes prior to packing, and graded by size
- 1 L of chilled water is poured into a 10 L plastic bag then 50 juvenile lobsters are added
- each bag is completely filled with pure oxygen before being tied at the top with rubber bands
- 10 of these bags are neatly placed into a 20 kg Styrofoam box then freighted to local and international buyers
- upon arrival at their new destination, the lobsters should be slowly acclimated by exchanging 10% of the bag water volume every 10 minutes until water quality parameters are the same in and out of the transportation bag.

### Nursery husbandry

Early cage-based results were excellent, even when suboptimal feeds were provided. This result may indicate substantial nutritional benefits can be derived from a sea-cage environment for *P. homarus*.

All tank-based husbandry experiments were compromised by poor nutrition, highlighting necessity of an effective formulated diet.

By mid-2010, the project's research focus switched to nutrition and led to the discovery of the ACIAR basal diet in September 2011. This diet has consistently supported survival rates of 65–85%, a vast increase from 20–45% previously experienced.

### Future research questions

- What is the optimum size to transport juvenile lobsters? Recent experience suggests that puerulus tolerate transport better than advanced juveniles.
- After feeding, how long does it take juvenile (and market size) lobsters to be fully purged?
- What is the lowest temperature at which tropical lobsters can be stored and freighted without adversely affecting survival? Over what time period should this cooling down occur?
- What is the maximum freight time allowed before survival and growth are negatively impacted?
- What is the optimum density for juvenile production in sea cages (20–50/m<sup>2</sup>)?
- What is the optimum density for grow-out production?
- At what density is maximum profitability achieved?

It is recommended that the density experiments be revisited using the ACIAR basal diet for varying sized lobsters in sea cages with a strong focus on survival, growth and profitability.

# 3.3 Preliminary assessment of dietary mannan oligosaccharides on juvenile *Panulirus homarus* lobsters

Hoang Do Huu<sup>1</sup> and Clive Jones<sup>2</sup>

## Introduction

This paper presents information on an experiment performed to assess the effects of dietary supplementation with mannan oligosaccharide on post-plerulus *Panulirus homarus*. This research was subsequently published (Do Huu and Jones 2014) and the following account is a summary only, as presented at the Symposium.

The lobster, *P. homarus* is a high-value species from fishery production throughout South-East Asia, and more recently also from aquaculture (Jones 2010). Together with *Panulirus ornatus*, aquaculture of *P. homarus* creates employment and provides an important source of income for communities in the central provinces of Vietnam, including Khanh Hoa, Phu Yen and Binh Dinh (Petersen and Phuong 2010). However, as a consequence of rapid expansion, a number of problems have arisen, including the spread of disease and significant mortality in late 2007 and again in 2012 caused by rickettsia-like bacteria (milky disease). In order to help the lobster culture industry develop sustainably, it is essential to better manage lobster health without the use of chemicals and antibiotics.

Prebiotics can improve growth performance and feed utilisation, boost health and enhance the disease resistance of aquaculture species (Delzenne 2003; Li and Gatlin 2004; Staykov et al. 2005; Staykov et al. 2007). Mannan oligosaccharide (MOS) is a prebiotic that has reputedly helped to remove pathogens from

the intestine and stimulated the immune system of animals to which it was fed (Delzenne 2003).

Although there are many studies supporting the health benefits of MOS on aquatic species, none have involved the lobster, *P. homarus*. The aim of the present study was to evaluate the effect of dietary mannan oligosaccharide (MOS) on growth performance and gastro-intestinal health of *P. homarus*.

## Methods

Three hundred puerulus of the lobster, *P. homarus* ( $0.16 \text{ g} \pm 0.02\text{SE}$ ) were collected from buyers, transported to a sea-cage facility and acclimated for five days before the experiment. After acclimation, 10 puerulus were randomly stocked to each of 30 30 cm  $\times$  50 cm diameter tall cylindrical cages. Water temperature was 27–28.5°C, dissolved oxygen  $6.5 \pm 0.2 \text{ mg/l}$  and pH 8.0–8.3 during the experiment.

There were six diet treatments (with five replicates each) including: a control basal diet with no MOS; basal diet with four levels of MOS supplementation; and trash-fish used as reference diet.

To prepare the diets, a basal formulation was prepared, as recommended by previous research that was minced and extruded twice to generate 2 mm diameter noodles. Four levels (0.2, 0.4, 0.6 and 0.8%) of mannan oligosaccharide (Bio-MOS®) were added to the control basal diet. Lobsters were fed slightly over satiation twice daily (25% at 07:00 and the remaining 75% at 17:00).

All lobsters in each cage were weighed and their carapace length was measured at the beginning of the experiment and at two-week intervals. At day 56 (end), five lobsters were randomly chosen for

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haemolymph sampling, proximate analysis and intestinal morphology examination. MOS level requirement was predicted using a compartmental model  $y = a \times e^{-bx}(1 - e^{-c(x-d)})$  (SAS 1990; Vedenov and Pesti 2008) in which MOS concentration was the independent variable, and daily growth coefficient (DGC) was the dependent variable. ANOVA was applied to compare means among treatments using SPSS 18.

## Results and discussion

The mean weight of lobsters among the treatments deviated significantly from day 28. Over the experimental period, lobsters fed with the various levels of MOS-supplemented diets significantly out-performed those fed on the basal diet. The greatest increase in weight was in the group of lobsters fed 0.4% MOS, at 31.51 times, followed by lobsters fed 0.6% MOS (31.43 times). The lowest weight increment was in the group of lobsters fed the basal diet (24.62 times). The weight of lobsters fed on by-catch increased by 26.20 times (Figure 1).

At the end of the experiment (day 56), survival rates of lobsters ranged from 68 to 78%. The higher survival rates were in lobsters fed diets D3, D2 and D6 which were 78%, 76% and 76% respectively, while the lower survival rates were for lobsters fed D1, D4 and D5 (Figure 1).

The intestinal surface area of lobsters fed with D2, D3 and D4 was significantly higher than that of lobsters fed on D1, D5 and D6 ( $P \leq 0.021$ ) (Figure 2). Protein content in the muscle of lobster ranged from

21.73% in the group of lobsters fed the control to 22.68% in the group fed 0.4% MOS (D3). Lipid content ranged from 2.08 to 2.31%. There was no significant difference in protein, lipid or ash content in lobsters fed the different diets ( $P > 0.05$ ).

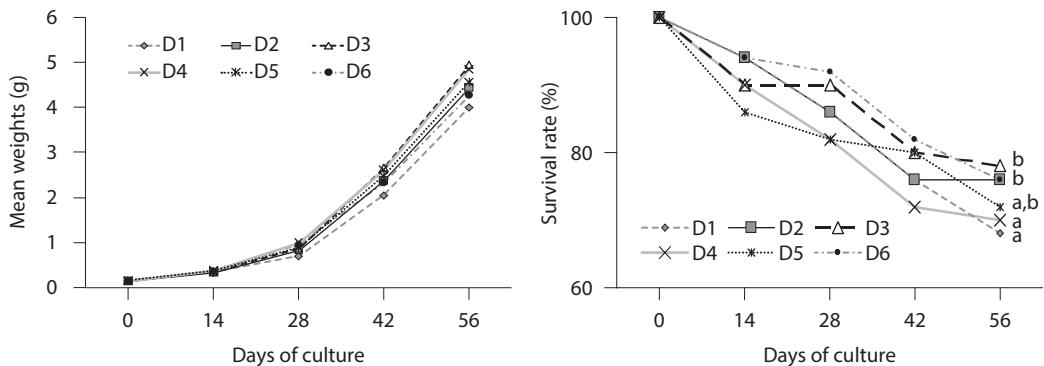
The total *Vibrio* count in the gut of lobsters fed any MOS diet was significantly lower than that of lobsters fed the control ( $P < 0.021$ ). There was no significant difference in *Vibrio* counts between lobsters fed control diets (D1) and those fed by-catch ( $P = 0.256$ ). Also, there was no significant difference between *Vibrio* counts for lobsters fed any MOS diet ( $P = 1.743$ ) (Figure 3).

Granulocytes, including both granular and semi-granular cells, contributed between 20.67% and 31.38%, while hyaline cells were the most dominant haemocytes in the haemolymph of lobsters, ranging from 68.62 to 79.33%. There was no significant difference in either hyaline or granulocytes in lobsters fed different diets ( $P = 0.495$ ) (Figure 4).

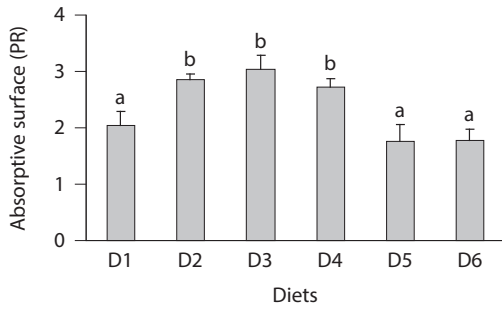
Predicted optimal levels of MOS in the diet for maximal growth reduced over time as the weight of lobsters increased. The optimal MOS requirement for maximal growth of lobsters is 0.69%, 0.55%, 0.48% and 0.47% at days 14, 28, 42 and 56, respectively (Figure 5).

## Conclusions and recommendations

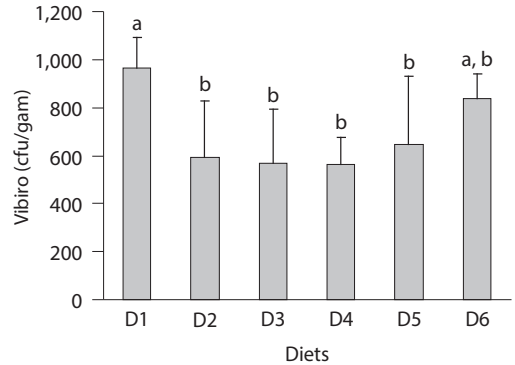
This report confirms that the inclusion of MOS in the diet improves growth, survival rate, intestinal flora and gut surface area of the lobster, *P. homarus*. The optimal level of dietary MOS inclusion for maximal



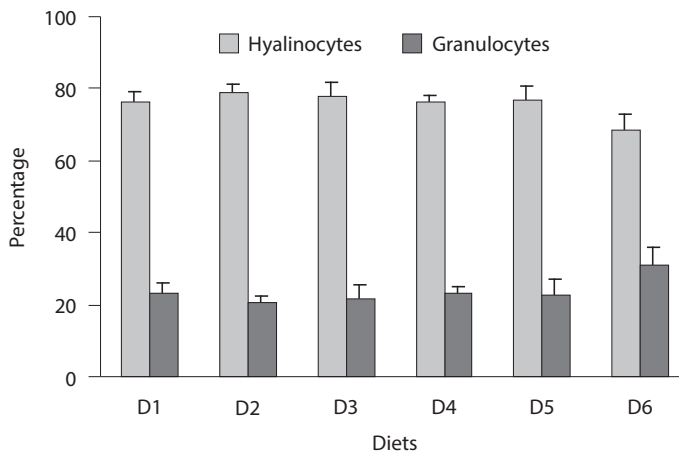
**Figure 1.** Average weight (left) and survival (right) of lobster fed different concentrations of MOS and by-catch. D1: control, D2: 0.2% MOS, D3: 0.4% MOS, D4: 0.6% MOS, D5: 0.8% MOS, D6: by-catch. Data are presented as mean  $\pm$  S.E



**Figure 2.** Intestinal absorptive area (PR = internal perimeter/external perimeter), arbitrary units of lobster *P. homarus* fed on different levels of MOS supplemented diets and by-catch at day 56. D1: control, D2: 0.2% MOS, D3: 0.4% MOS, D4: 0.6% MOS, D5: 0.8% MOS, D6: by-catch. Data are presented as mean  $\pm$  S.E



**Figure 3.** Total *Vibrio* spp. (cfu/gram) in the gut of lobsters at day 56 (n = 5). D1: control, D2: 0.2% MOS, D3: 0.4% MOS, D4: 0.6% MOS, D5: 0.8% MOS, D6: by-catch. Data are presented as mean  $\pm$  S.E



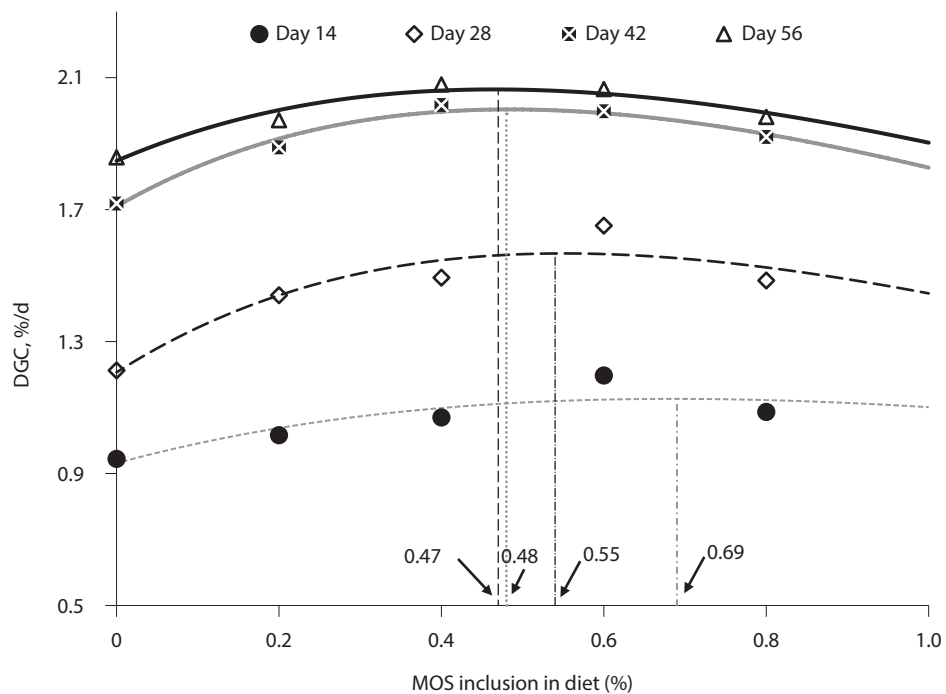
**Figure 4.** Percentage of haemocyte count of lobsters fed different concentrations of MOS. D1: control, D2: 0.2% MOS, D3: 0.4% MOS, D4: 0.6% MOS, D5: 0.8% MOS, D6: by-catch. Data are presented as mean  $\pm$  S.E

growth of lobster was also determined, indicating that MOS at 4–6 g kg<sup>-1</sup> be recommended. However, there are other potential positive benefits of MOS supplementation that are worthy of enquiry, such as increased resilience to environmental stress or pathogens, that should be investigated experimentally. It is also recommended that the effects of dietary MOS on different life stages beyond those in this study be examined.

## Acknowledgements

We would particularly like to thank the Australian Centre for International Agriculture Research (ACIAR) for funding. Special thanks also to Sharon Harvey, Simon Tabrett, David Smith, Tuan Le Anh, Phuong TH, Nguyen Thi Kim Bich and Tuyen Hua Thai for their assistance.





**Figure 5.** Predicted optimal MOS concentration in the lobster diet for maximal growth (DCG, %/day) at different days of culture of lobster, *P. homarus*



Puerulus lobster, *P. homarus* at the beginning of the experiment (left) and at 8 weeks (right)

## References

- Delzenne N.N. (2003). Oligosaccharides: state of the art. *Proceedings of the Nutrition Society* 62: 177–182.
- Do Huu H. and Jones C.M. (2014). Effects of dietary mannan oligosaccharide supplementation on juvenile spiny lobster *Panulirus homarus* (Palinuridae). *Aquaculture* 432: 258–264.
- Jones C.M. (2010). Tropical rock lobster aquaculture development in Vietnam, Indonesia and Australia. *Journal of the Marine Biological Association of India* 52(2): 304–315.
- Li P. and Gatlin D.M. (2004). Dietary brewers yeast and the prebiotic Grobiotic™AE influence growth performance, immune responses and resistance of hybrid striped bass (*Morone chrysops* × *M. saxatilis*) to *Streptococcus iniae* infection. *Aquaculture* 231 (1–4): 445–456.
- Petersen E.H. and Phuong T.H. (2010). Tropical spiny lobster (*Panulirus ornatus*) farming in Vietnam—bioeconomics and perceived constraints to development. *Aquaculture Research* 41(10): e634–e642.
- SAS (1990). *User's Guide*. Release 6.08. SAS Institute Inc., Cary, NC.
- Staykov Y. Spring P. and Denev S. (2005). Effects of dietary Bio-Mos® on growth rate and immunity of rainbow trout (*Salmo gairdneri irideus* G.) grown in raceways. Poster presented at Alltech's 21 st Annual Symposium, May 22–25, 2005; Lexington, KY, USA.
- Staykov Y. Spring P. Denev S. and Sweetman J. (2007). Effect of a mannan oligosaccharide on the growth performance and immune status of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture International* 15: 153–161.
- Vedenov D. and Pesti G.M. (2008). A comparison of methods of fitting several models to nutritional response data. *Journal of Animal Science* 86(2): 500–507.



## **4. Lobster Growout**

# 4.1 Comparative assessment of manufactured pellet feed and traditional trash fish feed on production of tropical rock lobster (*Panulirus ornatus*) and environmental effects in sea-cage culture in Vietnam

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Huynh Minh Sang<sup>1</sup>, Nguyen Trung Kien<sup>1</sup>, Nguyen Thi Kim Bich<sup>1</sup>,  
Hong Phan Thi Kim<sup>1</sup>, Khang Nguyen An<sup>1</sup>, Du Hoang Trung<sup>1</sup>,  
Tam Pham Huu<sup>1</sup> and Hoc Dao Tan<sup>1</sup>

## Introduction

The impact of disease on spiny lobster production in Vietnam has been significant over recent years, with production diminished in some years by more than 50%. Thuy et al. (2010) reported production in 2009 was approximately 700 tonnes while in previous years, production exceeded 1,500 tonnes. It is believed that disease has flourished due to environmental stress from localised pollution, largely caused by the traditional feeding practice of using trash fish which is often of poor quality and necessitates high feeding rates because of low food conversion ratio (FCR). Manufactured diet formulations provided in pellet form have been defined for tropical lobsters which support good growth under experimental conditions. These pellet diets are likely to have a much lower environmental impact and may help to reduce the stress that is leading to disease.

This notion prompted the design of a field-based comparison of traditional trash fish feeding with pellet feeding to confirm the efficacy of the pellet diet under normal commercial conditions, and to

measure the relative environmental impact of the two feeding approaches. To best gauge the difference, the experiment included production of lobsters at two locations representing high and low farming intensity. The low farming intensity or ‘pristine’ site provided an opportunity to measure the difference in environmental impact exclusive of any background environmental degradation. The high intensity or ‘degraded’ site was a site of existing lobster farming, where the immediate environmental benefit of pellet feeding could be measured.

The experiment provides both an assessment of the manufactured diet under practical, commercial conditions, and analyses the comparative benefit it provides environmentally. The experiment was administered by the Institute of Oceanography in Vietnam which has proven capacity in this area. The following report provides a summary of the experiment as presented in the following three papers at the Symposium.

- Sea cages experiment using manufactured pellet for production of spiny lobster (*Panulirus ornatus*) Nha Trang, Vietnam—Le Lan Huong, Huynh Minh Sang, Clive Jones, Nguyen Trung Kien and Nguyen Thi Kim Bich
- Environmental effects of sea-cage grow-out—Le Thi Vinh, Le Lan Huong, Tam Pham Huu and Du Hoang Trung

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- Benthic fauna at Dam Bay Lagoon—Hua Thai Tuyen, Phan Thi Kim Hong, Nguyen An Khang and Dao Tan Hoc

## Methods

Four replicate cages of  $3.5 \times 3.5 \times 6$  m deep were positioned within a floating frame in a  $2 \times 2$  arrangement at each of four sites within Dam Bay Lagoon on Tre Island to the east of Nha Trang in south-central Vietnam ( $12^{\circ}11'41.0''\text{N } 109^{\circ}17'35.8''\text{E}$ ). Two sites were within an existing lobster farming area and were nominated as ‘degraded’ sites, and two were located approximately 250 m away from the nearest commercial lobster farm, nominated as ‘pristine’ sites. Within these two locations, the two sets of four cages were positioned more than 10 0m apart to avoid interactive effects (Figure 1).

Juvenile lobsters of mean weight 47.5 g were stocked to each cage at a density of  $4.5/\text{m}^2$  (i.e. 55 lobsters per cage) and on-grown for 12 months from September 2010 to October 2011.

At each of the pristine and degraded sites, one set of four cages was fed with traditional trash fish and the other with a commercial lobster pellet (Lucky Star, Taiwan Hung Kuo Industrial Co., Ltd). Feed ration was as per a feeding schedule that was based

on 3% (dry weight) of biomass, adjusted daily by visual inspection to detect uneaten food. Food was delivered into each cage within a feeding tray consisting of a circular 100 cm diameter frame covered in shade cloth with 10 cm high sides.

The metrics for lobster production included size, growth rate, survival and food conversion ratio based on samples taken at stocking, day 95, day 200, day 271 and at final harvest on day 379. Two-way ANOVA was performed (location, diet) on final weight and survival data.

For water quality assessment, pH, salinity and temperature were measured once at each cage site every two months with a Horiba U-10 water quality meter. For analytical purposes, four samples of water were taken at each of the four locations, two at the surface from opposing corners of the cage frame and two from near the sea floor at the same position. Sampling occurred seven times at two month intervals from October 2010 to October 2011. The following 11 variables were measured from those samples: DO, BOD<sub>5</sub>, TSS, nutrients  $\text{NH}_{3,4}$ ,  $\text{PO}_4$ , chlorophyll-a, particulate organic phosphorus (POP), particulate organic nitrogen (PON), particulate organic carbon (POC), *E. coli* and fungi.

Four sediment samples were taken from each cage site at the four corners of the floating frame,



**Figure 1.** Locations for the experiment within Dam Bay Lagoon. Site A: degraded with pellet feed; site B: pristine with pellet feed; site C: pristine with trash fish feed; and site D: degraded with trash fish feed



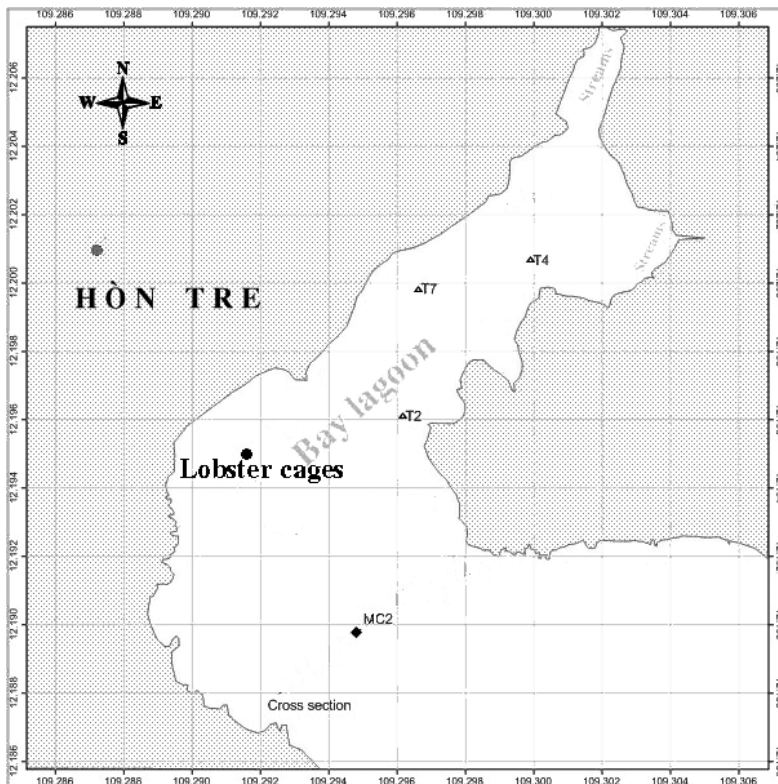
with a van Veen grab at four month intervals (i.e. four measurements). Variables measured were: *E. coli*, fungi, chlorophyll-a, organic C, N and P, and relative fractions of mud (<0.063 mm), sand (0.063 to 2.0 mm) and gravel (> 2.0 mm). Both water and sediment samples were preserved and analysed following standard procedures (APHA 2005; Austin 1988; FAO 1975; Parsons et al. 1984).

In addition to the environmental sampling at and below the experiment cages, water and sediment samples were also taken from four other sites within Dam Bay Lagoon on two occasions (August and October 2011) for comparative purposes. The location of these additional sampling sites is shown in Figure 2.

All analyses were conducted using SPSS (Version 21). Student t-tests were applied for pair-wise testing between subgroups of the water quality data. A three-way multivariate analysis of variance (MANOVA)

in which all factors (date, location and diet) were considered to be fixed, was applied to the water quality data.

A faunal study of the sediment beneath the cages was also performed, by examining the fauna within the sediment samples taken, as described above. Sediment was sieved with a 0.5 mm nylon mesh sieve. Echinoderms were preserved in 70% alcohol and all other specimens were fixed in 10% buffered formalin. All sieved material was maintained in this condition until sorted in the laboratory, where specimens were identified using taxonomic keys. Raw data were stored and analysed in Excel spreadsheets. Bray-Curtis similarity index was used for analysis of structure of species composition between months. Simper analysis was used to determine the contribution to similarity within a group.



**Figure 2.** Locations within Dam Bay Lagoon where additional water and sediment samples were taken for comparison with lobster cage location

## Results and discussion

### Lobster production

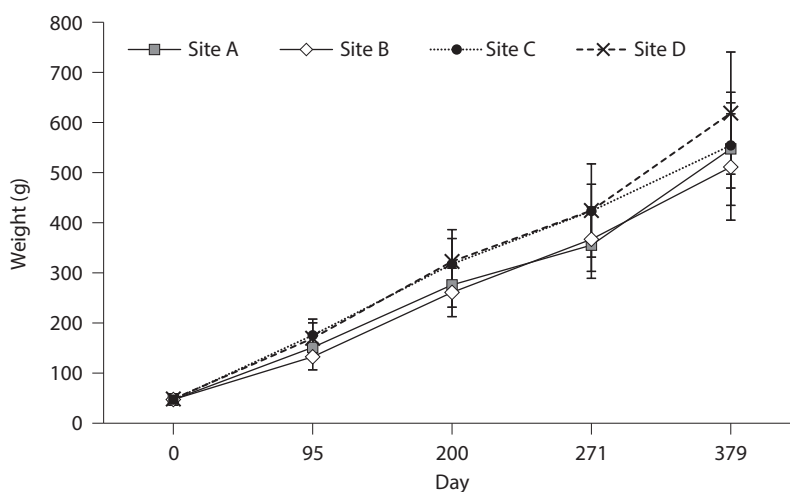
The mean weight of lobsters for each treatment at each of five sampling events, including stocking and harvest, are presented in Table 1 and Figure 3. Final (harvest) weight is presented in Figure 5. Survival at harvest is presented in Figure 4. Growth data and FCR values for each treatment are presented in Table 2.

A two-way ANOVA was conducted that examined the effect of diet and site on survival. There was a statistically significant interaction between the effects of diet and site on survival  $F_{(1, 12)}=6.037, p=0.03$ , although no significant simple main effect for either diet or site. The combination of trash fish diet at the pristine site resulted in the highest survival with a mean of 65.5%.

Similarly, a two-way ANOVA was conducted that examined the effect of diet and site on mean harvest weight. There was no statistically significant

**Table 1.** Mean weight (g ± SE) of lobsters through the duration of the experiment at the four sites

	Day 0	Day 95	Day 200	Day 271	Day 379
Site A Pellet feed Degraded area	47.0 ± 10.9	151.2 ± 23.6	276.0 ± 44.5	355.3 ± 66.3	547.4 ± 112.8
Site B Pellet feed Pristine area	47.3 ± 10.0	132.5 ± 26.0	261.0 ± 48.3	367.0 ± 64.1	511.2 ± 106.1
Site C Trash fish feed Pristine area	47.1 ± 10.4	175.5 ± 32.2	317.5 ± 51.0	423.3 ± 53.4	554.3 ± 85.1
Site D Trash fish feed Degraded area	48.4 ± 9.8	169.5 ± 30.8	322.7 ± 63.6	424.4 ± 93.1	618.7 ± 121.9



**Figure 3.** Mean weight g(SE) through 12 months of the experiment at four sites. Site A: degraded with pellet feed; site B: pristine with pellet feed; site C: pristine with trash fish feed; and site D: degraded with trash fish feed

interaction between the effects of diet and site on weight. The main effects analysis showed that both diet ( $p=0.010$ ) and site ( $p=0.013$ ) had a significant effect on weight. For diet, trash fish generated a larger harvest weight than pellets, and for site, degraded generated a greater weight than pellets. The combination of the trash fish diet at the degraded site resulted in the greatest weight (mean  $619.1 \text{ g} \pm 20.1$ ).

A number of environmental and health issues arose over the duration of the experiment which are likely to have impacted negatively on the survival and growth of lobsters both in the commercial farms and in the experiment. An outbreak of milky haemolymph disease occurred in the Dam Bay Lagoon starting in September 2010, causing about 10% loss in the commercial farms. Introduction of Babylon snail farming from January 2011 was believed to pollute the environment, causing lobster losses in the commercial farms. A fish kill event occurred starting in September 2011 affecting wild fish in the lagoon,

caused by an unidentified environmental issue that may have been linked to heavy rainfall and runoff from the island.

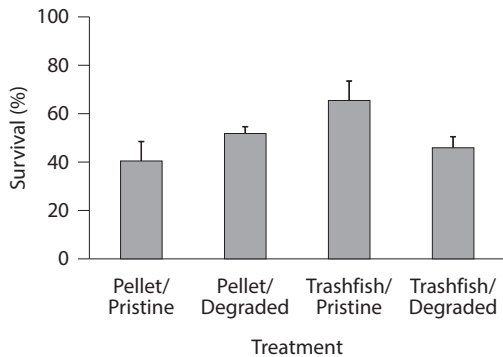
Growth of lobsters in the experiment was equivalent to standard industry levels, although survival was somewhat lower, possibly attributable to the negative environmental and health impacts described.

## Environmental assessments

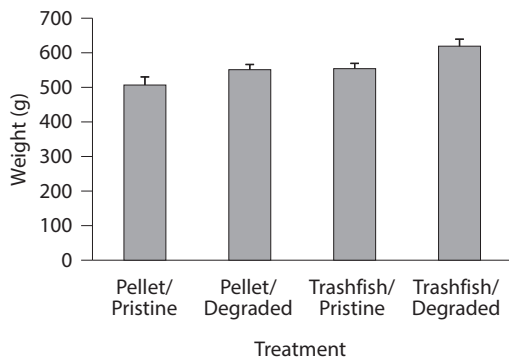
### Water quality

Temperature, salinity and pH values over the course of the experiment are presented in Table 3. There were no substantial differences in these variables among the experiment cage locations. Temperature ranged from  $25.5$  to  $29.6^\circ\text{C}$ , salinity from  $32.1$  to  $34.5\text{ppt}$  and pH from  $8.12$  to  $8.18$ .

Mean values for each of the seven bi-monthly measurements for the 11 water quality variables at the four treatment sites are presented in Figure 6.



**Figure 4.** Survival ( $\% \pm \text{SE}$ ) of lobsters after 12 months culture at four sites representing feeding with pellets or trash fish and at pristine or degraded locations



**Figure 5.** Final mean weight of lobsters ( $\text{g} \pm \text{SE}$ ) after 379 days of culture subjected to the four treatments

**Table 2.** Growth statistics and FCR for *P. ornatus* lobsters grown over 379 days at four sites

	Site A Pellet feed Degraded area	Site B Pellet feed Pristine area	Site C Trash fish feed Pristine area	Site D Trash fish feed Degraded area
Initial weight (g)	$47.0 \pm 10.9$	$47.3 \pm 10.0$	$47.1 \pm 10.4$	$48.4 \pm 9.8$
Final weight (g)	$547.41 \pm 13.40$	$511.22 \pm 20.70$	$554.13 \pm 15.16$	$619.06 \pm 20.11$
SGR (%/day)	$0.68 \pm 0.01$	$0.65 \pm 0.01$	$0.68 \pm 0.01$	$0.71 \pm 0.01$
AWG (g/week)	$9.73 \pm 0.27$	$9.02 \pm 0.40$	$9.85 \pm 0.28$	$11.09 \pm 0.36$
FCR	$7.93 \pm 0.41$	$8.74 \pm 0.59$	$47.29 \pm 7.71$	$63.28 \pm 10.51$

Data for the four other locations in Dam Bay Lagoon are presented in Figure 7, alongside pooled data (mean) for the lobster cage site. Analysis of variance was performed for each of the variables.

ANOVA of all water quality variables with depth as the fixed factor revealed no significant difference, and the data for surface and bottom measurements were then pooled. This suggests there was no stratification within the water column.

Using two-way ANOVA (location x feed type) there were no significant differences for any of the variables, with the only exceptions being a significant interaction for BOD5 ( $F_{(1,107)}=3.87, p=0.05$ ) for which mean values were highest for degraded location with trash fish (6.88 and 6.92 respectively), and for particulate organic phosphorus a significant effect for diet ( $F_{(1,107)}=8.97, p=0.045$ ), where trash fish had a mean POP value of 3.15µg/L and for pellet, the mean was 2.58µg/L.

The analyses indicate strong seasonal differences, most likely influenced by wet season rainfall and runoff from the adjacent land. Water quality variables were generally higher in October (both 2010 and 2011) when the wet season starts. At the time of each sampling, there were no significant differences in water quality between the locations or diets. This lack of difference may have been influenced by the prevailing current which is likely to have created sufficient mixing to minimise any differences.

Overall, there was no clear treatment effect and trash fish and pellets had an equivalent impact on water quality. Where higher readings of variables were recorded, it can be attributed to seasonal factors, particularly the influence of wet season and associated terrestrial runoff.

Comparison of water quality from the lobster cage area with that of the other four locations in Dam Bay Lagoon (Figure 7) suggests water quality was equivalent or better than the other locations.

### *Sediment quality*

Mean values for all sediment variables are presented in Figures 8 and 9. For sediment variables,

there were significant differences between dates, with some indication of higher values for the February and June readings particularly for organic Phosphorus, Nitrogen and Carbon, and proportion of mud. The higher values of *E. coli* and fungi in the sediment at the October readings can be attributed to seasonal factors, as October coincides with the onset of the wet season with increased terrestrial runoff.

Examining the data at each date for variance between location and diet indicated several significant differences, although none that could be interpreted as a clear treatment effect. It was apparent that sediment quality beneath the cages was not differentially affected by the different diets or by the localised farming activity (i.e. pristine versus degraded).

This conclusion was further supported by the comparison of sediment quality at the four other sites within Dam Bay Lagoon (Figure 9) which shows that sediment at the lobster cage area was equivalent or of better quality (i.e. lower values) than the other sites.

### *Benthic fauna*

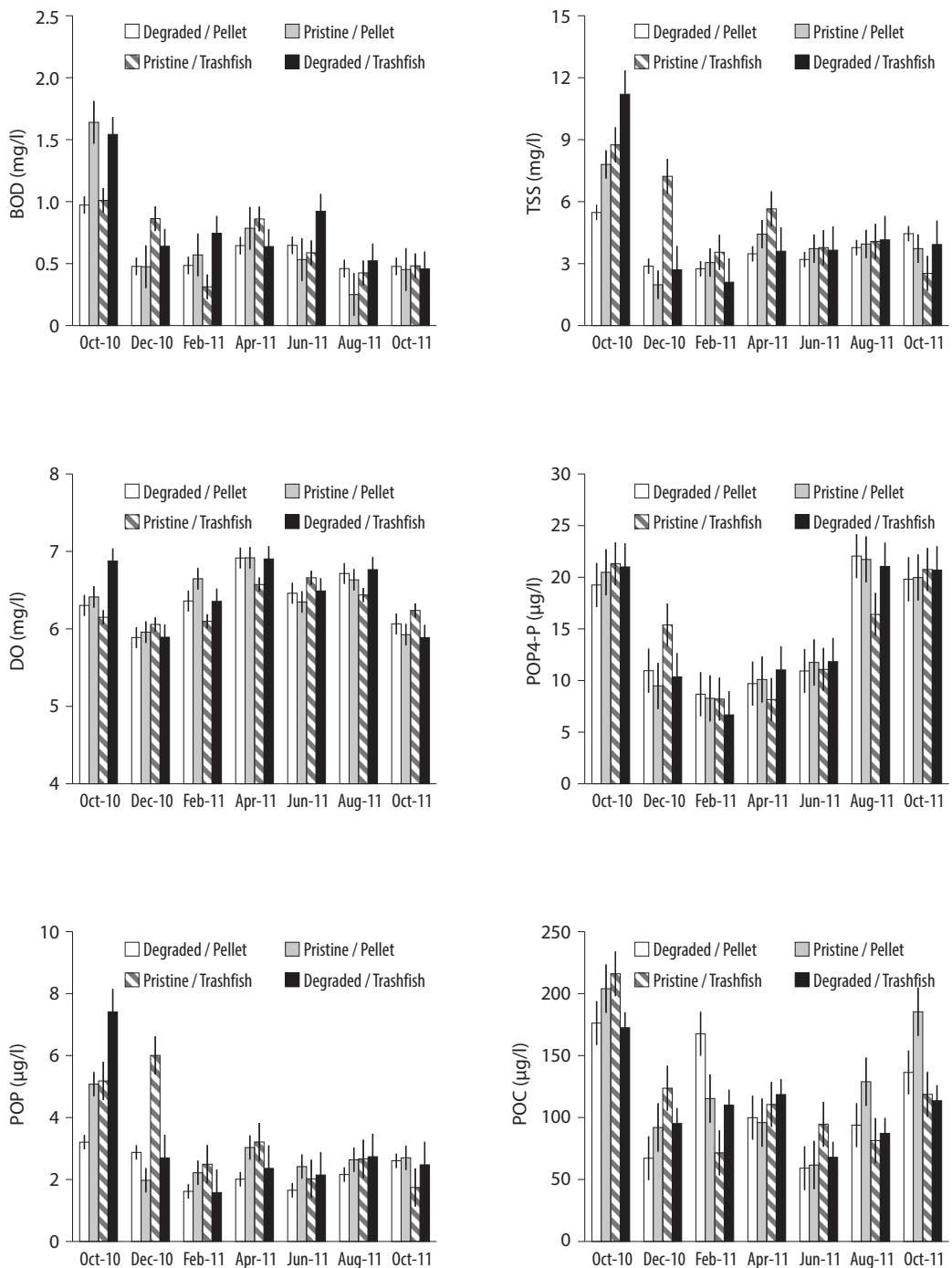
A total of 14,654 macro-invertebrate individuals were isolated from 94 sediment samples over the duration of the experiment. These individual specimens were assigned to 363 taxa, most to genus or species, from 136 families of four phyla of animals, as follows:

- Annelida—182 taxa (Polychaetes only)
- Mollusca—82 taxa
- Arthropoda—78 taxa
- Echinodermata—28 taxa.

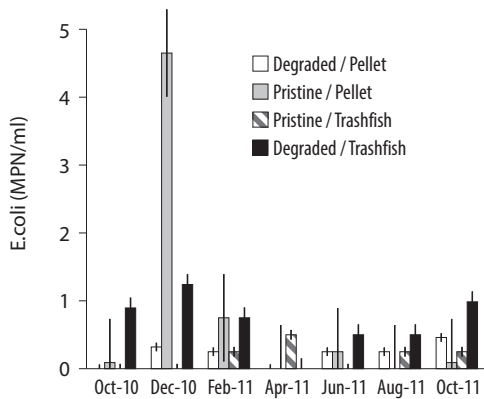
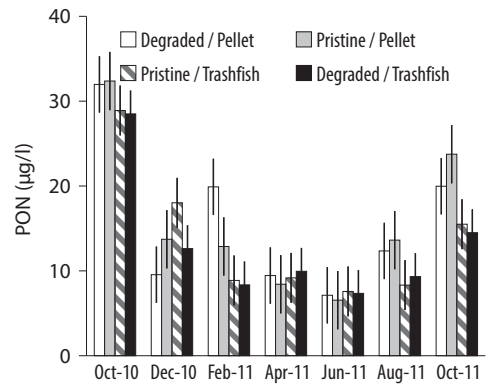
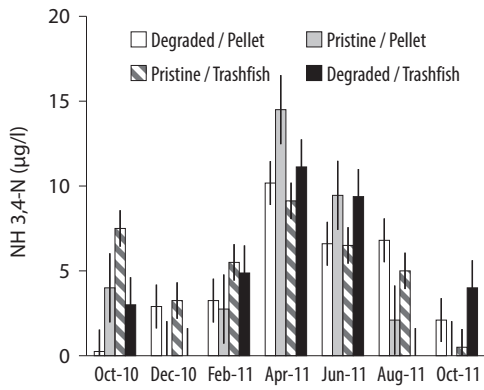
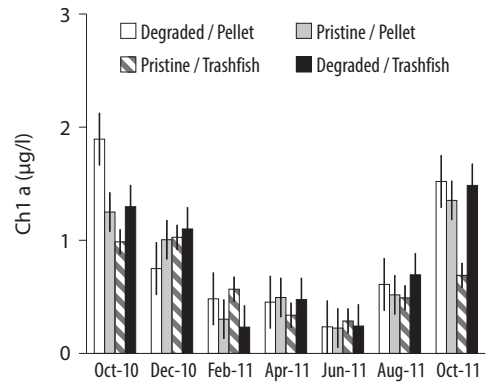
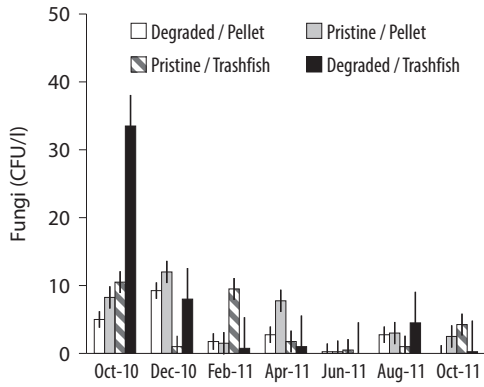
The number of invertebrate species at the lobster sea-cage locations was significantly higher than the surrounding areas in Dam Bay Lagoon. Similarly, the species composition at the lobster cage sites area was significantly different from the surrounding areas in the lagoon. The benthic fauna results also showed the species composition similarity changed over the course of the experiment. The faunal differences between the lobster cage sites and the surrounding bay sites were almost entirely attributed to changes in density and species composition of polychaetes.

**Table 3.** Water quality for the duration of sea-cage experiment

	Oct 2010	Dec 2010	Feb 2011	Apr 2011	Jun 2011	Oct 2011
Temperature °C	29.6	26.0	25.8	25.5	28.3	27.4
Salinity ppt	33.3	33.5	33.5	34.1	34.5	32.1
pH	8.18	8.18	8.14	8.13	8.12	8.13

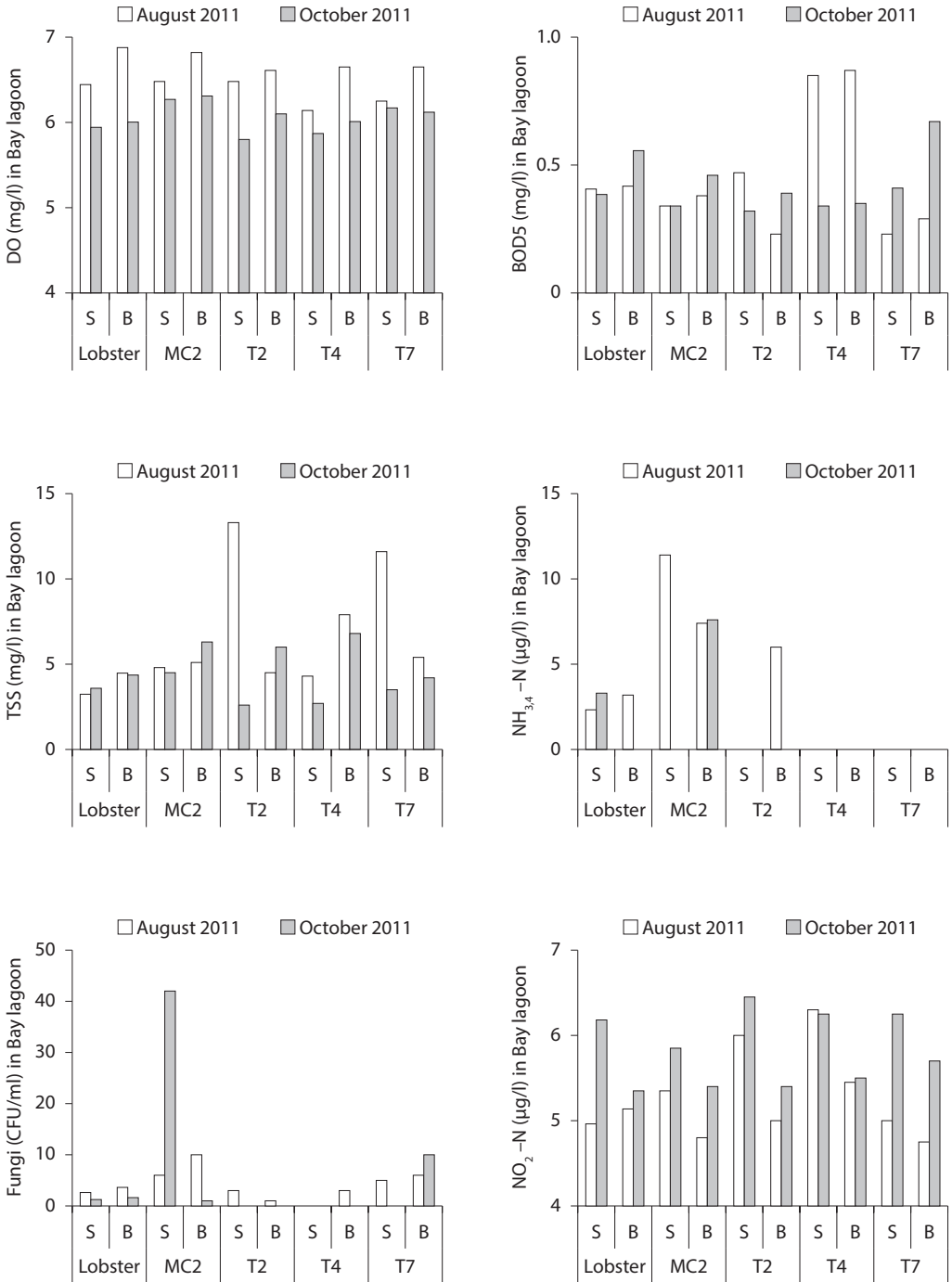


**Figure 6.** Water quality data (mean + SD) at each of the four treatment locations for the duration of the experiment (surface and bottom readings combined) (continued)

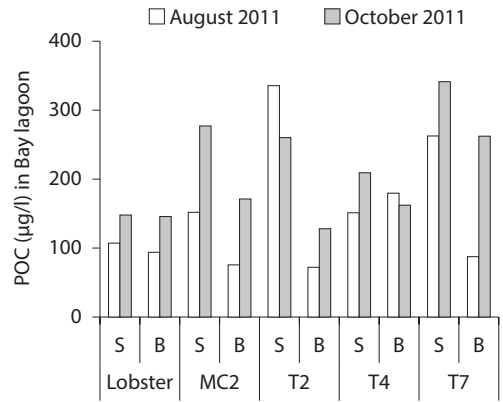
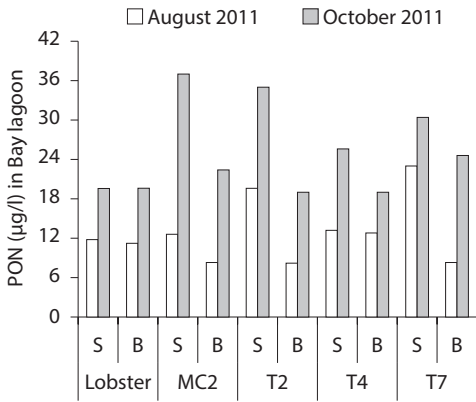
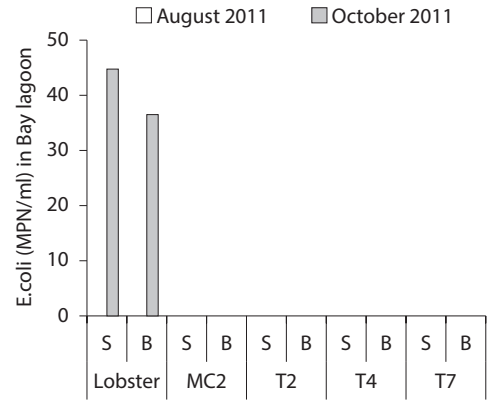
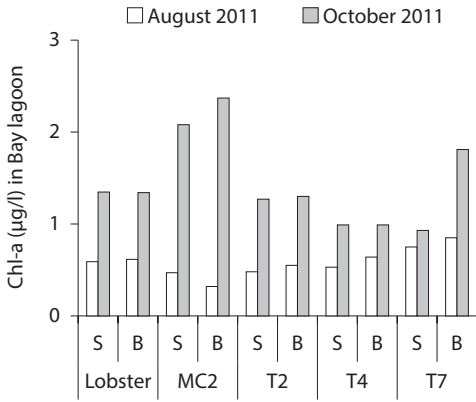
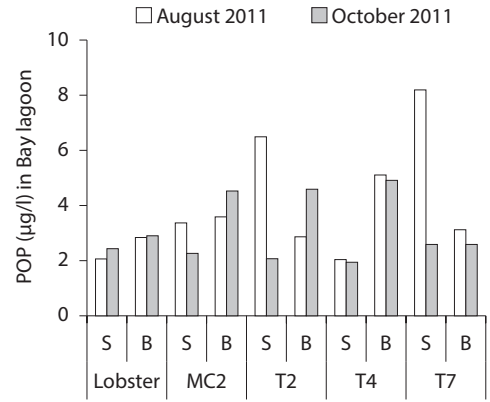
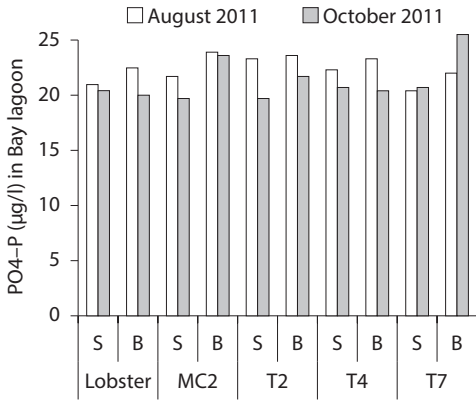


**Figure 6.** (cont'd) Water quality data (mean + SD) at each of the four treatment locations for the duration of the experiment (surface and bottom readings combined)

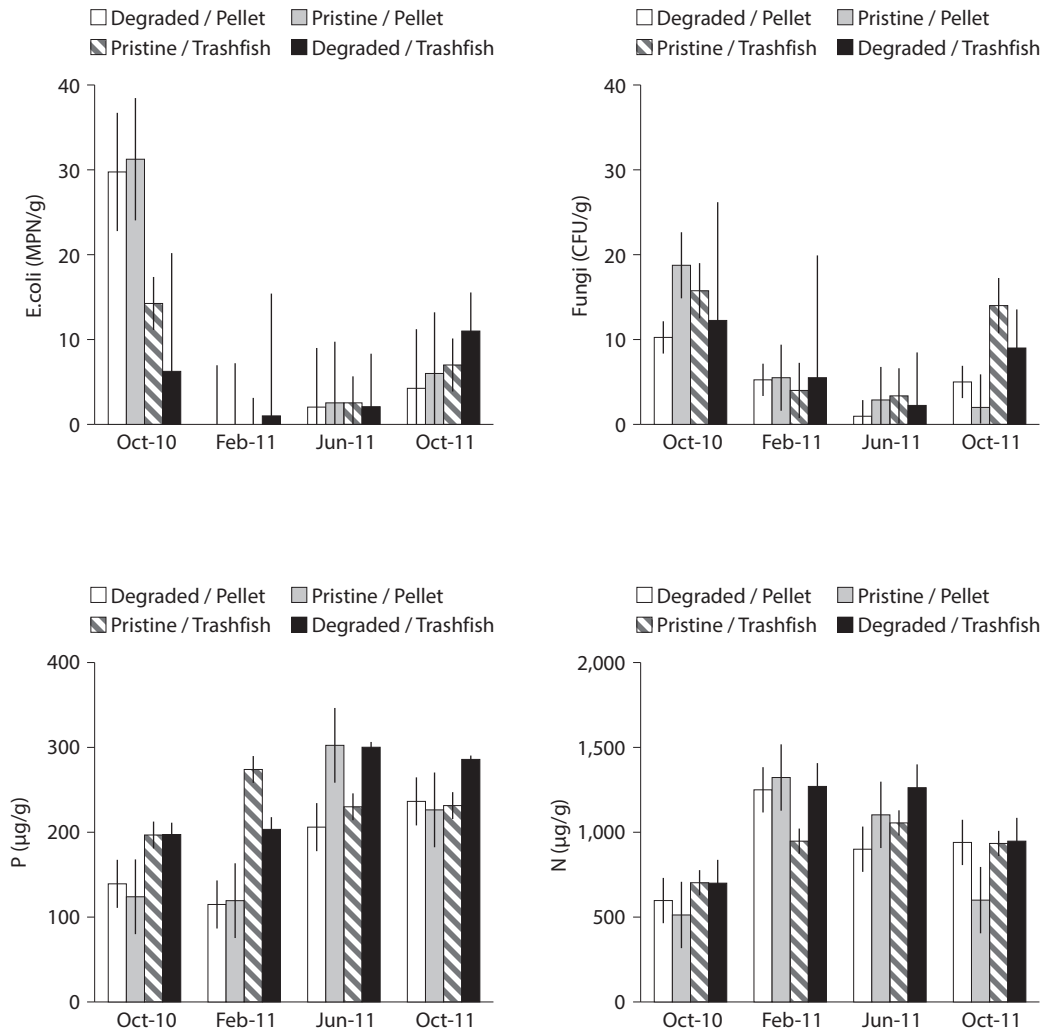




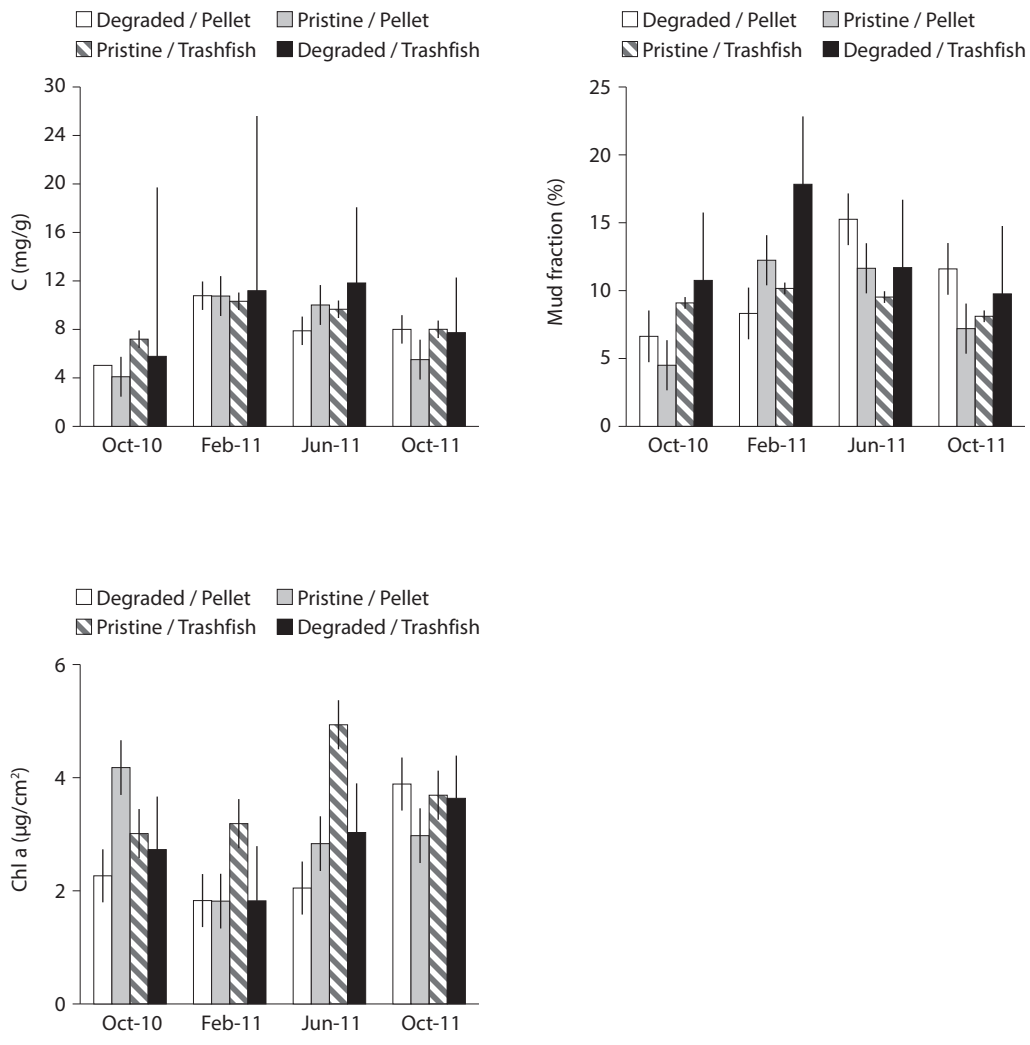
**Figure 7.** Water quality data (mean + SD) at four locations in Dam Bay Lagoon and at lobster cages in August and October 2011. S = surface reading; B = bottom reading (continued)



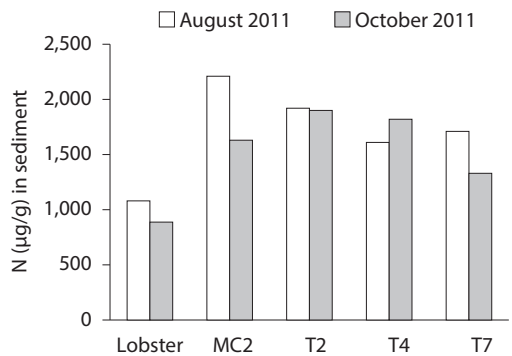
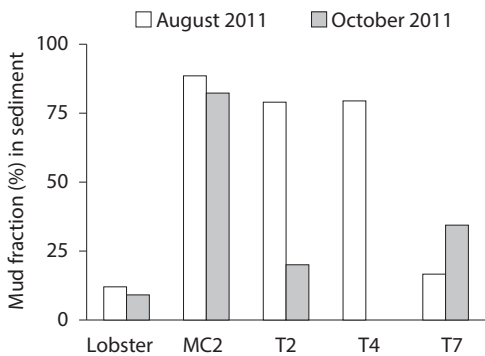
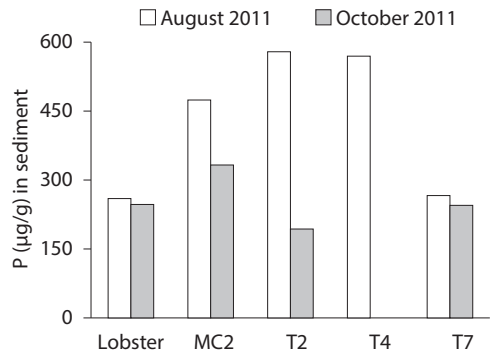
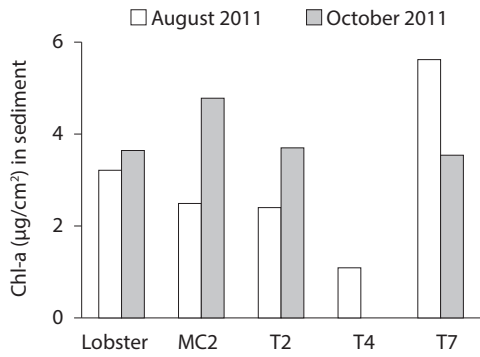
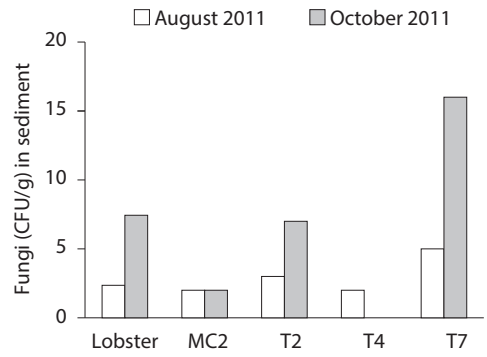
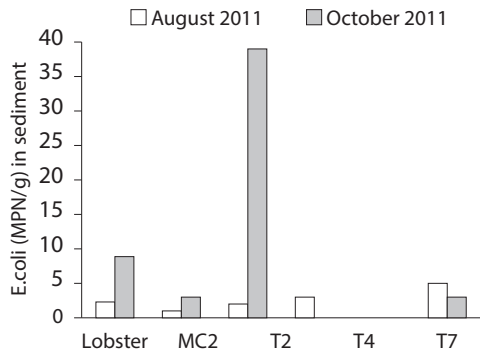
**Figure 7.** (cont'd) Water quality data (mean + SD) at four locations in Dam Bay Lagoon and at lobster cages in August and October 2011. S = surface reading; B = bottom reading



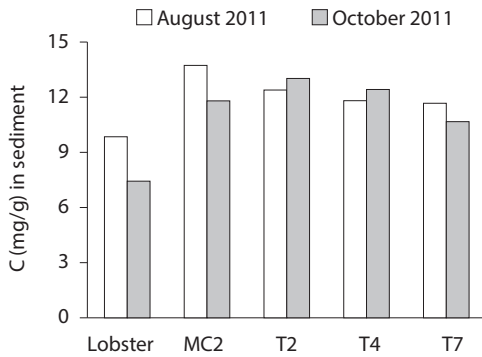
**Figure 8.** Sediment quality data (mean + SD) at each of the four treatment locations for the duration of the experiment (continued)



**Figure 8.** (cont'd) Sediment quality data (mean + SD) at each of the four treatment locations for the duration of the experiment



**Figure 9.** Sediment quality data (mean + SD) at four locations in Dam Bay Lagoon and at lobster cages in August and October 2011 (continued)



**Figure 9.** (cont'd) Sediment quality data (mean + SD) at four locations in Dam Bay Lagoon and at lobster cages in August and October 2011

## Conclusions and recommendations

Although trash fish generated slightly better growth, its effect on survival was equivalent to that of pellets. It can therefore be concluded that a pellet diet can be used as a successful alternative food source to trash fish in culture of *P. ornatus* at commercial scale. The pellet food used (Lucky Star lobster diet) is developmental, and further improvements to its nutritional adequacy and attractiveness are likely.

The FCR's experienced in this experiment (Table 2) suggest considerable wastage of feed. Clearly, an FCR for a high specification 'total diet' pellet should be less than three, and in this experiment it averaged 8.3. In laboratory, tank-based experiments on the same species using the same diet, FCR's under three have been achieved. It is highly likely that a considerable proportion of the pellets used in the experiment were lost from the cages due to wave and current action. Improving the design and application of feeding trays to best retain the pellets may mitigate such loss. The FCR for trash fish in the experiment averaged 55.3 which is somewhat higher than that which is typical for the Vietnam lobster farming industry. Anecdotal data suggest the typical FCR for the industry is in the range of 35 to

40. Nevertheless, based on the FCR's recorded for the experiment and the growth rates and survival achieved, the pellet diet at a cost of A\$5.00 per kg provides a cheaper overall feed cost (\$41.50/kg) than trash fish (\$55.30/kg) which is typically around A\$1.00 per kg. Under improved feeding management, FCR for pellets should be reduced to less than three, which equates to an overall feeding cost of \$15/kg, far cheaper than the industry average of \$35 to \$40/kg using trash fish.

The differences between water quality data from surface and bottom sample layers were negligible, suggesting good exchange of water and no stratification.

The variation of most of the water quality variables appeared to correlate with seasonal factors rather than factors relating to lobster production. Trash fish and pellets appeared to have an equivalent impact on the surrounding water quality, and that impact appeared to be negligible when compared to general background water quality in the surrounding bay. Nevertheless, once improved feeding husbandry for pellets is achieved (i.e. better FCR and therefore reduced feed quantity) pellet feeding is likely to result in less wastage of organic materials into surrounding waters due to the more stable nature of pellets and the significantly lower feed biomass applied.

## References

- APHA 2005. Standard methods for the examination of water and wastewater. 21st Edition. American Public Health Association: Washington D.C., USA
- Austin B. 1988. Methods in aquatic bacteriology. Wiley Chichester: USA.
- FAO 1975. Manual of methods in aquatic environment research. Part I: Methods for detection, measurement and monitoring of water pollution. Food and Agriculture Organization of the United Nations: Rome.
- Parsons T.R. Maita Y. and Lalli C.M. 1984. A manual of chemical and biological methods for seawater analysis. Pergamon Press: Oxford, United Kingdom.
- Thuy N.T.B. Decamp O. Visch S. Nam N.K. 2010. The use of pro-biotic as the supplemental microorganisms into foods in spiny lobster *Panulirus ornatus* brood stock culture at sea cages. International Conference on Recent Advances in Rock Lobster Biology, Aquaculture and Management, 4–8 January 2010, Chennai, India.



## 4.2 Status report of Vietnam lobster grow-out

Tuan Le Anh<sup>1</sup> and Clive Jones<sup>2</sup>

### Introduction

This paper presents information on the status of lobster farming in Vietnam including:

- status
  - history
  - production systems
  - scale and geographical location
- constraints
  - disease
  - mortality of wild caught puerulus
  - trash fish feeding issues
  - availability of sea-cage sites
- opportunities
  - land-based production systems
  - use of pellet feed
  - expansion from *Panulirus ornatus* to *Panulirus homarus*
  - impact of hatchery supply of juveniles.

### Status

The history of lobster farming in Vietnam is summarized in Table 1.

Production systems initially comprised fixed cages with an outer frame made of salt-resistant wood, 10–15 cm diameter and 4–5 m length, which were embedded every 2 m to create a rectangular or square shape. Each cage normally has a cover, and the cage may be resting on or suspended above the sea floor. Cages placed on the sea bed had a layer of sand across the floor, while those fixed off the bottom had a gap of about 0.5 m from the sea bed. The fixed cages were the earliest form of lobster farming systems (Figure 1).

**Table 1.** Key events in the history of lobster farming development in Vietnam

Period	Main events
1975–1985	Annual catch < 100 t; <i>P. ornatus</i> —moderate part of the supply, only modest local demand
1986–1991	Chinese demand for lobsters grew rapidly, especially for <i>P. ornatus</i> >1 kg
1992–1995	Fishers started fattening lobsters; fixed cages; production < 100 t
1996–1999	Fishers started collecting swimming pueruli; production < 300 t
2000–2006	Mainly floating cages; production 500–2000 t; signs of overload
2007–2009	Disease problems; production ~ 860 t (2008/2009); government-led industry planning implemented
2010–2014	The industry recovered; production for 2010 to 2014 about 1,500 t per annum

Submerged cages are also commonly used, particularly for nursery culture of smaller lobsters, although in some instances for grow-out to market size. The frame work is made of iron with a diameter of 15–16 mm. The bottom shape is rectangular or square, with an area normally between one and 16 square metres. The height is 1.0–1.5 m and the cage has a cover and a feeding pipe (Figure 2).

Floating cages are currently the most common production system for lobster grow-out in Vietnam. The cages are either square or rectangular with sides of 2.8–4.0 m with 4.0 x 4.0 m being the most common dimensions. The frame supporting the cages is made from timber planks with length of 3.5–5.0 m, width of 8–15 cm and thickness of 6–10 cm. The floats supporting the frame structure are re-used plastic drums of about 200 L or smaller plastic cans of 20 L capacity (Figure 3).

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Production of lobsters in lined earthen shrimp pond systems, as an alternative to sea-cage farming, was assessed in 2011. Due to high variability in salinity (20–35‰) and temperature (20–34°C) which caused growth inhibition, and at the extremes, significant mortality, earthen ponds are considered unsuitable for lobster production.

The geographical extent of lobster farming in Vietnam is depicted in Figure 4. Vietnam lobster production statistics, in terms of volume, value, productivity and number of sea cages, are presented in Figure 5.



**Figure 1.** Photo of typical fixed lobster farming cage in Vietnam



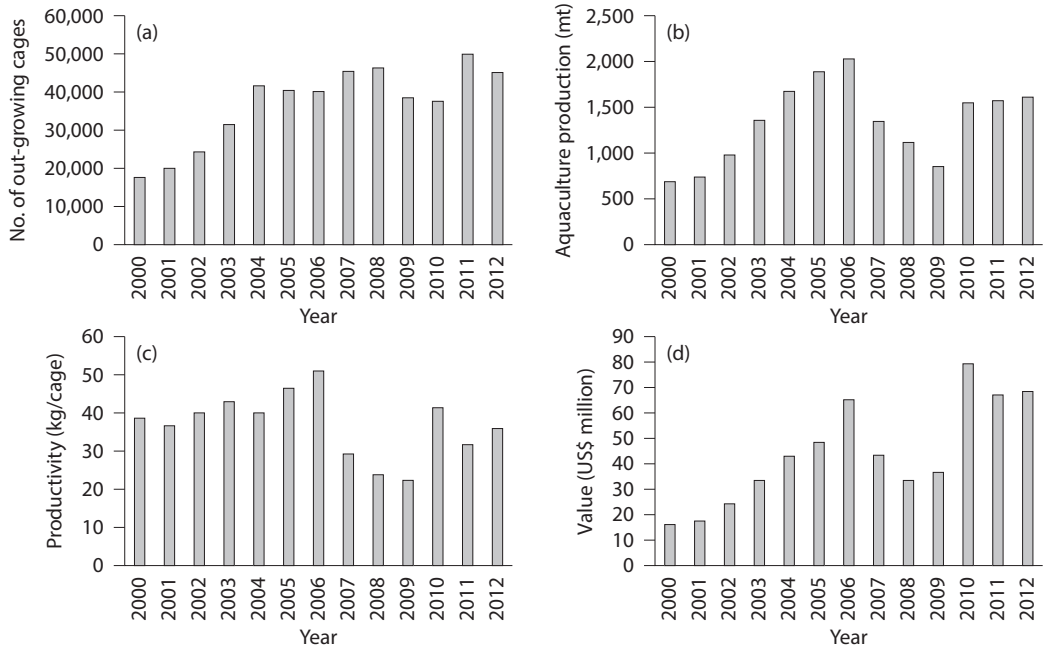
**Figure 2.** Photo of submerged cage for lobster farming in Vietnam



**Figure 3.** Photo of typical floating cages used for lobster farming in Vietnam



**Figure 4.** Map showing areas of lobster seed catch and sea-cage grow-out in Vietnam



**Figure 5.** Production statistics for Vietnam lobster aquaculture, including volume, value, productivity and number of cages

## Constraints

Several health and disease issues impact lobster farming and constrain production. The most common are: red-body disease, milky disease, black gill disease, big head syndrome and separate head syndrome. More detailed information on these is presented in Chapter 5.4.

The proportion of lobster farms impacted by milky disease in 2007 in the farming areas of Ninh Thuan, Binh Thuan, Phu Yen and Khanh Hoa provinces was 61%, 71%, 36% and 31% respectively. Approximately 50% of total production was lost due to milky disease from 2007 to 2009; equating to approximately US\$50 million lost and affecting more than 5,000 households.

Before 2002, the typical survival rate through the grow-out phase was 70%, but during the milky disease outbreak of 2007 to 2009 it dropped to around 50% with approximately US\$30 million lost annually.

The mortality of the captured lobster seed prior to stocking for grow-out is between 40 and 60%. This mortality can be attributed to a variety of factors, including capture technique, handling, transport,

and during the nursery phase to nutrition, husbandry issues. If lobster losses during the capture through nursery phase could be reduced to only 10%, Vietnam's total annual lobster production could be doubled without any increase in catch.

Vietnam's lobster production is currently constrained by suboptimal nutrition, resulting from reliance on a fresh diet of low-value marine species, collectively referred to as trash fish. Trash fish, as used by lobster farmers, is made up of a variety of species including molluscs (~10%) crustaceans (~17%) and fish (~73%). The molluscs comprise squid, cuttlefish and some shellfish. Crustaceans include shrimps, crabs and stomatopods. Fish include lizard fish (Siganidae), big-eye fish (Nemipteridae), pony fish (Leiognathidae) and others. Although an appropriate mix of these trash fish species can provide a reasonable diet, the condition of the fish when applied to the lobster cages is often poor, and over time this diet is deficient in essential nutrients. The food conversion ratio (FCR) of trash fish ranges from 17 to 30 on a fresh weight basis. It is estimated that the excess nitrogen introduced into the sea from uneaten particles and leaching of the trash fish is



between 150 and 410 g/kg lobster produced. Given average annual production of 1,500 tonnes, this equates to ~225 to 615 tonnes of nitrogen released into the environment each year. It is likely that such pollution is contributing to the lobster health issues referred to above.

Further compounding the unsuitability of trash fish as lobster feed is the increasing price of trash fish, which has quadrupled in the past 10 years from an average of US\$0.25 to more than US\$1.00 per kg. A formulated manufactured diet (i.e. a pellet diet) will be necessary to provide optimal and sustained nutrition.

Lobster farming in Vietnam is also constrained by availability of suitable sea-cage sites. Due to competing demands on marine areas, particularly for increasing tourism, many established lobster sea-cage sites have been closed to farming, forcing farmers to relocate or stop farming. Table 2 provides data illustrating this point for the two primary lobster farming provinces of Phu Yen and Khanh Hoa.

## Opportunities

Much of the early research on aspects of husbandry and feed development was conducted in tanks, and growth and survival in such systems was generally good. This suggests that commercial lobster production may be possible in tanks, although the cost of this approach is likely to be relatively high. In Vietnam, there is considerable interest in assessing underutilized shrimp/clam hatchery tank production systems as an alternative for lobster production, which in turn may enable disease issues to be better managed.

As the use of trash fish as a food source would be inappropriate for tank systems, where stocking density may be quite high, pellet feeds will be essential. Such a diet can provide good nutrition and minimal

waste; both of which are necessary for a land-based approach.

There is an opportunity in Vietnam to increase lobster production through expansion beyond the target species, *Panulirus ornatus*. Although this species is likely to remain the major cultured species in Vietnam, the availability of seed of *Panulirus homarus* presents an opportunity to produce a secondary species. Although *P. homarus* fetches a lower market price, it is believed to be more disease resistant and more tolerant to environmental variation. Its growth rate is as fast, if not faster, than *P. ornatus*, at least to a size of 300–500 g.

Having established a successful lobster farming industry, based on natural supply of seed, Vietnam lobster farming could expand significantly if a hatchery supply of reared pueruli could be established. At present, this appears to be some years away, but if it is successful, Vietnam is in a strong position to capitalize.

## Summary and conclusions

The Vietnamese spiny lobster aquaculture industry has developed for nearly 20 years with annual production now consistently about 1,500 t, with a value of more than US\$100 million.

The major constraints to the industry include:

- disease
- mortality of wild caught puerulus
- trash fish feeding issues
- availability of sea-cage sites.

The major opportunities are:

- land-based production systems
- use of pellet feed
- expansion from *P. ornatus* to *P. homarus*
- industry expansion when hatchery supply of juveniles is available.

**Table 2.** Data on sea cages and available sites for lobster farming in Phu Yen and Khanh Hoa provinces of Vietnam

Trait	Phu Yen province	Khanh Hoa province
Maximum number of lobster cages (2008)	19,414	27,000
Current number of lobster cages (2013)	17,100	20,300
Planned number of lobster cages (2015)	18,100	20,000 to 16,000
Current number of farming areas (2010)	3 (Song Cau, Tuy An, Dong Hoa)	4 (Van Ninh, Ninh Hoa, Nha Trang, Cam Ranh)
Planned number of farming areas (2015)	1 (Song Cau) ~320 ha	3 (Van Ninh, Nha Trang, Cam Ranh) ~800 ha

## 4.3 Preliminary assessment of tank-based grow-out of tropical spiny lobsters (*Panulirus ornatus*) in Vietnam

Tuan Le Anh<sup>1</sup> and Clive Jones<sup>2</sup>

### Introduction

Following an assessment of growing tropical rock lobsters in earthen shrimp ponds (both in Australia and Vietnam) which demonstrated that this environment was unsuitable, focus shifted to tank systems, where better control of water quality (particularly temperature and salinity) could be achieved.

ACIAR provided additional funding for this research through a small research activity project: FIS/2011/008 to supplement the assessment of land-based production systems which was the objective of the primary project: SMAR/2008/021. The research undertaken in Vietnam examined the use of typical Vietnamese shrimp hatchery tanks as an alternative to sea-cage farming. The research sought to examine density and shelter in regard to production of lobsters in tanks, and establish baseline production statistics for survival and growth.

### Methods

Three successive experiments were performed over durations of: 60 days (Experiment #1), 120 days (Experiment # 2) and 180 days (Experiment #3), using the same pool of lobsters. Two treatments were applied for stocking density and shelter setting with 4 replicates. Initial mean weight of lobsters in the experiments was  $25 \pm 9.5$  g,  $34 \pm 12.6$  g and  $84 \pm 38.1$  g. Three densities were applied in each successive experiment as follows: Experiment 1: 6, 8, 9.5; Experiment 2: 5, 6.5, 8; and Experiment 3: 4,

5.5, 7 lobsters per m<sup>2</sup>. For each density, there was one of two shelter settings: table shelter or pipe shelter. The table shelter consisted of a PVC rectangle  $25 \times 90$  cm supported off the tank floor by 10 cm legs on each corner. The pipe shelter consisted of a 25 cm length of 5 cm diameter PVC pipe placed on the tank floor. Experiment tanks were of concrete construction,  $2\text{m} \times 2\text{m}$  by 1m deep. For table shelter treatments, one shelter was provided per tank. For the pipe shelter treatments, 5 pipes were provided in each tank.

Lobsters were fed a laboratory-manufactured diet, as per Table 1, which had been used successfully in earlier tank experiments.

**Table 1.** Composition of manufactured diet used in the tank experiments

Ingredient	Percentage
Fresh fish	40
Fish meal	50
Shrimp powder	5
Fish oil	1
Others	4
TOTAL	100

### Results and discussion

Throughout all experiments, water quality remained quite stable, as shown in Table 2. Survival and growth data for the experiments is presented in Table 3. Two-way analysis of variance indicated no significant interaction between treatment main effects ( $P > 0.05$ ) in any of the three experiments. The only significant treatment effect was for density in Experiment #3,

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where survival was significantly less at the highest density than in the lower two densities.

There was no significant difference in the growth of lobsters between shelter settings ( $P > 0.05$ ) (Table 4). Table shelter setting resulted in a significant improvement ( $P < 0.05$ ) in survival.

## Conclusions and recommendations

Tank systems appeared to provide a suitable environment for culture of *P. ornatus* with survival and growth rate equivalent or better to that achieved in sea cages. Growth was unaffected by densities of between four and nine lobsters per m<sup>2</sup>. Survival was affected by density, but only for larger lobsters greater than around 80g. This highlights the weakness of using numerical density alone as a measure of quantity of lobsters that may be supported by the system. More effective may be a combination of density and size; the biomass. In Experiment 3 the

highest density of 7 per m<sup>2</sup> with lobsters at stocking of 84 g provided a biomass of 588 g/m<sup>2</sup>, and at this biomass, survival was significantly less than at the next biomass of 462 g/m<sup>2</sup>. This does not necessarily suggest biomass should be no more than 462 g/m<sup>2</sup>, but that other factors may need to be adjusted to ensure higher survival at higher biomass. For example, shelter can have a significant impact on survival as demonstrated in all three experiments. Of the two shelter types used, table shelters supported higher survival. By optimizing shelter type and availability, biomass in excess of 462 g/m<sup>2</sup> may be supported without impact on survival.

Overall, the experiments support the technical feasibility of tank culture of *P. ornatus*, although further research will be necessary to maximize productivity. Commercial viability of tank culture will necessitate economic assessment that accounts for the specific capital and operating costs of tank culture as compared with sea-cage systems.

**Table 2.** Water quality statistics over the duration of three successive experiments

Variable	Level
Water temperature	26 ± 2.1 °C
Salinity	28 to 34 ppt
pH	7.3 to 8.5
Dissolved Oxygen	4 to 6 mg/L
Nitrite	<0.3 mg/L
Ammonia	<0.03 mg/L

**Table 3.** Mean growth (expressed as specific growth rate) and survival of lobsters in relation to density

	Experiment #1 density			Experiment #2 density			Experiment #3 density		
	6.0	8.0	9.5	5.0	6.5	8.0	4.0	5.5	7.0
SGR %/d	0.47 <sup>a</sup>	0.45 <sup>a</sup>	0.50 <sup>a</sup>	0.72 <sup>a</sup>	0.70 <sup>a</sup>	0.74 <sup>a</sup>	0.78 <sup>a</sup>	0.69 <sup>a</sup>	0.68 <sup>a</sup>
Survival %	77 <sup>a</sup>	81 <sup>a</sup>	87 <sup>a</sup>	84 <sup>a</sup>	83 <sup>a</sup>	77 <sup>a</sup>	86 <sup>a</sup>	82 <sup>a</sup>	75 <sup>b</sup>

**Table 4.** Mean growth (expressed as specific growth rate) and survival of lobsters in relation to shelter

	Experiment #1		Experiment #2		Experiment #3	
	Table	Pipe	Table	Pipe	Table	Pipe
SGR %/d	0.483 <sup>a</sup>	0.466 <sup>a</sup>	0.74 <sup>a</sup>	0.70 <sup>a</sup>	0.713 <sup>a</sup>	0.723 <sup>a</sup>
Survival %	86 <sup>a</sup>	77 <sup>b</sup>	84 <sup>a</sup>	78 <sup>b</sup>	84 <sup>a</sup>	78 <sup>b</sup>

## 4.4 Effects of pellet shape and size on production of spiny lobster (*Panulirus ornatus*)

Hoang Do Huu<sup>1</sup> and Huong Le Lan<sup>1</sup>

### Introduction

Tropical spiny lobster, *Panulirus ornatus*, is a high-value commercial species now farmed in Vietnam. Aquaculture of this species started in the early 1990s, mostly in Khanh Hoa, Phu Yen, Binh Dinh, Ninh Thuan and Binh Thuan provinces of south-central Vietnam. Lobster farming is reliant on the collection of seeds from nature that are then reared in sea cages and fed fishery by-catch or trash fish. The industry has great potential for expansion but is faced with several problems, including over fishing of the trash fish required as food, environmental degradation and disease. These problems all involve, or stem from, the use of by-catch fishery product as food, the cost of which is about 60% of total production.

It is essential therefore to reduce the reliance on trash fish as the food source for lobster farming, and this can be achieved through the adoption of pellet feeds. Pellet feeds are likely to reduce the overall cost of feed, reduce environmental degradation, reduce incidences of disease and improve farmers' profitability.

Baseline nutrition information for *P. ornatus* has been gathered through earlier research (Barclay et al. 2006; Hung et al. 2010; Irvin and Williams, 2009; Williams 2007; Williams 2009) which provides robust data on protein, lipid, cholesterol, fatty acid, vitamin, carotenoid and mineral requirements. From this data, laboratory manufactured diets have been formulated. In testing these developmental diets, issues have arisen in relation to losses due to sea-cage design, wave action and currents. Further, there have

been problems with pellet water stability, hardness, size and shape; also contributing to losses.

An experiment was designed to examine the effect of pellet shape and size on growth, mortality and body composition of lobster. To achieve this, a commercial lobster pellet formulation which was available in different shapes and sizes was used.

### Methods

Five pellet types were used: a noodle shape in 1.5 mm and 3 mm diameter size; and a disk shape in 3 mm, 5 mm and 7 mm diameters. These five pellet diets were applied to juvenile lobsters in small sea cages alongside a control of typical by-catch fishery food.

Thirty-six cylindrical cages of 1,200 mm in diameter and 800 mm in height were used, made from 2 mm nylon mesh netting stretched over a frame consisting of two circles of 10 mm steel rod held apart with four timber supports. Six replicates of the five pellet types plus one control diet were applied. Juvenile lobsters that had previously been fed trash fish were purchased for the experiment. Mean size at stocking was 60 g, with 20 lobsters stocked to each cage (i.e. 20/m<sup>2</sup>). Lobsters were fed to satiation twice per day. Carapace length and weight of all individuals was measured at stocking, after one month and at two months, when the experiment was terminated. Two lobsters from each treatment were sacrificed at harvest to measure body composition (protein and lipid).

### Results and discussion

Growth expressed as mean weight over the duration of the experiment is presented in Figure 1 and survival in Figure 2. There was a significant difference

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in mean weight at harvest, with lobsters fed the trash fish diet around 100% heavier (mean 137 g) than those fed the commercial diet (73 to 83 g). A significant difference in survival was also measured, with lobsters fed 1.5 mm noodle and trash fish having a higher survival (mean 90%) than lobsters fed the other diets (mean 69%).

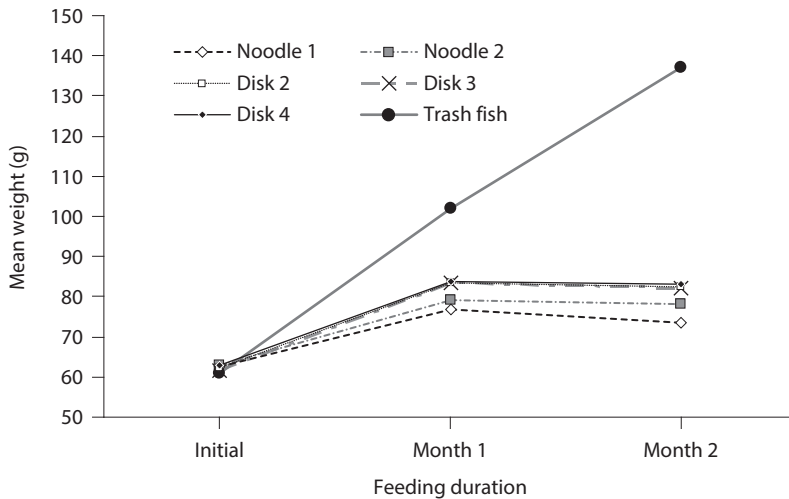
Observation of the lobsters at harvest revealed those fed trash fish were not only bigger on average, but had clean shells as compared with lobsters fed the pellet diet. The latter tended to have shells fouled with barnacles and coralline algae, suggesting suboptimal moult rate.

Proximate composition of body tissue revealed significant variation for total protein and lipid, although no clear correlation between diet and level. That is, the trash fish diet did not generate body composition consistently different to the pellet diet. The variation

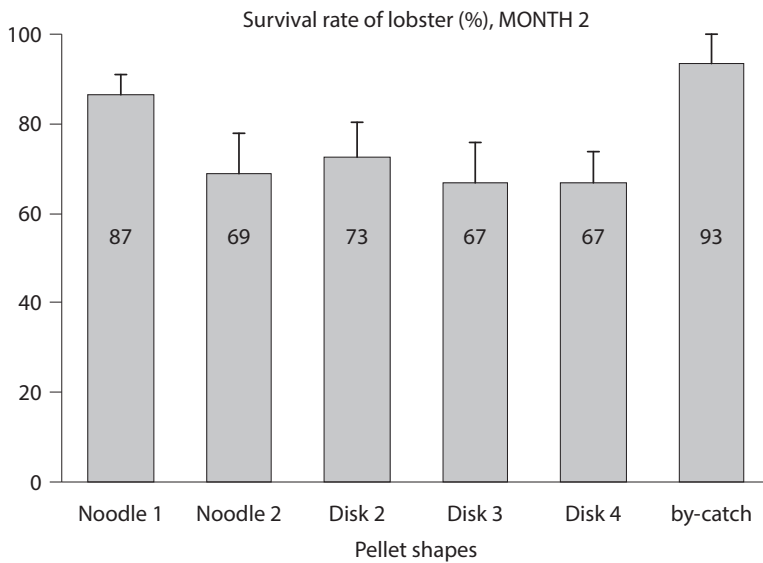
measured was therefore attributed to high variability between individuals, which may relate to moult stage, and also to the low sample size.

## Conclusions and recommendations

Overall, the pellet diet appeared to be nutritionally deficient, supporting poor growth and relatively poor survival compared with trash fish. This deficiency is likely to have masked any affect that the pellet form and size may have had. Of the five pellet types, the 1.5 mm noodle supported better survival than the other forms. This compares positively with observations of feeding behavior that suggest lobster feed ingestion is most effective with a small diameter noodle form diet. Nevertheless, the diet formulation of the pellet will need to be improved to make a more authoritative assessment of the effect of pellet form.



**Figure 1.** Mean weight of lobsters fed one of six diets over two months



**Figure 2.** Survival of lobsters fed one of six diets over two months

## References

- Barclay M.C. Irvin S.J. Williams K.C. and Smith D.M. 2006. Comparison of diets for the tropical spiny lobster *Panulirus ornatus*: astaxanthin-supplemented feeds and mussel flesh. *Aquaculture Nutrition* 12: 117–125.
- Hung L.V. Khuong D.V. Phuoc T.V. and Thao M.D. 2010. Relative efficacies of lobsters cultured using pellet feeds and “trash” fish at Binh Ba Bay, Vietnam. Network of Aquaculture Centres in Asia-Pacific website <http://www.enaca.org>
- Irvin S.J. and Williams K.C. 2009. *Panulirus ornatus* lobster feed development: from trash fish to formulated feeds. Pp 147–156 in ‘Spiny lobster aquaculture in the Asia-Pacific region’, ed. by K.C. Williams. Proceedings of an international symposium held at Nha Trang, Vietnam, 9–10 December 2008. Australian Centre for International Agricultural Research: Canberra.
- Williams K.C. 2007. Nutritional requirements and feeds development for post-larval spiny lobster: A review. *Aquaculture* 263: 1–14.
- Williams K.C. 2009. Nutritional requirements of juvenile *Panulirus ornatus* lobsters. Pp 131–146 in ‘Spiny lobster aquaculture in the Asia-Pacific region’, ed. by K.C. Williams. Proceedings of an international symposium held at Nha Trang, Vietnam, 9–10 December 2008. Australian Centre for International Agricultural Research: Canberra.

# 4.5 Bio-economics of spiny lobster farming in Indonesia

Liz Petersen<sup>1</sup>, Clive Jones<sup>2</sup> and Bayu Priyambodo<sup>3</sup>

## Introduction

This paper presents information on the bio-economics of lobster farming in Indonesia based on a farmer survey conducted in 2011, the results of which were subsequently published (Petersen et al. 2013). The purpose of the survey was to conduct preliminary bio-economic analysis of lobster grow-out in Indonesia to determine the sensitive factors of economic feasibility and the implications for the industry's growth.

Lobster is a highly-prized product, with most production from capture fisheries. In recent years, culture of lobster commenced in Vietnam, and by 2011 production of farmed lobster had grown to 1,600 tonnes with a value of US\$80 million. Expansion of production in Vietnam and elsewhere is constrained by availability of wild-caught puerulus and feed. Demand exceeds supply, resulting in relatively high price for lobster seed.

As efforts are made to establish lobster farming in Indonesia, using the Vietnam approach, it is prudent to assess the bio-economics of production in Indonesia. The small lobster farming communities of south-east Lombok provide such an opportunity. Lobster farming began here in the early 2000s, and when the survey was performed in 2011, grow-out production was estimated to be 60 tonnes with a value of US\$2 million. The primary species farmed was *Panulirus homarus*, the scalloped or sand lobster. The typical grow-out period was eight to 10 months, during which they grow from an average of 13 to 120 g. The survival rate over the grow-out period was

estimated to be 70%, and the price given to farmers was US\$35 to \$40 per kg.

## Methods

Face-to-face interviews of 11 lobster farmers were performed with five farmers at Telong Elong/Gili Belik and six at Ekas Bay, using a questionnaire with 42 questions. Bio-economic modeling involved inter-relating a biological model of lobster growth with an economic model of costs and returns.

## Results and discussion

Lobster seed (puerulus) are captured via traps which consist of cement bag bow-ties fastened to nets hung from cages or frames. These nets are raised twice a day and the pueruli are placed in nursery cages. Lobster fishers or collectors sell a portion (~65%) and retain the balance for their own nursing and/or grow-out. Price per seed in 2011 was US\$0.52/piece.

The nursery culture involved feeding low-value fish (sardines) for approximately 3 months to produce juveniles of 2 to 4 g individual weight which were then on-sold for US\$1/piece or retained for further grow-out. As demand for pueruli has increased, price has also increased, and by late 2014 it reached US\$2 per piece for pueruli and higher still for juveniles. This price increase has had a dramatic negative affect on local grow-out as farmers can no longer afford to buy the seed. Consequently they have focussed their attention on catching and selling seed to middlemen who are exporting the seed to other countries such as Vietnam, where they are then on-grown to market size.

Statistics on seed price, stocking density and total number stocked for grow-out at the two Lombok locations in 2011 are provided in Table 1 along with

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comparative figures for Vietnam. The relatively high price of seed in Vietnam is driving the demand for export from Indonesia, which in turn is constraining local grow-out. The much lower stocking density and total numbers stocked in Lombok compared with Vietnam is similarly a result of availability and the increasing price which is a further constraint to the viability of their farms.

Lobster grow-out farmers in Lombok use low-value finfish as feed for the lobsters, with 13–40% of farmers purchasing the fish from others, and the remainder catching their own. This finfish is bought at a price US\$0.46–58/kg, but the quantity used was not accurately known by the farmers of Telong Elong / Gili Belik as no measurements or records were made. The Ekas Bay farmers estimated that lobsters under 13g received around 1g of food per lobster per day, and lobsters over 13 g received 7 g per lobster per day. This relates to a food conversion ratio (FCR) of approximately 11.5 which seems quite low. It is therefore likely that greater feed quantities than those estimated are being used.

Lobster farmers were asked about their perceptions of pellet feeds for lobster. They were uniformly positive about adapting to pelleted diets. Most farmers did not know the relative prices of pellets versus low-value finfish. Farmers from Telong Elong / Gili Bilik expected pellets to lead to faster growth rates while Ekas Bay farmers did not know. Pellets are not currently available but farmers are willing to try them.

Discussion about lobster feeding indicated that nutritional deficiencies are evident in current feeding practices. The use of molluscs and crustaceans to supplement the fish is needed to improve nutrition. Pellets have the potential to improve lobster quality and provide a number of other benefits, including a reduction in local pollution and water quality degradation, longer shelf life, and potentially more stable supply.

The cost structure of Lombok lobster farms is presented in Table 2 and economic statistics presented in Table 3.

A sensitivity analysis was performed using the Ekas Bay farmers, whose bio-economic data revealed

**Table 1.** Statistics for seed price and stocking in Lombok in 2011 with comparative values for Vietnam

	Ekas Bay	Telong Elong/ Gili Belik	Vietnam
Average price of seed (US\$/seed)	0.43	0.95	13.00
Average stocking density (lobsters/m <sup>3</sup> )	24	7	93
Average number of seed stocked	1,500	520	2,000

**Table 2.** Cost structure of lobster nursing and grow-out in Lombok (% of total costs unless otherwise stated)

	Puerulus nursing	Grow-out	
	Ekas Bay	Telong Elong/ Gili Belik	Ekas Bay
% of total cost	100	100	100
Seed	0	22	24
Feed	0	5	3
Cage	10	4	2
Other capital items	24	25	23
Other variable items	61	17	17
Interest	0	22	25
Contingency	5	5	5
Total cost (US\$/crop)	2,000	2,300	2,700
Cost/kg production (US\$/crop)	47	44	22

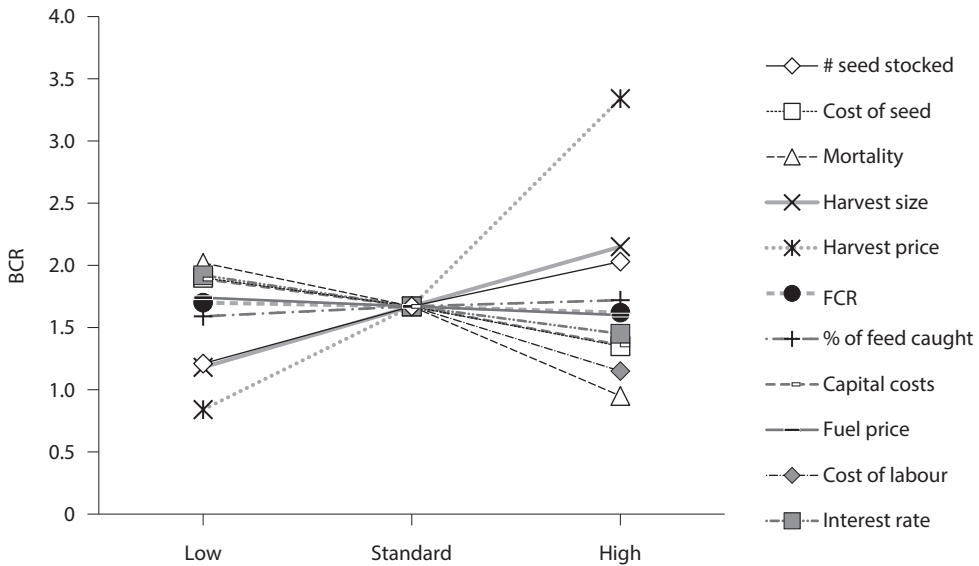
a cost benefit ratio of 1.7 (Figure 1). The model was particularly sensitive on the downside to harvest price and mortality. Harvest price is not expected to diminish given the strong demand for lobsters but mortality during grow-out must be kept to a minimum to maximise profitability. There was considerable upside opportunity revealed in the analysis, particularly for harvest size, demonstrating there are strong opportunities for greater profitability.

## Conclusions and recommendations

Lobster grow-out is a viable alternative for Indonesian coastal smallholders. Returns to investment are modest and dependent on seed price and availability as well as access to credit. There is some economic risk, in particular, susceptibility to disease epidemics.

**Table 3.** Economic statistics for lobster farming in Lombok

Annual statistics	Puerulus nursing	Grow-out	
	Ekas Bay	Telong Elong / Gili Belik	Ekas Bay
Total revenue (US\$/crop)	14,000	2,100	4,400
Net revenue (US\$/crop)	12,000	-190	1,800
Benefit cost ratio	6.8	0.92	1.70



**Figure 1.** Sensitivity analysis of the bio-economic modelling of tropical rock lobster farming in Lombok, Indonesia



The economic potential suggests significant benefits would be realized for delaying harvest (currently 100 g) until lobsters are larger (approximately 300 g) and shifting from low-value finfish to practical and functional pelleted diets. It is encouraging that farmers are willing to try pellets as these have the added benefit of reducing environmental impact.

Further research is required, including a continuation of regular farmer household surveys to capture the changing bio-economic statistics as the industry develops and expands. Identification of policy and institutional constraints should be added to assessments to assist in creating the best environment for

industry growth, which in particular needs to address improving access to inexpensive credit.

Research is also required to better understand, minimise and manage risk, and the impacts of hatchery-produced seed availability should the technology be commercialized. Lastly, it would be instructive to gather accurate annual lobster production statistics to monitor the growth of this new and exciting industry.

## References

- Petersen E.H. Jones C. and Priyambodo B. 2013. Bioeconomics of spiny lobster farming in Indonesia. *Asian Journal of Agriculture and Development* 10: 25–39.



## **5. Industry Development**

# 5.1 Assessment of spiny lobster farming in New Caledonia

Manuel Ducrocq<sup>1</sup>

## Introduction

New Caledonia is a French overseas territory with local autonomous government, located in the South Pacific (21°S 165°E) with a geographic area of 19,000 km<sup>2</sup>, a population of 256,000 and a GDP of US\$ 9.9 billion.

New Caledonia has one of the world's three most extensive reef systems, with low human and fishing pressure, very high diversity and endemism. UNESCO listed New Caledonia barrier reef on the world heritage list in July 2008, and a project to create a marine protected area that includes the entire exclusive economic zone (EEZ) of New Caledonia is currently being developed.

Currently, New Caledonia has a fishery production of 3,575 tonnes per annum and an aquaculture production of 1,562 tonnes, primarily from shrimp. Aquaculture provides a significant opportunity for the country, and its expansion is widely supported. Diversification of aquaculture is a key to success, and there is existing production of microalgae, sea cucumber, clam, oyster, lobster and finfish (snapper, grouper, and rabbitfish).

This paper summarises recent activity in support of developing lobster aquaculture in New Caledonia.

## Methods

To assess and encourage lobster aquaculture, a pilot project was established based on collection of naturally settling lobster seed, and their grow-out in sea-cage systems. The aim of the project was to: identify potential seed capture sites; implement trials with fresh feed and dry pellets to compare growth

and mortality; identify market response to farmed product; and quantify threshold profitability of spiny lobster farming in New Caledonia.

Seed collecting activity included identification of different locations (Figure 1) to collect seed and determine seasonality of their availability. Ten sites were assessed around New Caledonia within seven different bays, using two collecting traps at each location (net bundles and timber poles with holes—see Figure 2). There were 30 collectors per line, and the study extended over two years. Collectors were checked every two weeks to retrieve and count the lobster seed.

A series of grow-out trials were performed in a sea-cage system as depicted in Figure 3. Large cages had a volume of 27 m<sup>3</sup>, and smaller cages were 0.5 m<sup>3</sup>. Trial setup data is summarised in Table 1. Captured seed lobsters were stocked to the cages and fed either fresh feed (tuna by-products) or a combination of shrimp and finfish pellets.

## Results and discussion

In 2011, 2,037 lobster seed were captured, and in 2012, 1,025; 95% of which were captured at one site, Ouano Bay (Figure 1) from eight lines with 120 of each habitat trap type. All pueruli captured were *Panulirus ornatus*. There was distinct seasonality in the catch, with most puerulus caught between April and August, the winter period (Figure 4).

Table 2 presents results of an initial grow-out trial using sub-adults of around 170 g, fed with a shrimp brood stock diet. Although survival was reasonable, growth was very low and food conversion ratio (FCR) very high. Density appeared to have a significant effect on survival. The results did not support profitable production.

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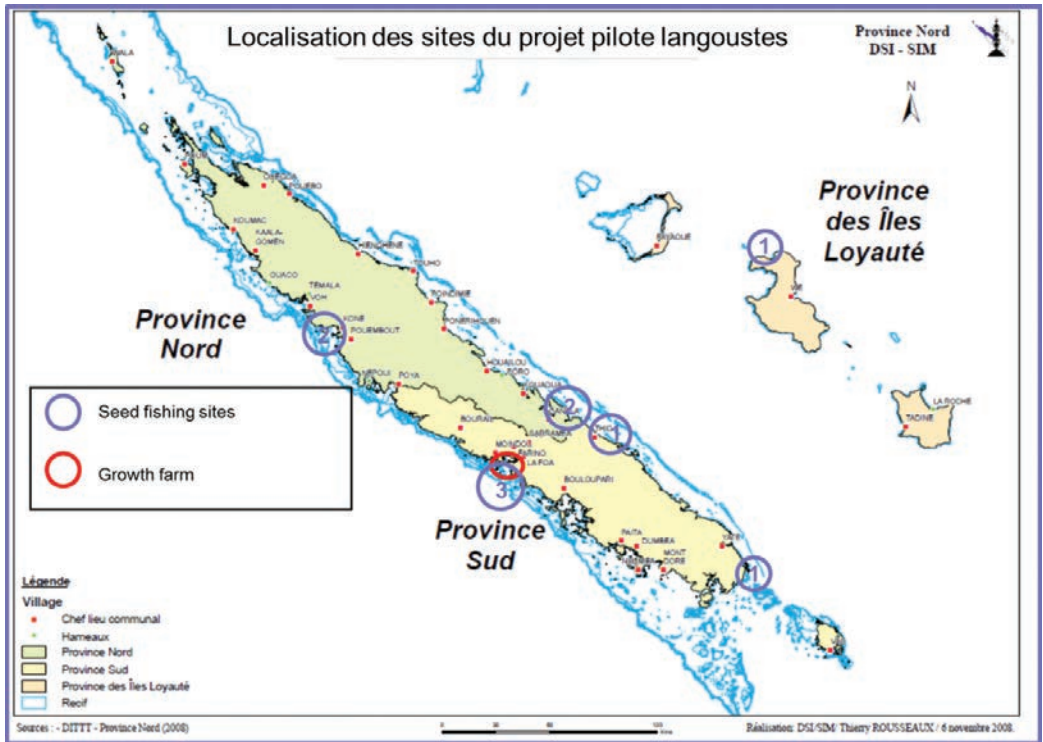


Figure 1. Map of New Caledonia showing sites for lobster seed catch assessment, and grow-out site at Oanao Bay



Figure 2. Two habitat trap types used to catch lobster seed

Grow-out trials using captured pueruli in year one examined production using different diets (fresh tuna by-product and finfish pellets). Survival was around 50%. Growth results from the first experiment are illustrated in Figure 5. Growth over four months was very low and the production was considered to be unviable.

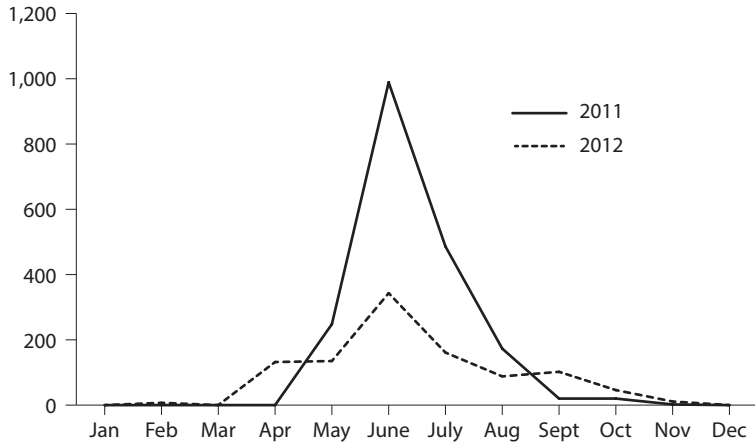
In year two, a puerulus grow-out trial used diets of tuna by-product and a laboratory formulated pellet. Results are depicted in Figure 6. Although survival was higher than in the year one trial, growth was lower. Results again did not support viable production.



**Figure 3.** Photo of sea-cage system used for grow-out trials

**Table 1.** Summary of the set-up for grow-out trials

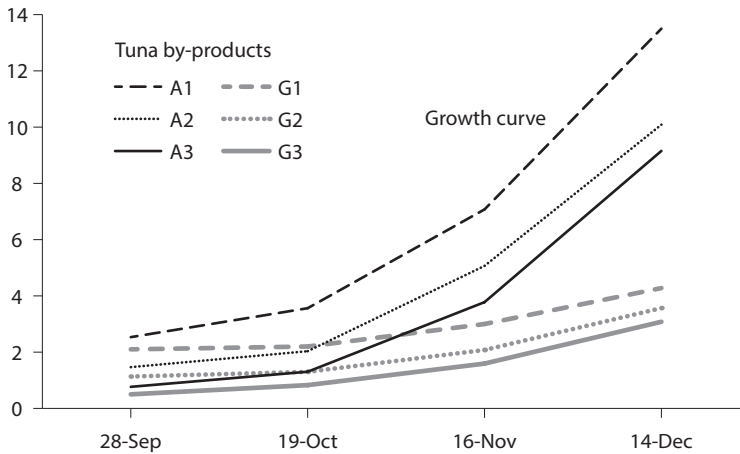
Trial	System	Density	Diet	Lobster weight	Duration
1	Large cage 27 m <sup>3</sup>	1.1/m <sup>2</sup>	Tuna by-product	280 g	4 months
			Shrimp pellet	306 g	
2	Large cage 27 m <sup>3</sup>	2.6/m <sup>2</sup>	Shrimp pellet	mean weight 170 g	9 months
		1.1/m <sup>2</sup>			
3	Small cage 0.5 m <sup>3</sup>	30/cage	Tuna by-products	mean weight 2 g	4 months
			Finfish pellet		
4	Small cage 0.5 m <sup>3</sup>	30/cage	Laboratory made pellet	7 g	5 months
				14 g	
			Tuna by-products	7 g	
				14 g	



**Figure 4.** Seasonality of lobster seed catch in New Caledonia

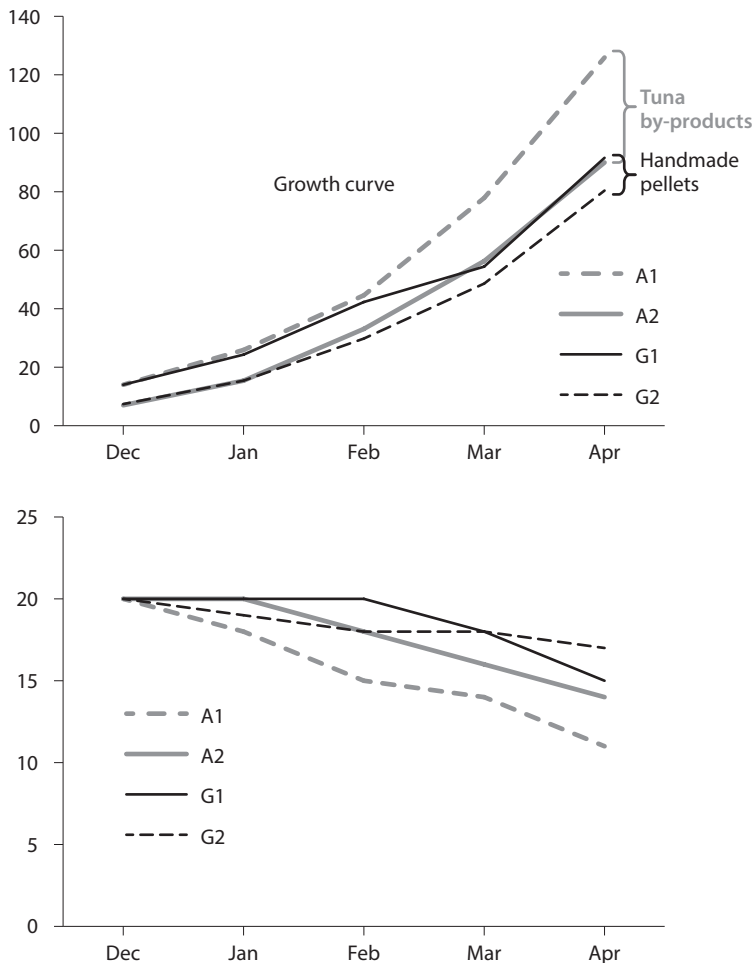
**Table 2.** Results from feeding lobsters with shrimp brood stock diet

Number of lobsters stocked	117	51	52
Density (m <sup>2</sup> )	2.6	1.1	1.1
Initial Biomass (g)	23,100	6,250	8,500
Final Biomass (g)	24,200	11,966	10,400
Growth (g/day)	0.77	1.02	0.68
Gain biomass (kg)	1.04	1.9	1.22
Mortality	32%	12%	27%
FCR	37	20	26



**Figure 5.** Growth of *P. ornatus* pueruli fed either tuna by-product or finfish pellets





**Figure 6.** Growth (top) and survival (bottom) of *P. ornatus* lobsters fed either tuna by-product or pellet diet in sea cages

## Conclusions and recommendations

Although a small seed resource of *P. ornatus* was identified, much higher numbers will be required to support a grow-out industry. Growth trials were significantly impacted by high mortality and low growth, resulting in productivity that cannot be considered commercially viable. It is possible nevertheless, that improving the diet will improve both survival and growth rate.

Further research should focus on optimization of seed collection, particularly identifying the most productive sites, and on reducing mortality, increasing growth and reducing feed cost.

Training of prospective seed fishers and lobster farmers will be necessary, and the first exercise to meet this requirement was performed when a group of New Caledonia operators participated in a training program at the Marine Aquaculture Development Centre in Lombok, Indonesia in April 2013.

## **Postscript**

In 2013, some 1,300 lobster seeds were captured and used for a grow-out trial, but a storm delivering heavy rainfall caused a significant drop in salinity at the grow-out site, causing 95% mortality. This highlights the importance of site selection where terrestrial run-off such as this cannot occur.

## 5.2 Tropical lobster aquaculture: Bridging the gaps and forging new frontiers

Jason S. Goldstein<sup>1,2</sup>

### Introduction

Based on information covered in a previous conference, the key topics for this paper are:

- sustainable lobster aquaculture
- improving nursery culture
- lobster grow-out systems
- lobster grow-out feeds and practices.

The most important knowledge gaps to be addressed through research and development are:

- phyllosoma culture
- ways to better enhance puerulus culture and grow-out
- environmental variables (e.g. temperature, light) of importance.

The new frontiers where breakthroughs will be critical include:

- feed and wild diets
- hatchery conditioning
- novel tank designs.

The information presented in this generalized summary is drawn from a wide variety of previous and ongoing research activities. This includes work with North American clawed lobsters (*Homarus americanus*) in New England (and an associated *H. americanus* research hatchery) and with tropical lobster projects in Mexico, Brazil, New Zealand and in the Florida Keys. Of particular relevance are the pilot-scale research activities in Japan with Dr Hirokazu Matsuda.

There is broad acceptance that lobsters are both ecologically and economically important. Of the

more than ~150 known species (spiny, slipper, clawed) there are few species that are of significant commercial value (Holthuis 1991; FAO 2014). In general, lobsters have complex life cycles that may include a protracted larval or egg stage (Phillips and McWilliam 1986). Lobsters are large, abundant and play a significant ecological role as predators within the communities they inhabit. Lobsters further support the livelihoods of many coastal regions through fishing and to a lesser extent through endeavors in aquaculture.

Despite the strong interest in further developing lobster aquaculture, at present, the volume of production is negligible (Figure 1). This is, however likely to change within the next few decades. One of the most influential reasons is the current status of wild fisheries for lobsters throughout the world. With only a few exceptions, most quantitative indicators (e.g. CPUE, catch, recruitment) suggest that lobster stocks are in decline, as measured by total landings and biomass of spawning stocks (Chavez 2009). These shortcomings provide the impetus for the improvement of current projects and the design and development of future lobster aquaculture efforts.

### Lobster aquaculture

Tropical spiny (palinurids) lobster species have garnered the most interest as candidates for commercial aquaculture over the past three decades (see reviews in Booth and Kittaka 2000; Jeffs 2010) for two primary reasons: 1) these species demand consistent and strong interest among international seafood markets; and 2) empirical data along with various pilot studies have created a wealth of biological data (e.g. growth, larval duration, feeds etc.) that contribute to, and advance further development (Jeffs and Davis 2003;

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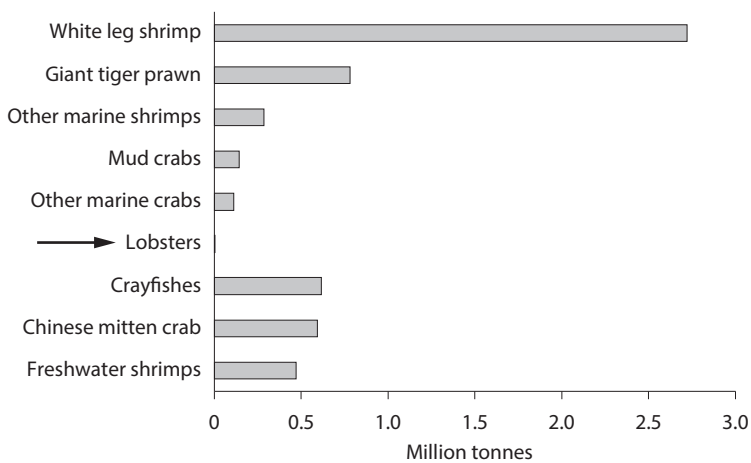
Jeffs 2010). Of the various life-history stages within the spiny lobster life cycle, the two that are of most interest in the expansion of lobster aquaculture are the pelagic phyllosoma (larval stage) and the transitional post-larva (puerulus) stage. Understanding the biology and the rearing requirements of the phyllosoma stage are pivotal to unlocking the commercial potential for large-scale, fully sustainable commercial lobster hatchery production from egg through grow-out.

The phyllosoma ('leaf-like') stage in spiny lobsters represents the larval phase and aptly describes the very delicate, dorso-ventrally flattened and transparent body. Across all spiny lobsters, phyllosomas spend between four and 12 months in the plankton (depending on species) and can undergo dozens of molts, instars, and intermediate stages (Phillips et al. 2006). It is this life-history phase that represents the greatest bottleneck to establishing fully-fledged lobster aquaculture. Current obstacles to successful large-scale phyllosoma production include: improvements to water quality; the development of nutritionally complete and cost-effective feeds; control of disease vectors; and the design of flow-efficient mass culture tanks (Matsuda and Takenouchi 2005; 2007; Jeffs 2010; Goldstein and Nelson 2011). More recent efforts have been aimed at understanding how other environmental factors (e.g. light, biofilms, flow rates) should be considered in the future development of phyllosomal culture (e.g. Bourne et al. 2006). Studying phyllosomas *in-situ* is difficult, and it is

only recently that accurate data have been gathered on larval duration for a few commercially important species through laboratory-based studies (Figure 2).

As a case in point, in 2005 adult Caribbean spiny lobster (*Panulirus argus*) were transported from Florida USA to Japan in a comprehensive effort to study reproduction and phyllosomal rearing in the laboratory. The fishery for *P. argus* is the largest in the world for any spiny lobster species, and development of successful aquaculture operations would be of great value. The research was successful, for the first time, in rearing phyllosomas of *P. argus* through all the stages through to metamorphosis to the puerulus stage, and then to on-grown lobsters (Goldstein et al. 2008). This experience highlighted the necessity of an integrated approach to establishing technology for mass rearing, which must involve an understanding of the biology, nutrition and physiology of these phyllosomas. These findings will help to ensure the engineering of beneficial tank designs and a healthy, suitable aquatic environment.

Our work in Japan has provided baseline information for the larval duration of *P. argus* and size-at-age for the 10 successive phyllosomal stages. The total time from egg hatch to final phyllosomal metamorphosis ranged from 140–198 days with a mean of 174 days. Further experiments examined the behavioral changes in phyllosomas in relation to light. We found that early-stage phyllosomas demonstrated a very strong positive phototaxis (i.e. phyllosomas actively swam towards a light source (Goldstein et al. 2008)).



**Figure 1.** Production of major species from aquaculture in 2010. Source: FAO 2012

This behavior persisted until ~ 100 days of age, at which point there was a profound switch to negative phototaxis, whereby phyllosomas swam away from a light source (Butler et al. 2011). These findings not only emphasize the importance and integration of environmental variables in phyllosoma cultures, but also provide correlates for our understanding of *in situ* larval dispersal which continues to be an active area of research (Butler et al. 2011).

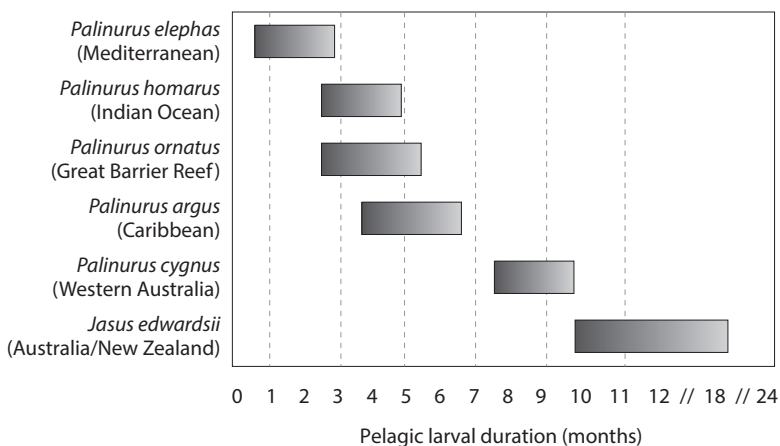
An assessment of the dietary needs for *P. argus* phyllosomas were also investigated in this work. The traditional laboratory diet for lobster phyllosomas, mussel gonad and *Artemia spp*, although successful, are not necessarily the most suitable for mass culture, nor do they provide optimal nutrition for growth and metamorphosis. In an effort to provide better guidance for more suitable diets for phyllosomas, studies have been carried out to investigate the natural diets of phyllosomas in the plankton using sophisticated molecular tools to identify prey items, the proportion of those items and their specific nutrient profiles (Saunders et al. 2012; O’Rorke 2013). Complementing this nutritional research are ongoing studies of the feeding morphology of phyllosomas, including examination of the appendages, mouthparts and digestive tracts, to better understand their capabilities and the form of diet best suited to this morphology (Johnston et al. 2004; Johnston et al. 2008).

In addition, there has been recent research of digestive physiology in regard to enzymes that might also elucidate the make-up of an optimal phyllosomal diet (O’Rorke 2013). Based on the information gathered to date, it may be concluded that manufactured phyllosomal feeds will need to be high in protein and energy (lipids and carbohydrates) easy to grasp and fleshy, inexpensive to produce and non-fouling of water quality (Jeffs 2010).

Nutritional research in other lobster species, such as clawed American lobsters (*Homarus americanus*) may provide useful information for spiny lobster nutrition. Simple dietary manipulations in *H. americanus* have been shown to alter lobster shell color, and may be an economically beneficial tool in lobster aquaculture to meet specific market demands (Tlusty et al. 2005a,b). Seeking out other species for answers to homologous challenges is an important exercise to continue undertaking.

### Challenges with pueruli

The puerulus stage is a critical stage both in the natural life cycle and for aquaculture. The puerulus is highly mobile, persists for between two and four weeks, has strong swimming ability and is a non-feeding stage reliant on lipid reserves. Pueruli display specific habitat preferences as they seek out a suitable settlement environment, and their abundance varies with both season and lunar periodicity. They tend to



**Figure 2.** Estimated duration of the larval phase of commercially important spiny lobsters

be most active at night and around the new moon (Phillips and McWilliam 1986; 2008).

With respect to this life stage, there are a number of ecological questions that may be examined, leading to better aquaculture practices. For example, how are pueruli locating suitable coastal habitat for settlement; what distance from the coast; using what specific cues or stimuli? (Jeffs et al. 2005; Fitzgibbon et al. 2013). There is now some evidence that pueruli of *P. argus* are able to cue to chemical signals in the water to direct their swimming. Furthermore, these chemical signatures may modulate a trigger for the transition from a swimming puerulus to a settled, benthic juvenile (Goldstein and Butler 2009; Kough et al. 2014). In attempting to answer these questions, simple choice experiments were performed, giving wild caught pueruli the option to move in one of two directions toward water that has been conditioned with different chemical scents. For example, when water conditioned with the red coralline alga (*Laurencia spp.*) was offered with an alternative of plain sea water (control), pueruli moved towards the alga-scented water, presumably as this represented suitable habitat for settlement. A similar result was achieved when oceanic water was offered with seawater from in Florida Bay, with a significant preference for bay water, as reported by Goldstein and Butler (2009).

As an extension to this research, an assay was performed where pueruli were placed in a variety of water baths representing the same chemical scents (e.g. secondary metabolites) as in the choice experiment, and the time to pigmentation (i.e. metamorphosis to the benthic juvenile stage) was measured. The change from the transparent, swimming puerulus stage to the pigmented, settled stage is considered to represent a significant transition that indicates the lobster has reached suitable habitat for its ensuing benthic life phase. Again, a clear result showed the time taken to transition to the pigmented 'juvenile' stage was significantly faster with water from the bay (or infused with *Laurencia* algal scent (Goldstein and Butler 2009)).

Taken together, these studies have important implications for aquaculture, as the duration of the puerulus stage may be minimized by introducing an appropriate chemical cue. The resulting juveniles with an accelerated transition are likely to be stronger, as they have moved through the non-feeding puerulus stage more quickly, and are therefore less

likely to have exhausted their energy reserves (Jeffs et al. 2005; Fitzgibbon et al. 2013).

This research is the first for any palinurid lobster to demonstrate enhancement of puerulus behavior to stimulate the transition from the swimming to the settled stage, which in turn may improve our ability to utilize conditioning techniques for aquaculture.

## Environmental effects on development

Environmental (abiotic) factors (e.g. light, temperature, current, substrate etc.) can be crucial for the settlement and survival of marine larvae. Research with clawed lobsters (*H. americanus*) has demonstrated that in captivity, the development of the claws is influenced by the substrate on which the lobsters are reared. The asymmetry between the two claws (in nature, lobsters typically have distinct crusher and cutter claws) is far less on a cobble stone substrate than when reared on a crushed shell substrate (Goldstein and Tlusty 2003). Temperature and photoperiod are both significant factors in the timing of metamorphosis of several species of phyllosomas, both in the lab and field (Kittaka 1997; Matsuda et al. 2003) and chemical cues (described above) have been implicated as settlement cues in a variety of marine organisms, including lobsters (reviewed in Grasso 2001). The influence of environmental variables on development suggests that the inclusion of environmental manipulation in aquaculture operations may be used to affect desired developmental outcomes for lobsters, including for spiny lobsters. These factors should be integrated as part of a large-scale design and production operation.

## Phyllosoma rearing tank design

Many tank designs have been applied to the rearing and culturing of phyllosomas, from older designs used for the larval rearing of other species to new designs customised specifically for phyllosomas (Illingworth et al. 1997; Matsuda and Takenouchi 2005; 2007, Goldstein and Nelson 2011). Tanks typically used for rearing and displaying jellyfish (i.e. gelatinous plankton kriesels) have been successfully used to culture phyllosomas (Raskcoff et al. 2003; Goldstein and Nelson 2011).

Not only do these tank designs provide a suitable environment for rearing phyllosomas, but the integration of jellyfish and phyllosomas in the same tank has

demonstrated a strong association between these species (already documented in the wild). Phyllosomas may benefit from this association in many ways. For example, phyllosomas may obtain nutrients by feeding on jellyfish and/or use jellyfish for transportation and thus energy conservation (Wakabayashi et al. 2012; O'Rorke et al. 2015). Continued development in this area of polyculture may become a viable alternative to the mass production of phyllosomas alone, however more studies are needed to determine the efficiency and compatibility of species.

## Alternative tropical spiny lobster species

Beyond the well-documented tropical species currently being cultured or under consideration for aquaculture potential, there are other species (e.g. *Panulirus laeviscauda* and *Panulirus guttatus*) that are poorly understood, but show promise as aquaculture candidates. Studies directed at a more comprehensive look at similar species and their life cycles may provide insight for potential development.

## Conclusions and recommendations

Given the continued trend in unreliable wild-caught fisheries, the prospects for aquaculture production that will help meet the global demand for lobster products is a real one. The ability to solidify the technology and develop proven and reliable methods for lobster aquaculture should focus on tropical spiny lobsters worldwide. Creating and sustaining viable lobster aquaculture involves the sharing of new ideas and fostering more studies aimed at addressing and resolving important biological roadblocks (e.g. diet, disease etc.) that still exist. Successes then need to be scaled up to meet the demands of commercial production that includes quality control and consistent, environmental conditioning as well as maintaining a healthy supply of animals. The integration of land-based (larval culture systems) with sea-cage culture (grow-out) may also be a strategy to support full aquaculture potential.

## References

Booth J.D. and Kittaka J. 2000. Spiny lobster grow out. Pp. 556–58 in: 'Spiny Lobsters: Fisheries and Culture' Second edition. Fishing News Books, ed. by B. F. Phillips and J. Kittaka: Oxford.

- Bourne D.G. Høj L. Webster N.S. Swan J. and Hall M.R. 2006. Biofilm development within a larval rearing tank of the tropical rock lobster, *Panulirus ornatus*. *Aquaculture* 260: 27–38.
- Butler IV, M.J. Paris C.B. Goldstein J.S. Matsuda H. and Cowen R.K. 2011. Behavior constrains the dispersal of long-lived spiny lobster larvae. *Marine Ecology Progress Series* 422: 223–237.
- Chavez E.A. 2009. Potential production of the Caribbean spiny lobster (Decapoda, Palinura) fisheries. *Crustaceana* 82: 1393–412.
- FAO. 2012. The State of the World Fisheries and Aquaculture. Report ISSN 1020-5489. 230 Pp.
- 2014. Fisheries Statistics Program (FISHSTAT). Accessed online at: <http://www.fao.org/fishery/statistics/programme>. Food and Agriculture Organization of the United Nations: Rome.
- Fitzgibbon Q.P. Jeffs A.G. and Battaglene S.C. 2013. The Achilles heel for spiny lobsters: the energetics of the non-feeding post-larval stage. *Fish and Fisheries*. Doi: 10.1111/faf.12018. 1–12.
- Goldstein J.S. and Nelson B. 2011. Application of a gelatinous zooplankton tank for the mass production of larval Caribbean spiny lobster, *Panulirus argus*. *Aquatic Living Resources* 24: 45–51.
- Goldstein J.S. and Butler IV, M.J. 2009. Behavioral enhancement of onshore transport by postlarval Caribbean spiny lobster (*Panulirus argus*). *Limnology and Oceanography* 54: 1669–1678.
- Goldstein J.S. Matsuda H. Takenouchi T. and Butler IV, M.J. 2008. The complete development of larval Caribbean spiny lobster *Panulirus argus* (Latreille, 1804) in culture. *J. Crustacean Biology* 28: 306–327.
- Goldstein J.S. and Tlusty M.F. 2003. Substrate determinants and development rate of claw asymmetry in American lobsters, *Homarus americanus*. *J. Crustacean Biology* 23: 890–896.
- Grasso F.W. 2001. Invertebrate-inspired sensory-motor systems and autonomous, olfactory-guided exploration. *Biological Bulletin* 200: 160–168.
- Holthuis L.B. 1991. FAO species catalogue. Marine lobsters of the world. An annotated and illustrated catalogue of species of interest to fisheries known to date. FAO Fisheries Synopsis. 13: 125. Food and Agriculture Organization of the United Nations: Rome.
- Illingworth J. Tong L.J. Moss G.A. and Pickering T.D. 1997. Upwelling tank for culturing rock lobster (*Jasus edwardsii*) phyllosomas. *J. Marine and Freshwater Research* 48: 911–914.
- Jeffs A. 2010. Status and challenges for advancing lobster aquaculture. *J. Marine Biology Association of India* 52: 320–326.
- Jeffs A.G. Montgomery J.C. and Tindle C.T. 2005. How do spiny lobster post-larvae find the coast? *NZ J. of Marine and Freshwater Research* 39: 605–617.



- Jeffs A. and Davis M. 2003. An assessment of the aquaculture potential of the Caribbean spiny lobster, *Panulirus argus*. Proceedings of the Gulf and Caribbean Fisheries Institute 54: 413–426.
- Johnston J., Johnston D., and Knott B. 2008. Ontogenetic changes in the structure and function of the mouthparts and foregut of early and late Stage *Panulirus ornatus* (Fabricius, 1798) Phyllosomata (Decapoda: Palinuridae). J. Crustacean Biology 28: 46–56.
- Johnston D. Ritar A. Thomas C. and Jeffs A.G. 2004. Digestive enzyme profiles of spiny lobster *Jasus edwardsii* phyllosoma larvae. Marine Ecology Progress Series 275: 219–230.
- Kittaka J. 1997. Culture of larval spiny lobsters: a review of work done in northern Japan. Marine and Freshwater Research 48: 923–930.
- Kough A.S. Paris C.B. and Staatterman E. 2014. *In situ* swimming and orientation behavior of spiny lobster (*Panulirus argus*) postlarvae. Marine Ecology Progress Series 504: 207–219.
- Matsuda H. and Takenouchi T. 2005. New tank design for larval culture of Japanese spiny lobster, *Panulirus japonicus*. J. Marine and Freshwater Research 39: 279–285.
- Matsuda H. and Takenouchi T. 2007. Development of technology for larval *Panulirus japonicus* culture in Japan: a review. Bulletin Fisheries Research Agency 20: 1–8.
- Matsuda H. Takenouchi T. and Yamakawa T. 2003. Diel timing of molting and metamorphosis of *Panulirus japonicus* phyllosoma larvae under laboratory conditions. Fisheries Science 69: 124–130.
- O’Rorke R. Lavery S.D. Wang M. Gallego M. Waite A.M. Beckley L.E. Thompson P.A. and Jeffs A.G. 2015. Phyllosomata associated with large gelatinous zooplankton: hitching rides and stealing bites. ICES Journal of Marine Science doi 10.1093/icesjms/fsu163.
- O’Rorke R. 2013. Determining the diet of spiny lobster phyllosomas: Using a prey enriched, amplicon pyrosequencing approach. PhD. dissertation. The University of Auckland.
- Phillip B.F. Cobb J.S. Jeffs A. and McWilliam P. 2006. Larval and postlarval ecology. Pp. 231–262 in ‘Lobsters: Biology, Management, Aquaculture, and Fisheries’, ed. by B.F. Phillips. Blackwell Publishing: Oxford, United Kingdom.
- Phillips B.F. and McWilliam P.S. 1986. The pelagic phase of spiny lobster development. Canadian J. Fisheries and Aquatic Sciences 43: 2153–2163.
- Phillips B.F. and McWilliam P.S. 2008. Spiny lobster development: where does successful metamorphosis to the puerulus occur?: A review. Rev. Fish. Biol. Fisheries doi 10.1007/s11160-008-9099-5.
- Raskoff K.A. Sommer F.A. Hamner W.M. and Cross K.M. 2003. Collection and culture techniques for gelatinous zooplankton. Biological Bulletin 204: 68–80.
- Saunders M.I. Thompson P.A. Jeffs A.G. Sawstrom C. and Sachlikidis N. 2012. Fussy Feeders: Phyllosoma larvae of the western rock lobster (*Panulirus cygnus*) demonstrate prey preference. PLoS ONE 7(5): e36580 doi 10.1371/journal.pone.0036580.
- Thlusty M.T. Fiore D.R. and Goldstein J.S. 2005a. Formulated diets as replacements for Artemia in the rearing of juvenile American lobsters (*Homarus americanus*). J. Aquaculture 250: 781–795.
- Thlusty M.T. Goldstein J.S. and Fiore D.R. 2005b. Hatchery performance of early benthic juvenile American lobsters (*Homarus americanus*) fed enriched frozen adult *Artemia* diets. J. Aquaculture Nutrition 11: 191–200.
- Wakabayashi K. Sato R. Ishii H. Akiba T. Nogata Y. and Tanaka Y. 2012. Culture of phyllosomas of *Ibacus novemdentatus* (Decapoda: Scyllaridae) in a closed recirculating system using jellyfish as food. Aquaculture 330–333: 162–166.

## 5.3 Student involvement in spiny lobster aquaculture research in Indonesia

Ihsan Muhsinul<sup>1</sup>

As a student of the University of Mataram, West Nusa Tenggara, Indonesia with an interest in lobster physiology, I was able to assist the ACIAR lobster aquaculture project in 2010 and continued my association through to 2013. During this time I participated in annual project meetings, and in 2012 I attended the lobster aquaculture industry development workshop. Through these experiences, I became familiar with the many students who participated in various activities with the ACIAR lobster aquaculture project.

Due to the significant amount of research required to answer many questions about lobster farming technology, staff from MADC Lombok approached the University of Mataram to request the assistance of Biology Department students to support research activities. The first instance of student involvement was in 2010 when 7 UNRAM students (including myself) spent 10 weeks at MADC Lombok assisting with lobster research.

Over the next three years, students continued to be involved, representing seven different Universities: Mataram University, Diponegoro University, Gadjah Mada University, Padjajaran University, Bogor Agriculture University, Hasanudin University and Fisheries University of Jakarta.

The students' participation included conducting research, collecting and processing data, and

introducing the Lombok culture to project staff. There were four advantages for students who joined the ACIAR lobster project: i) helping to complete our University study; ii) increasing our scientific knowledge; iii) exploring our potential; and iv) enabling us to develop a new business.

### Conclusions and recommendations

The opportunity for students to participate in the ACIAR lobster aquaculture research provided several advantages and no disadvantages. Such collaboration should be continued in future.

Personally, the involvement has led me to consider applying for an Australian Awards Scholarship to continue lobster research and to develop a lobster feed business.

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# 5.4 Summary of disease status affecting tropical spiny lobster aquaculture in Vietnam and Indonesia

Clive Jones<sup>1</sup>

## Introduction

Information presented here is primarily gathered from a lobster disease information audit conducted under the ACIAR project (ACIAR SMAR/2008/021) in Vietnam in 2009, and subsequent qualitative assessments based on discussion with industry participants and researchers. The audit was performed by Drs Richard Callinan and Flavio Corsin, as a contracted activity of the ACIAR project. Their unpublished report (Callinan, et al., 2010) is presented as Appendix 3.

Subsequent to completion of the audit, the Vietnam Ministry of Agriculture and Rural Development convened a workshop in November 2009 to generate a national response to disease within the lobster farming industry. The industry suffered particularly high levels of disease-related mortality in 2007 and 2008.

The following summary provides information on the five recognised diseases and health related syndromes, their symptoms, possible causes, treatment and prevention. Some farm management considerations are presented that may assist in minimising disease issues. Although there has been no formal assessment of lobster disease status in Indonesia, some qualitative assessment is presented.

## Red-body disease

Red-body disease has been observed in four species in Vietnam: *P. ornatus*, *P. homarus*, *P. longipes* and *P. polyphagus*, in both juvenile and adult stages. The symptoms include a distinctly red coloration

initially to the carapace and/or abdomen, which ultimately affects the whole body. Internal examination reveals necrotic (dead and blackened) tissue in the hepatopancreas. The pathogen implicated is *Vibrio alginolyticus*, although other viral pathogens and factors of stress may be involved. Mortality rate is high (estimated >90%) for lobsters affected. Prevention is via integrated preventive measures discussed below.

## Black gill disease

Black gill disease has been recorded for *P. ornatus*, *P. longipes* and *P. penicillatus* in sub-adults and adults. Symptoms are a gradual darkening in colour of the gill filaments from brown to black, followed by progressive tissue breakdown and shedding of the gills. The disease is typically not fatal but does impact negatively on growth and marketing quality of affected lobsters. The primary pathogen involved is the fungus *Fusarium*, although other pathogens have been implicated. Prevention is via integrated preventive measures discussed below.

## Milky disease

Milky haemolymph disease, most commonly referred to as milky disease, affects *P. ornatus*, *P. homarus*, *P. stimpsoni* and *P. polyphagus* at all life stages, from small juveniles to adults. Infection is apparent when abdominal tissue color turns from translucent to opaque white, as the cells become engorged with the pathogen, a Rickettsia-like bacterium. Mortality of infected lobsters is 70–100%. The disease can be treated effectively with properly administered antibiotics (oxytetracycline), although industry practice of mixing antibiotics with food is not particularly

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effective. Incidence of milky disease can be managed through integrated preventive measures.

### **Big head syndrome**

Big head syndrome is a health issue rather than a disease, and has been observed in *P. ornatus*, *P. homarus*, *P. longipes*, *P. penicillatus* and *P. versicolor*, primarily in adults. It is characterised by an abnormally big carapace relative to the abdomen, and affected lobsters appear to have their growth retarded, and experience difficulty in moulting. The syndrome results in poor marketing quality but is typically not lethal. The cause is believed to be nutrient deficiency, and thus can be treated with provision of improved feed quality through supplementation or preferably through use of a suitable manufactured pellet diet.

### **Separate head syndrome**

Separate head syndrome can affect all cultured species at any life stage. The symptoms involve a separation of the carapace from the abdomen, caused by excess body fluid which appears under the epidermis at the junction of the head and tail. Although typically not lethal, it impacts negatively on marketing quality and is thought to be caused by exposure to low salinity (<25 ppt). Treatment is to relocate lobsters to areas with higher and stable salinity (>25 ppt), and preferably at normal seawater salinity of 35 ppt.

### **Causes**

The causes of these diseases and health issues are in most cases attributable to farm and sea-cage design and management, and to feed quality and feeding management. The current industry practice of using trash fish as lobster food is likely to have nutritional deficiencies that will render lobsters more susceptible to disease. Further, the application of trash fish is wasteful, and a significant proportion of the food is lost from the cage either as fine particulate or dissolved organic material that has an immediate and on-going nutrient impact on the water and sea floor adjacent to the farm. The water quality that lobsters are exposed to is therefore suboptimal and causes physiological stress that increases disease risk.

Similarly, the location of farms, density and spacing between cages, and cage mesh size may all

contribute to the degree of flushing of cages, which in turn will influence water quality within the cage.

Although no analytical assessment has been made of the relative condition of lobster seed as supplied to farmers, there may be a link between poor condition of seed and disease susceptibility. Although all seed appear to be the same, there is a strong likelihood that their condition varies as a result of differences in duration since their metamorphosis from the phyllosoma stage. As the puerulus is a non-feeding stage, those individuals that have spent longer in the plankton will have expended more of their energy reserves and will be in a weaker condition. Such individuals may suffer health and disease problems more readily than others.

There is also a regulatory aspect to lobster disease with regard to: provincial planning (location and number of cages permitted within a given location); institutional capacity within each province to respond to disease problems; training in disease prevention and treatment; and communication of disease outbreaks.

### **Lobster disease impact**

The diseases and health issues detailed above have collectively cause substantial losses to lobster production each year. Significant additional loss occurred specifically from milky disease in 2007 and into 2008 in Vietnam when production losses of 31–71% were experienced across all provinces. The average across the entire industry was a 50% reduction in production due to milky disease in 2007–2008, valued at US\$50 million lost and more than 5,000 households affected. Prior to 2002, survival rate through the grow-out phase was 70%, and by 2008 this was less than 50% due to disease. By 2011, overall survival was back to 70% as a result of disease prevention measures. However, in 2012 a further milky disease outbreak had occurred, although with a much lower impact than 2007–2008.

Lobster disease in the Indonesian lobster farming industry has been a significant issue even though overall production is very small; less than 50 tonnes. Milky disease was confirmed in lobsters in the village of Telong Elong in eastern Lombok in 2012, with the same *Rickettsia*-like bacteria involved. This suggests that the milky disease agent, the *Rickettsia*-like bacteria, are endemic, and that milky disease is an ongoing threat to lobsters in compromised condition due to poor nutrition and environmental stress. Although

milky disease infected lobsters respond positively to antibiotic treatments, prevention is key to the long term sustainability of the industry.

## **Preventative measures**

There are a number of preventative measures that can be taken to reduce disease susceptibility, and when integrated, are likely to reduce the risk of losses from disease and health issues to a negligible level. Firstly, site selection is important, with a recommended depth of greater than 2.5 m from cage bottom to sea floor and a location with good water movement from tide and currents that enables constant flushing of the cages with clean water. Density of farming (i.e. the distance between farms and spacing of cages within each farm) is important to minimise the ratio of lobster biomass to volume of water. Cage design and mesh size are important to maximise the flow of water through the cage.

It is likely that the use of trash fish as lobster food is a major contributing factor to poor condition of lobsters and increased susceptibility to disease. Pelleted feeds will provide a much cleaner and nutritionally complete diet, and increase disease resistance. Where such pelleted feeds are unavailable, fresh flesh diets should be comprised of clean, fresh (less than 24 hours since capture) seafood materials and the use of crabs avoided.

Use of high quality seed is also likely to lead to less disease and health issues, therefore choosing the strongest looking seed is worthwhile. Using larger

juveniles rather than puerulus may provide an advantage in this regard, although the higher price would need to be accounted for.

Regular grading of stock within grow-out systems is also a useful disease mitigation technique with regard to minimising aggression between lobsters.

Effective maintenance of cages is beneficial to health management, including daily cleaning of waste and uneaten food from the cages, and periodic exchange of cage nets, including sun drying.

Farm workers should be well trained in disease symptom awareness and observation, with corresponding skills on how best to respond.

## **Conclusions and recommendations**

Fortunately, the diseases of tropical lobsters as outlined here are primarily the result of opportunistic infection and physiological degradation rather than from primary pathogens. They are all preventable, and with best practice husbandry and nutrition, can be avoided. As such, every effort should be made to provide an environment which maintains lobsters in optimal condition such that their susceptibility is as low as possible. Above all, optimal nutrition will likely mitigate infection with milky disease.

## **Reference**

Callinan R. Corsin F. and Nguyen Thi Bich T. 2010. ACIAR Project SMAR2008/021: Audit of Diseases of Farmed Spiny Lobsters in Vietnam. Australian Centre for International Agricultural Research: Canberra, Australia.

## 5.5 Development of the lobster farming industry in Indonesia

Bayu Priyambodo<sup>1</sup>

### Introduction

To assist in the introduction of lobster farming and facilitation of its development throughout Indonesia, demonstration grow-out farms were established at six sites in three provinces. This paper provides a summary of the demonstration farm program, its objectives, program of activities, outcomes and recommendations.

A number of other industry development activities were also performed as part of the program, and these are summarised below.

Current Indonesian lobster production is mainly from capture fisheries, with *Panulirus homarus* and *P. penicillatus* the major species. On average, the total aquaculture production from 2005 to 2011 contributed only 2.7% of the total national lobster production (aquaculture and fishery) as shown in Table 1.

Lobster aquaculture, including fattening of small sub-adults and full grow-out of puerulus, is developing at a very slow pace. ACIAR and the Indonesian Directorate General of Aquaculture (DGA) are collaborating to improve lobster aquaculture methods to provide alternative livelihoods for rural coastal

communities. A common and effective extension method employed in Indonesia for a variety of farming options is the establishment of demonstration farms, and therefore the lobster grow-out demonstration farms discussed here were established.

### Demonstration grow-out farms

Initially, interest in lobster grow-out was focused on Lombok, where the naturally settling pueruli have been found since the early 2000s. From 2000 to 2012 the lobster grow-out industry was able to produce 20 to 30 tonnes of marketable size lobster (up to 100 g each) per annum with a value of IDR 20 Billion or around US\$1.5 million (Petersen et Al. 2013). Lobster grow-out was seen as a new type of aquaculture that could alleviate poverty and provide many job opportunities for communities living in the rural coastal zone (Tuan and Jones 2014), and therefore demonstration farms were introduced to stimulate industry growth and facilitate extension of best-practice farming methods. Choosing the right sites and collaborators was done with support from the local fishery agencies in Bima, Sape, South Sulawesi, Takalar and Ujung Batee.

**Table 1.** Indonesian spiny lobster production from capture fisheries and aquaculture (MMAF, 2014)

Source	Production (tonnes)							Average
	2005	2006	2007	2008	2009	2010	2011	
Aquaculture	61	558	371	292	339	312	225	308
Fisheries	6,648	5,254	4,705	9,896	5,893	7,651	10,541	7,227
Total	6,709	5,812	5,076	10,188	6,232	7,963	10,766	7,535
Aquaculture %	1	1.1	1.6	3	6	4	2	2.67

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## Objectives

The aim was to establish six demonstration grow-out farms over the three years of the ACIAR project (two per year) at sites chosen for their proximity to likely puerulus supply and suitability for sea-cage farms. The intention was that smallholders from areas nearby the selected sites, who might be interested in trying lobster farming, could follow the example of the demonstration farm and adopt the cage construction and farming techniques being used. It was therefore hoped that through the demonstration grow-out farms, other farmers would engage in lobster farming to establish a viable and productive local industry.

## Project activities

Each demonstration farm consisted of a framed unit comprising six floating sea cages. The frames for the sea cages were made from locally available materials. Bamboo was chosen as the most suitable material because it is strong and has a relatively long lifespan. The cages were made from polyethylene netting with dimensions of  $3 \times 3 \times 3$  m. The diameter of the net was 25 mm. The floating frame supporting the cages was equipped with a small guard house (Figure 1).

One thousand to 1,200 lobster seeds of *P. homarus* were provided to each farm, for a stocking density of around 200 pieces per cage. Trash fish and a commercial lobster pellet (Lucky Star Brand) were used to feed the lobster. Other support provided by the ACIAR project staff and local fisheries agency included work equipment, extension, technical assistance and daily protocol.

## Collaborators

In Lombok, there were two demonstration farms established with local fishermen: Mr Pamit in Awang, Central Lombok and Mr Murdi in Telong Elong, East Lombok. In Sumbawa, there was a demonstration farm established in Teluk Sanggar in collaboration with the Bima Fisheries local district. In East Nusa Tenggara, a demonstration farm was established under management and support from the Tablolong Marine Aquaculture Centre, a technical implementation unit of Ministry of Marine Affairs and Fisheries. In South-east Sulawesi, Takalar Brackishwater Aquaculture Development Centre ran the demonstration farm in Laikang. The sixth demonstration farm was established at Pulo Aceh Nanggroe Aceh Darussalam, with Mr Muazzi as



**Figure 1.** Lobster grow-out demonstration farm, comprising six cages suspended from a floating frame, and small guard house for the operator



the person in charge. This demonstration farm was also supervised and monitored by Ujung Batee Brackishwater Aquaculture Development Centre. Details of the grow-out demonstration farms from 2010–2013 are summarised in Table 2.

### Demonstration farm results

The following key elements were identified as factors representing success in the new grow-out farms.

1. *Exposure of contracted farmers/collaborators to the activity.* Farmers who have previous experience in marine aquaculture tended to have much more motivation to be successful, particularly those in Awang, Telong Elong, Aceh and Laikang.
2. *Farmers' attitude, application and practice.* Attitude is an important element in aquaculture which requires relatively long production duration. Daily protocol will only be effective if farmers have a positive attitude to applying and practicing it.
3. *Farmers' knowledge and skills.* The knowledge and skills of contracted farmers can be improved through technology transfer and supervision by researchers from DGA centres and local fishery agencies, and through farmer meetings, publications etc.

Some possible reasons for failure experienced in the activity are as follows:

1. lobster disease outbreaks
2. farmers' lack of skill in nursery techniques using very small and fragile puerulus
3. transportation issues
4. lack of sufficient local seed available
5. technical issues, such as a high rate of cannibalism among farmed lobsters.

### Impact of demonstration farms

In Awang, Lombok between 2010 and 2012, there were 17 new grow-out farmers who started growing lobsters in the vicinity of the demonstration farms. However, from early 2013, due to a dramatic increase in puerulus catch, new grow-out farmers displayed an increasing preference to catch and sell pueruli rather than grow-out, as this involves lower risk and quicker cash flow compared with farming. In light of this, growing out lobster is much less attractive for them.

At Laikang Bay in South Sulawesi, there were 11 new cages established to cultivate lobster after the demonstration farm had been operating for three years (Table 3).

**Table 2.** Collaborators in the grow-out demonstration farms from 2010–2013

No	Locations	Collaborators	Year of activity	Unit	Crop cycle
1	Awang, NTB	A farmer group led by Pak Pamit	2010–2013	2	3
2	Telong Elong NTB	A farmer group led by Pak Murdi	2012–2013	1	2
3	Sanggar Bay	Local Farmers and DKP Kabupaten Bima	2012	1	1
4	Tablolong, NTT	Brackish water aquaculture center of Tablolong	2010–2011	1	1
5	Teluk Laikang, Sulsel	Brackishwater aquaculture center of Takalar	2011–2012	1	1
6	Pulo Aceh	A farmer group led by Pak Muazi	2010–2012	1	1

**Table 3.** The impact of grow-out demonstration farms in Laikang Bay, South Sulawesi

Years	Number of cages	Type of cages	Farmers involvement/status
2010	2 units	Holding	Individuals
2011	2 units	Grow-out	Individuals
2012	5 units	Grow-out	Individuals
2013	11 units	Grow-out	9 cages: Individuals 2 cages: Farmer groups

## Other industry development activities

During the project, pamphlets, brochures, a brief production manual and short movies on lobster aquaculture techniques were produced, including on seed collection methods, nursery and grow-out husbandry, disease management, and transportation techniques for seed and market size lobster (Figure 2).

An informal health monitoring and disease prevalence survey was performed within the Lombok lobster grow-out community in collaboration with the Lombok MADC laboratory of fish disease and provincial Dinas environmental group. The gathering of disease information and associated communication helped farmers to better understand disease issues and methods for prevention and treatment.



**Figure 2.** Lobster aquaculture brochure to provide practical information to farmers

The involvement of university students in lobster production experiments from 2010 to 2013 (see Chapter 5.3) has had an unexpected positive impact, with many of the students returning to their home towns and villages and communicating the opportunity for lobster farming. The students came from Mataram University (UNRAM), Gadjah Mada University (UGM), Diponegoro University (UNDIP), Bogor Agriculture Institute (IPB) and Brawijaya University of Malang (UNIBRAW).

A specific on-farm feed manufacture trial was performed in 2013 with Mr Werry at his farm in Telong Elong, East Lombok to examine the practicality of making lobster pellets on-farm to supplement the commonly used fresh fish diet. This exercise was very effective, and good quality pellets were made using simple and readily available ingredients and equipment. Although the particular formulation needs further improvement, the concept was proven. The need for such pellet manufacture will depend on interest among commercial aquafeed companies in providing a cost-effective diet.

During the course of the project, an industry development workshop was delivered once a year in Lombok. The workshops were attended by farmers, middlemen, exporters and other stakeholders, and provided an opportunity to communicate project research results and discuss industry issues. They provided a valuable information exchange to improve the performance of the industry.

## Conclusions and recommendations

Regular and effective contact with farmers to communicate best practice farming methods is key to the development of lobster grow-out farms in Indonesia. The farmers' attitude, capacity and skill level will be critical factors in the success of lobster farming. Consequently, social and economic considerations will be just as important as biological and technical support. Farmers' knowledge and skills will be improved through the supervision and monitoring by researchers and extension staff from the DGA centres and local DKP.

At the national level, the identification and promotion of the most suitable farming locations is required. Lobster grow-out has tended to occur in close proximity to the source of lobster seed in

locations that are not necessarily the most suitable for sea-cage production.

Constraints to industry development include access to lobster seed and to suitable pelleted diets. There appear to be sufficient seed available in Lombok for a large grow-out industry that may comprise multiple locations throughout Indonesia. Developing effective transportation techniques will be a factor in achieving such development.

Access to effective pelleted diets is a difficult issue for a small, developing industry like lobster farming. The small volumes of feed required makes manufacture unattractive to aquafeed companies,

but industry expansion and increased demand will only occur when such a diet is available. Research support and on-farm pellet production may help to bridge the gap.

## References

- Petersen E.H. Jones C. and Priyambodo B. 2013. Bio-economics of Spiny Lobster Farming in Indonesia. *Asian Journal of Agriculture and Development* 10(1): 25–39.
- Tuan L.A. and Jones C. 2014. Status report of Vietnam lobster grow-out. Paper presented at the ACIAR International Lobster Symposium, Senggigi Lombok, 22–25 April 2014.

## 5.6 Opportunity for developing tropical spiny lobster aquaculture in Australia

Clive Jones<sup>1</sup>

### Introduction

Aquaculture in Australia is relatively small scale, although it exhibits examples of strong commercial success (e.g. Salmonid farming in Tasmania) and many examples of failure. As a developed nation, operating costs for industry are comparatively high in Australia, particularly in regard to labour and regulatory compliance. This makes it difficult for Australia to compete with other nations farming the same or similar aquatic species. The opportunity to develop lobster farming must therefore be assessed in the context of Australia's competitiveness. Rock lobsters present a sound proposition for aquaculture development from a market price perspective, as they are one of the highest value seafoods and therefore have the capacity to absorb high production costs. However, the technical requirements for farming lobster are still developmental, and a guaranteed supply of seed lobsters does not exist.

Development of hatchery technology for lobsters will provide the necessary foundation for lobster farming, and to this end, Australia has invested heavily in research and development in this area (see Chapter 5.13). Nevertheless, at the time of the symposium, hatchery technology was still not available and not likely within five years.

Following the example of Vietnam, collection of pueruli for the purposes of aquaculture is a technically feasible option for Australia, although not a popular one due to perceived conflict with fisheries management. Although the value proposition of lobster aquaculture, based on collection of naturally settling seed has been considered in Australia (Gardner et al. 2006), it seems unlikely that it would be permitted.

An alternative proposition to enable lobster farming development in Australia is to grow-out sub-premium sized lobsters that are above minimum legal fishery size, but smaller than that which fetches the greatest price per kilogram. In the case of *Panulirus ornatus*, this represents lobsters of around 700g which could be on-grown to the premium size of 1 kg.

Such 'fattening' production of *P. ornatus* was considered a potential opportunity for existing shrimp/fish pond farms in tropical parts of Australia as a diversification, and for coastal Indigenous communities as an enterprise that complements their cultural connection to the sea. If such production could be successfully established, it would provide a foundation of experience and technology adaptation that could be applied to a broader scale and possibly more intensive lobster farming when a hatchery supply of seed becomes available.

Use of sea cages for lobster grow-out in Australia is likely to be the most cost effective option as the technology is well established in Vietnam and could easily be adapted to Australia. However, at present sea-cage aquaculture is not permitted along the east coast of Australia within the bounds of the Great Barrier Reef Marine Park, and the coastal areas outside the park are either climatically unsuitable or very remote. Consequently, only land-based systems were considered in the assessments reported here.

Tank-based experiments of lobster growth through the early 2000s demonstrated good production credentials for *P. ornatus* (Jones et al. 2001). These data provided the starting point for the assessment of pond-based production of lobsters using existing shrimp farm infrastructure, and an assessment of the opportunity to establish lobster grow-out at an Indigenous community.

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## Indigenous lobster farming

A scoping study to establish pilot grow-out facilities in Australian Indigenous communities was conducted. Grow-out of tropical rock lobsters in Australia will be best suited to locations north of Bowen through to the Torres Strait Islands, where climate and seawater access are most amenable to good growth and production. On this basis, there is strong opportunity for Indigenous community involvement. Using a SWOT analysis approach, the Yarrabah community was identified for the initial development with the intention of expanding to other communities as the project progressed.

The scoping study was completed in November 2010 and confirmed the potential for Indigenous Australian communities to grow lobsters in a land-based system. Specific sites within the Yarrabah community were identified as suitable for the establishment of a pilot lobster grow-out enterprise. Facilitated through engagement with Jaragun Pty Ltd, broad community consultation was achieved, including support from Council and the traditional owners. A young traditional owner who had completed TAFE Certificate 1 aquaculture training was chosen as the candidate for training to be the initial pilot grow-out operator, and who would subsequently train others from the Yarrabah community.

The scoping study generated a detailed report (Owen and Ahkee 2010)(Chapter 6.4 Appendix 4) outlining the opportunity and necessary steps to progress to a business plan.

The business plan was subsequently prepared (Owen and Ahkee 2012)(Chapter 6.5 Appendix 5), providing a detailed analysis of the necessary permits that would be required to enable a pilot lobster grow-out facility to be established. Unfortunately, the regulatory requirements were so onerous and expensive as to render the project unviable. Some relaxation of these requirements or identification of alternative locations where permission would be easier to achieve will be required to make further progress.

## Pond-based production

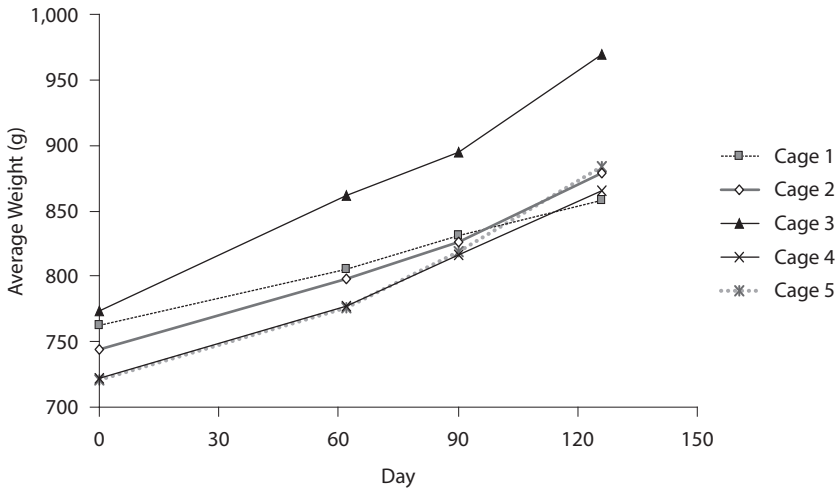
Field trials were conducted in Australia at two shrimp farms, firstly at Seafarm's farm near Port Douglas (16°30'16.1"S 145°27'04.4"E) north of Cairns, and subsequently at Pacific Reef Fisheries' prawn farm (19°29'53.9"S 147°26'27.8"E) north of Ayr.

At Seafarm, cages (2.5 × 2.5 × 1.5 m deep) were constructed to house lobsters, and were placed in pond inlet channels where water quality was equivalent to the adjacent shrimp ponds. Legal sized, live *P. ornatus* lobsters were purchased from a Cairns-based wholesaler for the trial and stocked at 20 lobsters per cage. They were fed a 7 mm moist pelleted diet manufactured in the laboratory and maintained in the cages for 126 days. Results were positive with survival overall of 78%, a specific growth rate of 0.14% per day and harvest size of around 900 g (Figure 1). Water quality during the trial was typical of prawn farms in north Queensland, with high turbidity and substantial variation in temperature and salinity. Although growth rate was not as great as experienced in tank experiments, and lobsters at harvest had moderately dirty shells due to bio-fouling, the results were sufficiently positive to justify further assessment (Jones and Shanks 2008).

Subsequent trials at Pacific Reef Fisheries' farm were conducted in four shallow, plastic lined raceways supplied with intake water as applied to adjacent prawn ponds. An experiment was performed in which each raceway was separated by a mesh barrier into two halves, one of which was furnished with table-type shelters and the other with no shelter. Lobsters were fed with a commercial lobster pellet (Lucky Star brand). Water quality during the trial is summarised in Table 1.

As can be seen from the water quality in the raceways (Table 1), conditions were far from optimal for a marine species accustomed to relative stability. Temperatures above 30°C and below 20°C can be considered extreme for *P. ornatus*. Similarly, salinity above 35 ppt and below 30 ppt will be stressful to this species (Jones 2009). As water quality varied outside of the preferred levels for *P. ornatus*, feed intake dropped and mortality increased, and as a result, the experiment was terminated.

Although *P. ornatus* appears to be an adaptable species that copes well with variations in its environment and is tolerant to average shrimp pond conditions, the extremes experienced in this case were beyond its tolerances. Such extremes in shrimp pond environments are common, even if they are of short duration. Consequently, it was concluded that this environment is not suitable for lobster production. This summation was similarly reached in Vietnam where pond-based trials were also underway (Jones and Anh 2013).



**Figure 1.** Growth of lobsters in cages in Seafarm pond water

**Table 1.** Water quality in raceways at Pacific Reef Fisheries during lobster production trial

Variable	Minimum	Maximum
Temperature °C	17.9	36.0
Salinity ppt	20.8	37.5
pH	7.68	9.3
Dissolved oxygen mg/L	2.7	15.1

Subsequent research efforts were directed towards tank-based production of lobsters on the basis that tank systems would confer greater control of water quality (see Chapter 4.3).

## Conclusions and recommendations

The opportunity for establishing lobster aquaculture in Australia remains uncertain. Hatchery technology will provide the necessary seed supply and independence from natural stocks to form a foundation for an Australian industry, but such technology is still developing and is some years from being commercially viable. In the meantime, fattening of subpremium size lobsters may be viable. Production trials in shrimp farm water clearly showed that this environment was not suitable due to extremes in salinity and temperature. However, tank-based production would

provide the necessary control of water quality to enable viable production.

Some preliminary economic analysis of tank-based production in Australia suggested that high capital and labour costs would necessitate an intensive approach, with a requirement to stock lobsters at very high densities. Given the social nature of lobsters, and advances in recirculation technology, it is technically feasible that super-intensive tank-based production might work. Specific research and development would be necessary to test this hypothesis, with a focus on maintaining lobsters throughout the full water column within production tanks.

Such economic constraints highlight that sea-cage production would be more cost effective and more immediately successful, if permits to enable this were forthcoming. This still appears unlikely in Queensland, at least on the east coast, but may be possible in the Northern Territory where there are fewer impediments to establishing sea-cage systems.

For Indigenous lobster aquaculture, a tank-based system was considered technically feasible but was precluded by a negative regulatory environment. The preferred option is for sea-cage based grow-out production. Constraints on achieving this include identification of sites where sea cages will be permitted, and effective training of Indigenous participants.

More broadly, the development of lobster aquaculture involving full grow-out from puerulus to



market size in Australia will necessarily involve intensive tank systems, whose productivity may compensate the high labour, capital and compliance costs. Research and development of such intensive systems is a priority for future research.

## References

- Gardner C. Frusher S. Mills D. and Oliver M. 2006. Simultaneous enhancement of rock lobster fisheries and provision of puerulus for aquaculture. *Fisheries Research* 80: 122–128.
- Jones C. and Shanks S. 2008. Growout of tropical rock lobster in shrimp pond conditions in Australia. *The Lobster Newsletter* 21: 18–21.
- Jones C. and Anh T.L. 2013. Development of Land-based Lobster Production Systems in Vietnam and Australia. Final Report FIS/2011/008. Australian Centre for International Agricultural Research: Canberra.
- Jones C.M. 2009. Temperature and Salinity Tolerances of the Tropical Spiny Lobster, *Panulirus ornatus*. *Journal of the World Aquaculture Society* 40: 744–752.
- Jones C.M. Linton L. Horton D. and Bowman W. 2001. Effect of density on growth and survival of ornate rock lobster, *Panulirus ornatus* (Fabricius, 1798), in a flow-through raceway system. *Mar. Freshw. Res.* 52: 1425–1429.
- Owen L. and Ahkee D. 2010. Scoping Study: Lobster Grow-out Pilot Project Yarrabah. Pp 34 in 'Queensland Department of Employment E.D.a.I.D'. Jaragun Pty Ltd: Cairns.
- Owen L. and Ahkee D. 2012. Lobster Grow-out Pilot Project: Yarrabah Business Case. Jaragun Pty Ltd on behalf of Australian Centre for International Agricultural Research (ACIAR): Cairns.



## 5.7 Genetics and recruitment of spiny lobsters *Panulirus ornatus* and *P. homarus* in the Indo-West Pacific

HocTan Dao<sup>1</sup>, Dean Jerry<sup>2</sup>, Carolyn Smith-Keune<sup>2</sup> and Eric Wolanski<sup>2</sup>

### Introduction

Lobsters from the genus *Panulirus* are commercially important species, occurring throughout the tropical eastern Indian Ocean, South-East Asia, Australia and the West Pacific. Spiny lobster puerulus (postlarval stage) are under heavy exploitation as seed stock for aquaculture, particularly in Vietnam and Indonesia. Of concern to managers of this fishery is the fact that large fluctuations in juvenile recruitment have been experienced in recent years, suggesting that the fishery may be subject to collapse in heavily exploited regions like Vietnam. In Vietnam, for example, total catch of *Panulirus ornatus* from eight provinces in the seasons 2006–2007 and 2009–2010 was only approximately 1 million puerulus, about half of that in other seasons. Whether the annual removal of 1 to 2 million puerulus by fishers is a factor in the absence of any recovery to adult stocks is unknown (Jones et al. 2010; Long and Hoc 2009). Recovery of fisheries in these exploited populations will be particularly problematic if recruitment is localized. An investigation into the genetic structure of spiny lobster species will therefore provide valuable data on the resilience and potential of populations to recover from heavy exploitation, as well as providing important information on sources and sinks for settling seed stock.

*P. ornatus* and *P. homarus* have lifehistories that provide the opportunity for long-distance dispersal, and consequently high rates of gene flow between populations. Firstly, adults are very adaptable in

where they can live. They are denizens of a diversity of habitats from shallow (1–8 m depth) to deep waters (>50 m) sandy or muddy substrates, rocky bottom, or even turbid coastal waters, often near the mouths of rivers. They also inhabit coral reefs (Holthuis 1991). Moreover, some spiny lobster adults are known to migrate hundreds of kilometers to form large spawning aggregations at locations that benefit larval pelagic dispersal through strong water flow. Tagged adult *P. ornatus* in northern Torres Strait, for example, were detected to migrate about 511 km to the Gulf of Papua to spawn (Booth and Phillips 1994; Moore and MacFarlane 1984; MacFarlane and More 1986). Secondly, larvae from spawning events have a long planktonic phase lasting from four to eight months before they settle as puerulus (Booth and Phillips 1994; Phillips and Matsuda 2011). This provides the opportunity for larvae to be transported long distances by ocean currents before they become resident on reefs or other preferred habitats. Considering these characteristics, and the potential for long-distance dispersal, it is hypothesized that these species may exhibit low levels of genetic structuring across their distribution. This study investigated the genetic structure of spiny lobster *P. ornatus* and *P. homarus* throughout the species' distribution; essential in enabling resource managers to effectively regulate this fishery. A potential dispersal pathway of *P. ornatus* was also inferred, based on a synthesis of data on regional oceanography and the lobsters' known biology, to explain the observed patterns of genetic structure.

### Methods

To determine the genetic structure among *P. ornatus* and *P. homarus* populations across a broad part of the

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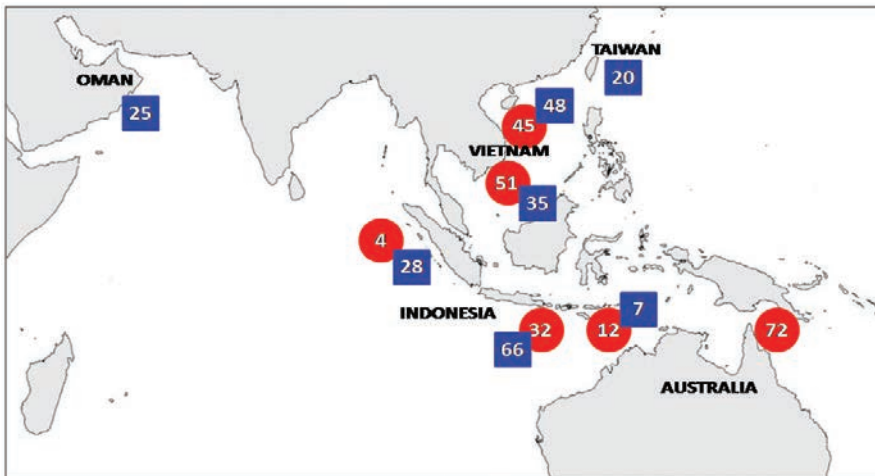
species' geographical distribution, a total of 216 *P. ornatus* individuals from two sites in Vietnam, three in Indonesia, and one in Australia were collected, while 229 *P. homarus* samples were collected from one population in the west Indian Ocean (Masirah, Oman) and six populations in the South-East Asian archipelago (Taiwan; Da Nang and Binh Thuan in Vietnam, along with West Sumatra, Lombok, and West Timor in Indonesia) (Figure 1). Specimens from Vietnam were all pueruli, while those from Indonesia and Australia were juveniles. Samples from Taiwan and Oman were adults collected from local fishing markets. All samples (pleopods from adults or abdominal muscle tissue from juvenile lobsters) were preserved immediately in a DMSO-salt preservative solution (Dawson et al. 1998). Genomic DNA (gDNA) from all lobster samples was extracted from 4 mm<sup>2</sup> pleopod clips, or from the abdominal muscle tissue of juveniles using a modified CTAB protocol (Adamkewicz and Harasewych 1996).

### Mitochondrial DNA (mtDNA) control region

DNA extracted from samples was diluted to 10–40 ng/μl for use in a polymerase chain reaction (PCR). The control region was amplified in 20 μl reaction volumes. PCR was performed on a BioRadC1000 Thermal Cycler. PCR products were then run on a 1.5% agarose gel for quantity and

quality verification. A repeat region in the start of the reverse primed sequence resulted in deterioration of sequence. Consequently, only DNA sequence from the forward primer was used. To verify nucleotide base calls, each sample was sequenced at least twice at the Australian Genome Research Facility (AGRF) in Brisbane, Australia. PCR primers previously designed for *P. ornatus* mtCR (PO\_F2 5' - ATAAAGGTAATAGCAAGAATC and PO\_R1 5' - CAAACCTTTTGTCCAGGCATC) were used for the amplification of 800 bp of the control region.

Sequence data were trimmed and aligned using Geneious ver. 6.1 with default alignment parameters and checked manually for misalignments. The statistical packages MEGA6 (Tamura et al. 2013) DNAsp 5.1 (Rozas et al. 2003) and ARLEQUIN ver. 3.5 (Excoffier et al. 2005) were used to perform partitioning of genetic structure  $\Phi_{ST}$  (using genetic distance). For calculation of the statistical significance of the  $\Phi_{ST}$  values obtained, a significance test with 10,000 permutations was carried out with ARLEQUIN ver. 3.5 (Excoffier et al. 2005).  $\Phi_{ST}$  and pairwise  $\Phi_{ST}$  comparisons between populations were estimated using the T92 model (Tamura 1992) with a gamma correction ( $\alpha = 0.633$ ) as determined by Model Selection in MEGA6. The median-joining network (Bandelt et al. 1999) for the haplotypes generated was constructed using NETWORK v. 4.6.1.0 (<http://www.fluxus-engineering.com>).



**Figure1.** Sampling sites and numbers of *Panulirusornatus* (red circles) and *Panulirus homarus* (blue squares) specimens collected from across species distribution

## Microsatellite markers

Ten and six highly polymorphic microsatellite markers developed for *P. ornatus* and *P. homarus*, respectively (Daoet al. 2013) were used for population genetic analyses based on the nuclear genome of all specimens belonging to different localities.

DNA was diluted to 10–40 ng/μl for use as template in a polymerase chain reaction (PCR). Microsatellites were individually amplified in 10 μl reaction volumes. PCR was performed on a BioRadC1000 Thermal Cycler. The PCR products were then checked for consistent amplification and pooled and purified using Sephadex G-50 resin before loading on a Megabace 1000 Capillary Sequencer for size separation of alleles (Amersham Biosciences). Alleles were scored on the basis of fragment size using the Fragment Profiler 1.2 package (Amersham Biosciences).

The level of genetic structure of *P. ornatus* and *P. homarus* based on microsatellite markers was analysed using an Analysis of Molecular Variance (AMOVA) with 10,000 permutations as well as by calculating pairwise  $F_{ST}$  comparisons between populations, both of which were carried out with ARLEQUIN version 3.5 (Excoffier et al. 2005). Further to these analyses, the Bayesian clustering algorithm implemented in STRUCTURE 2.2.3 (Pritchard et al. 2000) was used to determine spatial genetic discontinuities by inferring the highest probable number of genetic clusters present within the dataset with prior knowledge of the individual's origin. The package Structure Harvester (<http://taylor0.biology.ucla.edu/structureHarvester/>) was used to determine the optimum number of clusters used in the analysis and CLUMPP (<http://www.stanford.edu/group/rosenberglab/clumpp.html>) was also used to create averages across the replicate runs, after which the outputs were put through DISTRUCT (<http://www.stanford.edu/group/rosenberglab/distruct.html>) to graph average q values.

## Larval dispersal pathway map of *P. ornatus*

Physical and biological data were integrated to develop a larval dispersal pathway map of *P. ornatus*. This analysis could not include *P. homarus* due to a lack of knowledge about spawning grounds of this species. A literature review was undertaken, and expert opinion from relevant fisheries scientists in Australia, Vietnam and Indonesia was sought, to identify data on spawning grounds and pueruli settling locations within the archipelago (Daoet al. 2015). Biological data was then merged with oceanographic data to construct a map of the mean surface water circulation in the South-East Asian Archipelago, focusing on different months for different areas based on the known age of lobster larvae found during those months in those areas (Daoet al. 2015).

## Results

### Genetic variation of the mtDNA control region

No significant population subdivision was detected among the populations of *Panulirus ornatus* sampled, with a non-significant fixation index evident ( $F_{ST} = -0.008$ ;  $P = 0.922 \pm 0.003$ ). All of the genetic variation measured with mtDNA occurred within populations with no detectable among-population variance (Table 1). In addition, no evidence of genetic structure was detected across the wide geographical range sampled from the Torres Strait of Australia to Vietnam and Indonesia, with negligible and non-significant pairwise  $F_{ST}$  values between populations being very low (from  $-0.076$  to  $0.004$ ,  $P > 0.05$ ) (Table 2). As further evidence for widespread gene flow and lack of genetic structure the network tree showed no clustering of haplotypes into geographical regions or location based groups, with the majority of haplotypes being single or unique units (Figure 2).

**Table 1.** Summary table of analysis of molecular variance (AMOVA) describing the partitioning of genetic variation for six *Panulirus ornatus* populations based on both mtDNA control region sequences and 10 microsatellite loci

	Source of variation (%)		$\Phi_{ST}/F_{ST}$	P ± SD
	Among population	Within population		
mtDNA-control region	-0.80	100.80	-0.008	0.922 ± 0.003
Microsatellites	0.26	99.74	0.003	0.195 ± 0.004

Therefore, mtDNA based on the control region provided no evidence for genetic population structure in *P. ornatus* across the geographical range sampled.

In terms of *Panulirus homarus*, no population structure was revealed in AMOVA test using Tamura 1992 distance performed on the mtDNA control region sequence data set ( $\Phi_{ST} = 0.004$ ;  $P > 0.05$ ; Table 3). No significant population subdivision was detected among sampling sites. At the initial analysis, the pairwise  $\Phi_{ST}$  among populations shows a significant difference between samples collected in Taiwan and Binh Thuan ( $\Phi_{ST} = 0.029$ ) Taiwan and Sumatra

( $\Phi_{ST} = 0.023$ ) Taiwan and Oman ( $\Phi_{ST} = 0.034$ ) or Taiwan and West Timor ( $\Phi_{ST} = 0.077$ ) but were not significant after correction using False Discovery Rate (FDR) (Table 4). As further evidence for a lack of genetic structure, the haplotype network tree showed no clustering of haplotypes into geographical regions, or location based groups, with the majority of haplotypes being single or unique units (Figure 3). Therefore, analysis based on data of the mtDNA control region failed to detect genetic population structure in *P. homarus* across the geographical range sampled.

**Table 2.** Genetic differentiation between *Panulirus ornatus* from collection locations using pairwise  $\Phi_{ST}$  for mtDNA-control region (upper value) and for microsatellite loci (lower value). No significant  $F_{ST}$  value was found after correction using FDR

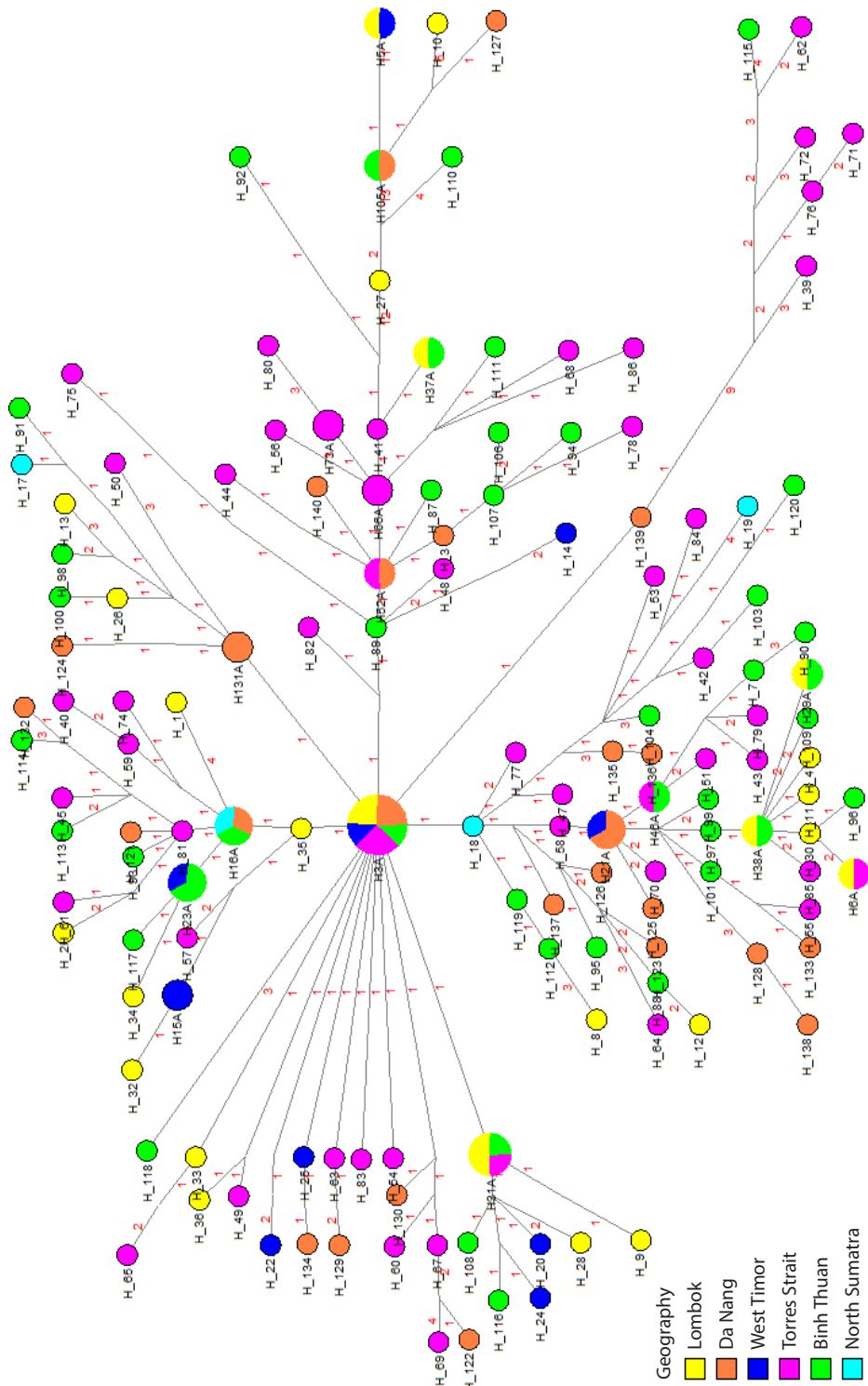
Localities	Torres Strait	West Timor	South Lombok	Binh Thuan	Da Nang
Torres Strait		-0.011	0.002	0.000	0.004
West Timor	0.006		-0.038	-0.018	-0.004
Lombok	-0.003	0.008		-0.015	-0.002
Binh Thuan	0.001	0.002	0.004		-0.007
Da Nang	0.000	0.009	0.001	0.002	

**Table 3.** Summary table of analysis of molecular variance (AMOVA) describing the partitioning of genetic variation for six *Panulirus ornatus* populations based on both mtDNA control region sequences and 10 microsatellite loci

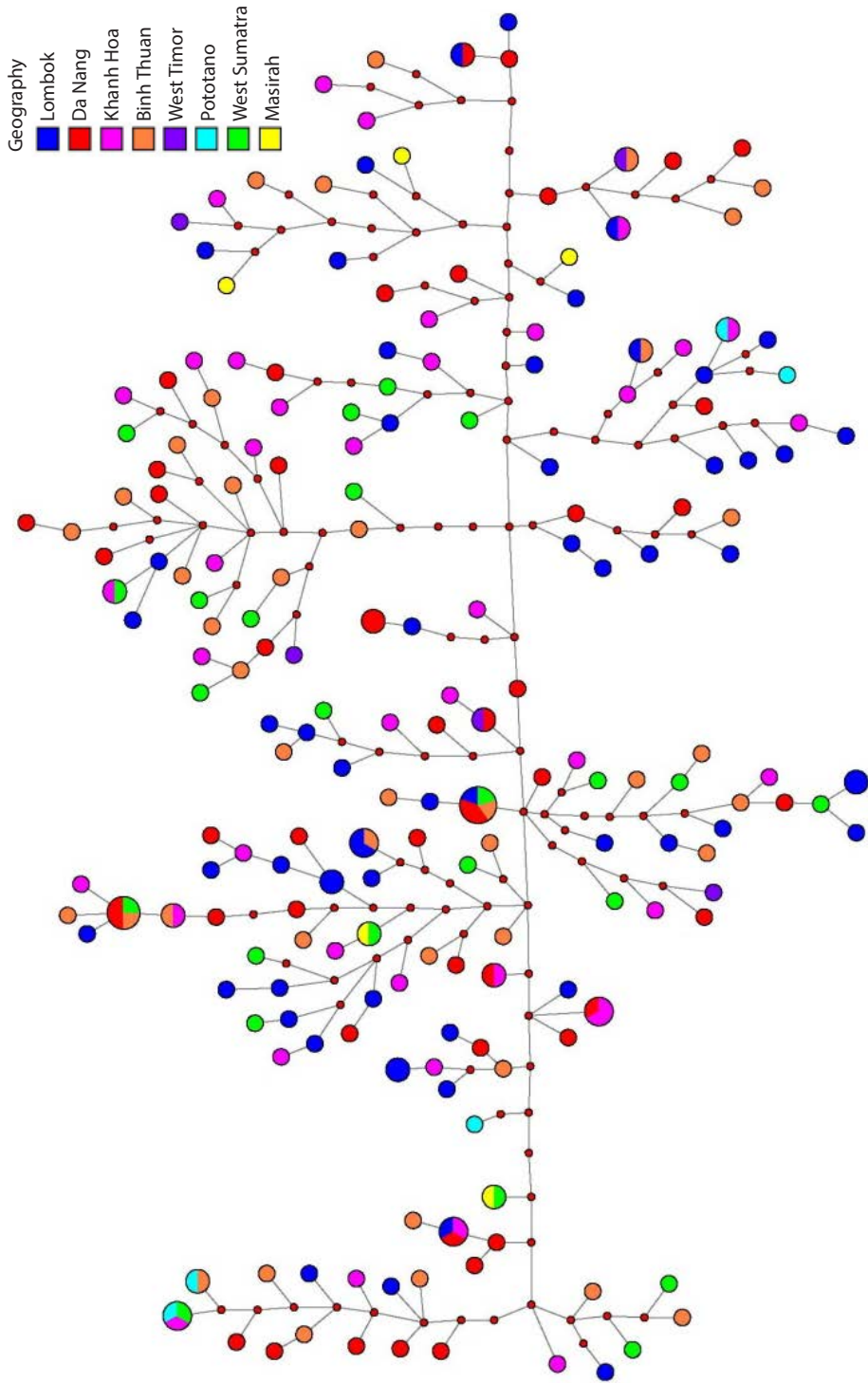
	Source of variation (%)		$\Phi_{ST}/F_{ST}$	P $\pm$ SD
	Among population	Within population		
mtDNA-control region	0.35	99.65	0.004	0.227 $\pm$ 0.004
Microsatellites	6.02	93.97	0.060	0.000 $\pm$ 0.000

**Table 4.** Genetic differentiation between *Panulirus homarus* from collection locations using pairwise  $\Phi_{ST}$  for mtDNA-control region (upper value) and pairwise  $F_{ST}$  for microsatellite loci (lower value)

Locality	Masirah	Binh Thuan	Da Nang	Taiwan	West Sumatra	Lombok	West Timor
Masirah		-0.001	-0.009	0.034	-0.001	0.015	-0.069
Binh Thuan	<b>0.198</b>		-0.010	0.029	-0.012	0.007	-0.012
Da Nang	<b>0.175</b>	0.010		0.017	-0.006	0.003	-0.019
Taiwan	<b>0.181</b>	0.001	0.005		0.029	0.006	0.077
West Sumatra	<b>0.075</b>	<b>0.058</b>	<b>0.041</b>	<b>0.051</b>		0.006	0.023
Lombok	<b>0.085</b>	<b>0.052</b>	<b>0.044</b>	<b>0.043</b>	-0.001		0.010
West Timor							



**Figure 2.** Network of *Panulirus ornatus* control region sequences from six collection locations from the South-East Asian archipelago. Each circle represents a haplotype, whose diameter is proportional to the number of individuals with that haplotype. The numbers on the connecting lines are the number of mutations between haplotypes



**Figure 3.** Haplotype network of *Panulirus homarus* control region sequences from six collection locations from the South-East Asian archipelago and one site from Arabian Sea. Each circle represents a haplotype, whose diameter is proportional to the number of individuals within that haplotype. The numbers on the connecting lines are the number of mutations between haplotypes. Small red dots are missing haplotypes.



## Genetic variation of microsatellite markers

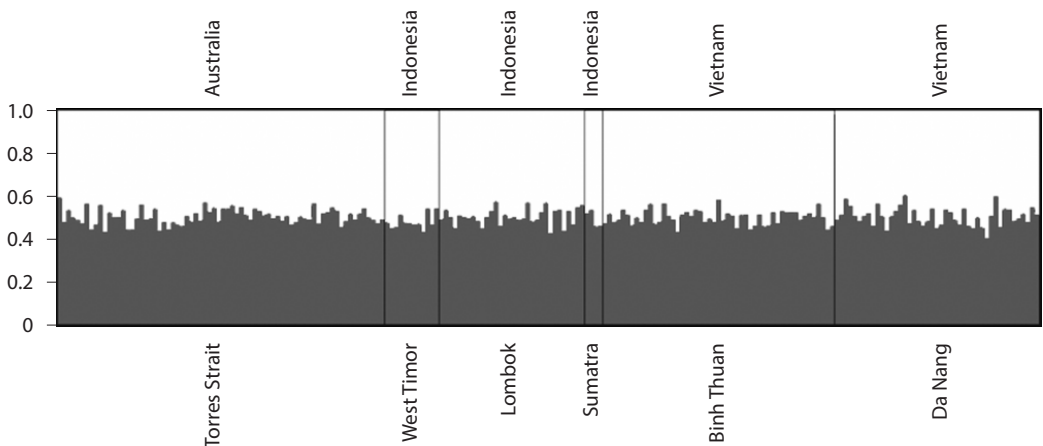
Ten polymorphic microsatellite markers were successfully amplified (Daoet al. 2013) and PCR products of all 216 samples of *P. ornatus* were genotyped for subsequent population genetics analyses.

As for the mtDNA control region, no significant population genetic structure was evident between the six sites when genotyped with the 10 microsatellite loci.  $F_{ST}$  estimates of population structure were again negligible and non-significant (AMOVA,  $F_{ST} = 0.003$ ;  $P = 0.195 \pm 0.004$ ) (Table 2). The microsatellite data indicated that less than 1% of genetic variation was present among populations. A similar lack of population genetic structure was evident in population pairwise comparisons across the Indo-West Pacific region ( $F_{ST}$  ranged from  $-0.003$  to  $0.031$ ; Table 3). The pairwise  $F_{ST}$  comparison between North Sumatra and other sampling sites were the highest observed (from  $0.017$  to  $0.034$ ) but were all insignificant after FDR correction ( $P > 0.05$ ). Due to the small sample size collected from Sumatra, these higher sample  $F_{ST}$  values are likely a result of sample size effects.

Individual based Bayesian assignment tests supported the lack of population genetic structure seen in

pairwise  $F_{ST}$  estimates. Although Structure Harvester suggests  $K = 2$  from multiple simulations run at values of  $K$  from one to 10, visual examination of individual bar plots for  $K = 2$  indicates an inability of the STRUCTURE algorithm to reliably assign any of the individuals to a distinct cluster, with assignment probabilities for each of the two populations of 50% for all individuals sampled (Figure 4). The inability to assign individuals using post-hoc plots if the true  $K < 2$  has been discussed in Evanno et al. (2005). Therefore, Bayesian analysis using STRUCTURE also suggests panmixia or lack of genetic structure among the six populations examined despite the widely spaced regional sampling employed here.

Six highly polymorphic microsatellite markers were successfully amplified in PCR and PCR products of 229 samples of *P. homarus* genotyped for the population genetics analysis. Significant genetic structure was detected among the seven sampling sites of *P. homarus* using  $F_{ST}$  estimates of population structure (AMOVA,  $F_{ST} = 0.060$ ,  $P = 0.0000 \pm 0.0000$ ). Due to the small sample size collected from West Timor (seven samples) the higher sample  $F_{ST}$  values involving this population are likely a result of random sampling effects and small sample



**Figure 4.** Bayesian individual assignment analysis for  $K = 2$  for *Panulirus ornatus* genotyped at 10 microsatellites across six Indo-Pacific sampling sites. Colours (grey or white) represent probability (y-axis) of individuals being assigned to each genetic cluster, whilst numbers (x-axis) represents population individuals sampled from 1 = Torres Strait, 2 = West Timor, 3 = Lombok, 4 = North Sumatra, 5 = BinhThuan (Vietnam) 6 = Da Nang (Vietnam). Sampling locations were used as priors



size. About 6.2% of the observed genetic variation occurred among localities (Table 4). Pairwise  $F_{ST}$  revealed significant genetic structure between three groups of sampling site. The first group includes only Oman samples (Masirah). The second were Vietnam (BinhThuan and Da Nang) and Taiwan sampling sites, and Indonesia sampling sites from Sumatra and Lombok were in the third group. About 17.5–19.8% genetic differentiation were detected between samples from Oman and the second group, while less different rates (from 0.075 to 0.085) were found among Oman and Indonesia samples (Table 4).

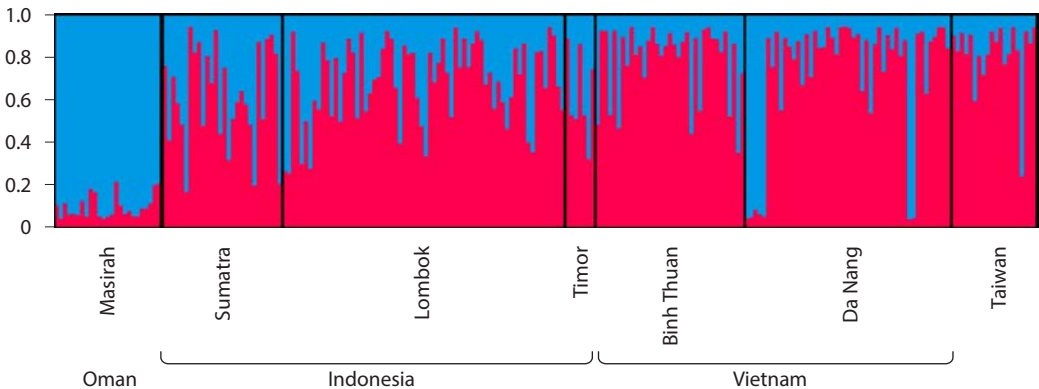
The population genetic structure differentiation seen in pairwise  $F_{ST}$  estimates were consistent with the results obtained using Bayesian assignment tests. Results applied to Structure Harvester (<http://taylor0.biology.ucla.edu/structureHarvester/>) suggests  $K = 2$  (Figure 5). Based on the pattern observed in the genetic clustering, we found regional structuring between Arabian Sea and Indo-West Pacific populations and within Indo-West Pacific populations of *P. homarus*, which explain the genetic variation (6.2%) between the regions. All samples from Oman were assigned to blue genetic cluster (more than 70% of blue colour) while most of samples collected in Vietnam and Taiwan were with more than 70% red proportion. Indonesian samples were a mixture of patterns from Oman and Vietnam-Taiwan samples.

### Larval dispersal pathway map of *Panulirus ornatus* throughout the South-East Asian archipelago

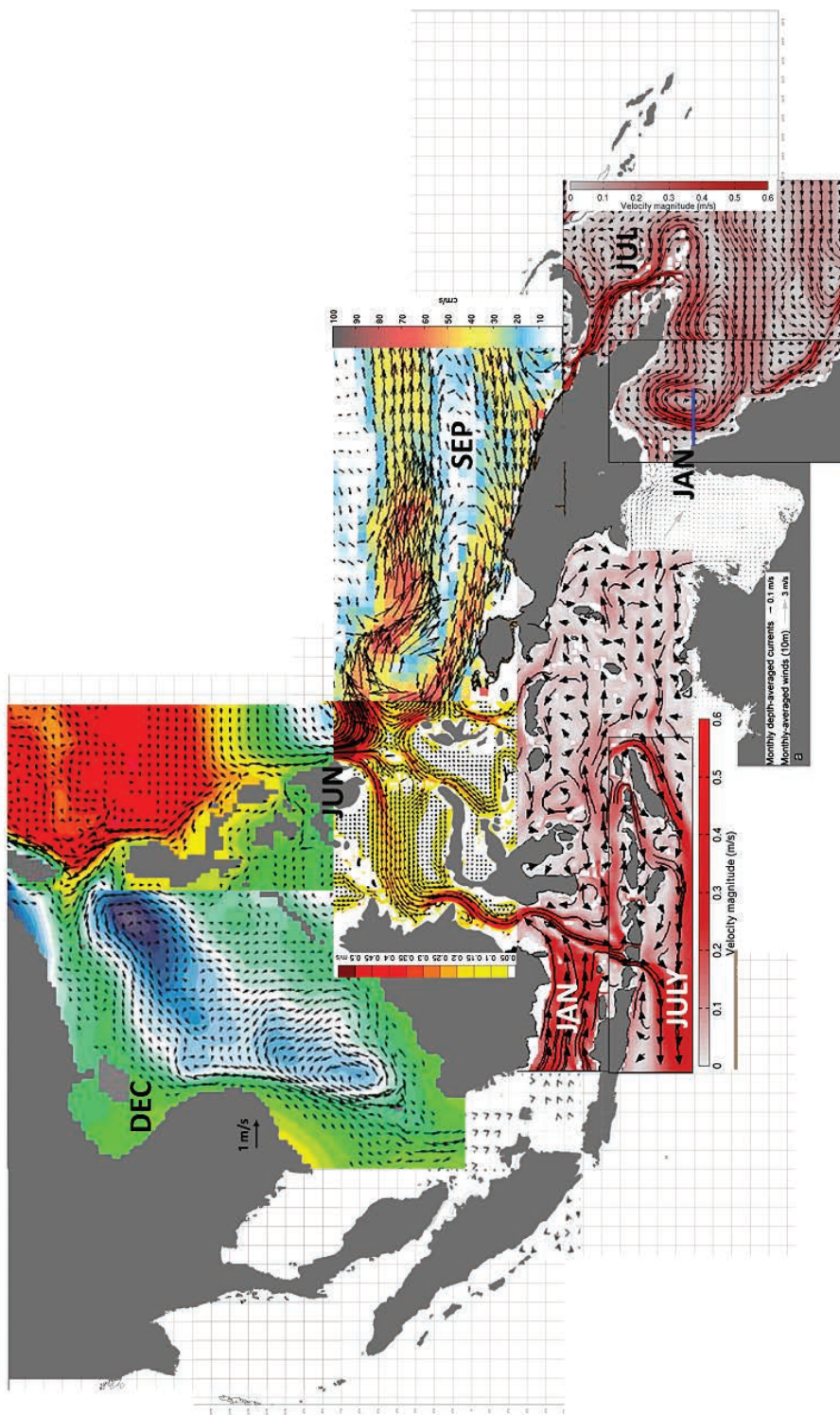
The above genetic studies using both mtDNA control region and microsatellites reveal a single genetic population of *P. ornatus* within the South-East Asian archipelago, implying high population connectivity of *P. ornatus* throughout this region. To explain how this connectivity may eventuate, the distribution of currents in the surface well-mixed layer in the South-East Asian archipelago is shown in Figure 6. The suggested connectivity network is shown in Figure 7 and further elaborated on in the discussion. Accordingly, the apparent lack of genetic structure in this tropical lobster species across the South-East Asian archipelago is explained by current-mediated larval transport that connects lobsters among spawning populations. This connectivity requires at least three generations (Daoet al. 2015).

### Conclusions and discussion

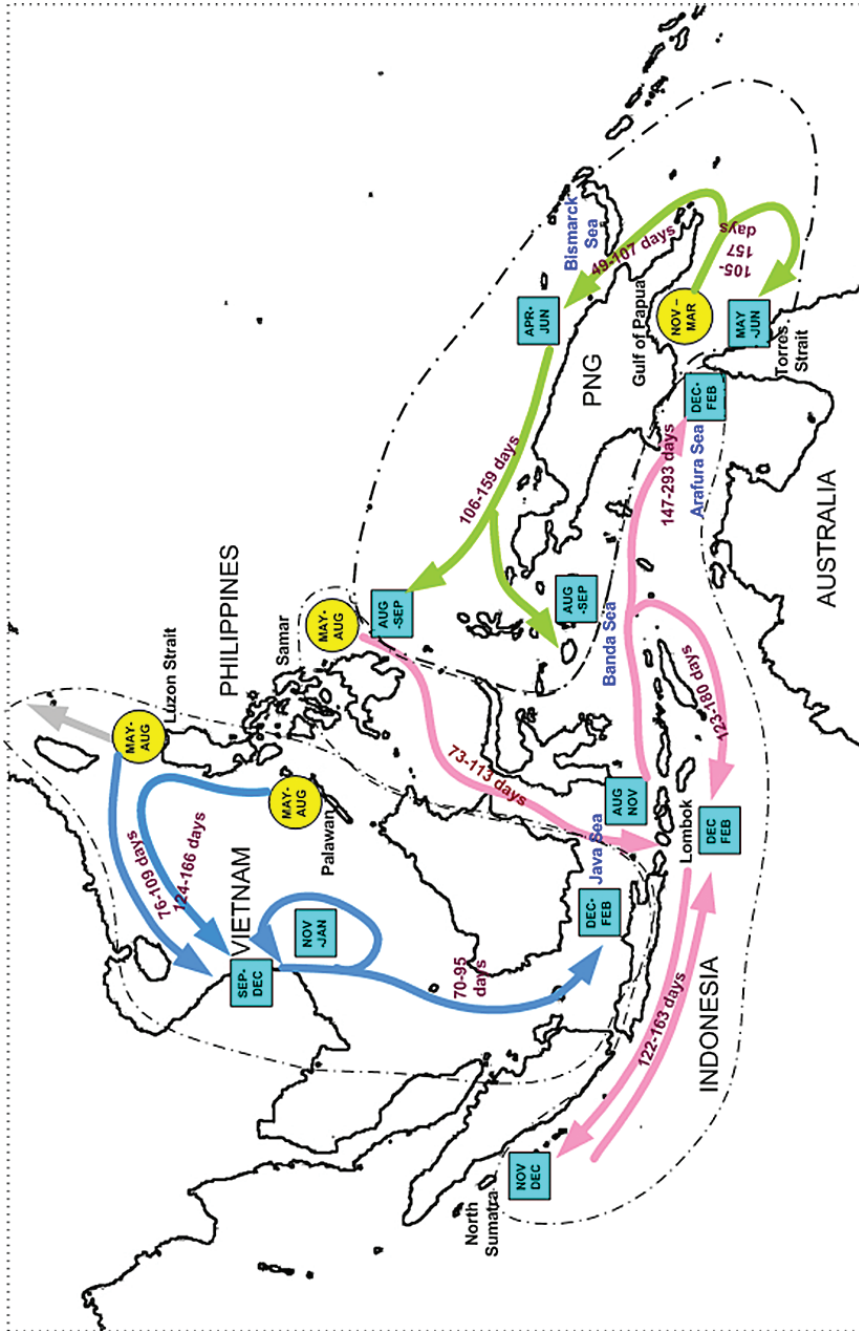
Both mitochondrial DNA (mtDNA) and microsatellites have been widely used for studies of genetic population in the spiny lobster genus, *Panulirus*. Genetic studies on Japanese spiny lobster, *P. japonicus*, failed to reveal any stock heterogeneity



**Figure 5.** Bayesian individual assignment analysis for  $K = 2$  for *Panulirus homarus* genotyped at six microsatellites across seven sampling sites. Colours (grey or white) represent probability (y-axis) of individuals being assigned to each genetic cluster, whilst numbers (x-axis) represents population individuals sampled from Oman (Masirah) Indonesia (West Sumatra, Lombok, West Timor) Vietnam (BinhThuan and Da Nang) and Taiwan. Sampling locations were used as priors



**Figure 6.** Seasonal surface ocean currents in the surface well-mixed layer in the South-East Asian archipelago at the times when *Panulirus ornatus* larvae are travelling between the various sites shown in Figure 7. To explain how this connectivity may eventuate, this figure shows the distribution of currents in the surface well-mixed layer in the South-East Asian archipelago during the periods of larval transport



**Figure 7.** Suggested larval dispersal pathways based on the surface water oceanography and the location of spawning grounds, dispersion patterns and connectivity for *Pamulirus ornatus* larvae throughout the South-East Asian archipelago. Round circles indicate spawning grounds where the larvae are released. Square boxes are estimated time that the larvae reach different locations as suggested by the oceanography and confirmed by field data. Of these, only two points have no field data, namely arrival times of larvae from Lombok in Torres Strait and the time of transit of the larvae along the north coast of Papua New Guinea. The different colours represent the different putative larval dispersal pathways, in order to distinguish separate flows

within the Japan Sea (Inoue et al. 2007) while low population divergence was observed for *P. gilchristi* in the deep shelf waters along the southern coast of South Africa. In addition, *P. cygnus* along the coast of Western Australia and *P. inflatus* in the Pacific coast of Mexico lack genetic structuring (Garcia-Rodriguez and Perez-Enriquez 2008; Thompson et al. 1996).

They also suggested that the panmixia is related to oceanographic flows in the area, coupled with a long larval period (Garcia-Rodriguez and Perez-Enriquez 2008; Inoue et al. 2007). However, panmixia is not always the situation. In *P. argus*, for example, genetic differentiation is present among Bermuda and Florida populations within the Caribbean Sea, as well as those sampled from Venezuela and Brazil (Sarver et al. 1998). Likewise, South African *P. delagoae* and *P. elephas* populations in the Atlantic Ocean and Mediterranean Sea exhibit shallow, but significant, levels of genetic structuring (Gopalet al. 2006; Palero et al. 2008). Recently, Chowet al. (2011) and Abdullah et al. (2013) found no genetic structure of pronghorn spiny lobster *P. penicillatus* within Western/Central Pacific populations, but high genetic variability was observed between Eastern and Western/Central Pacific localities.

In the present study, a combination of mitochondrial DNA control region and microsatellite DNA data suggest a single, genetically homogeneous stock of *Panulirus ornatus* across a broad region of the South-East Asian archipelago. Genetic differences were not detected between samples of *P. ornatus* from Vietnam, Indonesia and Australia-PNG, supporting the hypothesis by Williams (2004) of low genetic structuring of this species across the region due to its long oceanic larval development phase and wide larval transport capability. Neither population genetic ( $F_{ST}$ ,  $\Phi_{ST}$ , Bayesian) or phylogeographic network analyses indicated any evidence for restrictions on gene flow across the region, and integration of biological and oceanographic data show that genes can potentially circulate unimpeded throughout the entire region in only a few generations. Our oceanographic informed dispersal modelling suggests the potential for complete connectivity of *P. ornatus* populations within the South-East Asian archipelago within three generations of breeding (Figure 7).

For *Panulirus homarus*, the mtDNA control region failed to detect genetic differentiation among localities ( $\Phi_{ST} = 0.004$ ;  $P > 0.05$ ) which might be the consequences of small sampling size. In contrast to this limitation in our mtDNA control region data,

however, six polymorphic microsatellites revealed significant genetic structure (overall  $F_{ST} = 0.060$ ,  $P = 0.0000 \pm 0.0000$ ) among populations of *P. homarus*, with a strong differentiation between Indo-West Pacific and Arabian Sea (7.5–19.8%) and a shallower genetic variation within Indo-West Pacific (5.2–5.8%). Significant genetic divergence between Arabian Sea and Indo-West Pacific might be due to the ocean movement patterns which restrict the gene flow among these localities (Berry 1974; Pollock 1993).

The Bayesian individual assignment analysis (Figure 5) in our present study shows different genetic patterns among Oman populations and others. All samples from Oman were more homogeneous with the blue genetic cluster than most samples from other populations in Indonesia, Vietnam and Taiwan. However, some of individuals collected from West Sumatra, Lombok and Da Nang also had similar genetic patterns to Oman samples, which suggests a one-way dispersal pathway of *P. homarus* larvae from the Oman population to other localities.

### Implications for management

The existence of a single genetic population of *P. ornatus* characterised by drift connectivity (Lowe and Allendorf 2010) might have important implications for the sustainable management of this lobster, in that the species within the region need to be managed as one genetic stock. However, more work is required on the demographic connectivity of these populations so that the combined genetic and demographic connectivity datasets can inform management of this species as either one unit, or on the basis of individual spawning grounds (Ovenden 2013). Consequently, a multi-governmental fishery policy should be developed by Australia, Papua New Guinea, the Philippines, Vietnam and Indonesia, to ensure sustainability.

Our study findings provide genetic evidence to suggest genetic structuring *P. homarus* among populations across geographic distribution, as the species has a high dispersal potential throughout its life history, including adults spawning migration and long pelagic larvae duration. There are still knowledge gaps about the sources and sinks of recruited lobsters landing on the coastline of many countries. It is suggested that further studies be carried out on ecology, especially on the breeding grounds and spawning time of the species, and that these be applied to a bio-physical model to understand the oceanographic



dispersal pathway of *P. homarus* larvae in their large distribution. This may have major implications for fisheries managers.

While the sinks of *P. ornatus* larvae are known, the knowledge of larval sources for both species is still rudimentary, with only a few spawning sites confirmed to-date. The present study suggests that an additional spawning ground may be present in Indonesia, and its location needs to be identified and protected. More detailed studies on population connectivity are necessary to ensure the sustainability of lobsters in the South-East Asia archipelago. Genetic connectivity should be conserved as a priority.

## References

- Abdullah M.F. Chow S. Sakai M. Cheng J.H. and Imai H. 2013. Genetic diversity and population structure of pronghorn spiny lobster *Panulirus penicillatus* in the Pacific region. *Pacific Science* 68(2):197–211.
- Adamkewicz S. and Harasewych M. 1996. Systematics and biogeography of the genus *Donax* (Bivalvia: Donacidae) in eastern North America. *American Malacological Bulletin* 13(1): 97–103.
- Bandelt H-J. Forster P. and Röhl A. 1999. Median-joining networks for inferring intraspecific phylogenies. *Molecular Biology and Evolution* 16(1): 37–48.
- Berry P. 1974. A revision of the *Panulirus homarus*-group of spiny lobsters (Decapoda, Palinuridae). *Crustaceana* 27(1): 31–42.
- Booth J. and Phillips B. 1994. Early life history of spiny lobster. *Crustaceana* 66(3): 271–294.
- Chow S. Jeffs A. Miyake Y. Konishi K. Okazaki M. Suzuki N. et al. 2011. Genetic isolation between the Western and Eastern Pacific populations of pronghorn spiny lobster *Panulirus penicillatus*. *PloS One* 6(12) e29280.
- Dao H.T. Smith-Keune C. Wolanski E. Jones C.M. and Jerry D.R. 2015. Oceanographic currents and local ecological knowledge indicate, and genetics does not refute, a contemporary pattern of larval dispersal for the ornate spiny lobster, *Panulirus ornatus* in the South-East Asian Archipelago. *PloS One*, 10(5)e0124568.
- Dao H.T. Todd E.V. and Jerry D.R. 2013. Characterization of polymorphic microsatellite loci for the spiny lobster *Panulirus* spp. and their utility to be applied to other *Panulirus* lobsters. *Conservation Genetics Resources* 5(1): 43–46.
- Dawson M. Raskoff K. and Jacobs D. 1998. Field preservation of marine invertebrate tissue for DNA analyses. *Molecular Marine Biology and Biotechnology* 7(2): 145–152.
- Evanno G. Regnaut S. and Goudet J. 2005. Detecting the number of clusters of individuals using the software STRUCTURE: a simulation study. *Molecular Ecology* 14(8): 2611–2620.
- Excoffier L. Laval G. and Schneider S. 2005. Arlequin (version 3.0): an integrated software package for population genetics data analysis. *Evolutionary Bioinformatics Online* 1: 47–50.
- García-Rodríguez F.J. and Pérez-Enriquez R. 2008. Lack of genetic differentiation of blue spiny lobster *Panulirus inflatus* along the Pacific coast of Mexico inferred from mtDNA sequences. *Marine Ecology-Progress Series* 361:203–212.
- Gopal K. Tolley K. Groeneveld J. and Matthee C. 2006. Mitochondrial DNA variation in spiny lobster *Palinurus delagoae* suggests genetically structured populations in the southwestern Indian Ocean. *Marine Ecology Progress Series* 319: 191–198.
- Holthuis L. 1991. FAO species catalogue. Vol 13. Marine lobsters of the world. An annotated and illustrated catalogue of species of interest to fisheries known to date. FAO Fisheries Synopsis 125(13). Food and Agriculture Organization of the United Nations: Rome.
- Inoue N. Watanabe H. Kojima S. and Sekiguchi H. 2007. Population structure of Japanese spiny lobster *Panulirus japonicus* inferred by nucleotide sequence analysis of mitochondrial COI gene. *Fisheries Science* 73(3): 550–556.
- Jones C. Long N.V. Hoc D. and Priyambodo B. 2010. Exploitation of puerulus settlement for the development of tropical spiny lobster aquaculture in the Indo-West Pacific. *Journal of the Marine Biological Association of India* 52: 292–303.
- Long N.V. and Hoc D.T. 2009. Census of lobster seed captured from the central coastal waters of Vietnam for aquaculture grow-out, 2005–2008. Pp 52 in ‘Spiny lobster aquaculture in the Asia-Pacific region’, ed. by K.C. Williams. Proceedings of an international symposium, Nha Trang, Vietnam 9–10 December 2008. Australian Centre for International Agricultural Research: Canberra.
- Lowe W.H. and Allendorf F.W. 2010. What can genetics tell us about population connectivity? *Molecular Ecology* 19(15): 3038–3051.
- MacFarlane J. and Moore R. 1986. Reproduction of the ornate rock lobster, *Panulirus ornatus* (Fabricius). Papua New Guinea. *Australian Journal of Marine and Freshwater Research* 37: 55–65.
- Moore R. and MacFarlane J. 1984. Migration of the ornate rock lobster, *Panulirus ornatus* (Fabricius). Papua New Guinea. *Australian Journal of Marine and Freshwater Research* 35: 197–212.
- Ovenden J.R. 2013. Crinkles in connectivity: combining genetics and other types of biological data to estimate movement and interbreeding between populations. *Marine and Freshwater Research* 64(3): 201–207.
- Palero F. Abelló P. Macpherson E. Gristina M. and Pascual M. 2008. Phylogeography of the European spiny lobster (*Palinurus elephas*): Influence of current oceanographical features and historical processes. *Molecular Phylogenetics and Evolution* 48(2): 708–717.

- Phillips B. and Matsuda H. 2011. A Global Review of Spiny Lobster Aquaculture. Pp 22–84 in 'Recent Advances and New Species in Aquaculture', ed by R.K. Fotedar and B.F. Phillips. Wiley-Blackwell: Oxford.
- Pollock D.E. 1993. Speciation in spiny lobsters—clues to climatically-induced changes in ocean circulation patterns. *Bulletin of Marine Science* 53(3): 937–944.
- Pritchard J. Stephens M. and Donnelly P. 2000. Inference of population structure using multilocus genotype data. *Genetics* 155(2): 945–959.
- Rozas J. Sánchez-DelBarrio J.C. Messeguer X. and Rozas R. 2003. DnaSP, DNA polymorphism analyses by the coalescent and other methods. *Bioinformatics* 19(18): 2496–2497.
- Sarver S. Silberman J. and Walsh P. 1998. Mitochondrial DNA sequence evidence supporting the recognition of two subspecies or species of the Florida spiny lobster *Panulirus argus*. *Journal of Crustacean Biology* 18(1): 177–186.
- Tamura, K. (1992). Estimation of the number of nucleotide substitutions when there are strong transition-transversion and G+ C-content biases. *Molecular biology and evolution*, 9(4), 678–687.
- Tamura, K., Stecher, G., Peterson, D., Filipski, A., and Kumar, S. (2013). MEGA6: molecular evolutionary genetics analysis version 6.0. *Molecular biology and evolution*, 30(12), 2725–2729.
- Thompson A. Hanley J. and Johnson M. 1996. Genetic structure of the western rock lobster, *Panulirus cygnus*, with the benefit of hindsight. *Marine and Freshwater Research* 47(7): 889–896.
- Williams K. 2004. Spiny lobster ecology and exploitation in the South China Sea region. Proceedings of a workshop held at the Institute of Oceanography, Nha Trang, Vietnam, July 2004: Australian Centre for International Agricultural Research: Canberra

# 5.8 Study tour of Indonesian farmers to Vietnam lobster aquaculture industry in 2013

Bayu Priyambodo<sup>1</sup>

## Introduction

To assist in the transfer of lobster farming technology and stimulate expansion of lobster farming in Indonesia, a study tour was undertaken to Vietnam in March 2013. This paper provides a summary of the tour, its objectives, the participants' credentials, the program of activities, outcomes and recommendations.

Farming techniques in Indonesia are at an early developmental stage in contrast with Vietnam, where the lobster industry is highly developed. Over the past decade, ACIAR has supported the sustainable development of rock lobster farming in Vietnam and Indonesia. Given the success of the industry in Vietnam, it was deemed prudent to use a study tour as one method to transfer technology. By exposing Indonesian aquaculture farmers and government officials tasked with supporting aquaculture development directly to Vietnamese industry practices, effective technology transfer was facilitated.

To aid in the process and minimize communication difficulties, a translator fluent in both Indonesian and Vietnamese languages was employed to enable direct translation between Vietnam industry personnel and study tour participants.

## Study tour participants and program

The study tour took place over nine days in March 2013 in and around the city of Nha Trang, where lobster farming is well developed and represents

one of the most successful aquaculture industries in Vietnam. It was surmised that the lobster farming technology in Vietnam could potentially be adapted to Indonesia.

The objectives of the tour were to broaden the participants' knowledge of lobster aquaculture, to give them an idea of the scale in which an Indonesian industry might reach, and to stimulate participants to become agents of change in their farming areas.

The backgrounds of the tour participants are provided in Table 1. In addition to the core participants, the tour group also comprised a tour supervisor from ACIAR, a translator and a tour leader from Nha Trang University who managed all logistics and coordinated industry visits.

The program of activities is summarized in Table 2. The program was designed to expose the participants to all aspects of lobster farming from capture of lobster seed through to grow-out.

To assist in measuring the effectiveness of the tour, an interview-based survey of participants was performed, including pre and immediate post-tour interviews, with plans for a follow-up interview six months after the tour. The outcomes of the survey will form part of a PhD thesis by the author.

## Outcomes

The tour was performed without incident, and all participants were fully engaged and stimulated by the experience. A summary of industry statistics was prepared from the data gathered, presented in Table 3.

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**Table 1.** Background information on study tour participants

Profession	Experience with lobster (years)	Based at
Researcher	0	RICA Maros
Aquaculture engineering	2	Lombok MADC
Aquaculture extension	15	Lombok MADC
Aquaculture extension	3	Takalar BADC
Postgraduate student	7	UNSW Australia
Aquaculture extension	0	DKP NTB
Lobster farmer	15	Awang Lombok
Lobster farmer	6	Pulo Aceh
Aquaculture technician	1	Takalar
Aquaculture manager	15	Lombok

**Table 2.** Program of activities for study tour

Date	Activity	Place
1-Mar-13	Travel	Jakarta to Ho Chi Minh City to Nha Trang
2-Mar-13	Recovery and briefing Pre-tour participant survey / interview	Nha Trang city
3-Mar-13	Seed collection Interview seed fishers Q&A Lunch + discussion	Nha Trang city Bai Tien village catching area 1
4-Mar-13	Nursery farms Travel (boat) Inspect nursery farm Interview farmer Q&A Lunch + discussion	Nha Trang city to the nursing farms Bai Tien
5-Mar-13	Grow-out farms Inspect grow-out farms Interview farmers Q&A Lunch + discussion	Nha Trang city to Cu Lao landing port, to farm 1 Bich Dam ( <i>P. ornatus</i> ), to farm 2 Hon Mieu ( <i>P. homarus</i> )
6-Mar-13	Field trip Meeting with local fishers/farmers Travel (boat) Q&A Lunch + discussion with locals Visit to the catching area 2 Visit to the tank facilities	Van Ninh Distrit to Xuan Tu village, to the farming area Xuan Tu, back to Xuan Tu village. Ran Trao MPA's to the catching area 2 Luong Son, to the tank facilities Bai Tien
7-Mar-13	Lecture on lobster health and disease Travel Lecture + Q&A Lunch + discussion	Nha Trang University R&D Centre
8-Mar-13	Visit to fish landing port Visit to the museum Post-tour participants survey/interviews	Nha Trang city to the landing port Cau Da port Vien Dong hotel to the ION's museum
9-Mar-13	Travel, return to Indonesia	Nha Trang to Ho Chi Minh City to Jakarta

**Table 3.** Lobster farming industry statistics for Vietnam and Indonesia

Metric	Vietnam	Lombok
Annual puerulus supply	2–5 million	600,000 (2008–2012)
Annual production of live lobster	> 1,000 tons	20–25 tons (before 2012)
Number of sea cages	35–50,000 cages	2–3,000 cages
Puerulus price <sup>1</sup> (each)		
<i>Panulirus homarus</i>	\$2.00 to \$2.40	\$0.20 to \$0.60
<i>Panulirus ornatus</i>	\$5.00 to \$7.50	\$0.40 to \$0.70
Market price per kg		
<i>Panulirus homarus</i>	\$50 to \$60 (400 to 500g)	\$35 to \$40 (100 to 200g)
<i>Panulirus ornatus</i>	\$80 to \$120 (1kg)	Not applicable <sup>2</sup>
Lobster food price per kg		
Acetes shrimp	\$1.50	\$2.50
Baby crabs	\$0.95	Not available
Trash fish	\$0.70 to \$1.00	\$0.10 to \$1.50
Grow-out duration (months)		
<i>Panulirus homarus</i>	12 to 15	8 to 10
<i>Panulirus ornatus</i>	18 to 20	Not applicable <sup>2</sup>
Survival rate		
<i>Panulirus homarus</i>	80 to 90%	20 to 50%
<i>Panulirus ornatus</i>	70 to 80%	Not applicable <sup>2</sup>
Food Conversion Ratio		
<i>Panulirus homarus</i>	15	15
<i>Panulirus ornatus</i>	15 to 25	Not applicable <sup>2</sup>

<sup>1</sup> Prices in US dollars

<sup>2</sup> Lobster species in Indonesia are not distinguished for marketing or production

## Conclusions and recommendations

The study tour appeared to be very effective in improving the knowledge of participants, particularly in regard to detailed technical information on seed collection, nursery, grow-out (sea cages, submerged cages and tanks) and disease.

Qualitative assessment of farming practices since returning to Indonesia suggest there has been distinct improvement in grow-out management techniques, particularly management of cage depth and routine cleaning of cages, nutrition and lobster health.

The most dramatic impact of the study tour was the significant increase in lobster seed catch attributed to improved techniques, modified equipment and application of light to attract seed to the fishing equipment. In Lombok, more than 60% of farmers

modified their seed traps to improve the catch, particularly with the inclusion of lights.

The puerulus fishing grounds throughout Indonesia have expanded from three bays (Awang, Bumbang and Gerupuk Bays) in Lombok to the entire south coast area of Lombok, and also Dompu, Bima and several parts on the south coast of East Java. Based on the knowledge gained from the study tour, two new seed catching areas were identified in Aceh.

As reported in these proceedings (Chapter 2.1), seed catch in Lombok increased dramatically within one month of completion of the study tour, resulting in the subsequent annual catch for 2013 exceeding five million lobster seeds compared with 600,000 per annum previously. The lobster seed census for 2014 recorded five million lobster seeds caught in 2014.

The number of the puerulus fishers has also increased significantly from around 300 in the previous period (2008–2012) to 3,000 in 2014. This activity has generated very good income for the coastal communities involved.

Knowledge gained on diseases also assisted in the application of more effective preventive and curative measures, decreasing prevalence.

Suggestions for future study tours include: greater focus on grow-out techniques, longer periods of interaction with farmers, and bringing Vietnamese lobster farmers to Indonesia.

## Acknowledgements

The financial support of ACIAR is gratefully acknowledged and special thanks given to Dr Clive Jones for supervising the study tour. The leadership and guidance of Dr Le Anh Tuan from Nha Trang University is greatly appreciated. Thanks to Ms Hoa Dang Hoang for translation service. Many thanks to the Vietnamese farmers who shared their knowledge, and to the study tour participants for their enthusiastic attendance.



**Figure 1.** Study tour group assembled at Nha Trang, Vietnam.



**Figure 2.** Tour group uniform



**Figure 3.** On board lobster seed fishing vessel



**Figure 4.** Indonesian farmer discussing nursery culture techniques





Figure 5. Tour group on transport vessel to grow-out farms



Figure 6. High quality farmed lobster *P. homarus* (left) and *P. ornatus* (right)

# 5.9 Market perspective on farmed tropical spiny lobster

Clive Jones<sup>1</sup>

## Introduction

This paper provides a synopsis of market information for lobsters gathered by the project team through their experiences and project travel during the course of the ACIAR project SMAR/2008/021: Spiny lobster aquaculture development in Indonesia, Vietnam and Australia. The audience is advised to also read a market assessment report for tropical lobster prepared as part of a previous ACIAR project (Hart 2009).

The information provided covers primary markets for farmed lobsters, general observations, wholesale prices, import tariffs, seed supply and regional developments.

## General observations

Marine spiny lobsters are a premium seafood product representing esteem, wealth and fine dining. Farming of lobsters is not for production of protein to feed hungry people, it is rather to supply prestige to a specific market motivated to boast and impress for social eminence.

Much of the farmed lobster from Vietnam is supplied to Hong Kong live seafood markets, from where it is trans-shipped to other mainland Chinese cities. Insights from MG Kailis Australia Pty Ltd (Brett Arlidge pers. comm.) indicate that *P. ornatus* supplied from the north-eastern Australian fishery is considered the premium in the Chinese market, and that farmed product from Vietnam is now of equal value. In contrast, the farmed lobster coming from Indonesian farmers (primarily *P. homarus*) is considered to be of relatively low quality relative to fishery product of the same species. Farmed product

is generally in a weak condition, with poor colour. To increase their profitability, Indonesian farmers need to work towards price equivalency for their farmed product.

## Primary markets

The primary market for farmed tropical lobster is China, with Taiwan a valuable secondary market. Farmed *P. ornatus* and *P. homarus* from Vietnam are nearly all sold to these markets as live lobster. This supply joins wild fishery product of the same species from Australia, India, the Philippines and other South-East Asian countries. Farmed product from Indonesia is currently too small in volume to register on any formal databases. It is understood that nearly all Indonesian farmed lobster is supplied to domestic markets, primarily in Bali. As farmed production from Indonesia increases it should look towards China to achieve premium price.

In regard to tropical lobster species, the Chinese market displays a clear preference for *P. ornatus* at 1kg size and alive. Nevertheless, there is increasing acceptance of other species and price is trending upwards for all species. *P. homarus* is increasingly accepted as a substitute for *P. ornatus*. Wholesale price in China fluctuates around cultural events, when lobsters are traditionally sought or avoided, e.g. Chinese New Year (lantern festival) vs Tomb-sweeping Day. The increasing size of the Chinese upper class with a taste for fine dining continues to drive demand.

Although the China market is the primary market for farmed lobsters and offers the highest price, driven by strong demand that exceeds supply, there is some risk in complete reliance on this market. Decrees from the Chinese central government to reduce or avoid celebratory corporate events and

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dining can have a dramatic effect on demand for some products. In the past, this has significantly affected abalone and grouper sales, as these products were specifically mentioned in the government pronouncements. Some diversification in marketing of farmed lobster is prudent to mitigate such risk.

### Wholesale prices

At the time this report was prepared, Australian fishery sourced *P. ornatus* was fetching a wholesale price of \$90/kg in Australia, which equates to A\$130/kg in Hong Kong, which applies a 40% tariff. Vietnamese farmed product of *P. ornatus* and *P. homarus* are now generally transported directly to China overland by truck via Hanoi to avoid payment of import duties through Hong Kong. Under this arrangement, they achieve a wholesale price of A\$130/kg for *P. ornatus* and A\$80/kg for *P. homarus*. Indonesian farmed *P. homarus* is generally of low quality and small size (<300g) and fetches a wholesale price of A\$40/kg.

Wholesale price for all species of lobster have continued to increase over the past decade as demand increases and supply remains steady. This price trend is well illustrated for farmed *P. ornatus* prices as per Figure 1.

### Import tariffs

Both Vietnam and Indonesia are advantaged by having free trade agreements with China by virtue of their ASEAN (Association of South East Asian Nations) membership that precludes any import tariffs. Nevertheless, importation via Hong Kong still attracts significant costs in other taxes and duties which has prompted Vietnam to bypass Hong Kong for the importation of live lobster by using road transport overland via Hanoi.

Australia does not have a free trade agreement with China, and consequently attracts a 40% import tariff on imported live lobster coming from the fishery in north Queensland and the Torres Strait. This is to the advantage of Vietnam and Indonesia as they do not have such a tariff added to the cost of their lobster product.

Attempts by importers in Hong Kong to evade tariffs by clandestine trans-shipping of product to mainland China cities, thus avoiding customs inspection, have sometimes backfired, when Chinese authorities have issued temporary bans on all lobster imports from Australia.

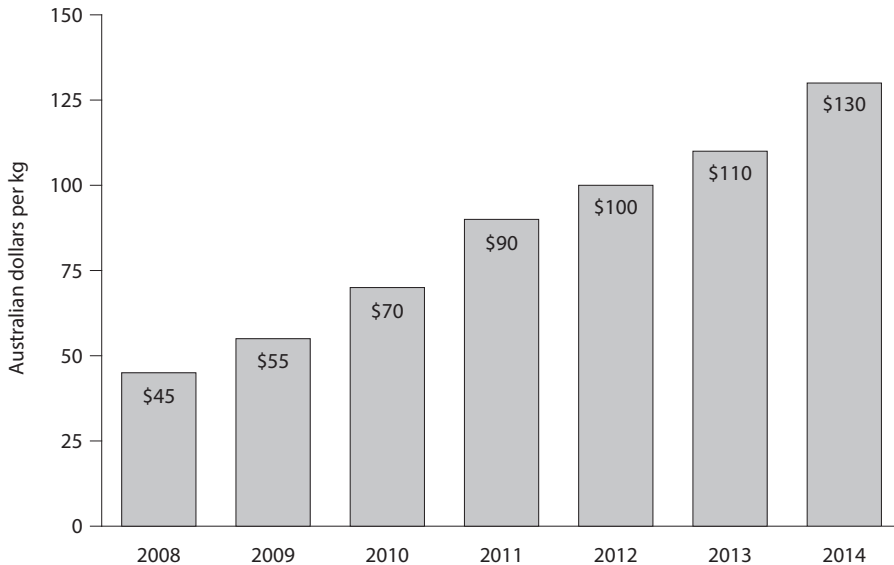


Figure 1. Price trend for farmed *P. ornatus* from 2008 to 2014 based on Vietnamese production



## Seed supply

Farm production of lobster is currently limited by the natural seed supply. In Vietnam, the seed catch has been consistently two to four million pieces per year, from which farmers generate around 1,500 tonnes of marketable lobsters. Opportunities to increase production to meet demand can come from increasing the survival rate of lobsters along the production chain through improved husbandry and nutrition, and from increased seed supply. It seems unlikely that any more seed can be captured in Vietnam as the fishery appears to be fully developed, however importing seed from other countries could be further developed.

Indonesia has increased its seed supply through improved seed fishing technology (see Chapter 5.8), and much of the increased catch has been exported to other countries, including Vietnam, for on-growing. The marketing of lobster seed is a relatively simple and low risk business that appeals to smallholders in Indonesia, but their potential returns would be far greater if they grew the seed lobsters to consumption market size. At present, Indonesia produces less than 50 tonnes of farmed, consumption-size lobsters from the seed they capture. Applying best practice production technology from Vietnam, and on-growing lobsters to larger sizes could generate more than 1,500 tonnes.

Hatchery technology for the production of lobster seed would enable even greater production of farmed lobster to meet market demand. However, given difficulties in commercialising the technology (see Chapter 5.13) it seems that such supply is many years away.

## Regional developments

Vietnam is the only country in the region supporting a viable and commercial-scale lobster farming industry. Production from Vietnam is steady at around 1,500 tonnes of farmed lobster per year. Indonesia is the next best positioned country to develop lobster farming, based on an established puerulus fishery in Lombok now producing in excess of five million lobster seed each year. The challenge for Indonesia is

to convert the seed into marketable lobsters to exploit available market opportunities.

In Malaysia, the establishment of an integrated lobster aquaculture park in Sabah was recently announced. The project is a joint venture between the United States-based Darden Corporation (owner of the Red Lobster restaurant chain) and Malaysian partners to establish both grow-out farms and a hatchery. However, to date, there has been no commercial output from this enterprise.

Anecdotal reports suggest there is some farmed lobster production in the Philippines, Thailand and India, although no confirmed statistics are available. It appears that such production is low in volume, irregular and likely represents simple fattening of smaller lobsters.

Australia has expressed considerable interest in developing lobster farming to bolster its successful fishery production, and to take advantage of market opportunities. However, to date, no farmed lobster production has been established for any Australian species.

## Conclusions

High market demand for lobster from China and Taiwan presents a significant opportunity for farmed product, and Vietnam has begun to seize this opportunity. Farming of lobster provides the additional opportunity of customizing product to meet specific market requirements in regard to size, vigor and possibly colour, such that farmed product could attract a premium over wild caught fishery lobster. Although the highest price is paid for *P. ornatus*, there is great demand and good price available for other tropical species, including *P. homarus*.

Indonesia has an opportunity to be a major producer of farmed lobster.

## Reference

Hart G. 2009. Assessing the South-East Asian tropical lobster supply and major market demands. ACIAR Final Report (FR-2009-06). Australian Centre for International Agricultural Research: Canberra.

## 5.10 Building Indonesia's lobster farming industry

Bayu Priyambodo<sup>1</sup> and Clive Jones<sup>2</sup>

### Introduction

This paper provides a broad perspective on the prospects for developing lobster farming in Indonesia, including a discussion of government support and a SWOT analysis. Barriers to development are identified, as well as recommendations for research and development activities that might enable lobster farming in Indonesia to reach its full potential.

### Vision

*A sustainable lobster farming sector engaging coastal communities throughout Indonesia producing high quality lobsters for the market.*

The goal is to establish Indonesia's most valuable aquaculture industry. This will be accomplished by researching, developing and extending best practice technology to coastal communities to provide them with the knowledge, capacity and confidence to engage in lobster farming.

The lobster farming industry is small but well established in Lombok. Strong potential exists for this nascent industry to flourish throughout Indonesia, benefiting impoverished coastal communities. Continued ACIAR support at this critical time will ensure development problems are addressed and benefits are maximised.

Based on puerulus availability of five million pieces, lobster production could reach more than 2,500 tonnes and a value of over \$130 million.

### Prospects

Indonesia has a coastline spanning some 54,716 km from a combined total of 17,508 islands. Consequently, there are many suitable sites to develop marine aquaculture in Indonesia, including lobster farming. Straddling the equator, the climate is a relatively benign tropical one that provides great opportunity for sea-cage culture of tropical lobsters.

Strong market demand from China and Taiwan for live lobsters provides a strong foundation, and the Vietnam experience suggests farmed lobsters can achieve the same high price as wild caught product. An enormous lobster seed supply has been established in Lombok that can support a significant industry, with strong prospects. This could be expanded from additional seed supply in Southern Sumbawa, Southern Sulawesi, South-east Sulawesi, Aceh and other parts of Indonesia.

### Government support

The Indonesian Directorate General Aquaculture (DGA) has developed a mid-term plan of Aquaculture Development 2015–2019. Although lobster is not specified as one of the main commodities for aquaculture development, it is included in the 'Other Commodities' category that is also well supported by central government.

Lobster is specifically included in the DGA program for the industrialisation of mariculture. Other species in this program include silver pompano, groupers, sea-bass, tuna, cobia, ornamental fish, crustaceans, sea cucumbers, sea horse and seaweeds. DGA is developing a draft of a National Standard of Indonesia for lobster aquaculture. The location of government-supported pilot lobster sea-cage operations in Indonesia are shown in Figure 1.

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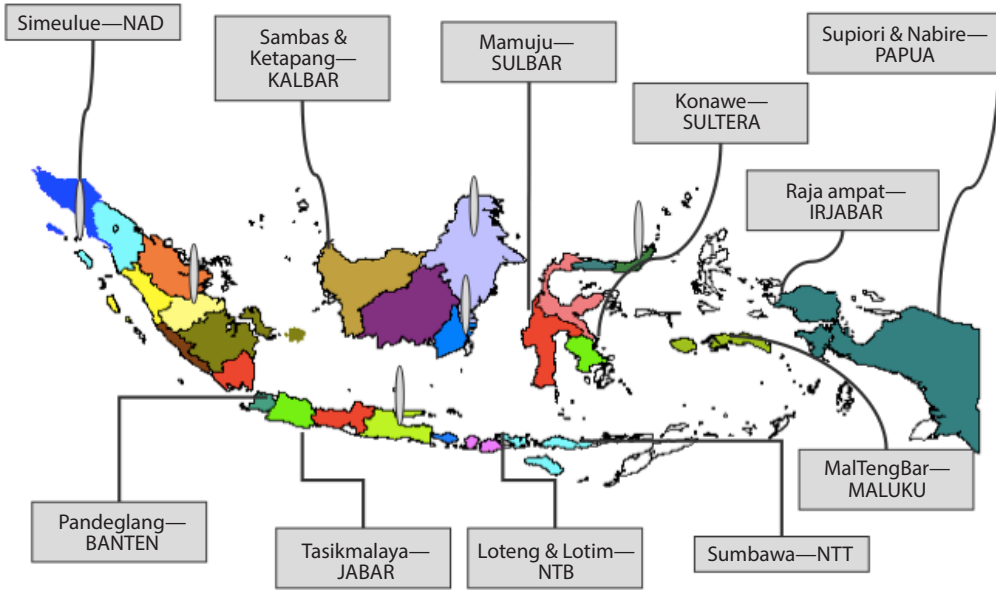
A SWOT analysis of lobster aquaculture in Indonesia is provided in Table 2. This will be useful in directing research and further government support.

### Constraints

Lobster farming in Indonesia is a small and fragmented industry that would be well served by communication between operators. There are no established lobster associations as yet, and this confers

a relatively weak negotiating position for farmers, particularly in regard to middlemen who purchase lobsters from the farmers and who tend to make the biggest profit.

In general, coastal communities rely too much on government support. The people living in the coastal zone prefer to sell puerulus rather than grow lobsters out to marketable size (aquaculture), as sale of seed provides quicker cash flow and has relatively low risk.



**Figure 1.** The location of government-supported pilot lobster sea-cage operations in Indonesia

**Table 1.** SWOT analysis of lobster aquaculture in Indonesia

No	Strengths	Weaknesses	Threats	Opportunities
1	Existing seed resource identified and exploited	Industry small with limited recognition	Climate change Seed availability	ACIAR support to grow
2	Grow-out established	Poor access to capital	Export of seed	Expansion of seed resource
3	Farmed lobsters being marketed	Poor decisions driven by cash flow constraints (harvest size)	Diseases	Significant number of suitable grow-out locations
4	Knowledge and capacity within Lombok	Lobster farming only known in Lombok	Poverty	Corporate investment
5	ACIAR support	Limited extension capability	Education/knowledge of farmers	Growing demand
6	High-value species	Limited farmer capability	Ignorance of opportunity	Improve product quality
7	Site availability and potential for development	Limited technology	Increasing cost of production	

A further constraint for poor coastal smallholders is their access to credit. There are some credit programs provided by the Ministry of Marine Affairs and Fisheries for coastal communities, but most smallholders are unfamiliar with how to access them. Most lobster farmers prefer to borrow money from their neighbours, private financiers and relatives, who charge very high levels of interest.

Industrial support for lobster farming is also limited or difficult for farmers to access. The government can provide manufactured cage systems for groups of farmers, but lobster farmers are yet to access this option. National aquafeed companies have not expressed interest in producing a pelleted feed for lobster, as the sector is too small and dispersed.

## Conclusions and recommendations

### Goals

- Increase puerulus catch to >five million pieces per year from multiple locations. This means that lobster production could reach more than 2,500 tonnes and a value of over \$130 million.
- Grow-out established in more than five provinces.
- Puerulus export abandoned in favour of local grow-out.
- Coastal communities advised, educated and engaged in lobster farming.
- Export of farmed lobsters to premium markets exceeds 1,000 tonnes.
- Average harvest size >500 g per lobster.
- Average farm gate price >\$50 per kg.

### Recommendations for industry development

	Duration	Description
1	Short term	Developing a supply of wild puerulus Establishment of grow-out techniques Regulation for controlling export of lobster seed Improvements in nutrition and feed supply Marketing system for export of farmed lobster Access to capital Extension and dissemination program
2	Mid term	National plan for lobster farming development Industrial support (feed manufacture and cage construction)
3	Long term	Hatchery supply

### Research required

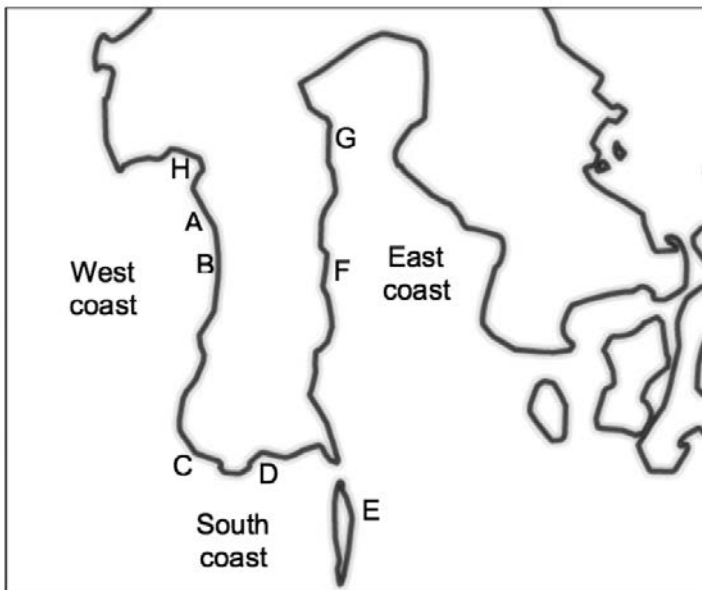
Project	Disciplines	Objectives	Priority
A	Biology Nutrition Husbandry Fisheries (puerulus)	Improve production survival and growth Increase productivity Increase production	1
B	Economics Social Science Technology adoption	Robust economic models as collateral for finance Understanding of social factors in engaging more people	2
C	Policy Planning	National plan for lobster farming development Identified grow-out locations with support	3
D	Disease	Identify key health and disease issues Develop mitigation strategies Develop treatments	2
E	Training Education	Knowledge and capacity development at the community level	1
F	Marketing Product development	Improve market access Increase farm gate price New products to meet market	3
G	Biology Recirculation Technology	Intensive lobster production systems Land-based production	2

## 5.11 Assessment of tropical spiny lobster aquaculture development in South Sulawesi, Indonesia

Muhammad Idris<sup>1</sup> and Samsul Bahrawi<sup>2</sup>

Aquaculture development in South Sulawesi is strongly supported by the Ministry of Marine Affairs and Fisheries through the Brackishwater Aquaculture Development Centre (BBAP) at Takalar. During 2010–2014, BBAP Takalar staff conducted a range of activities to assess the potential of lobster farming and support its development. These activities

were applied in the locations shown in Figure 1 and complement support for other aquaculture species, including swimming crab, abalone, grouper, sea bass, seaweeds (*Eucheuma cottoni* and *Gracillaria gigas*) and rabbit fish. Prior to 2011, there was no lobster farming activity at all in South Sulawesi but now there are around nine lobster farmers.



**Figure 1.** Map of South Sulawesi showing locations of lobster farming activity, including puerulus fishing and/or lobster grow-out: A—Baruru; B—Pangkep; C—Takalar; D—Bantaeng; E—Selayar; F—Bone; G—Luwu; and H—Polman

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<sup>2</sup> Marine Aquaculture Development Centre, Lombok, Indonesia

The species of lobster recorded from fishing in South Sulawesi include *Panulirus ornatus*, *P. homarus*, *P. versicolor* and *P. longipes*. Standardised ‘tripod’ collectors (see Chapter 2.3) for assessing puerulus availability have been deployed at these locations. Records collected are summarised in Table 1.

The catch of puerulus was seasonal, with all seed caught between October and March. A demonstration grow-out farm was established in Laikang Bay near Takalar in 2011. Due to the small number of puerulus caught locally, seed from Lombok were transported there for a grow-out trial. The seed supplied were on average 5 g in weight at stocking and on-grown for 13 months, with a survival of 62% and average growth rate of 0.5 g per day, to achieve an average harvest size of 205g. Following the example of the demonstration farm, by 2013 there were 11 lobster

grow-out cages established in Laikang Bay, two in Barru, one in Luwu and one in Polman.

Although the catch of lobster seed from the tripod collectors has been relatively low, the presence of the seed is a positive indication that with improved technique and fishing equipment, the catch may be much higher, and sufficient to support a lobster farming industry.

### Opportunities and constraints

There is a need to continue seed collection, including expanding into other areas that have potential lobster seed resources. Where seed are found, commercial fishing techniques should be applied, comparable to those already established in Lombok.

**Table 1.** Summary of information and data collected from lobster puerulus assessment activities in South Sulawesi from 2010 to 2014

Location	Activity	Comment
West coast—Makassar Bay (Polman, Barru, Pangkep)	8 tripods deployed	35 post-puerulus collected November 2012 to February 2014 100% <i>P. versicolor</i>
South coast—Flores Sea (Takalar, Bantaeng, Selayar)	16 tripods deployed	45 post-puerulus collected 2010 to 2012 60% <i>P. ornatus</i> , 20% <i>P. homarus</i> and 20% <i>P. versicolor</i>
East coast—Bone Bay (Bone, Luwu)	28 tripods deployed	190 post-puerulus collected 2011 to 2012 80% <i>P. versicolor</i> and 20% <i>P. ornatus</i>



## 5.12 Assessment of tropical spiny lobster aquaculture development in Aceh, Indonesia

Syafrizal<sup>1</sup>, Hasanuddin<sup>1</sup> and Samsul Bahrawi<sup>2</sup>

### Introduction

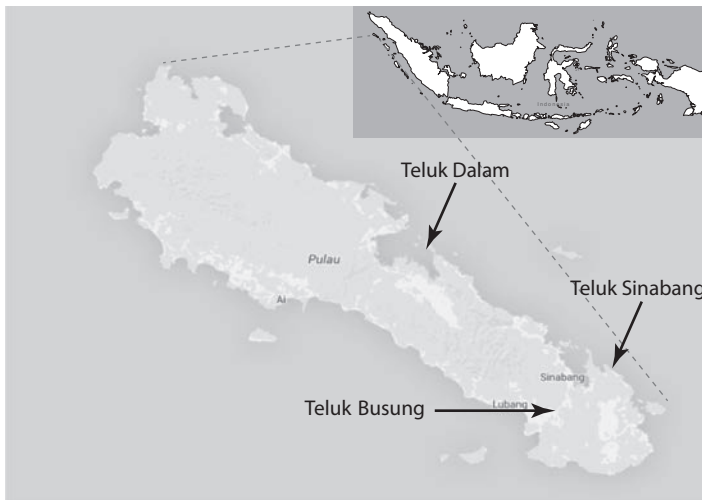
In connection with ACIAR project FIS/2007/124: 'Diversification of smallholder coastal aquaculture in Indonesia', a lobster seed resource assessment was conducted in Aceh Province in north-west Sumatra. Lobster fisheries in parts of Aceh are well developed, and so there was confidence that puerulus resources may be available that could form the basis of a local lobster farming industry.

Initially, seed assessment activities were focused on three regencies in Aceh: Pulau Simeulue, Pulo Aceh, and Aceh Jaya.

### Pulau Simeulue

The island of Simeulue (2°35'27.7"N 96°18'37.9"E) lies in the Indian Ocean, off the west coast of northern Sumatra, and supports productive lobster fisheries, primarily for *Panulirus penicillatus* and *P. versicolor*. Simeulue is serviced by ferries mainly from the Port of Meulaboh (Aceh Barat) around 200 km to the north, and by light plane from Medan.

Tripod lobster seed collectors, as described in Chapter 2.3, were deployed at three locations, as shown in Figure 1.



**Figure 1.** Simeulue Island on the west coast of Sumatra (Aceh Province), showing locations of lobster seed assessment

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<sup>2</sup> Marine Aquaculture Development Centre, Lombok

## Pulo Aceh

The first results of the seed assessment at Simeulue were gathered for the period June to October 2011. At Teluk Dalam, four tripods remained operational and three were damaged by wave action. No puerulus were caught. At Teluk Sinabang, there were no puerulus recorded, and this was attributed to low current, depth and high suspended solids. For Teluk Busung, no puerulus were found, and the reason for this is thought to be because the current was too strong and there was high turbidity.

In December 2011, four pueruli were collected from the tripods, both *P. ornatus* and *P. homarus*. Neither of these species is very abundant as adults in this area. Subsequently, small numbers of settled juvenile lobsters were found on the west coast of Simeulue, although not sufficient for farming purposes. The prevailing wind and waves along this exposed coast are not suitable for tripod-type collectors.

Seed collecting activities in Simeulue progressively declined due to the low catch and no further development has occurred.

Local knowledge in Pulo Aceh Regency suggested that lobster seed were present at Ulee Payaa Village, Pulau Aceh and Pulau Breueh. A brief survey in December 2011 confirmed this, and tripod collectors were subsequently deployed.

A local fisher from Pulau Breueh, Pak Muazzi became enthusiastic about developing lobster farming, and assisted with the seed assessment activities. He also established some sea cages for holding and growing lobsters.

In this location, 12 tripods were used for collecting the lobster seed, equipped with bundles of marlin net, rice bag or cement bag materials. In addition to the tripods, Mr Muazzi also used his sea cages to deploy more collectors, as shown in Figure 3.

The collectors were checked every three days by manually retrieving the traps and removing the pueruli. Captured pueruli were transferred to sea cages that were stocked with seaweed, as a form of shelter and to minimise cannibalism.



**Figure 2.** Pulo Aceh off the north-west tip of Sumatra

Results of the puerulus collection are presented in Table 1 for 2012 and Table 2 for 2013.

Subsequent grow-out of the captured pueruli from 2012 resulted in a harvest of 65 kg of 200 g+ lobsters in January 2014. The sea cages in this location are exposed to seasonal strong wind (wet season) and waves, causing damage to the puerulus collecting traps and grow-out cages. Heavy rain also caused high turbidity at times. Mr Muazzi has remained the only local person engaged in lobster seed collection and grow-out in Pulo Aceh.

## Aceh Jaya

Following an annual meeting of ACIAR Project FIS/2007/124 in Banda Aceh in 2013, a decision was made to examine the availability of lobster pueruli in Aceh Jaya. A survey on 6–7 November 2013 revealed three options as summarised in Table 3.

From the survey, Ujung Seudeun was chosen as a site to establish puerulus assessment. Arrangements were made for Mr Huzaimah to travel to Pulo Aceh to learn from Mr Muazzi about how to collect

**Table 1.** Puerulus catch data from tripods in 2012 using three different materials for habitat collectors

	Marlin net	Rice bag	Cement bag	Total
April	0	0	0	0
May	0	0	3	3
June	0	0	3	3
July	0	0	0	0
August	5	1	8	14
September	50	49	68	167
October	14	24	43	81
November	0	0	0	0
December	0	0	0	0

**Table 2.** Puerulus catch data from tripods in 2013

Month	Amount of Puerulus
January	8
February	10
March	7
April	36
May	25
June	36
July	9
August	60
September	34
October	42
November	64
December	65



**Figure 3.** Pak Muazzi inspects the collectors suspended from the sea cages

**Table 3.** Opportunities for puerulus assessment in Aceh Jaya

No	Location	Advantages	Disadvantages
1	Batee Rutong Desa Pantan Makmur	Near to the bay and water source	No sea cages at this location
2	Rigah	In the bay, far from freshwater source	No sea cages at this location No interest
3	Ujung Seudeun	Close to fresh water source Sea cages present, facilitating setting of tripod collectors Strong enthusiasm for puerulus	No culture yet

puerulus, how to make tripods and traps, and how to culture puerulus. Following the field excursion, Mr Huzaimah went on to make six tripods, from which puerulus have been collected.

### **Conclusions and recommendations**

From January 2012 to December 2013, 664 pueruli were collected at Pulo Aceh. With increased fishing equipment deployed, increased catches are likely. At Ujung Seudeun in Aceh Jaya, more than 162 pueruli were caught from six tripods from January to March 2014. This location has good potential for further development.

There is enough evidence of puerulus availability in parts of Aceh to expand the puerulus assessment activity to new locations, and to further develop the exploitation of seed resources in Pulo Aceh and

Ujung Seuden. Further extension is required to advise coastal communities on the economic potential of this activity. Collaboration with the University in Aceh will be helpful for lobster aquaculture development.

Future research and development activities should include the application of commercial techniques for puerulus collection, as applied in Lombok, support for sea-cage grow-out of lobsters and application of formulated feeds.

### **Acknowledgments**

We would like to express our gratitude to ACIAR for the financial support, to Dr Mike Rimmer, Dr Clive Jones and Abidin Nur for their great assistance; to Samsul Bahrawi and Bayu Priyambodo, our colleagues from BBL Lombok; and to Pak Muazzi and Pak Huzaimah who cooperated on this project.

## 5.13 Status of lobster hatchery technology development

Scott Shanks<sup>1</sup> and Clive Jones<sup>2</sup>

### Introduction

This paper presents an overview of tropical rock lobster hatchery research in Australia that has focussed on the tropical species *Panulirus ornatus*. Information is presented on the life cycle and technical challenges of rearing lobster larvae, the history of achievements across the research hatcheries, the status of the technology and plans for future development.

Research on hatchery technology of *P. ornatus* has been performed at four research hatcheries in Australia: that of the Queensland Department of Agriculture, Fisheries and Forestry at the Northern Fisheries Centre in Cairns; at the Australian Institute of Marine Science in Townsville, at Lobster Harvest Pty Ltd in Exmouth, Western Australia; and at the University of Tasmania in Hobart in collaboration with Darden Corporation (USA). At the time of the Symposium in April 2014, only the Hobart research hatchery was still in operation, with Darden committing significant funding to the program.

### Technical challenge

Lobster larvae (phyllosoma) are small, delicate creatures that moult frequently and are prone to *Vibrio sp.* infection. For *P. ornatus*, the duration of the larval phase in the hatchery environment is 100 to 150 days. This is relatively long when compared with most established aquaculture species that have hatchery (larval) durations of less than 30 days. However, the tropical species have a distinct advantage over temperate spiny lobster species, whose larval duration

is more than 300 days. Common to all aquaculture species, the key to success in hatchery production of lobsters is water quality and nutrition.

The life cycle of *P. ornatus* is depicted in Figure 1, showing the 11 successive stages of phyllosoma, which develop over 100 to 150 days in the hatchery, and possibly over longer periods in the wild.

### History

Research into the aquaculture of *P. ornatus* by the Queensland Government at the Northern Fisheries Centre in Cairns began in 1999, and the first attempt to rear larvae resulted in 100% mortality within 30 days. Progressive improvements in survival and growth were achieved with each batch as the bottlenecks were overcome one by one. After 10 years, survival of up to 80% to 100 days was consistently achieved. At 100 days old, phyllosoma are approaching their final stage, which precedes metamorphosis to the puerulus. Further research is required to resolve the final bottlenecks prior to metamorphosis so that commercially viable technology can be ensured.

Puerulus of *P. ornatus* were first produced in captivity in 2006 at the Lobster Harvest facility in Exmouth, Western Australia and at the Northern Fisheries Centre in Cairns, in 2009. Although many batches of larvae were subsequently reared, pueruli were produced on only three occasions. Nevertheless, progress on resolving obstacles and scaling up production was achieved through focusing research on the primary issues of nutrition and metamorphosis. By 2013, the only ongoing research in this area was being conducted in Hobart, and these researchers were confident that commercial technology would be developed within three to five years. Business analysis had clearly confirmed that a tropical rock lobster hatchery could be a viable business, based on

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<sup>1</sup> DAFF Queensland.  
Email: tropicalaquaculturesolutions@gmail.com

<sup>2</sup> James Cook University

existing and potential demand from grow-out industries in Vietnam and other parts of South-East Asia.

The Darden Corporation has indicated they will invest \$700 million in a lobster farming precinct in Malaysia that will produce one million pueruli and 1,000 tonnes of market-size lobster each year.

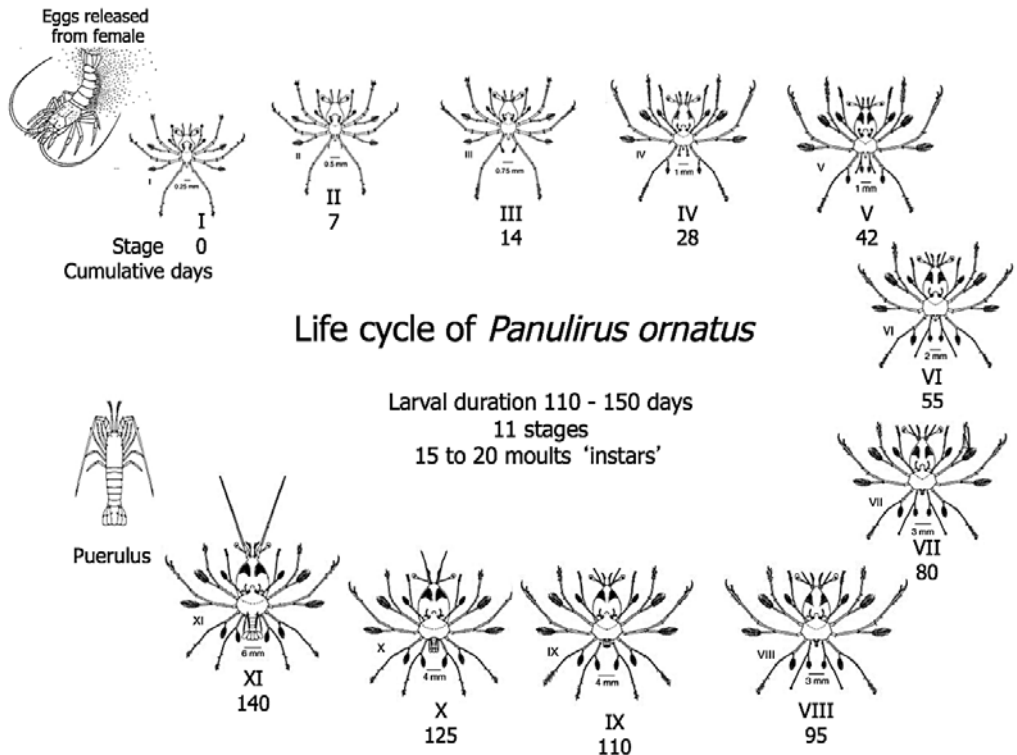
### Experimental approach

To develop robust larval rearing technology that can be scaled to commercial production levels requires a science-based approach, based on rigorous experiments with replication. Figure 2 shows the setup for small-scale larval rearing experiments at the Northern Fisheries Centre, Cairns.

The first requirement for running larval rearing experiments is to have a supply of egg-bearing female

lobsters to achieve regular hatching. Figure 3 shows aspects of the lobster breeding systems, including multiple breeding populations of five females with two males in 2,000 L tanks, whose reproductive phase was controlled by a specific temperature and photoperiod regime to simulate summer breeding conditions. In this way, breeding could be achieved in every month of the year, and newly hatched phyllosoma were available on a weekly basis.

To support the newly hatched larvae, a continuous supply of suitable food is required. This typically consists of enriched and on-grown *Artemia*. Enrichments typically consist of live micro-algae and proprietary larval crustacean nutritional supplements. Although *Artemia* is not the ideal diet, it represents the only viable option at present until a suitable manufactured diet is developed. Figure 4 shows a



**Figure 1.** Illustration of *P. ornatus* life cycle, with nominal duration for the successive larval stages in hatchery conditions



late stage phyllosoma and newly metamorphosed puerulus produced in the Northern Fisheries Centre hatchery.

### Summary and conclusions

Hatchery technology for the tropical rock lobster *P. ornatus* reached proof of concept in 2006 when the

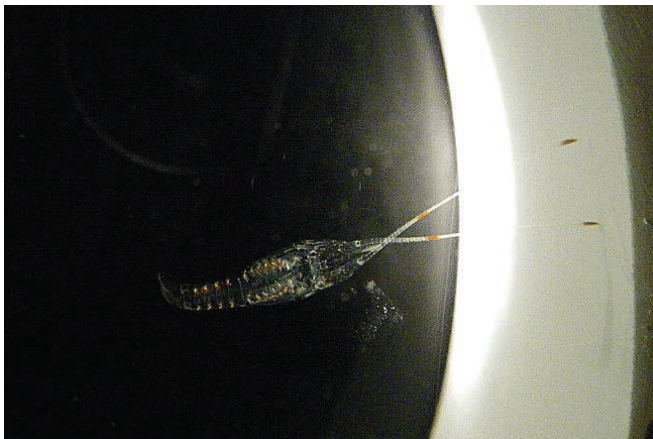
first puerulus were produced in a hatchery setting. Despite ongoing research efforts at four laboratories in Australia, commercial technology has not yet been achieved. Currently there is only one research hatchery operating in Hobart Tasmania, in collaboration with Darden Corporation (USA) which has invested significantly in establishing commercial hatchery production and grow-out in Malaysia.



**Figure 2.** Photos of larval rearing systems using 3L water jugs and 5L tubs for small-scale, replicated experiments



**Figure 3.** Brood stock system for year-round breeding of *P. ornatus*, comprising multiple populations (5F:2M) under controlled temperature and photoperiod



**Figure 4.** Photos depicting late stage phyllosoma, newly metamorphosed puerulus and 7 to 28 day old juveniles of *P. ornatus* produced in the Northern Fisheries Centre hatchery



## 5.14 Executive summary of Industry Development Workshop discussion

Prepared by staff of Directorate General Aquaculture, Indonesia<sup>1</sup>

The Lobster Aquaculture Industry Development Workshop of 2014 was conducted at The Santosa Hotel, Villas and Resort, Lombok, Indonesia on 25 April, 2014 and involved 70 participants. The objective of the workshop was to generate a reference of industry issues to inform policy implementation for the development of lobster aquaculture in Indonesia.

The workshop was opened by the Director of Production, Directorate General of Aquaculture and attended by Head of Dinas Kelautan dan Perikanan Province NTB (Provincial fisheries authority of NTB), a representative from the bureau of planning and regional development of NTB (Bappeda NTB), a representative from Echelon-1 Directorate General of Aquaculture, Marine Fisheries Aquaculture Development Centre of Lombok, a representative from Australian Centre for International Agricultural Research (ACIAR), private sector representatives, puerulus fishers and grow-out farmers.

Topics presented were as follows.

- Policy in development of lobster aquaculture in NTB, delivered by Head of Dinas Kelautan dan Perikanan Provinsi NTB.
- Spatial planning and zonation for lobster aquaculture, delivered by Bappeda Prop. NTB.
- Policy in development of lobster aquaculture, delivered by the Director of Production, DGA.
- Data on lobster seed exporting and destination, distributed by Fish Quarantine Province NTB.
- Status of lobster aquaculture in NTB, distributed by MADC of Lombok.

Based on the material delivered by presenters, and also from the results of discussion during the workshop, the following conclusions were reached.

### General condition

- Lobster is a very significant commodity in terms of business, public welfare, poverty reduction and transformation of mindset.
- Lobster aquaculture is growing through community initiatives.
- Seed collection is growing through community initiatives, and has been transformed with the opening of an international market.
- The number of grow-out cages in 2010 was 2,000 units.
- Dominant species is *Panulirus homarus* (90%).
- The number of puerulus fishers is currently increasing dramatically. On the other hand, the number of grow-out farmers has decreased significantly since early 2013.

**Table 1.** Potential area of lobster farming in Lombok

No	Districts	Potential area (ha)
1.	Central Lombok	628,50
2.	East Lombok	526,68
Total		1,155,18

### Problems and constraints

#### Problems

- There is tremendous fear that the exploitation of wild puerulus will disturb the natural balance of lobster populations.
- Supply and variation of trash fish as a food source are very limited in central Lombok.

<sup>1</sup> Email: ksp.djpb@gmail.com

3. Mastering of lobster farming skills and techniques is at a low level.
4. Grow-out farmers' knowledge is still very low.
5. Feed supply for the grow-out sector tends to be inconsistent in terms of quality and quantity.
6. Most grow-out farmers face challenges when buying lobster seeds, because the price is increasing; now reaching IDR 12,000 (US\$0.90). Grow-out farmers prefer to buy seeds for approximately IDR 5,000–7,000 (US\$0.38–0.52). The majority of grow-out farmers can only achieve a survival rate of less than 50% per unit crop as they have not mastered the required farming techniques.
7. There is large income gap between puerulus fishers and grow-out farmers.

### **Constraints**

1. Sustainability of the industry.
2. Legal protection/regulation.
3. Improvement of technical capabilities.
4. Improvement of business skill capabilities which comprise more than just selling raw material products.
5. Commitment.
6. Fostering empathy (i.e. concern to other groups in society).
7. Increasing lobster production rate 3.95% per year.
8. Importer countries can buy puerulus at a highly competitive price because they can produce market-size lobster with relatively high survival rate (> 60%).

## **Recommendations and solutions**

### **Regulations**

1. Urgent need to control the selling of lobster seed overseas.
2. Need to unite all stakeholders with a common vision for lobster aquaculture development.
3. Need zoning certainty for marine aquaculture.
4. Need to regulate the utilization of lobster seed.
5. Acceleration of Plan Zoning Bylaw on Coastal Areas and Small Islands.
6. Compilation of the NTB governor rule/regulation on the size limit and number of seed lobsters that may be caught and shipped out of NTB.
7. Encourage each region to have PERDA (district regulation) especially for fisheries.

8. Need to control the increasing number of cages in a given area, based on scientific studies (carrying capacity).
9. Determination of areas to be used by smallholders and by corporate investors.

### **Technical**

1. Provision of hatchery and nursery technology.
2. Improvements to lobster grow-out techniques to provide better survival rate (recommended for MMAF's technical implementation units).
3. Establish demonstration grow-out farms in the marine aquaculture central areas.
4. Develop pelleted feed for lobster.
5. Provision of information about seed handling.
6. Research to determine environmental conditions in the bay areas.
7. Stock population studies of lobster in Bumbang and Ekas Bays.

### **Human resources**

1. Technology dissemination for lobster aquaculture.
2. Improvement of business capability for grow-out farmers.
3. Improvement of capacity building of puerulus fishers and grow-out farmers.
4. Provide information about market demands in both quality and quantity.

### **Non-technical recommendations**

1. Build a partnership and integrated farming system.
2. Capital support to improve lobster farming.
3. Supporting infrastructure to develop lobster farming.

## **Action plan**

1. Establish a lobster farmers' association consisting of puerulus fishers, grow-out farmers, middlemen and exporters.
2. Further technical meetings on lobster will be conducted by provincial fisheries authority 'Dinas Kelautan dan Perikanan NTB Province', with core agenda as follows:
  - a. dealing agreement between puerulus middlemen and grow-out farmers
  - b. arrangement of rules/regulations on selling seed, both to domestic and overseas markets

- c. licensing (fisheries business license ‘SIUP’) and registration of fish farming for small-scale farmers
  - d. monitoring
  - e. district incomes (taxes).
3. Dissemination of spatial regulations and related zoning of lobster aquaculture development in NTB by the regional planning and development agency of NTB or ‘Bappeda NTB’.
  4. Technical training for puerulus fishers and grow-out farmers conducted by local and central government.
  5. Further research needed on stock assessment and carrying capacity in the targeted areas of lobster farming throughout Indonesia, to be carried out by the Agency of Marine Affairs and Fisheries Research and Development or ‘Balitbang KKP’.
  6. National or international research agencies conduct research on stock assessment.
  7. MMAF’s Technical Implementation Units conduct study on nursery techniques and feed.
  8. Dissemination of lobster aquaculture technology throughout Indonesia.





## 6. Appendices

**Note: the appendices for this report are available separately for download at:  
<http://aciar.gov.au/publication/pr145>**



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## **6.1 Symposium program and agenda**

International Lobster Aquaculture Symposium: ‘Positioning Indonesian lobster farming for significant expansion and increased productivity’—Santosa Resort and Villas, 22–25 April 2014.

### **Program**

#### **Welcome**

- Jointly supported by ACIAR and DGA
- End of project meeting for SMAR/2008/021 ‘Spiny lobster aquaculture development in Indonesia, Vietnam and Australia’
- Support for developing new ACIAR lobster aquaculture project in 2015
- Industry development focus

#### **Symposium goals**

- Summary of project outcomes
- Key recommendations to farmers
- Key research findings
- Identify knowledge gaps
- Identify industry development issues
- Inform development of future ACIAR research project

#### **Program**

- Two days of oral presentation—Tue/Wed
- Field day on Thursday to lobster farming area in Awang
- Industry development workshop on Friday
- Dinners hosted by ACIAR and DGA

#### **Agenda**

- Five sessions:
  - Puerulus
  - Nursery
  - Grow-out
  - Other perspectives
  - Industry development
- Sessions match project objectives
- Summary / plenary at end of each session

## Agenda

<b>Day 1: March 21, 2014—Monday</b>											
<b>14.00 –</b>	<b>Check in Santosa Senggigi Hotel, Lombok, Indonesia</b>										
<b>Day 2: March 22, 2014—Tuesday</b>											
<b>07.30 – 08.00</b>	<b>Registration</b>										
<b>08.00 – 08.20</b>	<b>Opening session:</b> Opening remarks: Nusa Tenggara Barat Province Representative, Director General of Aquaculture										
<b>08:20 – 08.40</b>	Program and agenda: ACIAR Representative, Dr Clive Jones										
<b>08.40 – 10.20</b>	<b>Peurulus session:</b> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 60%;">1. Seed census Indonesia</td> <td style="width: 40%; text-align: right;">Samsul Bahrawi</td> </tr> <tr> <td>2. Seed census Vietnam</td> <td style="text-align: right;">Dao Tan Hoc</td> </tr> <tr> <td>3. Seed assessment Indonesia</td> <td style="text-align: right;">Samsul Bahrawi</td> </tr> <tr> <td>4. Seed fishing, handling and transport in Vietnam</td> <td style="text-align: right;">Le Anh Tuan</td> </tr> <tr> <td>5. Improving puerulus catch and handling in Indonesia</td> <td style="text-align: right;">Samsul Bahrawi</td> </tr> </table>	1. Seed census Indonesia	Samsul Bahrawi	2. Seed census Vietnam	Dao Tan Hoc	3. Seed assessment Indonesia	Samsul Bahrawi	4. Seed fishing, handling and transport in Vietnam	Le Anh Tuan	5. Improving puerulus catch and handling in Indonesia	Samsul Bahrawi
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5. Improving puerulus catch and handling in Indonesia	Samsul Bahrawi										
<b>10.20 – 11.00</b>	<b>Coffee break and photo session</b>										
<b>11.00 – 11.40</b>	<b>Peurulus session (cont.):</b> 1. Puerulus summary / plenary <span style="float: right;">Mike Rimmer</span>										
<b>11.40 – 12.40</b>	<b>Nursery session:</b> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 60%;">1. Nutrition of post-puterulus lobsters</td> <td style="width: 40%; text-align: right;">Simon Irvin</td> </tr> <tr> <td>2. Husbandry and transport of post-puterulus lobsters</td> <td style="text-align: right;">Scott Shanks</td> </tr> <tr> <td>3. Industry uptake of pellet feeding</td> <td style="text-align: right;">Simon Irvin</td> </tr> <tr> <td>4. Nursery summary / plenary</td> <td style="text-align: right;">Mike Rimmer</td> </tr> </table>	1. Nutrition of post-puterulus lobsters	Simon Irvin	2. Husbandry and transport of post-puterulus lobsters	Scott Shanks	3. Industry uptake of pellet feeding	Simon Irvin	4. Nursery summary / plenary	Mike Rimmer		
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3. Industry uptake of pellet feeding	Simon Irvin										
4. Nursery summary / plenary	Mike Rimmer										
<b>12.40 – 13.40</b>	<b>Lunch</b>										
<b>13.40 – 15.00</b>	<b>Grow-out session:</b> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 60%;">1. Pellet vs trash fish in sea cage grow-out</td> <td style="width: 40%; text-align: right;">Le Lan Huong</td> </tr> <tr> <td>2. Environmental effects of sea cage grow-out</td> <td style="text-align: right;">Le Thi Vinh</td> </tr> <tr> <td>3. Macrobenthos communities associated with lobster</td> <td style="text-align: right;">Hua Thai Tuyen</td> </tr> <tr> <td>4. Status report of Vietnam lobster grow-out</td> <td style="text-align: right;">Le Anh Tuan</td> </tr> </table>	1. Pellet vs trash fish in sea cage grow-out	Le Lan Huong	2. Environmental effects of sea cage grow-out	Le Thi Vinh	3. Macrobenthos communities associated with lobster	Hua Thai Tuyen	4. Status report of Vietnam lobster grow-out	Le Anh Tuan		
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4. Status report of Vietnam lobster grow-out	Le Anh Tuan										
<b>15.00 – 15.30</b>	<b>Afternoon tea</b>										
<b>15.30 – 16.50</b>	<b>Growout session (cont.):</b> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 60%;">5. Tank based grow-out of lobsters</td> <td style="width: 40%; text-align: right;">Le Anh Tuan</td> </tr> <tr> <td>6. Comparison of pellet size and shape</td> <td style="text-align: right;">Do Huu Hoang</td> </tr> <tr> <td>7. Economics of lobster production</td> <td style="text-align: right;">Liz Petersen</td> </tr> <tr> <td>8. Grow-out summary / plenary</td> <td style="text-align: right;">Mike Rimmer</td> </tr> </table>	5. Tank based grow-out of lobsters	Le Anh Tuan	6. Comparison of pellet size and shape	Do Huu Hoang	7. Economics of lobster production	Liz Petersen	8. Grow-out summary / plenary	Mike Rimmer		
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6. Comparison of pellet size and shape	Do Huu Hoang										
7. Economics of lobster production	Liz Petersen										
8. Grow-out summary / plenary	Mike Rimmer										
<b>16.50 – 18.15</b>	<b>Free time</b>										
<b>18.15 – 21.00</b>	<b>Dinner hosted by Directorate General of Aquaculture</b>										

<b>Day 3: March 23, 2014 – Thursday</b>	
<b>08.30 – 10.10</b>	<b>Other perspective session:</b> <ul style="list-style-type: none"> <li>1. Presentation from South Pacific / New Caledonia      Manuel Ducrocq</li> <li>2. Worldwide perspective on lobster farming              Jason Goldstein</li> <li>3. Supplementing lobster diets with probiotics            Do Huu Hoang</li> <li>4. Student involvement in lobster research                Ihsan</li> </ul>
<b>10.00 – 10.40</b>	<b>Morning tea</b>
<b>10.40 – 12.00</b>	<b>Industry development session:</b> <ul style="list-style-type: none"> <li>1. Other perspectives summary / plenary                    Mike Rimmer</li> <li>2. Disease status and threats                                    Clive Jones</li> <li>3. Indonesian Industry development                        Bayu Priyambodo</li> <li>4. Opportunity for lobster farming in Australia            Clive Jones</li> </ul>
<b>12.00 – 13.30</b>	<b>Lunch</b>
<b>13.30 – 14.50</b>	<b>Industry development session (cont.):</b> <ul style="list-style-type: none"> <li>1. Population genetics of tropical rock lobster            Dao Tan Hoc</li> <li>2. Study tour of Indonesian farmers to Vietnam            Bayu Priyambodo</li> <li>3. Market perspective on farmed lobster                    Clive Jones</li> <li>4. Indonesian lobster farming industry development    Bayu Priyambodo</li> </ul>
<b>14.50 – 15.30</b>	<b>Afternoon tea</b>
<b>15.30 – 16.50</b>	<b>Other issues session:</b> <ul style="list-style-type: none"> <li>1. Lobster farming perspective South Sulawesi            Idris</li> <li>2. Lobster farming perspective Aceh                        Samsul Bahrawi</li> <li>3. Status of hatchery technology                              Scott Shanks</li> <li>4. Industry development summary / plenary                Mike Rimmer / Coco Kokarkin</li> </ul>
<b>16.50 – 18.15</b>	<b>Free time</b>
<b>18.15 – 21.00</b>	<b>Dinner reception—hosted by ACIAR</b>

<b>Day 4: 24, 2014—Thursday</b>	
<b>08.00-15.30</b>	<b>Field trip</b> <ul style="list-style-type: none"> <li>1. Assemble in lobby for field trip                            Organising Committee</li> <li>2. Travel to Awang</li> <li>3. Visit Lobster farms</li> </ul>



**Note: this document forms appendix 6.2 of the Australian Centre for International Agricultural Research publication *Spiny lobster aquaculture development in Indonesia, Vietnam and Australia*. The main report can be downloaded from: <http://aciarc.gov.au/publication/pr145>.**

## 6.2 Industry development workshop agenda

Time	Item	Presenter	Moderator
07.30 – 08.00	<b>Registration</b>		
08.00 – 09.00	<b>Opening session</b> Indonesia national anthem Welcome speech Keynote speech and remarks Prayer	Head of NTB Prov. Dinas Director of Production	MC: BBL Lombok Dirijen: BBL Lombok pembaca doa: BBL Lombok
09.00 – 09.15	Policy on Marine Aquaculture Development 2015–2016	Director of Production	
09.15 – 09.30	Potential of lobster aquaculture industry	Duta Bahari	Prof. Ketut Sugama
09.30 – 09.45	Policy on lobster aquaculture in NTB	DKP Prop NTB	
	Q&A		Ir. Nasrul Efendi, M.Si
10.00 – 10.30	Coffee break		
10.30 – 10.45	Lobster zoning plan in NTB	Bappeda NTB	Dr. Made L. Nurjana
11.00 – 11.15	Effective and efficient lobster aquaculture technology	ACIAR	Bayu/ Samsul
11.15 – 11.30	Lobster aquaculture in NTB Q&A	Pamit (pembudidaya lobster)	Arfiana Budiati Jindan, S.St.Pi
11.30 – 13.30	Prayer and lunch		
13.30 – 14.00	Discussion Planning and Follow up		Ir. Coco Kokarkin S, M.Sc Ir. Setiawan, MM
14.00 – 14.30	Coffee break		
14.30 – 15.30	Wrap up		Ir. Coco Kokarkin S, M.Sc
15.30 – 16.00	Presentation of wrap up		Ir. Setiawan, MM
16.00 – 16.30	Closing		Dian Sukmawan, S.Pi, M.Aq

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## **ACIAR Project SMAR2008/021**

### **AUDIT OF DISEASES OF FARMED SPINY LOBSTERS IN VIETNAM**



**Conducted by**

**Dr Richard Callinan (University of Sydney)**

**and**

**Dr Flavio Corsin (Consultant Aquaculture Advisor)**

**with coordination by**

**Dr Nguyen Thi Bich Thuy (Head, Information and International  
Cooperation Department, RIA3)**

**6 - 11 September 2009**

## Audit Report

Activities are summarized in the table below. For a full description of places visited, people interviewed, background and related issues, findings and discussions see R. Callinan's trip report (trip report final.doc). In addition to the information presented in the trip report and summarized below, a large body of information, most of it in electronic form and largely in Vietnamese language, was collected prior to and during the visit; this information is supplied separately on the memory stick herewith.

	<b>Activities</b>	<b>Participants</b>
<i>Sunday, Sep. 6</i>	<ul style="list-style-type: none"> <li>• Drs. Callinan and Corsin arrive Nha Trang</li> <li>• Drs Callinan, Corsin and Thuy ('the team') meet with Dr Dung (NTU)</li> </ul>	
<i>Monday, Sep. 7</i>	<ul style="list-style-type: none"> <li>• Travel to Tuy Hoa city</li> <li>• Meet with DARD staff, Phu Yen</li> </ul>	Team
<i>Tuesday, Sep.8</i>	<ul style="list-style-type: none"> <li>• Travel to Song Cau district</li> <li>• Meet with District staff</li> <li>• Visit lobster farms in Song Cau district, Phu Yen, meet with lobster farmers</li> <li>• Return to Nha Trang</li> </ul>	Team
<i>Wednesday, Sep.9</i>	<ul style="list-style-type: none"> <li>• Meet with DARD staff, Khanh Hoa</li> <li>• Visit lobster farm in northern Khanh Hoa, meet with key lobster farmer</li> <li>• Return to Nha Trang</li> </ul>	Team and Dr Dung
<i>Thursday, Sep. 10</i>	<ul style="list-style-type: none"> <li>• Meet with RIA3 lobster disease researchers; prioritise diseases; identify gaps; outline workshop</li> <li>• Drs Callinan and Corsin travel to Hanoi</li> </ul>	Team and Dr Dung
<i>Friday, Sep. 11</i>	<ul style="list-style-type: none"> <li>• Meet with Dr Dan, DDG/DAH/MARD and staff; confirm priority issues</li> <li>• Meet with Mr Geoff Morris, Ms An (ACIAR)</li> <li>• Meet with Dr. Tuan, Dept Science &amp; Technology/MARD; discuss workshop options</li> </ul>	Drs Callinan and Corsin
<i>Saturday, Sep. 12</i>	<ul style="list-style-type: none"> <li>• Dr Callinan departs Hanoi</li> </ul>	

Key audit findings are presented against each TOR below.

### **TOR 1**

**Through consultation with aquatic animal health counterparts and farmers, identify the important farmed lobster diseases and associated health issues (eg reduced growth rates, poor survival, poor condition, poor coloration etc) in Vietnam.**

Current and available knowledge on farmed lobster diseases in Vietnam is summarised in the Disease Status table below. Key criteria for prioritisation were

frequency and magnitude of lobster losses (usually as mortality). Based on this evidence, we grouped the diseases/syndromes according to our perception of their importance as follows.

### **High priority diseases**

- Milky haemolymph disease – spiny lobsters (MHD-SL)
- Red body
- Black gill

### **Disease whose importance needs clarifying**

- Incomplete moult

### **Low priority diseases**

- Tail rot
- Loose head
- Soft shell

Audit findings suggest that each of the 3 high priority diseases now causes comparable levels of production loss, but amongst different age/size classes, cage types and management regimes. However, evidence suggests research is most urgently needed on MHD-SL, for the following reasons:

- Even though MHD-SL in Vietnam currently occurs at levels which do not threaten the industry's survival, it is the only known farmed lobster disease in the region with the potential, on current understanding, to re-emerge at epidemic levels, particularly if antibiotic-resistant strains of the causal rickettsia-like bacterium (RLB) become widespread.
- Better understanding of pathogenesis and epidemiology of MHD-SL is urgently needed so that cost-effective, practical and sustainable control and prevention measures, acceptable to most farmers, can be developed.
- MHD-SL may become pandemic, given expansion of lobster farming in other regional countries, experimental evidence for horizontal spread of infection, and, at least currently, unregulated movement of seed between these countries.

Disease Status Table

Disease	Causal pathogen	Diagnostic test	Risk factors	Current control	Current prevention	Species affected (severity)
<b>MHD-SL</b>	RLB	Clinical signs Haemolymph smear Histopathology PCR	Tentatively identified, need more work <sup>1</sup> ; see reports. Cage placement and density need to be examined	Oxytet i/m (officially recommended); others, e.g. quinolones, effective but not recommended. Optimal oral treatment needed.	Shorter cropping period, prophylactic antibiotics in feed, vitamins, immunostimulant, probiotics all used. Develop BMPs based on risk factor identification	<i>P. ornatus</i> , <i>P. homarus</i> , <i>P. stimsoni</i> , <i>P. polyphagus</i> all affected ~ equally; <i>P. longipes</i> not known to be affected;
<b>Red body</b>	Vibrio spp., often <i>V. alginolyticus</i> , reported	Clinical signs Histopathology? Bacteriology	No formal study; farmer observation suggests: small lobster size, cage type related	Doxycycline 10% (3-7 g/kg feed) for 5-7 days; cage depth?	Tentative: maintain good hygiene; cage placement, depth.	<i>P. ornatus</i> , <i>P. homarus</i> , <i>P. stimsoni</i> , affected ~ equally; Not seen in <i>P. polyphagus</i> , <i>P. longipes</i> because small sizes not examined.
<b>Black gill</b>	Fungi, consistent with <i>Fusarium</i> spp	Clinical signs Wet mount Histopathology	No formal study; farmer observation suggests large size most susceptible, cage type.	Formalin (100-200 ppm) dip for 10-15 min. over 2 -4 consecutive days	Clean cage; move to clean site	No information, but probably all, esp <i>P. ornatus</i> since held to large size, longer growout.

1. Further analysis needed re 2007 survey work; further risk factor studies may be needed to address endemic situation rather than epidemic.

<b>Disease</b>	<b>Causal pathogen</b>	<b>Diagnostic test</b>	<b>Risk factors</b>	<b>Control</b>	<b>Prevention</b>	<b>Species affected (severity)</b>
<b>Tail rot</b>	Non-specific	Clinical signs Wet mount Histopathology	No formal study; no farmer observations recorded	As for black gill	Low stocking density, maintain cage hygiene	No information, but probably all, esp <i>P. ornatus</i> since held to large size, longer growout
<b>Loose head</b>	Not involved	Clinical signs	No formal study; possibly low salinity; no farmer observations recorded	Move cage to stable salinity (>28 ppt)??	Maintain cages in salinity >28 ppt??	All affected. Always seen in large size. Signif economic impact because mortalities.
<b>Soft shell</b>	Not involved	Clinical signs	No formal study		High quality feed (increased proportion of crustacean component in feed)	Can occur at any stage but most common at <100g. Can sell at lower price; not economic impt.
<b>Incomplete moult</b>	Not involved	Clinical signs	No formal study; observations indicate small size, possibly nutritional factor		Improve nutrition, vitamins, etc tried.	<i>P. ornatus</i> , <i>P. homarus</i> , <i>P. polyphagus</i> up to 100g; usually <1% mortality (Dr Thuy ~50% in some cases ??); provisional value is US\$20 each.

## **TOR 2**

**Establish what is known about each disease (pathology, microbiology, epidemiology, economic impact) and collate all documentation for this knowledge.**

Current knowledge is summarized in the Disease Status table above. Detailed information is available in the sources listed below.

### **MHD-SL**

At the peak of the MHD-SL outbreak in 06/07, annual mortalities were >50% and up to 100% in some areas. At the time of the 2007 MARD investigation more than 90% of the farms had been affected by the disease and 88% had an ongoing outbreak. Now, annual mortalities are estimated at 20-40% from all diseases, with about half of these due to MHD-SL, usually in larger lobsters.

Much of the large body of information on MHD-SL is in Vietnamese language and will need to be translated prior to, or at, the proposed workshop if all issues are to be fully considered.

### **Key English language sources are:**

- a) OIE (2007) Milky haemolymph Disease of Spiny Lobsters (*Panulirus* spp.). OIE Aquatic Animal Disease Cards, 2007 (see memory stick file: milky haemolymph disease of lobsters card 9-04-08.pdf).
- b) A presentation 'Study on milky syndrome in farmed lobster in Vietnam – preliminary results' given by Dr Dung (NTU) at a SEAFDEC meeting in Bangkok in December 2007 (see memory stick file: Lobster Milky Syndrome BKK Workshop.pdf)
- c) A preliminary analysis of data obtained under the epidemiology component of the large MARD investigation into MHD-SL conducted in 2007 (see memory stick file: Flavio's input to Milky Disease report.doc).
- d) Status report from Phu Yen province obtained during the audit visit; translation arranged by Dr Thuy stored on memory stick (Phu Yen province.doc).

### **Key Vietnamese language sources are:**

- a) Reports from the 2007 survey. Directories, containing individual files (with apparent content in each case shown below) are grouped on the memory stick as follows:
  - i) Dr Do Thi Hua
    - Bao cao ket qua 1.doc (laboratory-based investigations)
    - Bao cao ket qua 2.doc (laboratory-based investigations)
    - Bao cao ket qua tom hum 2.ppt (laboratory-based investigations)
  - ii) Dr Nguyen Huu Dung
    - Bao Cao Dac Diem Dich Te Benh Sua Tom Hum – Phan 2.doc (epidemiological investigations)
    - Bao Cao Dac Diem Dich Te Benh Sua Tom Hum – Phan 1.doc (epidemiological investigations)
    - Bao Cao Dac Diem Dich Te Benh Sua Tom Hum.ppt (epidemiological investigations)
  - iii) NGUYEN TU CUONG va ctv – Nhom Dieu tra hien trang



- BAO CAO TGOAN QUOC 3.12.07.ppt (background survey design and findings)
  - BC TOAN QUOC 7.12.doc (background survey design and findings)
- b) Additional Vietnamese language information on 2 CDs from Dr Dung (NTU) grouped on the memory stick as follows:
- i) Dr Dung CD1
    - Lecture on Milky Syndrome\_Preliminary Findings, Treatment a.ppt
    - Milky Syndrome Treatment Method.doc
  - ii) Dr Dung CD2
    - EpiGroup Movies
      - Lobster Injection 2.wmv
      - Lobster Injection.wmv
      - Net Cleaning.wmv
      - Net Washing.wmv
    - EpiGroup Pictures
      - North Khanh Hoa Group Pictures
      - Various untitled
- c) MHD-SL section in booklet ‘Mot So Bien Phap Phong Tri Benh O TOM HUM’ by Mr Vo Van Nha (2008). Scanned copy of title page stored on memory stick (Nha 2008.jpg).

### **Red body and black gill**

Information collected during the audit visit is presented in the Disease Status table above. A key source of information, largely unavailable to us during the audit, is the Vietnamese language booklet (which covers all significant diseases of farmed lobsters) ‘Mot So Bien Phap Phong Tri Benh O TOM HUM’ by Mr Vo Van Nha (2008). As noted in the trip report, Mr Nha was ill and unavailable for questioning re pathogenesis, epidemiology etc of these diseases during the visit.

### **TOR 3**

**Determine the extent to which risk factors for each important disease have been formally identified and whether or not programs to reduce losses have been devised and implemented.**

#### **MHD-SL**

Risk factors under epidemic (2006/7) conditions have not yet been fully identified. Dr Corsin’s preliminary analysis of data collected under the epidemiology component of the 2007 MARD investigation into MHD-SL is available (see memory stick file: Flavio’s input to Milky Disease report.doc). Preliminary findings include:

- Cages held on the seabed present higher risk of disease. There are 3 types of cages – fixed, floating and submerged on seabed. Typical cage dimensions are 4m x 4m x 6m (depth). There are usually ~100 lobsters per cage
- Outbreaks in a single cage are usually protracted, with 2-5 animals dying per day, so that it can take up to 2 months for the entire cage population to be lost.
- Poor hygiene appears to increase risk of disease. Farmers who clean nets regularly and who dispose of waste away from the site report lower losses. This suggests the RLB is an opportunist pathogen but its sources in the environment are unknown

Under the 2007 MARD survey, the pathogenesis group established that the agent could be transmitted horizontally via water and intramuscularly via injection of unfiltered tissue extract. They did not do feeding trials.

**Currently recommended control and prevention interventions are based on the above and include:**

- 1. Environmental protection (minimize pollution in the locality);**
- 2. Maintain good cage conditions, including regular net cleaning;**
- 3. Maintain good lobster health. Suggested interventions include supplementary feeding of vitamins, immunostimulants, probiotics, minerals;**
- 4. Encourage community-based sustainable development in the locality;**
- 5. At the first sign of a MHD outbreak in a cage, inject oxytetracycline intramuscularly into all animals in the cage.** Note that this antibiotic is generally accepted by regulators, provided withholding periods are observed. The group had no information about residue requirements re the major market, China, from where lobsters are reportedly forwarded to arguably stricter markets (e.g. Japan).

Some of the above evidence-based (some from first principles) prevention and control measures appear to have been loosely adopted and adapted to varying degrees only by individual farmers, probably in part because the package is operationally complex. In particular, we found little evidence that farmers complied with Intervention 5, seemingly because of (unwarranted) concerns about long term physical damage to lobsters, and hence lower price, arising from the injection. Instead, in an attempt to prevent losses, most farmers mix various antibiotics with feed, some maintain clean nets and some harvest early.

**No formal work has been done on risk factors under current, endemic conditions and, importantly, the reasons for the decline in mortalities from 50-100% in 2006/7 are not clear.**

### **Red body, black gill**

We found no English language information on risk factors or control/prevention programs for these diseases. However, there is considerable Vietnamese language information in the booklet 'Mot So Bien Phap Phong Tri Benh O TOM HUM' by Mr Vo Van Nha (2008). As noted above, Mr Nha was ill and unavailable for questioning re pathogenesis, epidemiology etc of these diseases during the visit.

### **TOR 4**

**Determine the effectiveness of these programs and the constraints, if any, to broad program adoption.**

As noted above, annual mortalities in farmed lobsters are currently estimated at 20-40% from all diseases, with about half of these due to MHD-SL, usually in larger lobsters. Audit findings suggest losses due to red body and black gill have remained relatively constant over the past 5 years. However, reasons for the decline in MHD-SL losses are not clear, but probably include the widespread practice of feeding antibiotics (not officially endorsed), regular net cleaning and, because larger sizes are more susceptible, early harvest, with farmers accepting lower returns.

Lack of basic knowledge about pathogenesis and epidemiology of the 3 main diseases under current conditions appears to be the major constraint to health-related BMP program formulation and adoption. For example, Phu Yen Provincial staff report that their lack of knowledge re cost-effective interventions re these diseases, combined with a lack of knowledge at farmer level is a major constraint to developing and implementing effective health management programs for farmed lobsters. Similarly, Song Cau District staff reported that they lack reliable information about lobster disease, i.e, they don't know the source(s) of infection, don't know when/how infection is first initiated and don't know how to prevent outbreaks.

These constraints notwithstanding, it appears a functional extension service is in place and able to disseminate programs. Dr Dan, DDG/DAH/MARD noted that Vietnam has a very effective extension system, as demonstrated under shrimp BMP programs, especially in coastal areas, so scale out of BMP programs for lobsters should not be a problem.

#### **TOR 5**

#### **Identify key social, economic or political factors influencing the occurrence and control of important diseases**

We noted the selection by Dr Dung (NTU) of a key farmer in Khanh Hoa province to disseminate control and prevention measures re MHD-SL within the locality.

Dr Dung also mentioned the importance of using national and local TV programs aimed at farmers to disseminate information.

#### **TOR 6**

#### **Based on the above, determine the current status of each disease – distribution, trends re impacts on productivity and profitability.**

As detailed above, annual mortalities in farmed lobsters generally are currently estimated at 20-40% from all diseases, with about half of these due to MHD-SL, usually in larger lobsters. Information is summarized in Disease Status table above.

Audit findings suggest losses due to red body and black gill have remained relatively constant over the past 5 years. Early harvest of small sized *P. ornatus* reduces returns to farmer.

Using information from one farmer in Phu Yen, profits can be made in spite of disease, although these are very limited. Using only information on cost of seed and feed (i.e. without taking into account additional operating/capital costs), a farmer with 10 cages (average in Phu Yen) would make a profit of about USD 1,000/year.

Item	N	Cost/unit	Total (mil VND)
Stocking (animals)	50	136	6,800
Feed (kg)	360	13	4,680
Partial operating cost			11,480

Harvest – size 600g (kg)	24	550	13,200
Profit/cage			1,720
N cages	10		
Profit/farm			17,200
Survival	80%		
FCR	15		

In this calculation several factors needs to be taken into account:

- Survival was sometimes reported to be significantly < 80% (about 40%)
- RIA3 studies reveal that the FCR is more often 20, rather than 15
- The cost of seed varies significantly and, on the previous year, it reached USD20/animal (approximately VND340-350,000/animal)
- Because some lobster farmers are also involved in capture fisheries, they can procure most of the feed which in reality would be considered as lost income from fishery.

Discussion with DARD Khanh Hoa revealed that if survival over a period of 14-16 months of culture is >75%, profits are considered acceptable by farmers. This shows the limited expectations and the huge potential for improvement. It is worth highlighting that farmers in Khanh Hoa province appeared to better managers and more prosperous than those in Phu Yen.

#### **TOR 7**

**Identify what (if anything) Vietnamese agencies would be seeking in relation to follow-up ACIAR support.**

Dr Dan, DDG/DAH/MARD proposed the following as important, immediate areas of need, with a particular focus on MHD-SL.

1. Improve understanding of pathogenesis and epidemiology of major diseases; in particular, identify sources of RLB infection, with focus on trash fish, seed.
2. Develop practical, evidence-based, cost-effective control and prevention methods.
3. Identify ways of eradicating MHD-SL and maintaining freedom in farming areas

Note that the above would also be highly relevant re development of a farmed lobster industry in Indonesia under SMAR/2008/021.

Elaborating on these items, the audit team identified the following needs.

#### **Needs specific to MHD-SL:**

1. To better understand the pathogenesis of MHD-SL, and to support formal refutation/confirmation of involvement of other pathogens, we need full descriptions of pathology at various stages of disease in typically affected individual lobsters;
2. We need to better understand the epidemiology of MHD-SL, including:

- source(s) of RLB infection for individual lobsters, especially horizontal infection pathways via (a) trash fish (components include finfish, molluscs, crustaceans) and (b) other infected lobsters;
  - main transmission pathways between cages, farms and districts;
  - main risk factors for emergence of MHD-SL (important re protecting the new industry in Indonesia: need to complete the analysis of 2007 epi survey findings);
  - main risk factors for MHD-SL occurrence under endemic conditions (relevant to Vietnam; new study required);
3. We need accurate test(s) to detect and localize early RLB infection in individual lobsters and identify possible sources of infection in feed, environment etc,
  4. Applying the above information, selected farmers, extensionists and technical people need to work together to develop and implement cost-effective treatment and control programs;
  5. Understanding patterns of spread etc requires accurate, complete and systematically collected data re health status of farmed lobster populations - need to improve and harmonise province-based surveillance programs;
  6. Need to better understand dissemination risks, if any, associated with unregulated movement of seed
  7. There is some, possibly contradictory (depending on whether informant is provider or recipient), evidence of limited effectiveness of the government extension system re lobster health management programs – wide adoption of cost-effective control and prevention measures will require an effective, well informed service.
  8. Relatively poor surveillance and reporting mechanisms limit notification of lobster health problems, thereby risking propagation to epidemic levels. Examination of the current system and identification of cost-effective, incentive-led notification mechanisms are needed.
  9. There is currently no market-led mechanism to promote implementation of health management practices (e.g. responding to demand for product via responsible use of chemicals, etc), although markets worldwide increasingly require safer products cultured under environmentally and socially sustainable conditions. Such mechanisms do exist for other aquaculture products (e.g. shrimp, salmonids, etc.)

Some of the above needs may also be relevant to red body and black gill, depending on what is known re pathogenesis, epidemiology and management for each condition – will need to translate Mr Nha’s booklet (or interview him further) to determine this.

## **TOR 8**

**Assuming a request for support appears strongly justified, identify key Vietnamese participants for the proposed workshop, at which a funding proposal could be framed up.**

Dr Tuan (MARD, Hanoi) outlined plans for a MARD workshop proposed for December 2009:

- to review the findings of Dr Thuan's study and other current research;
- to review previous research;
- to identify future research needs

Dr Tuan agreed that the proposed MARD and ACIAR workshops could be combined under the following arrangements.

- A (probably 2-day) workshop will be held in Nha Trang in December 2009.
- The program will address causes, control and prevention of important diseases - current knowledge and future needs.
- Approximately 30-40 Vietnamese will attend, mainly drawn from key MARD departments (e.g. Dept of Science and Technology, DAH, Fisheries General Office) the 4 lobster-farming provinces and including provincial-level staff, researchers and, possibly, key farmers. Their attendance will be funded by GoV. The audit team suggests participants should include: Dr Thuy, Mr Dung, Mr Nha (all RIA3); Dr Hoa, Ms Thuy (both DARD, Khanh Hoa); Dr Dung and Mr Hich (NTU, fish pathology), Dr Duy (NTU, microbiologist), Dr Tuan (NTU, feed, management).
- Several foreign experts are suggested, including Dr Clive Jones (linkage with SMAR/2008/021); Dr Richard Callinan (aquatic animal health management, linkage with USyd farm health group); Dr Flavio Corsin (epidemiologist, linkage with Vietnamese agencies and programs); Dr Jenny-Ann Toribio (epidemiologist, USyd); Dr Brian Jones (lobster disease, WA Fisheries); Prof Leigh Owens (molecular biotechnology, JCU). These attendees, plus selected Vietnamese attendees (notably Dr Dung, NTU acting as facilitator and key participant) likely to be involved in any follow-on ACIAR work, could be funded by ACIAR.
- Presentations and discussion will be primarily in English.

## **TOR 9**

**Prepare a draft proposal for the lobster disease workshop including list of participants, venue, date, program and funding required**

Not yet done. Will require further post-audit discussions re program, participants, funding, etc involving Dr C Jones, Dr Tuan, Dr Dung, Dr Corsin, Dr Callinan.

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# Scoping Study

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Lobster Grow-out  
Pilot Project  
Yarrabah

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Prepared by Jaragun P/L

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## RECOMMENDATIONS

### **Recommendation 1**

Members of the Department of Employment, Economic Development and Innovation (DEEDI, Cairns) and Traditional Owner project team conduct a further scientific/technical and environmental site assessment of King Beach to ascertain its suitability for the pilot project in conjunction with the Department of Environment and Resource Management and the Great Barrier Reef Marine Park Authority.

### **Recommendation 2**

The project team organize a meeting of relevant Commonwealth and Qld state government agencies to identify and negotiate licensing/permit challenges for King Beach.

### **Recommendation 3**

Members of the DEEDI project team obtain overall support from DEEDI to progress the project as a state priority for Far North Qld as a means of achieving resources to upgrade road access to King Beach.

### **Recommendation 4**

The project team organise a roundtable meeting of relevant Commonwealth and state government agencies to negotiate funding and resource inputs for establishment of the pilot project at King Beach.

### **Recommendation 5**

Traditional Owners register cultural heritage sites within the vicinity of the proposed pilot project site at King Beach.

## 1 EXECUTIVE SUMMARY

This report was prepared for Department of Employment, Economic Development and Innovation (DEEDI), as the lead agency for the project “Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia”. The project is funded by the Australian Centre for International Agricultural Research (ACIAR), as part of the Australian Government’s development program that encourages Australia’s agricultural scientists to use their skills for the benefit of developing countries and Australia. One objective of the Australian component is to establish spiny lobster (*Panulirus ornatus*) grow-out enterprises in Indigenous communities in North Queensland. The report addresses the first stage – a scoping study for the establishment of a pilot lobster growout enterprise at the Aboriginal community of Yarrabah.

The project team consisted of the ACIAR Lobster project staff from DEEDI, Jaragun P/L and Traditional Owners of Yarrabah.

Four sites within Yarrabah were assessed as to their suitability for establishing pilot lobster growout, using an above-ground raceway or tank aquaculture system. All sites are located on land that is designated as Deed of Grant in Trust (DoGIT), managed by the Yarrabah Aboriginal Shire Council (YASC).

Two sites, King Beach and Wungu (north end of Back Beach), were found suitable. King Beach is the preferred site, having good acreage available for later expansion to a full-scale commercial facility, access to high quality sea water, and protection from the prevailing south easterly winds. This compares with Wungu that would be restricted to a pilot project only because of the limited availability of flat land and its high usage as a recreation area. Wungu could also involve significant cost associated with the long distance to the sea water intake.

King Beach has significant licensing/permit considerations that require resolution before it can be confirmed as the site to establish the Pilot Project. Being located in a Marine National Park Zone, no aquaculture permits are permissible. While the proposed technology is a land-based system, water would indirectly discharge into the Marine National Park Zone. This would most likely be via a tidal mangrove-lined creek that provides a natural filtering system. Further site inspection is required to determine the proximity of the creek to the proposed site, i.e. its feasibility for water discharge. Commonwealth and State authorities will need confidence that the level of residue nutrient drop-out will not negatively impact on either the local ecology or the Marine Park.

King Beach will require significant infrastructure development to overcome lack of mains power supply and all year round road access. The Pilot Project can operate using generators for the supply of electricity. The project, however, will need State Government support to fund an upgrade of an existing road and longer-term maintenance.

Traditional Owners support a Pilot Project on the basis of economic, employment and training opportunities afforded to local Aboriginal people. Traditional Owners support the selection of King Beach as the preferred site. The Native Title Working Group has provided written support for the Pilot Project.

The report contains details of the project context, site selection process, site attributes and the strategies required to redress the shortcomings of individual sites. The report contains five recommendations to progress the Pilot Project at King Beach.

## 2 BACKGROUND

### Context

DEEDI proposes to establish a pilot lobster growout enterprise for the production of spiny lobster (*Panulirus ornatus*) at the Indigenous community of Yarrabah, Qld. The Pilot Project involves the grow-out of spiny lobster from the minimum legal size to approximately one kilogram to meet an increasing demand for established markets in China. The Pilot Project is part of the international “Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia” project, managed by the DEEDI. An overview of the Spiny Lobster Project is provided at **Attachment A**.

The Spiny Lobster Project involves complementary activities to establish sustainable ‘grow-out’ enterprises in rural communities of Vietnam, Indonesia and Australia. The Project includes enhancing existing small-scale, family-based sea cage enterprises in Vietnam and using similar technologies to establish enterprises in Indonesia and Australia. Of significance, the Vietnamese enterprises involve ‘low-tech’ solutions that make this type of aquaculture development highly suitable for communities in similar circumstances in other countries.

In February 2010, the Spiny Lobster Project received a funding commitment of \$1.3 million from ACIAR for the three year period 2010-12. As a statutory authority, ACIAR operates as part of the Australian Government's development cooperation programs that encourages Australia's agricultural scientists to use their skills for the benefit of developing countries and Australia.

The Spiny Lobster Project is based on over ten years R&D by DEEDI (Cairns, Qld) and its partners in closing the species cycle and in the development of specialised artificial feeds/diets. The scientific breakthrough into closing the species cycle allows for grow-out of hatchery-reared juvenile lobster seed-stock (pueruli). This compares with the current unsustainable practice that involves the grow-out of lobster juveniles caught from the wild. The development of artificial formulated feeds promote optimal growth rates, by reducing dependence on wild caught ‘trash’ fish feed that is linked to the outbreak of diseases in Vietnam.

The R&D underpins the objectives of the Spiny Lobster Project to promote sustainable aquaculture in rural communities through the following key activities:

- commercialisation of the hatchery technology in Australia
- establishment of the grow-out Pilot Project at Yarrabah
- following the Pilot Project, establishment of grow-out enterprises in north Qld Indigenous communities between Bowen and the Torres Strait (the natural habitat for the spiny lobster)
- establishment of grow-out enterprises in Indonesia
- provision of hatchery-reared lobster seed-stock across the three country's grow-out enterprises, and
- introduction of artificial formulated feeds.

The Spiny Lobster Project has significant industry support. Lobster grow-out trials are being conducted in prawn ponds at Pacific Reef Fisheries, Ayr (Qld). The trials will assess the suitability of pond-based production of lobster as a potential alternative species for prawn and barramundi farmers. This is in anticipation of the availability of hatchery-reared lobster seed through the current

commercialisation of hatchery technology, which is being undertaken by DEEDI's Lobster project staff at the Northern Fisheries Centre (Cairns).

### Phased Approach

Over the life of the ACIAR Lobster project (2010 – 2012), it is proposed to establish a pilot (non-commercial) scale lobster production enterprise through three successive activity phases. This report represents Phase 1, to scope the opportunity and identify preferred sites at an Indigenous community in North Queensland. Phase 2 will involve development of a business plan and completion of feasibility study which addresses constraints (including permitting) identified in Phase 1. Phase 2 will also include a training component to initiate training of a Yarrabah Traditional Owner to operate the pilot production system. Phase 3 will comprise the establishment of the pilot production facility to confirm lobster production capacity and economic assumptions.

### Selection of Yarrabah

Several communities between Bowen and the Torres Strait were identified as possible sites to conduct the Pilot Project.<sup>1</sup>Yarrabah was given priority for the following reasons:

- It has access to high-quality, deep sea water all year, which is needed for optimal grow-out conditions
- It is close to the DEEDI Northern Fisheries Centre, which will facilitate project management and technical support from the Centre's lobster grow-out and hatchery research facility, and
- Jaragun P/L has established business relationships with Traditional Owners, which will ensure community protocols are followed in relation to site selection and community consultation.

The selection of Yarrabah focused the objectives of the Scoping Study on identifying a suitable site to conduct the Pilot Project.

DEEDI anticipates the Pilot Project to create approximately five employment outcomes for local Aboriginal people from Yarrabah. The Project will need to be supported through accredited and non-accredited training, and capacity building. The Centre's scientist/s will be involved directly in teaching practical animal husbandry techniques. Other initial training requirements include: vocational aquaculture; and language, literacy and numeracy skills. Additional training in small business management will be needed to establish an aquaculture enterprise following the pilot.

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<sup>1</sup> Communities that were considered suitable for the Pilot Project included Bowen, Palm Island, Cooktown, Mornington Island, Lockhart River and Badu (Torres Strait).

### 3 SITE SELECTION ASSESSMENT CRITERIA

#### Selection of suitable sites for inspection

Eight locations were identified as potential locations to conduct the Pilot Project at Yarrabah, including the following:

- Fitzroy Island
- Turtle Bay
- Little Turtle Bay
- East False Cape
- West False Cape
- King Beach
- Back Beach (Wungu and Jilji), and
- Buddabadoo.

Figure 1 – Map of locations



The assessments were to be conducted via road access, with boat access for those locations that were only accessible by water.

Priority was given to Fitzroy Island as the most likely suitable site. It was the preferred location of Traditional Owners, with access to deep sea water, an existing aquaculture facility and a current aquaculture permit/licence. Nevertheless, the site was excluded after preliminary research found that the current lessee had already entered into an agreement with another party, making the



facility unavailable to the Pilot Project. No other sites are available on Fitzroy Island because of restrictions on land tenure/zoning. Following completion of site assessments at Yarrabah, the leaseholder of the facility at Fitzroy Island indicated a willingness to negotiate with DEEDI. Subsequently, DEEDI has prioritised the aquaculture facility for establishment of a hatchery.

A subsequent decision initially excluded locations only accessible by water. These included Turtle Bay, Little Turtle Bay and King Beach. It was considered that inclement weather would impede accessibility by water all year round, affecting successful implementation of the Pilot Project. Further, the logistics of boat access would add significant cost and/or delay to start-up if feasibility of the Pilot Project depended on construction of a road.

Despite this, the project team expressed continuing interest in King Beach. While it may have permit challenges because of its zoning in the Great Barrier Reef Marine Park as a Marine National Park Zone (green zone), aerial views and Traditional Owner knowledge indicated potential for both a commercial grow-out facility following the Pilot Project and the establishment of a hatchery. King Beach also has a disused road that could be upgraded. As a result, a decision on the preferred site was delayed until an inspection of King Beach was conducted via boat access.

Of the locations accessible by road, the preferred location involved a property at False Cape. The property was on the market and had the advantage of cleared land. While seeking permission to conduct the site inspection, it was established that the property was already under contract. This effectively eliminated False Cape as a potential location to conduct the Pilot Project.

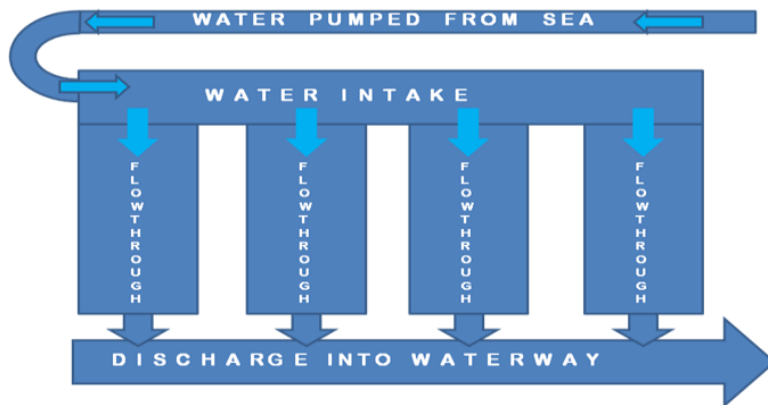
The site inspections at Back Beach were conducted at Wungu (northern end) and Jilji (southern end). The sites are within the jurisdiction of both the Qld State Parks (intertidal area between low and high water mark) and the Great Barrier Reef Marine Park Authority (GBRMPA). A fourth site was inspected after Mr Bob Patterson, a Traditional Owner, confirmed that Buddabadoo had been included as Gunghangi country during court hearings with respect to the Traditional Owner's native title determination application. As it was agreed on arriving at Buddabadoo that the location was not feasible for the Pilot Project due to lack of an available area for a site on the north side of Oombunghi River, a site assessment has not been included in this report.

As a result of the above, three site assessments are contained in this report, including those for King Beach, Wungu and Jilji.

### Technology requirements

The preferred technology for conducting the Pilot Project is an above-ground raceway system. Raceway technology typically includes a simple, flow-through system where water is pumped to a holding tank and gravity fed through the raceways. The technology provides for optimal grow-out conditions of spiny lobster, i.e. maintenance of a salinity level of approximately 35 parts per thousand.

Figure2 – Above-ground raceway system



The technology is considered appropriate for Indigenous communities in Australia, and provides for the trial of an additional technology in the Spiny Lobster Project. That is, sea cages are deployed in Vietnam and Indonesia and earthen ponds in the research being conducted at Ayr. DEEDI has indicated that an above ground tank system, which requires similar ground area to the proposed raceway system, provides an alternative proven technology if required for the selected Yarrabah site.

DEEDI proposes using four x 20m<sup>2</sup> raceways in the Pilot Project, each raceway 2 metres wide by 10 metres long. Further information on funding, site availability and environmental specifications are required before the dimensions of both the pilot and commercial grow out systems can be clearly defined. The system will require year-round access to high volumes of clean sea water.

The presence of a tidal mangrove creek is also a favourable site characteristic. Such creeks provide a natural filtering system for water discharge. The level of reduction in 'nutrient drop-out' will be a key consideration of GBRMPA in approving an aquaculture permit in the Great Barrier Reef Marine Park. In addition, discharge into an existing tidal creek will have minimum impact on the flora/fauna.

### Rating system

DEEDI determined a set of criteria to assess and rate site suitability; covering scientific, technical, environmental, economic and social considerations (see **Attachment B**)<sup>2</sup>. The criteria were grouped into the following categories to facilitate readability:

- Technology
- Geography
- Water intake & discharge
- Infrastructure
- Permits & licensing, and
- Community.

Each criterion was given a score of "1" for Suitable, "0" for Unsuitable, or "0.5" if further investigation were required. Scores were tallied to give a total score at each site. Criteria were not weighted.

<sup>2</sup> The suitability for sea cages and ponds were not included in the assessment, given the preference for a raceway system. It should be noted that site characteristics would be similar for ponds and raceways.

The methodology required SWOT analysis for development of management strategies to progress the project. Cost factors were not assessed, as these will be considered in the Feasibility Study/Business Planning exercise.

## 4 THE PREFERRED SITE

### Introduction

The set of criteria was applied to assess suitability of the three sites for conducting the Pilot Project. The locations achieved the following site scores:

- Wungu, 14
- King Beach, 10.5, and
- Jilji, 10.

King Beach had the best attributes for establishing an aquaculture facility and, for this reason, is the preferred site despite having a lower score than Wungu. King Beach scored lower because of its location within a Marine National Park Zone and absence of infrastructure. These factors will need to be resolved before King Beach can be confirmed as the site to conduct the Pilot Project.

Wungu also has potential sites available to conduct the Pilot Project. However, unlike King Beach, Wungu is perhaps less suitable due to the type of vegetation and, potentially, less flat ground for expansion to a commercial facility.

Jilji was not considered suitable for an aquaculture facility.

### King Beach site assessment

King Beach is located east, south east of Yarrabah. It is directly opposite Fitzroy Island, which is separated from the mainland by a deep water channel. King Beach is approximately two kilometres in length and is surrounded by mountains on the southern, western and northern boundaries. A tidal mangrove creek runs along the valley and empties into the sea mid-way along the beach.

The location is not currently accessible by road, although a disused road previously provided access from Yarrabah to the southern headland.

A site at the southern end of the beach was assessed and scored for suitability to conduct the Pilot Project. The site is approximately 100 metres from the low water mark, and abuts the southern mountain face, giving it protection from the prevailing south easterly winds.

**Figure 3: King Beach**



### *Site score*

King Beach achieved a site score of 10.5, based on the following assessment.

### **Technology**

The site is suitable for a land-based system, with close proximity to a reliable source of good quality sea water.

### **Geography**

The site has sufficient area available to construct both the Pilot Project and a commercial facility.

### **Water intake & discharge**

Good quality sea water is accessible off the rocky headland. Further inspection is required to determine the proximity and suitability of the creek for water discharge.

### **Infrastructure**

King Beach is approximately 12.0 kilometres from Yarrabah. The disused road would need to be upgraded for King Beach to be a viable site to conduct the Pilot Project.

YASC was approached as to the possibility of upgrading the road. Several presentations were made to YASC by Traditional Owners, Jaragun P/L and the Northern Fisheries Centre. These outlined the project benefits to the community and the project establishment challenges. While YASC initially supported the project, YASC later withdrew its support for the project. See **Attachment C**.

At a subsequent meeting with Jaragun P/L and Traditional Owners, Qld Department of Environment and Resource Management (DERM) suggested an alternative process. This requires the State Government to identify the project as a state priority for Far North Qld, based on the potential training, employment and economic development opportunities for Aboriginal people in Yarrabah. In turn, the road upgrade would be deemed a state matter rather than a local council responsibility.

The nearest electricity is at least six kilometres from King Beach. This makes the Pilot Project dependent on a generator for electricity, as the Council has no plans to extend the power grid in the foreseeable future.

### **Permits/licensing**

There have not been any previous applications for development work or aquaculture activities at King Beach. The Pilot Project would require both Commonwealth and State Government approvals to carry out aquaculture activities and undertake the associated facilities development. Key agencies include GBRMPA, Department of Environment, Water, Heritage and the Arts (DEWHA) and DERM.

An initial assessment is required by DERM to assess suitability of the site for a land-based aquaculture permit, particularly in relation to water discharge in respect of the impact of nutrient levels on the natural flora/fauna or Great Barrier Reef Marine Park.

### **Community**

Traditional Owners support opening up access to King Beach for economic development. Access is currently restricted to boat or a 6-8 kilometer walk over rough terrain.

They further believe that improved access would enable Traditional Owners to better meet their cultural obligations on a regular basis, while providing recreation advantages for the wider community.

The headland has a burial site close to the proposed Pilot Project site. The site (and other sites in the vicinity) will need to be registered as a cultural heritage site under the *Aboriginal Cultural Heritage Act 2003* to ensure its integrity/preservation.

Details of the site assessment are provided at **Attachment D**.

*SWOT*

The SWOT indicated considerable site strengths, the most important being its suitability for land-based system technology, high quality water intake, availability of acreage to extend the Pilot Project into a commercial-size facility and protection from the prevailing south easterly winds.

However, the SWOT also shows considerable threats to the Pilot Project being conducted at King Beach. The most substantial is its designation as Marine National Park Zone, which does not permit aquaculture activities. The SWOT is provided at **Figure 4** below.

**Figure 4: King Beach SWOT Analysis**

STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> <li>● Suitable for land-based system technology</li> <li>● Sufficient area to conduct pilot project</li> <li>● Availability of several sites to conduct pilot</li> <li>● Sufficient area to commercialise post pilot</li> <li>● Land surface is flat</li> <li>● Site within 250 metres of Low Water Mark</li> <li>● Sufficient water depth off beach</li> <li>● Site is above 5 metres AHD</li> <li>● Access to water &gt; 5 metres</li> </ul>	<ul style="list-style-type: none"> <li>● Questionable ability to discharge into creek</li> </ul>
OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> <li>● Traditional owner support</li> <li>● Yarrabah Economic Development Forum support for the pilot project</li> </ul>	<ul style="list-style-type: none"> <li>● Lack of mains electricity at site</li> <li>● YASC has no plan to extend power grid</li> <li>● No road access</li> <li>● Presence of a cultural heritage site</li> <li>● Refusal of development approval to undertake aquaculture</li> <li>● Adjacent to Marine National Park Zone</li> </ul>

The strategies arising from the site’s SWOT analysis follow.

*Weaknesses*

While the creek is permanent, there is need to determine whether it is sufficiently close to the proposed site be feasible as a point of water discharge. A second seasonal creek that empties into the permanent creek might also provide an alternative, given its proximity to the proposed site.

Scientific advice, however, is required to determine whether there would be environmental impact from discharging salt water into what appears a fresh water environment.

### *Opportunities*

The involvement of Traditional Owners offers the project greatest potential for success, in terms of broader community engagement and support for the Pilot Project. Traditional Owners have indicated that this project is a priority because of its potential to deliver training and employment outcomes for the Yarrabah community over the long term. The project should continue to retain Traditional Owner involvement in all project planning and implementation.

YASC waived from its initial position of support for the project. The CEO stated the Council has unexpended funds earmarked for aquaculture purposes, which it initially indicated could contribute towards the Pilot Project. This was the basis for three presentations to the Council, at which time support was expressed for the project. A subsequent Council meeting resulted in a decision not to support the project. No reason was given.

Separately, Michael Reid, Director-General Queensland Health, recently facilitated the Yarrabah Economic Development Forum (21 October 2010), which gave the project a second priority status for Yarrabah because of the potential for economic development and employment opportunities for the community. The Forum established a Working Group to draft a Feasibility Study. The DEEDI member indicated interest in follow-up discussions.

### *Threats*

The absence of mains electricity does not threaten the Pilot Project, as a generator has been deemed adequate for the needs of a pilot. In addition, solar power opportunities should also be thoroughly explored. The lack of mains electricity would impact on a commercial development, the project would need to garner YASC's commitment to extend the power grid to the site. This should be pursued only after successful implementation of the pilot project, as part of a reassessment of the site as the most suitable location to establish a commercial facility. At this time, the employment outcomes to the community will be proven and new councilors will have been elected.

The lack of a road to the site is a threat to the Pilot Project, as small boat access will not support the project needs. DERM has indicated that the road could be upgraded and maintained by main roads, if the project were regarded a State Government priority.<sup>3</sup> This is possible, given the potential employment opportunities for disadvantaged job seekers at Yarrabah, and the requirements for the Northern Fisheries Centre to include Aboriginal and Torres Strait Islander people and communities in the ACIAR project.

Traditional Owners have indicated that the Pilot Project facility can be built without interference to cultural heritage sites. Any sites in the area should be registered as cultural heritage sites and the appropriate buffer zone determined prior to mapping of the site facility requirements.

The need to discharge water from the raceway system into a Marine National Park Zone Habitat Protection Zone will impact on the likelihood of licensing/permitting approvals. The project will need

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<sup>3</sup>YASC was consulted extensively about upgrading the road. The Council has responsibility for the area under its classification as Deed of Grant in Trust (DoGIT). As indicated, YASC is not prepared to upgrade the road on the basis that it does not support the project for reasons that have not been specified.



to include scientific and technical solutions in the design of the raceway system to address concerns of licensing and permitting agencies.

Community support for the project is critical to counter the potential for vandalism of the site facility. A communication strategy is needed to inform and consult the community about the project.

### Back Beach – Wungu site assessment

Wungu is located at the northern end of Back Beach, directly south of Fitzroy Island and separated from King Beach to the north by a rocky headland. The headland drops off steeply into a deep water channel formed between the mainland and Fitzroy Island. A permanent, mangrove-lined tidal creek runs behind the sand dune and empties into the sea at the base of the headland. The creek, which is fed by an inland spring, flows most of the year.

The location is a recreation area for locals during the dry season, with road access and a car park at the beach proper. Two basic beach shelters and a camping area have been constructed, which are located on either side of the car park. Three residences have been built in the bush between the road access and the headland, two of which are inhabited.

A site close to the beach was assessed and scored for suitability to conduct the Pilot Project. The site is approximately 150 metres from the low water mark, and is situated between a recreation shelter and a seasonal drain that feeds into the tidal creek.

**Figure 5: Wungu**



#### *Site score*

Wungu achieved a site score of 14, based on the following assessment.

#### **Technology**

The site is suitable for a land-based system, with close proximity to a reliable source of good quality sea water.

### Geography

The site has sufficient area available to construct a Pilot Project facility. More detailed inspection is required to assess whether the site has sufficient space to establish a commercial facility following the Pilot Project.

Wungu has several other area/s that may be suitable either to conduct the Pilot Project or to establish a commercial facility. These area/s are located further inland from the site inspected, sharing similar characteristics apart from a greater distance to the sea water intake point.

### Water intake & discharge

Good quality sea water is available off the headland or beach. The headland is more favourable in terms of access to deep water, but could be a greater distance to pump/pipe. A water intake pipe off the beach would be more costly to install and maintain, as the pipe would need to be buried and require ongoing stabilization works to address shifting sands.

### Infrastructure

Wungu is some 11.1 kilometres from Yarrabah township by road (measured from the Post Office). This includes 7.6 kilometres of unsealed road from the Murigan Creek turnoff. The road is in reasonable condition, although it is only accessible at times by 4WD during the wet season. Previous attempts by the YASC to permanently stabilize the road surface for year round access have been unsuccessful.

The site would require a generator for power, as the nearest electricity is 6.4 kilometres from Wungu. The Council has no plans to extend the power grid from Yarrabah.

### Permits/licensing

There have not been any previous applications for development work or aquaculture activities at Back Beach. The Pilot Project will require both Commonwealth and State Government approvals to carry out aquaculture activities and undertake the associated facilities development. Key agencies include GBRMPA, DEWHA and DERM.

DERM's initial response was favourable. A site assessment would be required with DERM and GBRMPA to assess likely outcomes of applications for site development and an aquaculture permit.

### Community

The headland has cultural heritage sites consisting of three shell middens. The sites would need to be registered under the *Aboriginal Cultural Heritage Act 2003* to protect their integrity/preservation.

Details of the site assessment are provided at **Attachment E**.

### SWOT

The SWOT indicated considerable site strengths, the most important being its suitability for land-based system technology, high quality water intake and the availability of multiple sites that could house/accommodate a commercial-size facility in future. The SWOT analysis is provided at **Figure 6** below.

**Figure 6: Wungu SWOT Analysis**

STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> <li>● Suitable for land-based system technology</li> <li>● Sufficient area to conduct Pilot Project</li> <li>● Availability of several sites to conduct pilot</li> <li>● Land surface is flat</li> <li>● Site is within 250 metres of Low Water Mark</li> <li>● Sufficient water depth off beach</li> <li>● Site is above 5 metres AHD</li> <li>● Access to water &gt; 5 metres</li> <li>● Ability to discharge into tidal creek</li> </ul>	<ul style="list-style-type: none"> <li>● No current aquaculture permit</li> <li>● Insufficient area to commercialise post Pilot Project</li> </ul>
OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> <li>● Traditional owner support</li> <li>● Yarrabah Economic Development Forum support for the Pilot Project</li> </ul>	<ul style="list-style-type: none"> <li>● Lack of mains electricity at site</li> <li>● YASC has no plan to extend power grid</li> <li>● Road inaccessible all year</li> <li>● Cultural heritage sites</li> <li>● Location adjacent to Habitat Protection Zone</li> <li>● Recreation area</li> </ul>

The strategies arising from the site’s SWOT analysis follow.

*Weaknesses*

The lack of an existing aquaculture permit is a project weakness that needs to be addressed through application to Commonwealth/State agencies. It is a priority to confirm that securing an aquaculture permit is achievable, given that the Pilot Project cannot proceed without a permit.

*Opportunities*

The involvement of Traditional Owners offers the project greatest potential for success, in terms of broader community engagement and support for the Pilot Project. Traditional Owners have indicated that this project is a priority because of its potential to deliver training and employment outcomes for the Yarrabah community over the long term. The project should continue to retain Traditional Owners involvement in all project planning and implementation.

As with King Beach, the Yarrabah Economic Development Forum supported the Pilot Project at Wungu because of the potential for economic development and employment opportunities for the community.

*Threats*

The absence of mains electricity does not threaten the Pilot, as a generator has been deemed adequate for the project needs. However, as lack of mains electricity would impact on a commercial development, the project would need to garner YASC’s commitment to extend the power grid to the

site. This should be pursued only after successful implementation of the Pilot Project, as part of a reassessment of the site as the most suitable location to establish a commercial facility.

The condition of the road is a manageable threat to the Pilot Project. It is expected to be countered by use of 4WD transport in order to provide year round access to the site, particularly during the wet season. The Council has already shown commitment to stabilizing the road surface to meet its obligations to provide for the recreation needs of the community.

Traditional Owners have indicated that the Pilot Project facility can be built without interference to heritage sites. A consultation process will nevertheless be required to define the perimeter of the cultural heritage sites and to establish an appropriate buffer zone.

Discharge of nutrients into a Habitat Protection Zone will impact on licensing/permitting approvals. The project will need to include scientific and technical solutions in the design of the raceway system to address concerns of licensing and permitting agencies.

Community support for the project is critical to counter the potential for vandalism of the site facility. A communication strategy is needed to inform and consult the community about the project.

### Back Beach – Jilji site assessment

Jilji is located towards the southern end of Back Beach. The location is situated between a permanent, fresh water creek (north) and a small rocky outcrop(south). The creek, which runs from north to south, drains a large swampy area behind the beach. The creek empties large volumes of water onto the beach, causing the mouth to change course amid shifting sands throughout the year.

The location includes residential zoning on the southern side, and is a high use recreation area by locals. The location is accessible by road and car park behind the beach. The car park includes two shelters.

A site at the northern car park shelter was assessed and scored for suitability to conduct the Pilot Project. The site is approximately 150 metres from the low water mark, on an elevated area that sits between the swamp and mouth of the creek.

**Figure 7 – Jilji**



### *Site score*

Jilji achieved a site score of 10, based on the following assessment.

### **Technology**

The site was assessed as unsuitable for a land-based system due to the influence of the fresh water creek. The high volumes of fresh water flowing into the sea during the wet season would impact on the quality of the water intake, by reducing salinity to unacceptable levels.

### **Geography**

The site has sufficient area available to conduct a Pilot Project, with space available for expansion to a commercial facility. There are no alternative sites at the location.

### **Water intake & discharge**

There is insufficient depth of sea water off the beach to counter the large volumes of fresh creek water during the wet. It would be difficult and costly to install and maintain a water intake pipe off the beach, as the pipe would need to be buried and require ongoing stabilization works to address shifting sands. The need for a navigation buoy for large scale pumping would add to the difficulty of obtaining an aquaculture permit.

### **Infrastructure**

Jilji is some 10.2 kilometres from Yarrabah by road (measured from the Post Office). This includes sealed road and power to Oombunghi, which is 1.6 kilometres from Jilji. The road is in good condition, with all year round access. The Council has plans to extend the power grid as part of the future residential development. This would take the power to the perimeter of Jilji.

### **Permits/licensing**

As with Wungu, there have not been any previous applications for development work or aquaculture activities at Jilji. Approval of an aquaculture permit might be possible for the Pilot Project but not a commercial facility due to the need for a navigation buoy on the water intake pipe.

### **Community**

The swamp has cultural heritage sites, although Mr Patterson indicated that there would be no interference from development associated with a Pilot Project.

Details of the site assessment are provided at **Attachment F**.

### *SWOT*

The SWOT analysis shows that Jilji is unsuitable to conduct the Pilot Project. The threat of poor water quality during the wet season is unable to be countered in a cost-effective manner. As such, no further assessment of the site is required. The SWOT analysis is provided at **Figure 6** below.

**Figure 8: Jilji SWOT Analysis**

STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> <li>● Sufficient area available for Pilot Project</li> <li>● Land surface area is flat</li> <li>● Site is within 250 metres of Low Water Mark</li> <li>● Site is above 5 metres AHD</li> <li>● Ability to discharge into tidal creek</li> <li>● Road access all year</li> </ul>	<ul style="list-style-type: none"> <li>● No current aquaculture permit</li> </ul>
OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> <li>● Traditional owner support</li> <li>● Yarrabah Economic Development Forum supports the Pilot Project</li> </ul>	<ul style="list-style-type: none"> <li>● Unsuitable for land-based system</li> <li>● Insufficient area to commercialise Pilot Project</li> <li>● Lack of other sites</li> <li>● Insufficient water depth off beach</li> <li>● Distance too great to water &gt; 5 metres depth</li> <li>● Proposed expansion of nearby residential area</li> <li>● Lack of mains electricity to site</li> <li>● Habitat Protection Zone</li> <li>● Cultural heritage site/s</li> <li>● Recreation area</li> </ul>

## 5 ADDITIONAL REQUIREMENTS/CONSTRAINTS

### Local and state government development permit/s

The Traditional Owners will require several development permit/s from Queensland state planning authorities to proceed with the Pilot Project at King Beach. Development applications are assessed under the Integrated Development Assessment System (IDAS), which incorporates all state and local government assessment and approval processes for development in Queensland.

Relevant legislation includes:

- The *Coastal Protection and Management Act 1995* and the associated *State Coastal Management Plan – Queensland’s Coastal Policy (SCMP)*. Development applications for coastal work may be required if the Pilot Project falls within the definition of Prescribed Tidal Work, which applies to development between the high and low water mark and/or work that is an integral part of the development work that falls outside the tidal area
- The *Sustainable Planning Act 2009 (SPA)* and the *Sustainable Planning Regulation 2009<sup>4</sup>(SPR)*. These require “development” applications for “assessable development” in terms of work carried out completely or partly on land adjacent to the western boundary of the Great Barrier Reef Marine Park<sup>5</sup>, and
- The *Fisheries Act 1994*. The Pilot Project falls within the definition of aquaculture under the *Fisheries Act 1994* which covers the cultivation of live fisheries resources for sale.

The SPA also points to other processes and legislation that may be relevant, for instance:

- An Environmental Impact Statement (EIS) requirement for development prescribed under a regulation, where the development is subject to a development application<sup>6</sup>, and
- Vegetation clearing on Indigenous land<sup>7</sup>, under the *Vegetation Management Act 1999*.

The relevant development applications will need to be clarified/confirmed following confirmation of King Beach to conduct the Pilot Project. This should include the role of state and local government authorities.<sup>8</sup>

### Federal Government approvals

GBRMPA, as the agency responsible for managing the Great Barrier Reef Marine Park, is responsible for issuing permits.

<sup>4</sup>SPA. See Section 238 Assessable development and Section 240 Types of approval, p. 176.

<sup>5</sup> SPA Chapter 9 Miscellaneous, Part 7 Notification stage for particular aquaculture development, Section 744(1)(b)(ii)

<sup>6</sup> SPA, Chapter 9 Miscellaneous, Part 2 Environmental impact statements, Section 688 When EIS process applies, p. 454.

<sup>7</sup> See SPA, Sections 38, 4.3.1(1), 4.3.3(1), 4.3.3(5) and 4.3.15(1).

<sup>8</sup> SPA, Schedule 6 Assessment manager for development applications. Compare: Table 1, Item 1, involving Local government being the assessment manager for tidal areas; Table 3, Item 6, involving the Chief executive of *Coastal Protection and Management Act* being the assessment manager for tidal areas; and, Table 3, Item 13, involving Chief executive of the *Environment Protection Act* being the assessment manager for the Great Barrier Reef wetland protection area.



As indicated above, aquaculture may not be permissible at King Beach due to its location adjacent to a Marine National Park Zone. As the preferred site, the project team would need to consult DERM and GBRMPA. GBRMPA and Traditional Owners have previously discussed economic development in the Wet Tropics.

Wungu is located adjacent to a Habitat Protection (Dark Blue) Zone. The Zone provides for the conservation of area, by giving protection to sensitive habitats. This includes that the habitat is generally free from potentially damaging activities. Despite the sensitivity of the area, GBRMPA is able to issue permits for 'reasonable use' in Habitat Protection Zones. This includes aquaculture.

A key consideration relating to permit approvals in the Great Barrier Reef Marine Park is discharge from the aquaculture facility. As the Marine Park is also part of the World Heritage Area, GBRMPA must consider the effect on the Park's World Heritage Values. In the event the proposal is considered to have a significant impact on a matter of National Environmental Significance, referral is required under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to DEWHA as the agency responsible for administering that Act.

The EPBC Act regulates actions that have, will have or are likely to have, a significant impact on matters of national environmental significance. Matters of national environmental significance include the Great Barrier Reef Marine Park, the World Heritage Values of a declared World Heritage property, listed threatened species and migratory species, and the environment of a Commonwealth marine area.

In November 2009, the Great Barrier Reef Marine Park was inserted into the EPBC Act as a matter of national environmental significance. As a consequence, the environmental impact assessment and approval requirements under the EPBC Act will apply where an action in the Marine Park has, will have or is likely to have, a significant impact on the environment; and where an action outside the Marine Park has, will have or is likely to have, a significant impact on the environment in the Marine Park.

Initial discussions with DEWHA indicated their focus on risks from disease and discharge into the Marine Park, based on the proposed technology. In particular, there should be no net increase in the background levels of nutrients, consistent with the Great Barrier Reef Marine Park Zoning Plan 2003.

It should be also noted that GBRMPA charges Permit Application Assessment Fees. In particular, an activity that requires GBRMPA's preparation of an EIS would attract a fee of \$99,250.

## Training and employment

The Northern Fisheries Centre expects the Pilot Project to employ up to ten local Aboriginal people. This will require vocational training and skills development in seafood/aquaculture.

The Northern Fisheries Centre has indicated that an opportunity exists for a member of the Yarrabah community to learn animal husbandry prior to establishment of the Pilot Project. This would involve working alongside scientists in the Centre's lobster grow-out and hatchery research facility. The project team has identified a suitable individual, a job seeker who has already completed a Certificate I in Seafood Industry (Aquaculture).

The Scoping Study conducted some preliminary research on training/employment options for job seekers, given that the Northern Fisheries Centre does not currently have a suitable staff position to employ the individual. The project team identified the following employment options, if funding were sourced to engage the individual:

- (i) Unpaid work experience for up to four weeks, with guarantee of an employment outcome if the individual is found suitable,
- (ii) Wage subsidies, for a salaried position, or
- (iii) Traineeship over 12 months.

The Job Services Australia provider can also provide assistance with the individual's costs of relocating from Yarrabah to Cairns to take up the position.

A project priority is to identify a source of funding to employ the individual as soon as possible to maximize the individual's skills development prior to the establishment of the Pilot Project facility.

## 6 POTENTIAL SOURCES OF FUNDING

Discussions have been held with a range of stakeholders to canvas funding opportunities for the Pilot Project.

Two organisations indicated the availability of funds that are earmarked/designated for Indigenous aquaculture purposes. The CEO of YASC indicated that the Council has unexpended funds from previous proposals for aquaculture development at Yarrabah. As indicated, several presentations were made to the Council, including a written briefing at the request of the CEO. A community information session was also held at the Council's request, and several letters sought and received confirming various Traditional Owner support for the project. However, given YASC's subsequent decision not to support the Pilot Project, the project team no longer considers Council funding a possibility at this time. The project team notes that the Working Group associated with the Yarrabah Economic Development Forum may produce change, as the Forum ranked the project as a second priority for Yarrabah.

At the time this report was prepared, the Department of Agriculture, Fisheries and Forestry (DAFF) indicated that it has uncommitted funds remaining from the Indigenous Aquaculture Unit. The funds, which are quarantined, are subject to Ministerial decision. At DAFF's request, Jaragun P/L prepared a brief for DAFF to inform the Minister about the Project, including the economic and employment benefits to accrue for Yarrabah[and other Indigenous communities in future].

The project team has also explored options to fund a position in the Northern Fisheries Centre's lobster grow-out and hatchery research facility. Such a position would increase the chance of project success by enabling a member of the Yarrabah community to learn animal husbandry techniques prior to the establishment of the Pilot Project. The position is earmarked for a Traditional Owner, Mr Wyndham Ludwick, who has a Certificate I in aquaculture. Initial representation was made to YASC, on the basis that it could access subsidised traineeships from the Qld State Government. The withdrawal of Council support meant that the traineeship could not be pursued. The Northern Fisheries Centre has since made a request to ACIAR to fund the position, which is pending.

The project team also applied to the Fisheries Research Development Corporation (FRDC) for a \$10,000 Indigenous Development Scholarship to support Mr Ludwick's traineeship. The purpose of the scholarship is for individuals to undertake a personalised and supported program to further develop their skills, knowledge and networks in the fishing industry. It was anticipated that Mr Ludwick would have been able to see firsthand the broader project in Vietnam and Indonesia, and better understand the project's community development objectives in terms of its applicability to Yarrabah. The Northern Fisheries Centre will be in a position to reapply for the Indigenous Development Scholarship in 2011 should ACIAR fund Mr Ludwick's position.

Various Commonwealth and state government agencies have expressed interest in holding discussions to progress the Pilot Project. The timing should follow confirmation of King Beach as the location of the Pilot Project and focus on funding commitments, project processes and timing.

ATTACHMENT A – Spiny Lobster Aquaculture Development in Indonesia,  
Vietnam and Australia

## ATTACHMENT B – Site assessment criteria

- Is the location suitable for sea cages?
- Are land sites available within 250m of sea?
- Is there more than one potential site at the location?
- Is there a creek or river mouth within 1km of the site?
- Is area available for a land-based system?
- Is the site suitable for ponds?
- Does the site comprise clay, soil or sand?
- Is the site suitable for tanks?
- Is electricity available?
- What is the distance to nearest power (m)?
- Is there deep water off the beach?
- What is the distance to deep water (>5m depth)?
- Is there road access to the site?
- Is the site covered by an existing aquaculture permit?
- Are there native title issues?
- Are there Marine Parks / GBRMPA issues?

ATTACHMENT C – Traditional Owners letter to Yarrabah Aboriginal Shire Council

ATTACHMENT D – King Beach site assessment

<b>Site inspection: King Beach</b>			
<b>Criterion</b>	<b>Meets criterion Yes/No</b>	<b>Comment</b>	<b>Rating 0 or 1</b>
<b>Technology</b>			
Suitability for land-based system, i.e. raceway or tank	Yes	Suitable for above-ground raceway or tank system. Proposed location is less than 100 metres from low water mark. Good water quality (salinity), with access to deep sea water intake off the southern headland/beach.	1
<b>Geography</b>			
Availability of area for land-based system	Yes	The site has more than 20 <sup>2</sup> metres available for the requirements of raceway system, involving 4 raceways each with a dimension of 5 metres x 2 metres.	1
Suitability for expansion	Yes	The site has considerable additional ground area suitable for expansion to a commercial-sized facility.	1
Topography, including slope	Yes	Site location is flat and has protection from prevailing south easterly winds.	1
Soil type, i.e. clay, soil or sand	N/A	Sand/soil mix.	-
Other potential site/s	Yes	The northern end of the beach has potential. The suitability of the southern site did not warrant further inspection at King Beach.	1
<b>Water intake &amp; discharge</b>			
Proximity to sea water, i.e. within 250m of sea	Yes	Site is approximately 100 metres (or less) from low water mark.	1
Height above or below 5m AHD <sup>1</sup>	Yes	Location is not subject to flooding, being above the 10 – 25 metre AHD	1
Depth of water off beach	Yes	Deep water off the beach provides access to high quality sea water.	-
Distance to deep water (>5m depth)	Yes	Approximate 550–600m from the proposed site (directly into the National Marine Park Zone (green)).	1
Proximity of a creek/river mouth within 1km of site	Yes	Presence of permanent tidal creek that drains onto beach less than 0.5 kilometres north of the site. Following the site inspection, Traditional Owners indicated the creek runs close to proposed site. A further inspection is required to determine the feasibility of using the creek for water discharge, i.e. to filter nutrient drop-out to minimise impact on flora/fauna.	0.5
<b>Infrastructure</b>			
Road access	No	Location is approximately 12 kms from Yarrabah. Disused road would need to be upgraded and maintained for all-year-round access.	0
Electrical supply	No	Nil electricity at site. The Council has no plans to extend the power grid, meaning that the Pilot Project would be dependent on generator for power.	0
Distance to nearest power (m)	No	Approximately 10 kilometres to mains power.	0
<b>Permits &amp; licensing</b>			
Existing aquaculture permits	No	No aquaculture permits are available for the	0



		location. Negotiations will be required with relevant authorities.	
DERM / GBRMPA issues	No	King Beach is located adjacent to the Great Barrier Reef Marine Park. The sea is designated Marine National Park Zone (Green), which does not provide for aquaculture. The zoning, however, provides for research permits.	0
<b>Community</b>			
Cultural heritage sites	Yes	A cultural heritage site is located in the vicinity of the proposed site. Traditional Owners have indicated the facility would not interfere with the sites.	1
Traditional Owners	Yes	Traditional Owners support economic development, and selected King Beach as the most suitable of all the sites inspected to conduct the Pilot Project.	1
Yarrabah Economic Development Forum	Yes	The Forum supports the Pilot Project as one of Yarrabah's priorities economic development initiatives.	1
<b>Total</b>			<b>10.5</b>

## ATTACHMENT E – Wungu site assessment

<b>Site inspection: Wungu, Site 1</b>			
<b>Criterion</b>	<b>Meets criterion Yes/No</b>	<b>Comment</b>	<b>Rating 0 or 1</b>
<b>Technology</b>			
Suitability for land-based system, i.e. raceway or tank	Yes	Suitable for above-ground raceway or tank system. Proposed location is 100 metres from low water mark. Good water quality (salinity), with access to deep sea water intake off the headland/beach.	1
<b>Geography</b>			
Availability of area for land-based system	Yes	Initial site inspected is approximately 20 <sup>2</sup> metres. This is against the requirements of raceway system, involving 4 raceways each with a dimension of 5 metres x 2 metres.	1
Suitability for expansion	Yes	The site has some potential for expansion of the Pilot Project, although more detailed inspection is required to assess whether the area is sufficient to meet the needs of a commercial facility.	1
Topography, including slope	Yes	Site locations are flat.	1
Soil type, i.e. clay, soil or sand	N/A	Sand/soil mix.	-
Other potential site/s	Yes	At least two sites at the location are suitable for above ground land-based systems. One site has sufficient area to construct a commercial facility.	1
<b>Water intake &amp; discharge</b>			
Proximity to sea water, i.e. within 250m of sea	Yes	Site is approximately 100-150 metres from low water mark.	1
Height above or below 5m AHD <sup>1</sup>	Yes	Location is not subject to flooding, being above the 10 -15 meters AHD.	1
Depth of water off beach	Yes	Approximately 800-850m from the proposed site.	-
Distance to deep water (>5m depth)	Yes	200-300 metres to access deep water off headland or 150 metres from beach low water mark.	1
Proximity of a creek/river mouth within 1km of site	Yes	Presence of permanent mangrove-lined tidal creek that drains onto beach. The creek would act as a filter for nutrient drop-out, while fluctuations in water levels from discharge would not affect flora/fauna.	1
<b>Infrastructure</b>			
Road access	Yes	The location is 11.1 kms from Yarrabah, involving 7.6 kms of unsealed road. Access during the wet season (up to three months) is often only by 4WD. The Council has previously attempted to upgrade the road but has experienced difficulty in achieving permanent stabilisation. The road access is not expected to cause disruption to provision of supplies/technical support due to the 4WD access.	1
Electrical supply	No	Nil electricity at site, with a distance of 6.4 kilometres to power near Murigan Creek turn-off (1.2k along unsealed road).The Council has no plans to extend the power grid, meaning that the Pilot Project would be dependent on generator for power.	0

Distance to nearest power (m)	No	6.4 kilometres to mains power.	0
<b>Permits &amp; licensing</b>			
Existing aquaculture permits	No	There has not been any previous application for an aquaculture permit for the location. Negotiations will be required with relevant authorities.	0
DERM / GBRMPA issues	Yes	Wungu is located adjacent to the Great Barrier Reef Marine Park. The sea is zoned Habitat Protection (Dark Blue) Zone. The zoning allows reasonable use of the area, including possibility of aquaculture permits.	1
<b>Community</b>			
Cultural heritage sites	Yes	Significant cultural heritage sites are located at the headland. The proposed construction would not interfere with these site/s.	1
Traditional Owners	Yes	Traditional Owners support economic development, and selected the site/s as suitable for the proposed development. However, the site is part of a recreation area that would require community consultation.	1
Yarrabah Economic Development Forum	Yes	The Forum supports the Pilot Project as one of Yarrabah's priorities economic development initiatives.	1
<b>Total</b>			<b>14</b>

ATTACHMENT F – Jilji site assessment

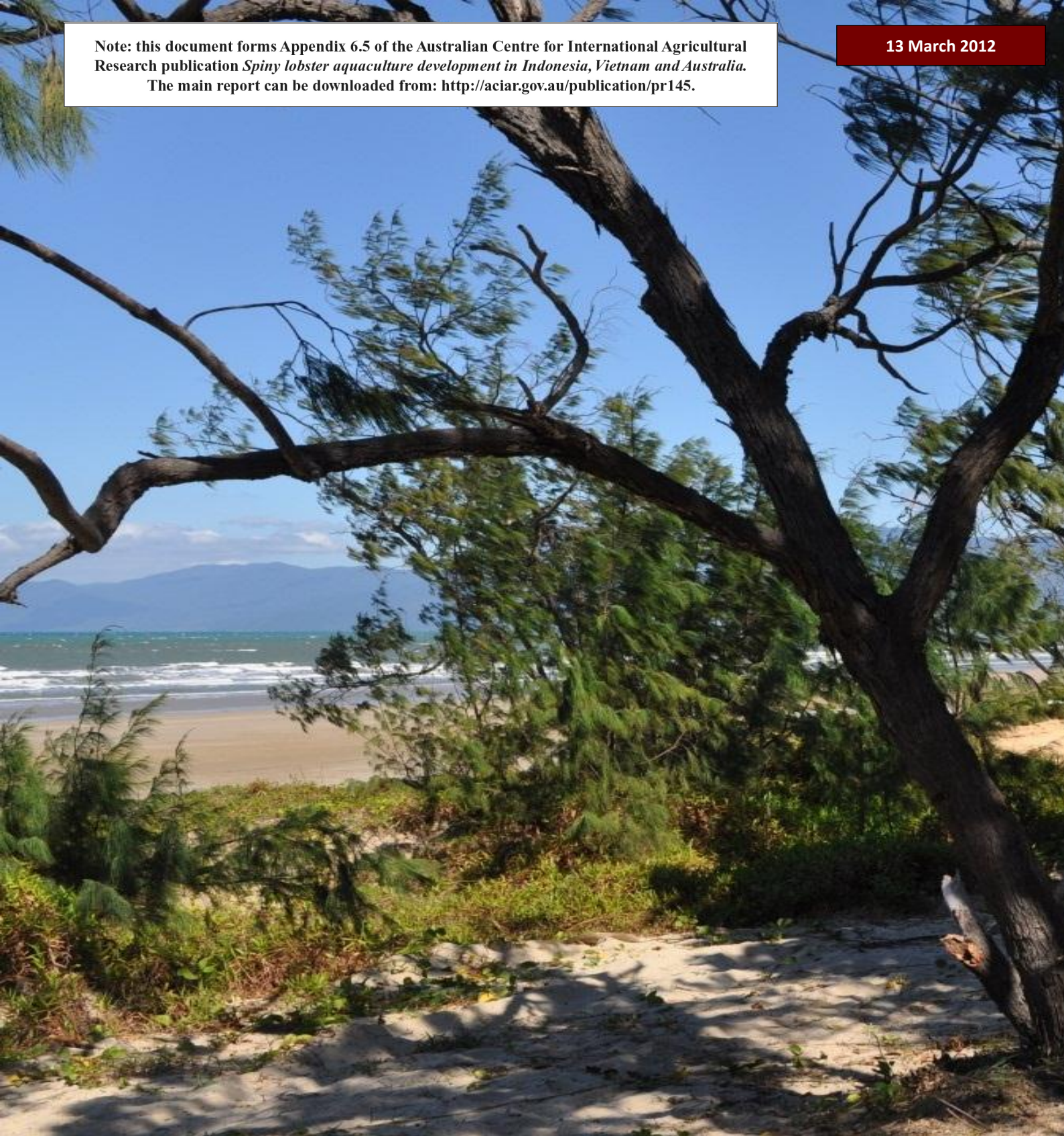
Site inspection: Jilji			
Criterion	Meets criterion Yes/No	Comment	Rating 0 / 1
<b>Technology</b>			
Suitability for land-based system, i.e. raceway or tank	No	A fresh water influence is likely on the quality of the sea water intake. High volumes of fresh creek water draining into the sea during the wet season would reduce salinity (intake) to unacceptable levels. The intake pipe would need to extend a considerable distance at sea to access optimal salinity levels. This would increase the exposure of the intake pipe to shifting sands, increasing maintenance costs. The need for a navigation buoy would increase the difficulty of obtaining an aquaculture permit.	0
<b>Geography</b>			
Availability of area for land-based system (Pilot Project)	Yes	Site is sufficient size, being approximately 10 <sup>2</sup> metres against the requirements of raceway system, i.e. four raceways, each with a dimension of 5m x 2m. Additional area is available for support facilities.	1
Suitability for expansion (Pilot Project)	No	The location has limited area to expand to commercial scale. The site is sandwiched between beach and swamp at rear.	0
Height above or below 5m AHD <sup>1</sup>	Yes	The location is above the 5 metre AHD.	1
Topography, including slope	Yes	Site location is flat.	1
Soil type, i.e. clay, soil or sand	N/A	Sand/soil mix.	-
Other potential site/s	No	Location has only one site suitable for construction of the Pilot Project.	0
<b>Water intake &amp; discharge</b>			
Proximity to sea water, i.e. within 250m	Yes	Site is approximately 150 metres from low water mark.	1
Depth of water off beach	Yes	The depth of water is possibly sufficient off the beach for access to good quality water. However, water salinity levels are reduced by fresh water drainage from the creek.	1
Distance to deep water (>5m depth)	Yes/No	Approximately 550 – 600m from the proposed site.	-
Proximity of a creek/river mouth, i.e. within 1km of site	Yes	Presence of permanent mangrove-lined tidal creek. The mangroves would filter nutrient drop-out. Discharge from the Pilot Project would not affect creek flora/fauna, as the creek has naturally occurring fluctuation in water levels from tidal influence.	1
<b>Infrastructure</b>			
Road access	Yes	The location is 10.2 kms from Yarrabah, with all year round road access. The road is sealed, apart from the last 1.5 kms.	1
Electrical supply	No	Nil electricity at site, with a distance of 5.1 kilometres to power at Oombunghi. The Council's	0

		plans to extend the power grid would take power close to the site in future. The Pilot Project, however, would be dependent on a generator.	
Distance to nearest power	No	1.6 kilometres to mains power.	0
<b>Permits &amp; licensing</b>			
Existing aquaculture permits	No	There has not been any previous application for an aquaculture permit for the location. Negotiations would be required with relevant authorities.	0
DERM / GBRMPA issues	No	The need for a navigation buoy would reduce the possibility of obtaining an aquaculture permit, given Jilji's location adjacent to a Habitat Protection (Dark Blue) Zone of the Great Barrier Reef Marine Park.	0
<b>Community</b>			
Cultural heritage sites	Yes	Traditional Owners have indicated the tidal creek has a significant cultural heritage site, although this would not interfere with the proposed development.	1
Traditional Owners	Yes	Traditional Owners support economic development, and selected the site/s as suitable for the proposed development. However, the site is part of a recreation area that would require community consultation.	1
Yarrabah Economic Development Forum	Yes	The Forum supports the Pilot Project as one of Yarrabah's priorities economic development initiatives.	1
<b>Total</b>			<b>10</b>



Note: this document forms Appendix 6.5 of the Australian Centre for International Agricultural Research publication *Spiny lobster aquaculture development in Indonesia, Vietnam and Australia*.  
The main report can be downloaded from: <http://aci-ar.gov.au/publication/pr145>.

13 March 2012



**Jaragun Pty Ltd**

*Quality is Our Business*

**Lobster Grow-out Pilot Project**

**Yarrabah Business Case**





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## 1. EXECUTIVE SUMMARY

### 1.1 Introduction

This Business Case has been prepared for the establishment of an aquaculture facility to grow out spiny lobster at Yarrabah, Qld. The project is being conducted in two stages. A Pilot Project will demonstrate proof of concept and allow further R&D on the biometrics of spiny lobster farming, which is a new industry in Australia. A commercial facility will be established post pilot to provide training, employment and economic development opportunities for the Aboriginal community.

The Qld Department of Employment, Economic Development and Innovation (DEEDI) commissioned the Business Case after more than a decade of R&D on spiny lobster at its research facility, located in the Northern Fisheries Centre, Cairns. DEEDI has successfully grown out a premium quality product in a tank-based system over several years. This has been accompanied by significant scientific breakthrough into closing the species cycle, which means that it is now possible to supply juvenile lobsters for grow-out from hatchery-produced seed stock rather than take from the wild. DEEDI's R&D program has brought spiny lobster husbandry to a stage where it is ready for development in a farm setting. Establishment of the industry will allow Australia to take advantage of the huge and growing Chinese market for spiny lobster worth \$190 million USD in 2011.

### 1.2 Project proponent

The Gunggandji PBC Aboriginal Corporation (Gunggandji PBC) is the proponent for the Pilot Project. The organisation represents Traditional Owners and descendants of people who were forcibly removed off traditional homelands to Yarrabah. On conclusion of the Native Title process, the Gunggandji PBC will be trustee of Lot 207, the site selected for the aquaculture facility.

The Gunggandji PBC will partner with DEEDI to implement the Pilot Project. DEEDI's technical support and extension services are critical to the successful establishment and operation of the grow-out facility. DEEDI will have a key role in developing the community's animal husbandry skills that are needed to operate the facility post pilot.

### 1.3 Preferred site

The preferred site to conduct the Pilot Project is adjacent to the foreshore of Mission Bay at Yarrabah. The site was selected by Traditional Owners and DEEDI, with support from the Qld Department of Environment and Resource Management (DERM). This was preceded by a Scoping Study that reviewed all possible locations available to the project on the Yarrabah peninsula at the time.

The Pilot Project will need to address several environmental management challenges to obtain the development permits and approvals needed from Australian and State Government agencies to conduct aquaculture farming at the site. The location is:

- Adjacent to the Great Barrier Reef World Heritage Area, the Great Barrier Reef Marine Park (GBR Marine Park) and State Marine Park

- Potentially inhabited by threatened species, ecological communities and migratory species listed as Matters of National Environmental Significance (MNES)
- Contains two regional ecosystems for protected areas, wildlife and critical habitats associated with remnant vegetation
- Potentially within a declared erosion prone area, and
- Contains wetlands of High Ecological Significance.

## 1.4 Business Case

The Business Case provides the information necessary to progress the Pilot Project. The information covers socio-economic factors, marketing opportunities and competition, production systems and processes, biometric data and financial data. The Business Case had two underpinning objectives.

Firstly, the Business Case sought to identify all the requirements needed to meet permit and approval conditions for establishment of the aquaculture facility at Mission Bay, including associated application processes and costs. The review indicates that environmental management agencies have a varying level of confidence associated with approvals. DERM and the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) consider that environmental aspects are likely to be met, albeit with permit conditions. The application to SEWPaC will need to present a strong case of the socio-economic benefits of the development to the Yarrabah community. The Great Barrier Reef Marine Park Authority (GBRMPA) has a more cautionary approach, requiring the aquaculture facility to have a negative impact on the GBR Marine Park.

The application process is complex, involving five permits and approvals for construction of the aquaculture facility. These require collection of a significant amount of scientific and technical information and data. The estimated upfront cost is between \$0.85 million and \$1.11 million, which is largely associated with:

- Possible need for an Environmental Impact Statement (EIS), which would require 12 months of data collection, and
- Need for an engineer-endorsed design of the production facility and intake/outfall pipelines, which would include developing applications and management plans to specifications agreed with environmental management agencies.

GBRMPA will decide the need for an EIS, in conjunction with SEWPaC, based on the level of nutrient discharge relative to existing water quality in Mission Bay. A key determinant will be the sufficiency of existing water quality data held by the Yarrabah Aboriginal Shire Council, against the need for further data collection through a baseline study.

Preliminary estimates from engineers indicate that between \$6 million and \$8 million is required to establish the Pilot Project. The main costs are associated with project management and construction of the intake/outfall infrastructure.

Secondly, the Business Case aimed to demonstrate long-term commercial viability of the aquaculture facility. GBRMPA stipulated this as a requirement for assessment of a Marine Parks Permit application to operate the Pilot Project adjacent to the GBR Marine Park.

The analysis shows that a commercial facility is not viable at this point in time, due to operational costs outweighing sales over the long-term. A great deal of caution is needed in basing a decision on whether or not to pursue the Pilot Project on the financial analysis alone.

Analysis of financial data for a commercial-scale facility is premature at this time. A key role of the Pilot Project is to continue R&D into identifying the optimal biometric conditions for farming spiny lobster in Australia, particularly to determine stocking densities, grow-out rates and number of production cycles. Current experience with the establishment of other aquaculture species in Australia, such as prawns and barramundi, has involved significant advances in culture methods and farming viability as a result of ongoing R&D programs.

Further, the financial analysis is underpinned by an 18 month grow-out period to meet GBRMPA's requirement for a business case that supports a commercial facility. This does not reflect the operation of the Pilot Project, which was expected to involve only a six-month grow-out period based on the purchase of spiny lobster at minimum legal size, rather than an 18 month grow-out period based on supply from hatchery-produced seed.

Because of these constraints and inappropriate use of the data, DEEDI requested that the financial analysis in this report be prepared for the Pilot Project, rather than for a commercial-scale facility. This was to avoid prejudice associated with consideration of any future business case prepared for a commercial facility. As such, the Business Case in this Report is not suitable for GBRMPA's needs.

## 1.5 Recommendations

The Business Case shows significant challenges to proceeding with the Pilot Project at Yarrabah at this point in time. The preferred site is an environmentally sensitive area that, as a result, presents additional cost to the project. The biometric data needed to develop the business case required by GBRMPA to assess an application for a Marine Park Permit is not currently available. The cost associated with construction of marine infrastructure is potentially unaffordable.

The Business Case points to the need to review how to take the Pilot Project forward in a location with less prohibitive financial and permit and approval constraints. Other locations along the Qld coast will face similar constraints due to the environmental sensitivities. The most cost-effective solution is a site that has an existing aquaculture permit and land-based infrastructure, such as Fitzroy Island. It is recommended that:

- (i) Consideration of Yarrabah as the site for the Pilot Project is discontinued at this point in time
- (ii) A suitable site is identified to conduct the Pilot Project, including the process and timeframe for taking the project forward, and
- (iii) Yarrabah be considered for a commercial facility, once R&D on biometric data becomes available as an outcome from the Pilot Project.

## 2. PROJECT OVERVIEW

This Part provides the rationale for conducting the Pilot Project at this point in time. This includes the link between the Pilot Project and the associated international R&D program, the target market for spiny lobster and the development status of the industry in Australia.

### 2.1 Objective

The project objective is to establish a spiny lobster (*Panulirus ornatus*) grow-out enterprise in the Aboriginal community of Yarrabah. The project involves establishment of a pilot facility to demonstrate proof of concept for the grow-out of spiny lobster in an Aboriginal community. The longer-term aim is to provide employment and training opportunities through commercialisation of the pilot facility and establishment of similar enterprises in other Aboriginal and Torres Strait Islander (ATSI) communities across northern Australia. The Business Case is limited to the pilot facility at Yarrabah (Pilot Project).

### 2.2 Reasons for proposing the activity now

The timing of the Pilot Project coincides with the status of R&D, with the grow-out of spiny lobster ready for development in a non-scientific setting. DEEDI has successfully grown out a premium quality product in a tank-based system at the Northern Fisheries Centre over several years. The survival rate is currently 51 per cent, with the animal grown from seed stock to a commercial size within an 18 month period.

The ability to grow-out lobster in a tank-based system is the result of improved animal husbandry techniques and development of artificial feeds. These have underpinned increased grow-out rates and stocking densities. This compares with overseas practices where poor water quality and disease outbreaks are connected to the use of 'trash' fish for feed.

It is also anticipated that hatchery produced seed stock will be available to supply the commercial facility. DEEDI's R&D has involved significant scientific breakthrough into closing the species cycle, which means that it is now possible to supply juvenile lobsters for grow-out from hatchery produced seed stock. The ability to source juveniles from an artificial setting, rather than rely on the unsustainable practice of wild-caught seed, will enhance the ability to obtain an aquaculture permit approval.

DEEDI is pursuing establishment of a commercial hatchery at the same time as the Pilot Project. The hatchery project is recognised by the Qld Government as one of eight priority projects for 2012. The official opening of the Tropical Spiny Rock Lobster Pilot Commercial Hatchery, which is located at the Northern Fisheries Centre in Cairns, will enable prospective investors to see first-hand the technology involved. It was launched by the Honourable Tim Mulherin MP, Minister for Agriculture, Food and Regional Economies on 16 December 2011.

### 2.3 Market demand for spiny lobster

The demand for farmed spiny lobster has grown exponentially over the last two decades to an industry worth \$190 million USD in 2011. The main market is China, where the animal is highly valued for banquet-based entertainment activities.

Vietnam is the main supplier of product to the Chinese market. The industry involves small-scale, family-based, sea cage enterprises, with seed stock for grow-out taken from the wild. The industry is not regulated, having developed rapidly from a few hundred sea cages in 1992 into a large export-oriented, village-based industry involving some 49,000 sea cages. Production levels reached approximately 1,900 tonnes in 2011. Growth of the industry has been accompanied by increased market price (farm gate) for the animal, which rose from approximately US\$50 per kg live into Hong Kong in 2007 to US\$100 plus per kg in 2011.

The development of the Vietnamese industry has been accompanied by significant signs of stress due to reliance on wild take for the supply of seed stock and trash fish for feed. The industry depends on an abundance of naturally settling late larval stage juvenile lobsters (puerulus), which are collected along the coastline of central Vietnam. Collection rates rose from 500,000 in 1999 to 2,500,000 in 2003. Disease devastated the industry in 2007, with production cut to 1,400 tonnes. The disease outbreak was attributed to the environmental degradation associated with unmanaged industry development and from inappropriate feeding practices.

### 2.4 Industry establishment in Australia

DEEDI's R&D program has centred on the Vietnamese industry, with the current research period 2010-12 involving \$1.30 million for the international "Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia" project (International Project), managed by Dr Clive Jones of the Northern Fisheries Centre.

The International Project is funded by the Australian Centre for International Agricultural Research (ACIAR). The funding forms part of the Australian Government's international development cooperation program that encourages Australia's agricultural scientists to use their skills for the benefit of developing countries and Australia. R&D is aimed at technology transfer and capacity building of local communities. Aquaculture is recognised internationally as having a vital role in promoting better use of fishery resources and alleviating poverty in rural communities.

The International Project has three broad objectives to promote sustainable aquaculture in rural communities of the three participating countries, involving:

1. Enhancing sustainable lobster production in Vietnam
2. Transferring lobster farming technology from Vietnam to establish a new industry in Indonesia, and
3. Facilitating commercial establishment of tropical spiny lobster grow-out aquaculture in Australia (i.e. northern Queensland).

The key activities include:



- Commercialisation of the hatchery technology in Australia
- Supply of hatchery-reared lobster seed stock for grow-out in the enterprises of each participating country
- Introduction of artificial formulated feeds
- Enhancement of existing small-scale, family-based sea cage enterprises in Vietnam and using similar animal husbandry techniques to establish enterprises in Indonesia and Australia, and
- Establishment and subsequent commercialisation of a grow-out Pilot Project in an Aboriginal community in Australia.

## 2.5 Conclusion

The spiny lobster industry has grown exponentially to meet the soaring demand for the product, particularly the Chinese banquet market. Demand for product is expected to continue to grow well into the foreseeable future, in terms of both the volume and wholesale price of the live product.

The R&D associated with the International Project is needed to grow the Australian industry. The high regulatory regime of wild commercial fisheries inhibits growth of the industry without the establishment of aquaculture. The International Project has facilitated the R&D needed for an environmentally sustainable industry in Australia, independent of wild caught seed stock and feed. DEEDI's R&D program has taken the spiny lobster husbandry to a stage where it is ready for development in a farm setting.

ATSI communities are the target group for development of the aquaculture industry in Australia. The Australian Government's international development cooperation program is premised on R&D programs for the benefit of impoverished communities, based around technology transfer and capacity building. This makes the project suitable for participation by coastal ATSI communities in areas where spiny lobster occur naturally in the wild.

### 3. PROJECT DETAILS

This Part contains details of the Pilot Project, including its purpose, the site selection process, features of the system technology and training needs of the community.

#### 3.1 Proof of concept

##### **Role of Pilot in establishing production capacity and economics of a commercial facility**

The intention of the Pilot Project is to furnish the information and data needed to design a commercial aquaculture facility that is suitable for establishing spiny lobster farming as a new industry in ATSI communities across northern Australia. The Pilot Project will be conducted over a three-year period.

A different technology is required to the sea cages used to establish the industry in Vietnam. Regulatory requirements prohibit the use of sea cages along the Qld coast, due to the environmental management requirements of GBRMPA. The alternative land-based technologies include ponds, raceway or tank-based systems.

The Pilot Project will determine the biometric conditions required for optimal grow-out rates of spiny lobster, according to the type of land-based technology used. Key influencing factors are the size/design of the tank, maintenance of water quality and feeding regimes. These will determine grow-out rates, survival rates and stocking densities. The outcomes will inform production capacity, in terms of the length of production cycle, number of crops per annum and farm gate sale prices (i.e. based on the quality of product).

The Pilot Project will determine the biometrics for farming spiny lobsters in Australia on a commercial scale. Cost factors include: aquaculture system and facility design and construction, infrastructure (e.g. roads, electricity supply and fencing), ongoing repairs and maintenance, training and labour, lobster feeds, and financing. The outcomes will inform the break-even point, in terms of the minimum scale and timeframe for the commercial facility to be financially viable.

##### **Engagement of ATSI community**

The involvement of the ATSI community is required during the conceptual design and implementation of the project.

The project proponents will be a registered Indigenous organisation to own and take the project forward from the pilot stage through to commercialisation. The organisation will have a key role in developing the support needed for successful operation of an aquaculture facility in the community.

Training and extension services will be critical to capacity building and achievement of the ATSI employment objectives. The training focus will be on spiny lobster husbandry techniques, gained by working alongside DEEDI scientists and completion of Certificate III qualification in aquaculture (minimum requirement).

The individuals selected for training will need to be available during the construction phase. This will promote understanding of the workings of the technology/equipment and overall operation of the facility.

The timing of the qualification will commence shortly after the facility becomes operational. This will provide for hands-on learning, where theory can be applied in practice.

The qualification training is expected to be supported by Language, Literacy and Numeracy (LLN) skills development.

### 3.2 Site selection process

#### Selection of Yarrabah

Grow-out of spiny lobsters in Australia is best suited to tropical northern Australia<sup>1</sup>, where climate and seawater access are most amenable to good growth and production. The facility must be located on the coastline, providing access to high quality sea water.

In Qld, several ATSI communities between Bowen and the Torres Strait were considered as possible locations for the Pilot Project.<sup>2</sup> Yarrabah was given priority for the following reasons:

- It has access to high-quality, deep sea water all year, which is needed for optimal grow-out conditions
- It is close to the DEEDI Northern Fisheries Centre, which will facilitate project management and technical support from the Centre's lobster grow-out and hatchery research facility
- There is Traditional Owner support for the Pilot Project, and
- Jaragun P/L has established business relationships with Traditional Owners, which will ensure community protocols are followed in relation to site selection and community consultation.

A key consideration in the selection of a site at Yarrabah was involvement of Traditional Owners. Traditional Owners have previously expressed interest in economic development, have a body corporate needed to carry out a business activity<sup>3</sup>, are best positioned to garner broader community support and have access to property that can be developed through native title tenure over sizeable areas of Deed of Grant in Trust (DoGIT) land.

Traditional Owners and DEEDI identified nine possible locations on private and DoGIT land. These were at:

- Fitzroy Island
- Turtle Bay (and Little Turtle Bay)
- False Cape

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<sup>1</sup> Longitude north of Bowen.

<sup>2</sup> Communities that were considered suitable for the Pilot Project included Bowen, Palm Island, Cooktown, Mornington Island, Lockhart River and Badu (Torres Strait).

<sup>3</sup> At the time of the Scoping Study, the Yarrabah Aboriginal Shire Council managed DoGIT land. The Gunggandji PBC is expected to assume management following the native title determination in December 2011.

- Buddabadoo
- King Beach
- Back Beach (Wungu and Jilji), and
- Mission Bay, Yarrabah.

Figure 1: Map of locations



Mission Bay was selected after completion of a Scoping Study and need to identify an additional site due to either permit issues or unsuitability of the other locations.

### Scoping Study

Preliminary investigations eliminated four locations from further consideration due to land tenure issues, poor access and general unsuitability for an aquaculture development. These included Fitzroy Island, Turtle Bay, False Cape and Buddabadoo.

Fitzroy Island had been the preferred location. It was favoured by Traditional Owners, with access to deep sea water, an existing aquaculture facility and a current aquaculture permit/licence. The location was excluded after it was found that the lessee had already entered into an agreement with another party, making the facility unavailable to the Pilot Project. No other sites are available on Fitzroy Island because of restrictions on land tenure/zoning. Following completion of site assessments at Yarrabah, the leaseholder of the facility at Fitzroy Island indicated a willingness to negotiate with DEEDI.

Turtle Bay was excluded due to its isolation and access only by sea. It was considered that inclement weather would impede all-year-round access, affecting successful implementation of the Pilot Project. Further, construction of an 'all weather' road to overcome the logistics of boat access would add significant cost and delay start-up of the Pilot Project.

False Cape was the preferred location accessible by road. This involved a freehold property that already had cleared land suitable for development. The property was on the market at the time of

the assessment. However, while seeking permission to conduct the site inspection, it was established that the property was under contract. This effectively eliminated False Cape as a potential location to conduct the Pilot Project.

Buddabadoo was found unsuitable due to its rough terrain, need for significant land clearance and high potential for flooding on lower ground during the wet season.

#### **Site assessments at King Beach and Back Beach**

Three sites were assessed at the two remaining locations of King Beach and Back Beach. These included King Beach, Wungu at the northern end of Back Beach and Jilji at the southern end of Back Beach. The sites are within the jurisdiction of both the Qld State Parks (intertidal area between low and high water mark) and GBRMPA.

The assessments were based on a set of criteria<sup>4</sup> developed by DEEDI appropriate to an above-ground raceway or tank-based aquaculture system.

None of the sites met all criteria.

#### *King Beach*

King Beach was the preferred site, being located on DoGIT land, having good acreage available for later expansion to a full-scale commercial facility, having access to high quality sea water, and being protected from the prevailing south easterly winds.

King Beach is located east, south east of Yarrabah. The beach is approximately two kilometres in length and is surrounded by mountains on the southern, western and northern boundaries. A tidal mangrove creek runs along the valley and empties into the sea mid-way along the beach.

The location is not currently accessible by road, although a disused road previously provided access from Yarrabah to the southern headland.

A site at the southern end of the beach was assessed and scored for suitability to conduct the Pilot Project. The site is approximately 100 metres from the low water mark, and abuts the southern mountain face, giving it protection from the prevailing south easterly winds.

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<sup>4</sup> The criteria were: suitability of location for sea cages, ponds and tanks; potential site within 250m of sea; more than one potential site at the location; area available for construction of a land-based system; presence of a creek or river mouth within 1 km of site; depth of water off the beach; distance to deep water (>5m depth); soil composition, in terms of clay, soil or sand; availability of mains power and road access; coverage of the site by an existing aquaculture permit; permit issues of Marine Parks/GBRMPA; and, native title issues.

Figure 2: King Beach



King Beach, however, has significant licensing/permit challenges. Being located in a Marine National Park Zone, no aquaculture permits are currently permissible. While the proposed technology is a land-based system, water would indirectly discharge into the Marine National Park Zone. This would most likely be via a tidal mangrove-lined creek that provides a natural filtering system. Further site inspection is required to determine the proximity of the creek to the proposed site, i.e. its feasibility for water discharge. Commonwealth and State authorities would need confidence that the level of residue nutrient drop-out would not negatively impact on either the local ecology or the Marine Park.

In addition, King Beach requires significant infrastructure development to overcome lack of mains power supply and all year round road access.

### *Wungu*

Wungu is located at the northern end of Back Beach, directly south of Fitzroy Island and separated from King Beach to the north by a rocky headland. The headland drops off steeply into a deep water channel formed between the mainland and Fitzroy Island. A permanent, mangrove-lined tidal creek runs behind the sand dune and empties into the sea at the base of the headland. The creek, which is fed by an inland spring, flows most of the year.

The location is a recreation area for locals during the dry season, with road access and a car park at the beach proper. Two basic beach shelters and a camping area have been constructed on either side of the car park. Three residences have been built in the bush between the road access and the headland, two of which are inhabited.

The assessment was conducted for suitability of a site close to the beach. The site is approximately 150 metres from the low water mark, and is situated between a recreation shelter and a seasonal drain that feeds into the tidal creek.



Figure 3: Wungu



Wungu was found unsuitable, on the basis that it was only appropriate for conducting the Pilot Project due to unavailability of sufficient land suitable for commercialisation.

Other significant issues included poor or no road access during the wet season and lack of mains power supply. The location may also lack community support, as it has high usage as a recreation area.

#### *Jilji*

Jilji is located towards the southern end of Back Beach. The location is situated between a permanent, fresh water creek (north) and a small rocky outcrop (south). The creek, which runs from north to south, drains a large swampy area behind the beach. The creek empties large volumes of water onto the beach, causing the mouth to change course amid shifting sands throughout the year.

The location includes residential zoning on the southern side, and is a high use recreation area by locals. The location is accessible by road and car park behind the beach. The car park includes two shelters.

The site assessment was conducted at the northern car park shelter. The site is approximately 150 metres from the low water mark, on an elevated area that sits between the swamp and mouth of the creek.



**Figure 4: Jilji**

Jilji was found unsuitable, primarily due to the threat of poor water quality during the wet season. It was considered that the fresh water influence would not be able to be countered in a cost-effective manner.

The site lacked access to mains power supply.

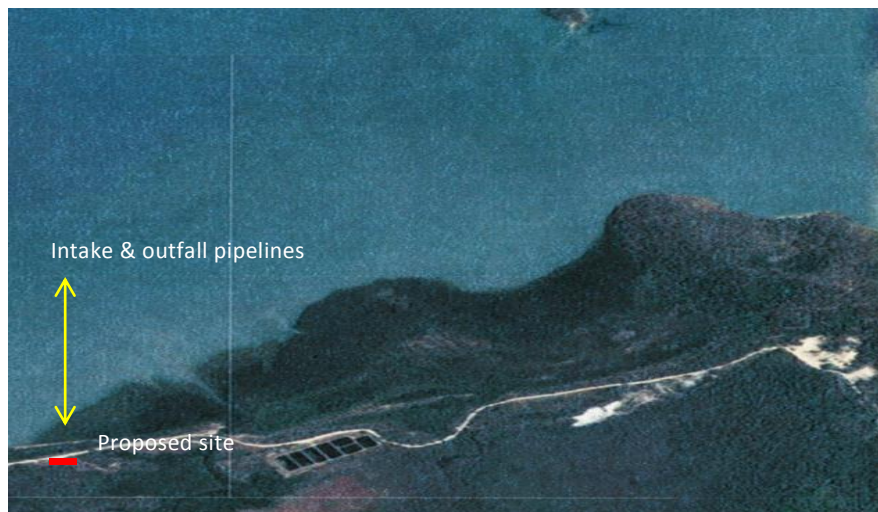
### **Mission Bay**

Traditional Owners responded to the lack of a suitable site at the preferred locations by identifying a site on Mission Bay, within the town boundaries.

Lot 207 has an approximate area of 15,600h on the False Cape peninsula. The area extends from the eastern perimeter of Yarrabah township to the Coral Sea. The area includes both urban and Environmental Conservation and Management zones. The development footprint for the Pilot Project is expected to be within the urban zone, while the commercial facility is expected to extend into the Environmental Conservation and Management zone.

The tenure of Lot 207 is DOGIT. The Lot was transferred to the Gunggandji PBC, following native title determination in December 2011.

Figure 5: Mission Bay



The site was found suitable, following assessment by DEEDI. The site is accessible to key infrastructure, having all-year-round road access and proximity to mains power supply to support operations of the facility. Being DoGIT land, there are no tenure issues, with sufficient area for expansion to a commercial size facility, subject to development application conditions associated with the Environmental Conservation and Management zone. A creek runs close to the site, providing the option of a natural filtration system for nutrient discharge.

Limitations of the site include the poor quality water in Mission Bay. The Bay itself is shallow, while there is effluent discharge from the nearby sewage treatment works and seepage from the town dump. Initial assessment anticipates the need for intake pipes to be extended some 300-400 metres in length to access deeper, high quality sea water.

### 3.3 Facility and technology

The Pilot Project has several infrastructure components. These include the production facility, intake/discharge pipes and overall facility requirements.

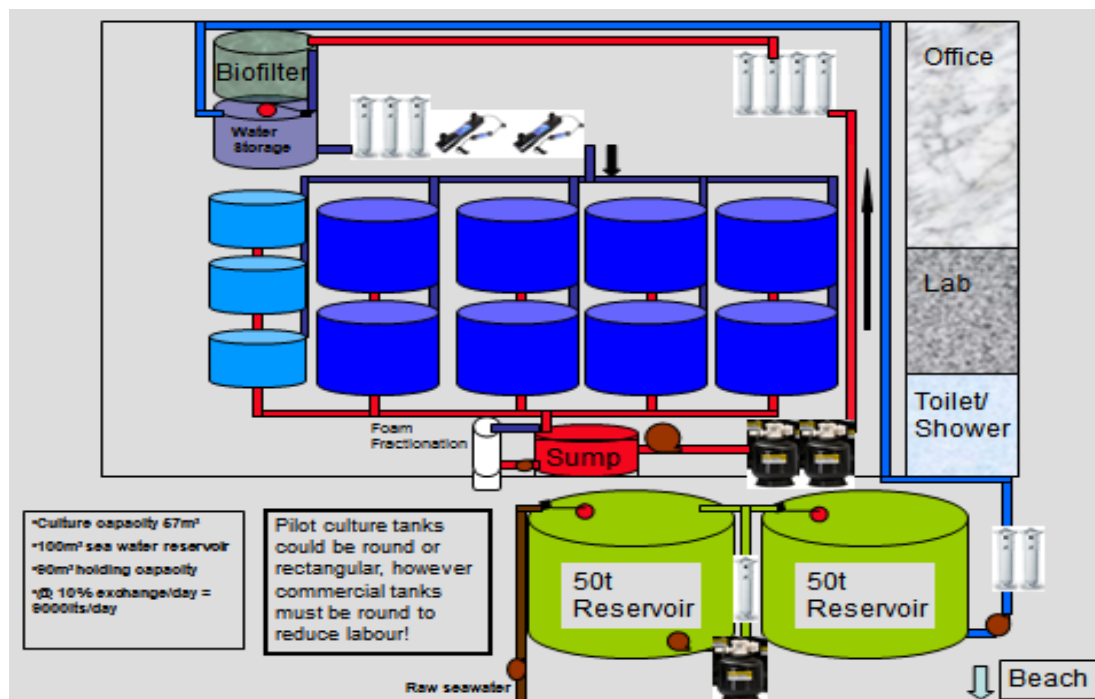
#### Production facility

The spiny lobster will be grown out in the production facility. A tank-based recirculation system has been selected to conduct the Pilot Project.

The design features of the recirculation system include the following components:

- Filtration systems
- Water storage tanks
- Water inlet
- Water outlet (discharge), and
- Solid waste concentration (sump).

Figure 6: Tank based recirculation system



The technology has several significant advantages over other systems. This best practice technology will maximise outcomes from the Pilot by:

- Giving almost total control of the grow-out environment (providing for optimal grow-out rates of the spiny lobster)
- Reducing impact on the GBR Marine Park, and
- Minimising costs associated with a land-based grow-out system.

Spiny lobsters need a constant supply of high quality sea water, with salinity levels maintained at approximately 35 parts per thousand. Recirculation systems are able to maintain the required salinity levels by providing for ongoing replenishment of sea water through ocean intake and outlet pipes. DEEDI scientists used a recirculation system at its Northern Fisheries Centre to conduct the R&D for both the hatchery and the grow-out aspects of the Spiny Lobster Project, with DEEDI having designed the Pilot Project facility for Yarrabah based on a technical configuration best suited to the location and purpose. The technology is also proven for the culture of other marine and freshwater species in commercial settings.

GBRMPA requires the aquaculture facility to use recirculation technology to manage any possible negative environmental effects on the GBR Marine Park. The main potential for impact is associated with nutrient discharge, or the waste (uneaten food and faeces) associated with the stocking and feeding regimes of aquaculture production systems. The facility will reduce the level of nutrient discharge by: filtering water prior to discharge; and, recirculating 90 per cent of water to reduce the overall volume of discharge.

Recirculation systems have several potential economic advantages. They reduce costs associated with power consumption through the ability to:

- Minimise the draw on sea water, that is, they pump water to top up the facility on a needs basis.<sup>5</sup> The Pilot Project will reduce the volume of sea water the facility needs by as much as 90 per cent, and
- Pump water intake at high tide, with use of gravity feed for returning water to the tanks.

In addition, the size of the facility can be limited to a small area of land, while the filtration systems provide the high water quality needed to maintain higher stocking densities.

### **Intake and outfall pipelines**

The design specifications of water intake and outfall pipelines associated with the production facility have significant bearing on the overall ability to manage water quality and to reduce any potential environmental impact on the GBR Marine Park.

A registered engineer is required to design and document suitable pipeline infrastructure. The general specifications for the scope of work will relate to the characteristics of the Mission Bay site and integration of the pipeline infrastructure with the production facility. The specifications include:

- Analysis of site conditions (e.g. through a site survey and geotechnical investigation) to determine geotechnical and bathymetric conditions at the Mission Bay site and along the proposed pipeline alignments<sup>6</sup>
- Analysis of the proposed operation of pipelines (e.g. flow rate characteristics through the intake/outfall) to determine the size of the pipelines and pumping infrastructure, and
- Review of the design of the aquaculture tank system to determine how the intakes and outfalls will connect to this infrastructure.

The exact location of the production facility is required to perform this work.

Conditions set by GBRMPA and DERM will determine other design specifications associated with minimising any environmental impacts from either the level/quality of nutrient discharge or construction activities associated with the intake and outfall pipelines. The types of conditions are likely to include water intake and outfall pipeline alignments, diffusion points, water intake and nutrient discharge intervals (i.e. to take advantage of high tides and ocean currents), materials, design type (e.g. floating or submerged pipelines) and distance to the point of discharge from the shoreline or any sensitive receptors. This preliminary information will be required to accurately cost these aspects of design work.

Other factors will include required operational characteristics, such as use of pumping and gravity feed water system.

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<sup>5</sup> By contrast, flow-through systems require continuous pumping of water to maintain water quality.

<sup>6</sup> Geotechnical information associated with construction on the site is required, especially the engineering properties of subsurface conditions and materials to determine how they will interact with the proposed construction.

### Other facilities

Other facilities needed to support the production facility will include:

- Office, for management purposes
- Research laboratory, for on-going R&D
- Refrigerated unit, for storage (e.g. feeds)
- Workshop, for minor repairs and maintenance, and
- Rest area and amenities, for management and staff.

### 3.4 Conclusion

The Pilot Project is expected to provide proof of concept that farming of spiny lobster is financially viable in ATSI communities in northern Australia. The need to refine technology and demonstrate financial viability in a real farm setting underpins the staged approach to establishment of the industry in Australia, involving a Pilot Project prior to establishment of a commercial facility. In particular, the Pilot will provide the information/data needed for realistic economic modelling, with the R&D expected to achieve improvements in viability at levels consistent with what has occurred with other aquaculture species in Australia, e.g. prawns and barramundi. For the ATSI community where there is little or no previous experience in aquaculture, the Pilot Project will establish the foundation needed to advance the project onto a commercial footing.

The selection of Mission Bay at Yarrabah to conduct the Pilot Project is underpinned by the ease of access afforded to scientists of DEEDI's Northern Fisheries Centre. The Pilot Project requires a high level of technical support over several years to succeed. Mission Bay is the most suitable site on Yarrabah peninsula, taking into account access to high quality marine water, access to infrastructure, land tenure and area available for expansion to a commercial facility. Traditional Owners support the establishment of an aquaculture enterprise that will result in training and employment opportunities for community people.

GBRMPA's requirement for the use of a recirculation system resulted in the choice of tank-based technology for the facility. The best practice technology has greatest ability to reduce impact on the GBR Marine Park and is a proven technology for the culture of other marine and freshwater species in commercial settings.

## 4. PROJECT IMPLEMENTATION

This Part provides an overview of the stakeholders consulted about the Pilot Project. It identifies the roles and responsibilities of the partner organisations, and areas for further consultation with permit and approval agencies.

### 4.1 Consultation process

Consultations have been held with a range of organisations and individuals, including from the Yarrabah community, government regulators and the private sector (expertise/engineering advice). These have resulted in identification of the project proponent, individuals who will be affected by the project and organisations that will need to contribute expertise and resources.

#### Yarrabah Aboriginal community

The Yarrabah community needs to support the establishment of an aquaculture enterprise for the Pilot Project to be successful. Traditional Owners have expressed their support on the basis of economic, employment and training opportunities afforded to local Aboriginal people.

Traditional Owners are represented by the Gunggandji PBC. Prior to incorporation, the Native Title Working Group (NTWG) provided written support for the Pilot Project. The NTWG established a Working Group to progress the Pilot Project.

The Gunggandji PBC has been involved in all stages, involving initial selection of locations for consideration on the Yarrabah peninsula, site assessments and eventual identification of Mission Bay as the preferred site.

Separately, individual Traditional Owner family groups expressed strong support for the project. Information sessions were held for the broader community.

A Community Consultation Plan will be needed to advance the project. It is important to:

- Inform locals about visitors expected in the community and the purpose for their presence, in accordance with community protocols, and
- Build ownership and responsibility for the project, as a strategy for involvement in security of the site.

The Plan should include reengagement with the broader Yarrabah community through information sessions, prior to commencement of project implementation. The Plan should outline the project areas, roles and responsibilities of all stakeholders, and implementation timeframes.

#### Government planning and management agencies

Various Australian, State and Local Government agencies have been consulted about the application processes (including fees) and requirements for development approvals. A summary of the purpose of these consultations and nature of ongoing consultation required for approval of an aquaculture development at the Mission Bay site is provided in the following table.

**Table 1: Agency consultations**

Type of approval	Agency consultation	Project requirement
<b>Resource entitlement</b>		
DERM (SLAM)	Entitlement to use Lot 207 for aquaculture purposes	Verification of: <ul style="list-style-type: none"> <li>(i) Owner's consent to the resource/use of the land</li> <li>(ii) Development is consistent with an 'allocation of use'</li> </ul>
YASC	Permission from property manager to use Lot 207 for aquaculture purposes	Provision of lease agreement, as evidence of resource entitlement. This only applies if management of the DoGIT has not transferred to the Gunggandji PBC at the time of application
DERM (SLAM)	Entitlement to draw sea water from the State Marine Park, i.e. taking or interfering with a State resource	Confirmation from DERM (QPWS): <ul style="list-style-type: none"> <li>(i) Giving consent to use the marine water resource</li> <li>(ii) The development is consistent with an 'allocation of use'</li> </ul>
Adjoining property owner	Proposed aquaculture development will not prejudice the property owner's access rights	Provision of letter of support
<b>Marine Parks Permit</b>		
GBRMPA DERM (QPWS)	Protection of the GBR Marine Park	Need for: <ul style="list-style-type: none"> <li>(i) Joint application</li> <li>(ii) Application that demonstrates commercial viability (GBRMPA requirement)</li> <li>(iii) Assessment against mandatory and discretionary criteria, which may include requirement for either: <ul style="list-style-type: none"> <li>a. Public Environment Report</li> <li>b. Environmental Impact Statement and associated: <ul style="list-style-type: none"> <li>- Deed of Agreement</li> <li>- Environmental Management Plan and Advisory Committee</li> </ul> </li> </ul> </li> </ul>
<b>Development approval</b>		
DEEDI	Confirmation of Assessment Manager for the application	Submission of the development application to DEEDI
	Protection of marine and terrestrial ecologies from aquaculture activities and measures to minimise attracting wildlife	Need for: <ul style="list-style-type: none"> <li>(i) Geomorphology/ecological assessment to determine attributes at risk</li> <li>(ii) Technical specifications of facility in place to control risk factors</li> <li>(iii) Aquaculture Site Management Plan to rehabilitate site following construction, operate facility safely, prevent fish escape and manage disease</li> </ul>
DERM	Protection of erosion prone areas	Need to meet requirements for Declared Coastal Management Districts, outlined in



		<i>Queensland Coastal Hazards Guidelines</i>
	Protection of wetlands of High Ecological Significance within the Great Barrier Reef Wetlands Protection Area	Assessment is against an Applicable Code that identifies acceptable outcomes during construction and operation that prevent degradation. To avoid duplication, assessment is not required if already performed for erosion prone areas
	Management of Acid Sulfate Soils	An applicable code contains management strategies where acid sulfates are exposed through disturbance of soil during construction
<b>EPBC Approval</b>		
SEWPaC	No threat to Matters of National Environmental Significance, including listed threatened species, ecological communities and migratory species, within either: (i) GBR Marine Park World Heritage Area (ii) Lot 207	Assessment of application, involving either: (i) Formal approval under the EPBC as a 'controlled action', or (ii) A conditional approval as a 'not controlled action particular manner'
<b>Nature Conservation Approval</b>		
DERM	Protection of native vegetation from land clearance	(i) Consult YASC as to urban boundary once Town Plan is finalised (ii) Map the boundary of the development to establish whether it is subject to a Nature Conservation Approval, noting that developments inside the urban zone are excluded from the requirement (iii) Where approval is required, a vegetation survey to establish whether any listed species of ecological significance are at the site (iv) Where listed species are in a clearance area, determine an 'off-set' area for relocation of the species (v) Relocate listed species
<b>Infrastructure</b>		
YASC Telstra	Supply of mains power	Following a decision to proceed with the Pilot Project at Mission Bay, YASC and Telstra will need to be consulted about power supply to the site.
Maritime Safety Qld	Need for warning sign	A seaward facing warning sign will need to be erected on land, if the opening for the intake and outlet pipelines are above the seabed

Key: DERM, Qld Department of Environment and Resource Management  
 SLAM, State Land Asset Management  
 YASC, Yarrabah Aboriginal Shire Council  
 GBRMPA, Great Barrier Reef Marine Park Authority

QPWS, Qld Parks and Wildlife Service

DEEDI, Department of of Employment, Economic Development & Innovation

SEWPaC, Department of Sustainability, Environment, Water, Population and Communities

EPBC, *Environmental Protection and Biodiversity Conservation Act 2000*

Part 5 – Permits and Approvals contains detailed requirements of the various permits and approvals.

### **Other organisations**

Two engineering organisations were consulted about the scope of work required to design the facility according to site and environmental permit conditions. This included indicative project management and construction costs, which included collection and preparation of data and information needed for the permit and approval process.

## **4.2 Management arrangements**

The Pilot Project will require a partner arrangement between Gunggandji Traditional Owners and DEEDI, underpinned by a MoU. Community ownership will meet economic objectives of both the broader project and Yarrabah community. Gunggandji are able to provide the land for construction of the facility. DEEDI's technical support and extension services are needed for successful establishment of the grow-out facility, transfer of the skills needed by the community to operate the facility independently and ongoing R&D.

### **Project proponent**

The Gunggandji PBC is expected to be the project proponent. The Gunggandji PBC was established through Native Title to look after the interests of Yarrabah Traditional Owners and the broader community.

The Pilot Project is consistent with the PBC's economic development objective. Its tenure of DoGIT land is pivotal to performing this role in respect of the Pilot Project.

Recent change of Directors underpins the need to confirm previous interest in pursuing the project. A resolution from the Board is required that commits to their role in the Pilot Project and to a partner agreement with DEEDI.

The mission will be to establish a pilot aquaculture project that will:

- Lead to a commercially viable aquaculture business
- Set the standard for the grow-out of spiny lobsters in Australia, and
- Encourage other A&TSI communities to become involved in the industry.

Specific responsibilities will include:

- Permit and approval processes
- Community engagement
- Selection, training and management of staff
- Sourcing funding
- Project management

- Grow-out of spiny lobster
- Facilities management in conjunction with DEEDI, and
- Security arrangements.

The PBC will need resources to perform this role. This will include small business support to build the organisation's capacity (including governance) to manage the facility. This needs to occur in the lead-up to and during commercialisation of the Pilot Project.

#### **Project partner**

DEEDI will be involved across the duration of the Pilot Project. This includes for the development application process, where DEEDI's expertise is needed for the design specifications of the aquaculture facility.

Specific responsibilities will include:

- Technical design of the facility
- Skills transfer (animal husbandry and operation of the facility)
- Technical support and extension services (installation, operation and maintenance of plant/equipment)
- R&D aimed at increasing production rates
- Sourcing seed stock for grow-out, and
- Facilitating initial sales of live product through existing market supply chains.

DEEDI will separately pursue commercialisation of the hatchery technology during implementation of the Pilot Project.

### **4.3 Intellectual Property**

The Pilot Project could involve further Intellectual Property, beyond that which DEEDI has already developed on grow-out of spiny lobster. Gunggandji PBC and DEEDI will require agreement on the ownership and management of Intellectual Property.

### **4.4 Timeframe**

A timeline for implementing the Pilot Project will be developed after a decision is taken to pursue the Pilot Project at Yarrabah and the Gunggandji PBC confirms its commitment to the Pilot Project.

The Pilot Project is expected to run for a three-year period. The timeframe comprises:

- Construction of the facility, of six months
- Sourcing seed stock and establishing animal husbandry regimes, of six months
- Grow-out of spiny lobster to point of sale (minimum legal size), of 2 years.

The timeframe does not include the permit and approval process, which will take a minimum of 12 months if an EIS were required to collect water quality data at Mission Bay.

## 4.5 Conclusion

A partner arrangement between Gunggandji Traditional Owners and DEEDI is necessary to implement the Pilot Project. Traditional Owner support is integral to obtaining the community support and DEEDI support is necessary to provide the technical skills and extension services. The partner arrangement should be underpinned by a MoU that clearly identifies roles, responsibilities and timeframes for implementation.

## 5. PERMITS AND APPROVALS

This Part contains details of the permits and approvals required to construct an aquaculture facility at Yarrabah. This includes the criteria that will be used by environmental management agencies to assess applications, including the extent to which challenges can be addressed. Some indicative costs are provided for the work involved.

### 5.1 Introduction

The characteristics of the proposed location underpin the need to obtain five permits/approvals with Australian, State and Local Government authorities for the development to proceed. These include:

- 1) Resource entitlement
- 2) Development Permit
- 3) Clearing Permit (Nature Conservation Permit)
- 4) Marine Parks Permit (for aquaculture)
- 5) *Environmental Protection and Biodiversity Conservation Act 2000* (EPBC Act) Approval.

The permit/approval process has several significant challenges to meet environmental protection requirements of both Australian and State Governments. This is due to the proposed location of the aquaculture facility adjacent to the GBR Marine Park and requirements for development proposals within the coastal zone, as follows:

- Under State legislation, Lot 207 is potentially within a declared erosion prone area, contains wetlands of High Ecological Significance, and contains two regional ecosystems for protected areas, wildlife and critical habitats associated with remnant vegetation, and
- Under Australian Government legislation, the GBR Marine Park has several listings under the EPBC Act as Matters of National Environmental Significance (MNES), including:
  - The GBR Marine Park as a World and National Heritage Area, and
  - Potential for the GBR Marine Park and Lot 207 to contain threatened species, ecological communities and migratory species.

The GBR Marine Park also overlaps with the State Marine Park.

DERM has recommended that the Gunggandji PBC apply for permits for the commercial facility, rather than just the Pilot Project. This on the basis that the PBC would otherwise be required to reapply for permits for the commercial facility at a later date, which would unnecessary duplication of resources and application fees. Further, much of the material required for assessments by GBRMPA and SEWPaC for the Pilot Project will meet DERM's requirements for a Development Permit for the commercial facility.

Details of requirements for each permit/approval, together with the assessment agency and associated project costs<sup>7</sup>, are detailed below.

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<sup>7</sup> The costs are estimates only, and would need to be subject to tendering processes.

## 5.2 Resource entitlement

The Pilot Project will be constructed on an undeveloped urban block<sup>8</sup> and draw sea water from the State Marine Park. The Gunggandji PBC will need to verify its entitlement to use the two resources for aquaculture purposes, through application with supporting documentation to DERM (SLAM).

### Development proposals on State land

Evidence of resource entitlement for Lot 207 is required as a result of a Material Change in Use of Premises, involving the construction of the facility on vacant State land for commercial purposes.<sup>9</sup> DERM will need to be satisfied that:

- Gunggandji PBC has the owner's consent to the resource/use of the land, and
- Development is consistent with an 'allocation of use', i.e. the intended purpose of entitlement.

Gunggandji PBC will require either:

- (i) A copy of the certificate of title for the land, or
- (ii) A lease agreement with the YASC.

The need for a lease versus evidence of land tenure depends upon which organisation is trustee of Lot 207 at the time of application, given its designation as DoGIT. As previously indicated, management will transfer from YASC to the Gunggandji PBC as a result of the native title determination of December 2011. A lease agreement will need to specify commercial aquaculture as the purpose of land use.

Gunggandji PBC will also require evidence that the proposed work will not prejudice the access rights of adjoining property owners. The one property owner potentially affected by the development will be required to provide a letter of support.

Should the Gunggandji PBC change Lot 207 to Aboriginal freehold land following its transfer from YASC, the land would no longer be state land (i.e. a State resource), and evidence of resource entitlement would not apply.

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<sup>8</sup> Lot 207, Map no. NR7310.

<sup>9</sup> The proposed development meets several criteria for a Material Change of Use of Premises, including the start of a new use of the premises, a material increase in the intensity/scale of the use of the premises and the start of an Environmentally Relevant Activity on the premises. See *Sustainable Planning Act 2009*, Section 10(1).

### Use of marine water

Evidence of resource entitlement from the State is required as a result of the need to draw marine water from the State Marine Park to support operations of the aquaculture facility, i.e. taking or interfering with a State resource.

The chief executive of the department administering the resource, in this case DERM (QPWS), will need to confirm that the development is consistent with an allocation or entitlement to the resource.<sup>10</sup>

There are no fees associated with the assessment process.

### 5.3 Development Permit

Development Permits are required for applications that are deemed 'assessable' under the *Sustainable Planning Act 2009* (SPA). The purpose of the Permit is to ensure the development meets environmental protection requirements of State legislation.

The aquaculture facility potentially triggers the need for assessment in relation to the *Fisheries Act 1994*, *Coastal Protection and Management Act 1995*, *Environmental Protection Act 1994*, *Vegetation Management Act 1999*, and *Nature Conservation Act 1992*.

Applications for Development Permits are assessed through the Integrated Development Application System (IDAS). IDAS provides for appointment of an Assessment Manager, in this case DEEDI, to coordinate assessment and approval processes by those State and local government agencies with relevant legislative responsibilities.

The referral agencies associated with the above legislation include:

- DEEDI, in respect of aquaculture
- DERM, in respect of:
  - Erosion prone areas
  - Wetlands of High Ecological Significance
  - Native vegetation
- Marine Safety Qld, in respect of vessel safety at sea, and
- YASC, in respect of development in an urban zone, road access and power supply.

The agencies are required to take account of Qld coastal planning policy. The policy is in a state of transition. The *Queensland Coastal Plan*<sup>11</sup> is expected to replace the *State Coastal Management Plan* and the associated *Wet Tropical Coast Regional Coastal Management Plan*.

The *Queensland Coastal Plan* provides for updated information on those coastal areas projected to be at risk from extreme weather conditions that can cause coastal erosion, permanent inundation

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<sup>10</sup> The agency to sign on behalf of the State of Qld is determined according to the status of the land and/or the purpose of the work, in this case, the works are to be used for commercial purposes.

<sup>11</sup> DERM advised to plan the Development Application on the *Queensland Coastal Plan*, in anticipation of its imminent introduction.



and storm tide inundation up to the year 2100<sup>12</sup>, including from the impact of climate change.<sup>13</sup> The Plan has been publicly available since March 2011 but is yet to come into effect.

The *Queensland Coastal Plan* provides for the preservation of the natural qualities of the coast, by providing an integrated approach to management and planning of urban development in the coastal zone (including coastal waters). It does this by incorporating State Planning Policies on coastal management and protection. In particular, the *State Planning Policy for Coastal Protection* specifies several new policy outcomes and associated criteria for assessing development proposals. The policy outcomes cover land-use planning, coastal hazards, nature conservation, scenic amenity, public access, coastal-dependent development and canals and artificial waterways.

The requirements of the Development Permit process have been prepared in accordance with the *Queensland Coastal Plan*. This is on the advice of DERM—the key agency with responsibility for State coastal planning. If the Development Application were made prior to the *Queensland Coastal Plan* coming into effect, DERM would assess the Development Application against the *State Coastal Management Plan*.

The cost of a Development Permit is approximately \$0.30 million in professional fees. The professional fees would be reduced to approximately \$0.14 million, if an EIS were also required for the Marine Parks Permit (for aquaculture) and *Environmental Protection and Biodiversity Conservation Act 2000* (EPBC Act) Approval, as detailed separately below.

These fees are separate to environmental management agency fees, which are estimated at \$0.50 million, if an EIS assessment were not required.

Each of the approval requirements for the above legislation and the *Queensland Coastal Plan* follow.

### **Aquaculture**

Aquaculture development is assessable under IDAS due to the discharge of waste into Qld waters.<sup>14</sup> Approval is dependent upon the ability of the aquaculture facility to meet environmental guidelines for the preservation of ecological values. Key criteria for assessment are set out in the *Environmental Protection (Water) Policy 2009*,<sup>15</sup> which includes requirements for protection of marine and terrestrial ecologies from aquaculture activities.<sup>16</sup> There is also a requirement that the development is designated, constructed and operated to minimise attracting wildlife.

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<sup>12</sup> Coastal erosion, permanent inundation and storm tide inundation that are a result of extreme weather conditions are collectively known as coastal hazards. Climate change is expected to increase coastal hazards through rising sea levels and more severe extreme weather events.

<sup>13</sup> The expected impacts include a sea-level rise of 80 centimetres and a 10 per cent increase in the maximum potential intensity of cyclones.

<sup>14</sup> Aquaculture development is classed as either 'self-assessable development' or 'assessable development, with criteria set out in the *Code for Self-Assessable Development* (AQUA01).

<sup>15</sup> The application for aquaculture development is expected to be assessed against three sets of criteria. It will be assessed as an Environmentally Relevant Activity under the *Environmental Protection Act 1994*, the *Fisheries Act 1994* and, potentially, against the *Queensland Coastal Plan*.

<sup>16</sup> This includes the management of ponds to minimise leakage to groundwater systems during normal operating conditions, as well as risk of overflow during storm and flood events.

*Assessment criteria*

The information required for the application covers three areas: characteristics of the site's geomorphology and ecology, the facility's design features, and the facility's management arrangements, as follows.

Information on the ecology of the location is required to assess the potential environmental impacts at the development location. The information needs to include the geomorphological/ecological attributes of the site, including:

- Physical characteristics, such as extent and nature of marine plants and water courses
- Contour lines, including Q100 flood event level and topographic features like gullies and waterways, and
- Depth of expected excavation in relation to the 5 metre Australian Height Datum (AHD) contour level.<sup>17</sup>

Information on the technical specifications of the aquaculture facility is required to assess the controls in place to reduce ecological degradation and to control disease outbreaks. This includes water intake and discharge structures, water storage ponds and water distribution channels, nursery and grow-out ponds, water treatment ponds and aquaculture furniture.

The technical specifications need to be accompanied by an 'Aquaculture Site Management Plan' on arrangements to monitor and manage risks, including throughout the construction phase. The operating procedures need to include details of:

- Operational considerations, in relation to production tanks, water supply system, water storage, water distribution system, water treatment, drainage, discharge system and storage of feed
- Details of measures to prevent fish escape, in relation to fencing of facility, screening of intake and outlet pipelines, treatment of water before discharge, maintenance of tank walls, predator exclusion systems, daily monitoring of equipment and surface water runoff management, and
- Details of disease prevention and management practices, in relation to monitoring for disease, source of broodstock, quarantine practices for new stock introduced to the facility, veterinary monitoring of stock, and daily/natural disaster control measures.

A further consideration for the application is the *Queensland Coastal Plan*. The Plan indicates that new aquaculture areas are to be identified and designated using the aquaculture development area methodology. It requires aquaculture development to occur within designated areas, unless the project proponent can demonstrate that an alternative development site is suitable using the methodology. It is currently unclear whether the location of the aquaculture project at Mission Bay is within a designated aquaculture area, as neither the areas nor the methodology are public information.

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<sup>17</sup> Any works at or below the 5 metre AHD level may trigger referral for acid sulphate soils assessment and treatment.

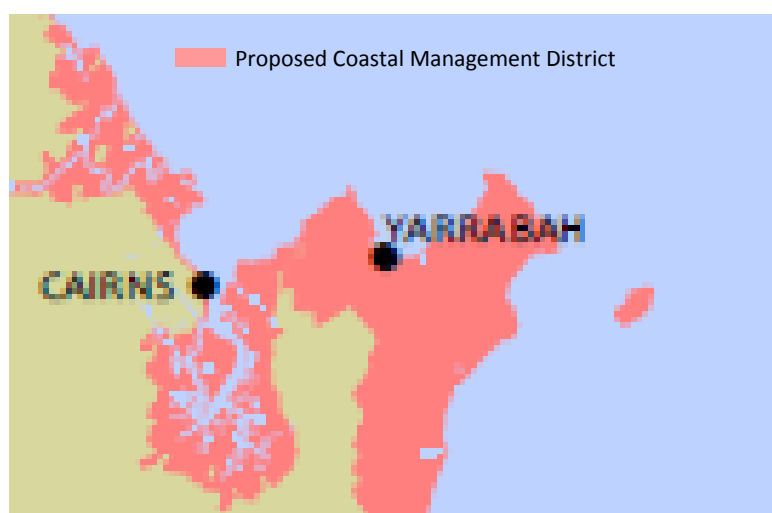
### Coastal hazards—erosion prone areas

Development applications are assessable for operational work carried out in tidal zones. Approval is dependent upon meeting requirements for areas declared as Coastal Management Districts.<sup>18</sup> These require special development controls and management practices for coastal hazards, i.e. areas subject to coastal erosion, storm tide inundation and permanent inundation due to sea level rise.<sup>19</sup>

The proposed Coastal Management District for Mission Bay is yet to be published under the *Queensland Coastal Plan*. In its absence, the Wet Tropical Coast Coastal Management District<sup>20</sup> (under the current *State Coastal Management Plan*) designates the Erosion Prone Area as 80 metres landward from mean high water springs (MHWS) along Mission Bay.<sup>21</sup>

The aquaculture facility is likely to be deemed assessable development, given the proximity of the site to the foreshore of Mission Bay. The Gungandji PBC will be in a position to receive confirmation from DERM on completion of the engineering design for the aquaculture facility when the exact mapping coordinates of the facility are known.

**Figure 7: Coastal Management Plan**



### Assessment criteria

DERM's assessment methodology for development applications in the Erosion Prone Area is outlined in the *Queensland Coastal Hazards Guidelines*.<sup>22</sup> These require a buffer zone to mitigate the risk of permanent loss of land due to shoreline recession. Development must:

<sup>18</sup> Coastal management districts are established under the *Coastal Protection and Management Act 1995*. Coastal management districts are referenced under the *Sustainable Planning Regulation 2009* to trigger assessable development and the concurrence referral of certain development application types to DERM.

<sup>19</sup> Coastal erosion involves shoreline recession due to sea erosion, causing permanent loss of land. Erosion prone areas are declared under the *Coastal Protection and Management Act 1975*.

<sup>20</sup> Map 33.8 (segment number 73) for Queensland, Far North Qld.

<sup>21</sup> Map 21.

<sup>22</sup> Note: these apply to the *State Coastal Management Plan*, rather than the *Queensland Coastal Plan*.

- Maintain vegetation, sediment volumes of dunes and coastal landforms, and physical coastal processes outside the development footprint, and
- Not increase the risk of shoreline erosion for areas adjacent to the development footprint.

The *Qld Coastal Plan* provides a set of acceptable circumstances for not fully achieving the policy. These include where the development:

- Provides an overriding need in the public interest, including where overall social, economic and environmental benefits outweigh any detrimental effect upon the natural values of the site/adjacent areas or policy outcome
- Cannot be located elsewhere, and
- Is a development commitment or for a public benefit asset.

The development, however, is still required to achieve the policy outcome to the extent possible. This includes provision: of an environmental offset for any residual adverse impacts on areas of High Ecological Significance that cannot be avoided; and, for the natural effect of physical coastal processes to continue outside the development area.

### Wetlands

Assessment for impact on wetlands is required where developments are close to wetlands of High Ecological Significance within the Great Barrier Reef Wetlands Protection Area<sup>23</sup>. Run-off must be filtered to protect the Reef from the damage caused by sediment and nutrients associated with land-based activities.

The need for assessment is determined by the distance of the development from the wetland protection area and the amount of soil disturbance<sup>24</sup>. For urban areas, the legislative trigger is:

- Less than 100m<sup>25</sup> from the wetland protection area of High Ecological Significance, and
- Operational work involving 100m<sup>3</sup> or more of excavation or fill, i.e. High Impact Earthworks.

The aquaculture facility is expected to trigger need for assessment. DERM's mapping shows the location of the aquaculture facility is close to wetlands of High Ecological Significance and construction is expected to involve more than 100m<sup>3</sup> of excavation or fill.<sup>26</sup> However, as the map is not precise, DERM will require mapping coordinates to confirm the exact location of the site relative to the wetlands protection area.

Due to overlap in assessment information requirements and criteria, assessment for impact on wetlands is not required for development applications that are assessed for impact on Erosion Prone Areas (as per the above requirements).

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<sup>23</sup> The wetland protection area represents the area of hydrological influence of the wetland.

<sup>24</sup> High impact earthworks have potential to divert water to or from a wetland.

<sup>25</sup> The short distance recognises the natural drainage of land has already been substantially altered.

<sup>26</sup> A wetlands protection area of High Ecological Significance covers large areas of Lot 207. The development site for the pilot is expected to be within the urban footprint but close to a trigger area, i.e. is within 100m of the wetlands protection area of High Ecological Significance. The footprint for the commercial facility could extend outside the urban area and into the trigger area.

The Gungandji PBC will need to approach DERM when the exact location of the site is known to clarify assessment requirements against either wetlands of High Ecological Significance or Erosion Prone Area<sup>27</sup>, as discussed above.

#### *Assessment criteria*

Development applications requiring assessment for impact on wetlands of High Ecological Significance are assessed against the ‘applicable code’, contained in the State Planning Policy.<sup>28</sup> The code specifies a set of acceptable outcomes to demonstrate that the aquaculture facility is “planned, designed, constructed and operated to minimise or prevent the loss or degradation of the wetlands and their values, or enhances these values”. See **Attachment A: Wetlands of HES, Demonstrating compliance with overall outcomes.**

The code provides for ‘acceptable outcomes’ where adverse effects on wetlands of High Ecological Significance cannot be avoided. The development achieves the policy outcome in urban areas when those effects are minimised (compliance is assessed against Development Outcome 3). If these circumstances arise, the Gungandji PBC will need to provide justification for a reduced buffer zone and provide an environmental offset for any remaining environmental impacts.

Reduced buffer zones may require a Wetland Buffer Implementation Plan that documents the Buffer Design Method to reduce impact and an ongoing monitoring/management program. The requirements for buffers and offsets are outlined in the *Queensland Government Buffer Planning Guidelines* and *Queensland Government Environmental Offset Policy 2008*, respectively.

The State Planning Policy also provides for circumstances for ‘not fully achieving the policy outcome’. This includes where the development provides for an “overriding need in the public interest”, specifically:

- The overall social, economic and environmental benefits of the development outweigh
  - any detrimental effect upon the natural values of the land and adjacent areas
  - conflicts with the policy outcome, and
- The development cannot be located elsewhere so as to avoid conflicting with the policy outcome.

#### **Figure 8: Wetlands trigger area**

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<sup>27</sup> It will be clear at this time whether the development will be assessed against existing or proposed maps of erosion prone areas, that is, the current Erosion Prone Areas (Map 21) of the Wet Tropical Coastal Management District or the proposed Far North Qld Coastal Hazard Area Maps of the Coastal Management District for Queensland (Cairns Region).

<sup>28</sup> State Planning Policy 4/11 Protecting Wetlands of High Ecological Significance in Great Barrier Reef Catchments, Annex 1, Table 1.



#### Legend

- GBR Wetland Protection Area HES wetland
- GBR Wetland Protection Area trigger area

The Gunggandji PBC will need to provide evidence to support the fact that the aquaculture facility will provide significant social, environmental and economic benefits to the community. Furthermore, DERM requires justification as to why alternative sites were disregarded in favour of the current site.

### 5.4 Clearing Permit/Nature Conservation Permit

Clearing Permits provide for clearing where the native vegetation includes listed species of ecological significance within an area of remnant vegetation<sup>29</sup>, or 'an of concern regional ecosystem'. The need for a Clearing Permit is identified during the application process for a Development Permit and, as such, a Clearing Permit is required for approval of that Development Permit.

Urban areas are exempt from the need for Clearing Permits.<sup>30</sup> The exemption is likely to apply to the Pilot Project, as the site boundary is expected to be within an urban zone. However, this is not the case for the commercial facility, given the expectation that it will extend beyond the urban boundary.

The location of development contains remnant vegetation.<sup>31</sup> A desk-top review has identified the presence of two regional ecosystems systems.<sup>32</sup> A Clearing Permit will be required if a vegetation survey confirms the development area contains listed species of ecological significance and is more

<sup>29</sup> Remnant vegetation refers to predominantly undisturbed vegetation, where the canopy includes: 50% undisturbed, 70% (on average) undisturbed height, and a composition of species that are characteristic of the vegetation's undisturbed canopy.

<sup>30</sup> Clearing of native vegetation that is exempt from development approval under the *Vegetation Management Act 1999* includes freehold and Indigenous land in urban areas, as described in Schedule 24, Part 2, Item 2(g) or 3(g) of the *Sustaining Planning Regulation 2009*, respectively. Urban areas include those identified in zoning maps.

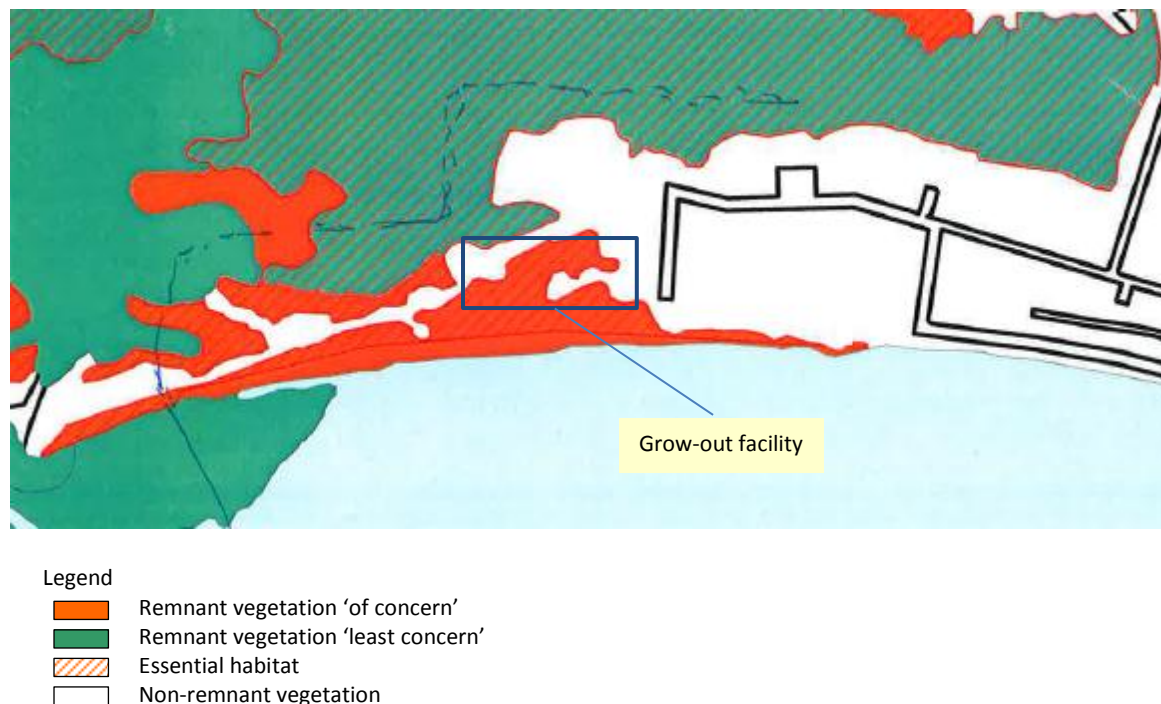
<sup>31</sup> Yarrabah is located within the Wet Tropics Bioregion.

<sup>32</sup> Regional Ecosystems 7.2.3 and 7.3.25 potentially contain 'ant plants', which are required to support other species germane to the local ecology.



than two hectares in size (see **Attachment B: Regional Management Code for Bioregions, Part P, AS P.4**).

**Figure 9: Remnant vegetation 'of concern'**



#### *Assessment criteria*

To obtain a Permit, Gunggandji PBC must demonstrate<sup>33</sup> that:

- The development has first avoided/minimised the impacts
- An equivalent area is set aside ('offset areas') that exceeds the extent and value of the area impacted by the development, and
- Clearing meets Part P of the Code the Regional Vegetation Management Code for Coastal Bioregions for maintaining biodiversity and ecological processes.

The Permit will provide for the relocation of species to the 'off-set area', which must be within the location of the development. This includes the applicant's agreement to conserve or rehabilitate the offset area. The offset area to be conserved/rehabilitated must meet the vegetation offset criteria set out in the Policy for Vegetation Management Offsets.<sup>34</sup> These are designed to take into account the current level of protection of the vegetation in the offset area, the location and size of the offset area and the ecological equivalence of the vegetation in the offset area to that of the vegetation in the area to be cleared.

<sup>33</sup> Performance Criteria of the Concurrence Agency Policy for Material Change of Use apply. These are PR F1, PR F2, and PR F3.

<sup>34</sup> Policy for Vegetation Management Offsets, Version 3, 30 September 2011. The seven criteria relate to: offset limitations; performance requirements; obtaining ecological equivalence; ensuring the offset area is legally secured; information requirements; when an offset ceases to have effect; and offset requirements to satisfy concurrence agency policies, assessment criteria Table F-1.



DERM has advised that a suitable off-set area for transplantation purposes is highly likely, given the size and similarity of ecosystems across the block. Lot 207 involves an approximate area of 15,600h on the False Cape peninsula, extending from within the urban footprint at Mission Bay to the Coral Sea.

To minimise cost to the project, the following process is recommended:

1. Determine the need for a vegetation survey, based on the size of the development area, i.e. after the engineering design establishes map coordinates for the development site associated with the production facility. A vegetation survey is required if the facility exceeds two hectares (including any other specific requirements at AS P.4).
2. Determine the need for a Clearing Permit, by conducting a vegetation survey to determine whether any listed species of ecological significance are in the vegetation to be cleared.
3. Determine the timing for relocation of species, confirming with DERM that relocation is only required for the commercial facility. This will include confirmation from YASC that the boundary of the pilot project is within the urban area, once the Town Plan is finalised. Seek agreement from DERM through the application process that the timing for relocation of species should occur after completion of the pilot project, when the decision is taken to commercialise the facility.

The cost of a vegetation survey is approximately \$0.01 million (this cost is included in the Development Permit cost above). Relocation work would be at additional cost.

## 5.5 Marine Parks Permit (for aquaculture)

A Marine Parks Permit is likely to be issued through the joint permitting system of GBRMPA and DERM (QPWS)<sup>35</sup>. The requirement for GBRMPA's involvement will be confirmed, once the engineering design verifies that the discharge outfall pipeline will extend into the area of the GBR Marine Park below the mean low water mark.<sup>36</sup> The decision also takes account of the likelihood of EPBC approval, as detailed below.

The Marine Parks Permit will be issued for aquaculture, which is permissible as a result of Mission Bay being defined as a 'Conservation Park Zone' (yellow). Conservation Parks provide opportunities for ecologically sustainable use where the use is consistent with the primary management objective for the long-term protection and conservation of GBR Marine Park's environmental, biodiversity and heritage values.

The *Marine Parks Permit Application* can be submitted to either GBRMPA or QPWS. The application will need to meet both commercial viability and environmental considerations.

### Commercial viability considerations

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<sup>35</sup> This is due to the overlap between the GBR Marine Park and the State Marine Park.

<sup>36</sup> Responsibility for assessment of development proposals is delineated at the mean low water mark where: QPWS has responsibility for the area between the mean low water mark and highest astronomical tide; and, GBRMPA for the area below the mean low water mark.

GBRMPA has stipulated that the application must address the commercial viability of the project in order to be assessed. The requirement adds an upfront cost of approximately \$0.30 million for an engineer-endorsed design of the aquaculture facility<sup>37</sup> that meets conditions of approval.

The need to demonstrate commercial viability is within a context where the Mission Bay site was chosen as suitable for conducting the pilot but not necessarily for establishing the commercial facility. This is due to the more stringent environmental management needs associated with the extra land area required for a commercial facility. The further area required will likely extend the development, that is:

- Into a protection area for wetlands of High Ecological Significance<sup>38</sup>, and
- Beyond the urban<sup>39</sup> boundary.

GBRMPA's need for the application to demonstrate commercial viability is also likely to result in additional cost for any redesign work required of the commercial facility post the Pilot Project. This is because the Marine Parks Permit application will precede the availability of more detailed information from the Pilot Project—further research on animal husbandry techniques in particular is expected to result in higher stocking densities and grow-out rates by the end of the Pilot Project. As such, there will be need to reassess the design and scale required of the commercial facility following the Pilot Project to account for any changes of underpinning assumptions. The additional upfront cost, however, is likely to be offset by reduced overall application fees, since GBRMPA (and other agencies) will require only one permit application rather than separate applications for the Pilot Project and subsequent Commercial Project.

### Environmental considerations

GBRMPA is required by legislation to assess proposals for commercial development against a set of mandatory conditions.<sup>40</sup> GBRMPA may also assess against discretionary considerations and/or set conditions to a permit approval. A copy of the mandatory and discretionary considerations is provided at **Attachment C: Great Barrier Reef Marine Park regulations**.

The foremost mandatory consideration is the potential environmental impact of the proposed development on the GBR Marine Park. An immediate management goal is to halt and reverse the decline in water quality entering the Reef by 2013, for instance, by reducing the amount of nutrients, pesticides and/or sediments entering the Reef.<sup>41</sup> The onus is on the applicant to establish the acceptability of any environmental impacts, including the options for monitoring, managing and mitigating impacts.

GBRMPA applies four different levels of project assessment, according to the environmental risk of the development to the GBR Marine Park. Each level has accompanying management requirements

<sup>37</sup> The aquaculture facility includes the production facility and the intake/discharge pipes.

<sup>38</sup> The wetlands protection area will only be significant if the area is not subject to assessment for either a declared erosion prone area or coastal hazard area.

<sup>39</sup> Urban areas are exempt from development approval under the *Vegetation Management Act 1999*.

<sup>40</sup> See *Great Barrier Reef Marine Park Regulations 1983*, Sections 88Q Consideration of applications—mandatory considerations and 88R Consideration of applications—discretionary considerations.

<sup>41</sup> See the *Reef Water Quality Protection Plan 2009*, p. 14.

that cover monitoring for compliance, management arrangements<sup>42</sup>, deeds of agreement and monetary bonds. Examples of assessment levels are provided at **Attachment D: Great Barrier Reef Marine Park environmental impact management tools**.

Two primary sources of information are needed for GBRMPA's risk assessment of the aquaculture facility:

- Baseline data of the water quality in Mission Bay, and
- Level of nutrient discharge expected from the aquaculture facility.

GBRMPA may require the applicant to undertake an EIS to collect such data. This compares with the less demanding Public Environment Report for developments that are considered low risk to the GBR Marine Park, i.e. an impact may be present but not to the extent that it would impair the overall condition of the ecosystem, sensitive population or community in the long-term. An EIS involves an approximate cost of \$0.50 million compared with \$0.10 million for a Public Environment Report.

**Table 2: Marine Parks Permit—Assessment information**

Type of cost	Environmental Impact Statement	Public Environment Report
Professional	\$400,000	\$40,000
Assessment fee	\$105,000	\$39,000
Public notice	-	\$7,800
<b>Total</b>	<b>\$505,000</b>	<b>\$105,000</b>

The need for an EIS will depend upon whether GBRMPA accepts water quality data that is understood to be held by YASC. YASC undertakes water quality testing for the sewerage works, which discharges via a creek into Mission Bay. This is within a context where the aquaculture facility is expected to have negligible environmental impact because:

- Water quality in Mission Bay is already known to be poor as a result of discharge from the sewerage works and seepage from Yarrabah's rubbish dump, and
- Nutrient discharge levels from the aquaculture facility are expected to be minimal.

To enable a decision on the requirement or otherwise for an EIS, Gunggandji PBC will need to:

- Follow up with YASC the extent of water quality testing to determine its suitability to meet GBRMPA's needs, and
- Request from DEEDI more precise nutrient load levels expected from the pilot and commercial facility.<sup>43</sup>

<sup>42</sup> Level 3 and 4 assessments require an Environmental Management Plan and Advisory Committee, and Level 4 an Environmental Site Supervisor.

<sup>43</sup> DEEDI recently commenced research on nutrient discharge levels for spiny lobster grow-out in anticipation of the project application needs.

GBRMPA's other key information requirements relate to the design and management of the aquaculture facility. GBRMPA has stipulated that the design should involve a recirculation system to reduce the level (volume) of discharge from the facility. A registered engineer needs to endorse the design to give assurance that design specifications will result in the purported/claimed nutrient discharge levels and in reduced environmental impact (e.g. the point/s of nutrient discharge to take advantage of ocean currents, diffusion of nutrient discharge to lower concentration levels across Mission Bay, and discharge times to take advantage of discharge from the sewerage facility and/or tidal activity).

GBRMPA will likely require an Environmental Management Plan<sup>44</sup> to monitor and manage environmental risks. The Plan is expected to include identification of potential environmental impacts, how activities will be managed to reduce impacts, a monitoring program, emergency response plans and any relevant issue-based plans. The plan is accompanied by a monetary bond of \$0.25 million for Level 3 projects and \$0.50 million for Level 4 projects.

## 5.6 EPBC Act Approval

If required, an EPBC Act approval will be issued by SEWPaC in respect of MNES. The application will be assessed against a set of criteria for each type of MNES in the area of the aquaculture facility to determine the significance<sup>45</sup> of environmental impacts. The relevant MNES include: World Heritage Properties, GBR Marine Park, National Heritage Places, listed threatened species and ecological communities, and listed migratory species. The assessment will involve consideration of short and long-term direct and indirect impacts on MNES, including appropriate mitigation measures and consideration of offsets where residual impacts exist. The EPBC Act also requires the assessment to consider social and economic factors. A copy of the significant impact criteria for each relevant MNES is provided at **Attachment E: Significant impact criteria**.

### *Assessment criteria*

There are three levels of assessment for applications, depending on the significance of the impact on MNES. Where the development is unlikely to have a significant impact, no further consideration of the application is required.<sup>46</sup> Applications that need further assessment will involve either a formal approval under the EPBC as a 'controlled action' or a conditional approval as a 'not controlled action particular manner'.

The depth of assessment for a controlled action is determined at the time the decision is taken to assess the application as a controlled action. Factors considered include the nature and scale of the development, the number of MNES affected and the level of information already provided in the application. Several assessment levels are possible, ranging from assessment on referral information (no additional information required) to a full EIS. Gunggandji PBC would be responsible for providing any additional information, including the EIS.

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<sup>44</sup> The requirements specified in DEEDI's Aquaculture Site Management Plan could be accommodated in GBRMPA's Environmental Management Plan.

<sup>45</sup> The general test for significance is whether an impact is 'important, notable or of consequence, having regard to its context or intensity'.

<sup>46</sup> This assumes the project is carried out in accordance with the application.

The assessment process for applications that involve a controlled action is coordinated with GBRMPA, providing a single assessment for the Minister to make decisions under both the EPBC Act and GBR Marine Park Act.<sup>47</sup> SEWPaC generally coordinates with GBRMPA regarding the EIS, with the approval decision is subject to any other Commonwealth, state or local government requirements. Further, as the EPBC Act requires triple bottom line factors<sup>48</sup> to be taken into account, it is expected that the Yarrabah community will have a strong case for approval of the project based on economic and social advantages.

SEWPaC does not charge an assessment fee. Gunggandji PBC, however, may be required to cover costs associated with any need for public consultation at the assessment stage. The need for public consultation depends on the depth/nature of assessment.

SEWPaC has indicated that the approval decision will take account of the project's long-term objective to establish a commercial facility. A key focus will be the likely levels/volume of nutrient discharge into the GBR Marine Park and the mitigation measures to avoid, reduce or offset impacts on MNES. The Environmental Offsets Policy may be relevant, depending on the levels of nutrient proposed to be discharged and the baseline quality of the receiving environment.

As with GBRMPA, the need for a full EIS is unclear until such time as it is established whether SEWPaC will accept the baseline water quality data held by YASC. SEWPaC will need data on whether the poor water quality in Mission already exceeds current Great Barrier Reef water quality guidelines, including all available information on the key contributors (i.e. the sewerage system and rubbish dump). SEWPaC will give careful assessment to any proposals that further increase the nutrient load against this backdrop.

In terms of listed threatened species/ecological communities and listed migratory species, some data may need to be collected for both the marine and terrestrial environment. The terrestrial data would be collected through a vegetation survey at a cost of approximately \$0.01 million, with the vegetation surveys not inclusive of any cost associated with the need for relocation of species found at the site.

If a full EIS were required, both SEWPaC and GBRMPA's data requirements would be met through the same EIS.

Favourable factors for an EPBC Act approval include:

- Yarrabah community has a strong case for economic and social considerations
- Small scale of the commercial aquaculture development, and
- Low predicted nutrient discharge from use of recirculation and filtration systems (better practice), concentration of solid waste and artificial feeds.

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<sup>47</sup> The Minister makes a single decision under both the EPBC Act and GBR Marine Park Act.

<sup>48</sup> Triple bottom line accounting principles include consideration of environmental, social and economic factors.

## 5.7 Conclusion

There are significant environmental management requirements associated with development at Mission Bay. Apart from the potential to be in an Erosion Prone Area, several requirements are only expected to apply if the site is also used for expansion to the commercial facility. These include wetlands of High Ecological Significance, an 'of concern' regional ecosystem and Matters of National Environmental Significance.

Qld regulators have advised that permits and approvals are likely with development conditions. GBRMPA and SEWPaC are required to coordinate their permit and approval assessments. Approval under the EPBC Act will likely involve heavy reliance on the socio-economic advantages of the aquaculture facility to the Yarrabah community, where SEWPaC applies triple bottom line accounting principles to the assessment.

The greatest prohibitive factor to the Pilot Project proceeding at this point in time is the cost of permit and approval processes. The total cost is expected to be between \$0.85 million and \$1.11 million. The cost of the EIS accounts for the majority of the difference. The second major cost is the engineering design at a cost of \$0.30 million.

## 6. BUSINESS CASE

This Part provides an analysis of the factors that contribute to the Business Case for establishment of the Pilot Project at Yarrabah. These include details of the business applicant, socio-economic considerations, marketing opportunities and competition, production systems and processes, and economic data.

### 6.1 Scope

The timeframe of the Pilot Project is three years. The projected profit and loss is based on economic modeling provided by DEEDI for a pilot scale facility, using data for a commercial operation over a ten-year period. This includes construction and operating costs of the commercial facility, based around having nursery tanks in addition to grow-out tanks.

The main production data includes assumptions of grow-out rates, stocking densities and per annum production cycles prior to preparation of the Business Case. Since provision of data for this Report, DEEDI's ongoing R&D program has reduced nutrient discharge levels to almost nil. DEEDI expects to continue the R&D program at its Northern Fisheries Centre and the Pilot Project. A central focus of the program is on factors affecting the economics of farming spiny lobster in Australia. Additional R&D associated with the hatchery will also enhance the economics, including in relation to the efficiency of feeding regimes (accompanied by reductions in waste) and supply of seed stock (i.e. more reliable and cost-effective supply than wild caught seed stock).

### 6.2 Business applicants

**Name:** Gunggandji PBC Aboriginal Corporation

**Mission:** To establish a commercially viable aquaculture business that:

- Sets the standard for the grow-out of spiny lobsters in Australia, and
- Encourages other ATSI communities to become involved in the industry.

**Objective:** To establish a pilot facility that demonstrates proof of concept for the grow-out of spiny lobster in an Aboriginal community

**Location:** Lot 207, Mission Bay, Yarrabah, Australia

**Products:** Spiny Lobster *Panulirus ornatus*

The Gunggandji PBC Aboriginal Corporation is a Registered Native Title Body Corporate under the *Corporations (Aboriginal and Torres Strait Islander) Act 2006*. The organisation represents Traditional Owners and descendants of people who were forcibly removed off traditional homelands to Yarrabah. The Gunggandji PBC is, or will be, trustee for the location selected to conduct the Pilot Project, with the ability to convert Lot 207 to freehold title.

The Gunggandji PBC is the applicant body that will source funding to establish the Pilot Project, on the expectation that the facility will become a commercially viable enterprise. As the business owners, the PBC will be responsible for sourcing a combination of grant and loan funding for:



licensing and permitting, planning and construction, training and employment of local community people, purchasing of seed stock and feed, and operating costs for the three-year period of the Pilot Project.

The PBC is in its early stage of development, having been established in December 2012. Directors of the organisation will require business support funding to assist with the Pilot Project. The focus of business support will be on governance, management capacity and the organisational structure needed to manage the business effectively.

The PBC will require a MoU with DEEDI for the provision of technical support and extension services. DEEDI's primary focus will be:

- R&D and extension services to support the Pilot Project, and
- Commercialisation of the hatchery technology.

### 6.3 Community profile

The socio-economic circumstances of the Yarrabah community are expected to have a significant bearing on the outcome of the assessment process. Yarrabah is the second largest discrete Aboriginal community in Australia, having a population of 2,371<sup>49</sup> people. According to the 2006 Census<sup>50</sup>, it comprises 2,297 Indigenous residents, 50 other Australians and a further 24 people who did not state their cultural background. It should be noted that the total Indigenous population may be understated. Compared with the Census data, YASC believes the population to be approximately 4,300 people.

The Yarrabah Indigenous population has a high proportion of young people, with 37.5 per cent aged between 0—14 years and a further 19.1 per cent aged 15—24 years.

School attendance is low. Of the 544 children aged between 5—14 years, only 263 attend school, i.e. 48.3 per cent. The proportion of early school leavers increases with age, with only 37 of the 248 youth aged between 15—19 years, or 14.9 per cent, continuing in either high school or other education institution. The total school attendance rate is only 37.9 per cent for 5—19 year olds. Further, the average student attendance may be on the decline. The quarterly reports by the Qld Department of Health *Quarterly Report on Key Indicators in Queensland's Discrete Indigenous Communities* (July–September 2009) indicate that Yarrabah was one of a number of communities where school attendance for children aged 5—14 years had declined by over 5 per cent in Term 3 2009 compared with the same period in the previous year, the others communities being Doomadgee, Hope Vale, Kowanyama, Pormpuraaw and Woorabinda. This contrasts with a steady rate of attendance at Cherbourg, Lockhart River, Mapoon, Mossman Gorge, Northern Peninsula Area and Palm Island, and improvements in attendance for Aurukun, Coen, Mornington Island and Wujal Wujal.

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<sup>49</sup> Commonwealth of Australia 2007, Australian Bureau of Statistics, *2006 Census Community Profile Series*, Yarrabah, Indigenous Profile, Catalogue No. 2002, '101 Selected Person Characteristics by Indigenous Status by Sex'.

<sup>50</sup> 2011 Census data is not yet available.

The high rate of early school leavers has a corresponding low level of school attainment across the community. Of the 59.9 per cent of Yarrabah's Indigenous population who indicated their highest year of school completed, 63.1 per cent only completed Year 8, 9 or 10. The Year 11 completion rate was 16.6 per cent and Year 12 completion rate 20.0 per cent. Anecdotally, older people have better literacy and numeracy skills.

The number of Indigenous people of work age was 1,415 people, or 59.7 per cent. This number equals the total population aged 15–64 years. Of the group, 981 were in the labour force, 419 were not in the labour force and 15 did not indicate their status. Approximately 84.8 per cent (832 individuals) of the labour force were registered as job seekers.

The Yarrabah Aboriginal community strongly supports the Pilot Project as a result of employment opportunities associated with the aquaculture facility.

## 6.4 Market analysis

### Current state of industry and market demand

Aquaculture is the fastest growing fishery in the world, not only commercially but as a food security production system for poor rural communities in developing countries. The rapid increase in the demand for seafood includes the spiny lobster, particularly in China where a growing economy and a rising middle class will continue to increase demand for spiny lobster. The Chinese market was worth \$190 million USD in 2011.

The Pilot Project will not target a proportion of the market share, due to the status of the project as proof of concept and the small numbers of live product involved. The objective of the Pilot Project is to test 'live' product into the Chinese market through the commercial wholesaler.

The market opportunities will be reassessed as part of commercialization, taking into account the quantity of product to be produced, market prices, and contract conditions offered by exporters at this time. Selling direct to Chinese customers may also be a future consideration. Selling plate size lobster, i.e. under 600 gr, will also be a consideration. The latter will be feasible as a result of DEEDI's hatchery technology and aquaculture production, where there are no controls over the size/quantity of spiny lobster product compared with the Australian wild take commercial lobster fishery.

### Competition and competitive advantage

In Australia, the Gunggandji PBC will always face competition from the wild take commercial lobster fishery, which consists of both live and frozen tails. There are no other major competitors in Qld.

The commercial lobster fishery in Qld is a dive-based hand collection fishery that primarily targets the spiny lobster. DEEDI manages and regulates the fishery through:

- A limited entry fishery, with restrictions placed on new primary boat and tender boat (dory) boat licenses since 1996
- A quota system since 1996, with an industry Total Allowable Catch of 195 metric tonnes,
- A minimum size limit, with a 115 mm tail length (or 90 mm carapace length), and

- A closed season (commercial & recreational), with the closure applied to all species of tropical rock lobster from 1 October to 1 February in Qld tidal waters.<sup>51</sup>

The annual seasonal closure is in place to reduce fishing mortality on breeding stocks. The closure applies to all commercial and recreational fishing within the commercial fishery area. The current zoning of the Qld east-coast lobster fishery does not extend south from the Aboriginal community of Lockhart River, where the community established the Pichiwu Fishing Ltd based on the wild capture of mud crabs and spiny lobsters for sale to seafood markets in Cairns.

Competition outside Australia includes Vietnam. The Vietnamese industry was developed around the collection of live lobster juveniles (seed) from the wild, grown out in floating sea cages and fed trash fish.

Vietnam is one of the two countries involved in the ACIAR project with Australia, the other being Indonesia. In Vietnam, the total transition from wild caught seed and use of trash feed to a sustainable industry that uses hatchery-produced seed and formulated diets is expected to take many years. This is because (1) Australia will take some time before sufficient numbers of seed is produced to satisfy expected demand, and (2) the culture of the industry and current supply chain of wild caught and trash feed supplies are well-established.

Nevertheless, Vietnam will continue to be a major competitor in the marketplace. Vietnam has a fully established distribution chain and is exporting at a much larger scale than Australia's current commercial spiny lobster industry.

Indonesia may also pose a threat to establishment/growth of Australia's spiny lobster industry. Indonesia has advantages of less regulation and significantly lower establishment and operating costs.

The competitive advantage for developing the industry in Australia is the involvement of DEEDI scientists, which place the Pilot Project at the leading edge in terms of improvements in grow-out rates and production cycles. Australia is also recognized internationally as a producer of high quality seafood products.

### SWOT Analysis

The Pilot Project has significant strengths and opportunities that provide the best prospect of successfully establishing spiny lobster farming for Yarrabah and Australia. These include application of best practice system technology and proximity of DEEDI scientists to provide technical expertise and ongoing R&D. Collectively, these aspects:

- Minimise any adverse environmental impacts, which may otherwise affect the ability to obtain the necessary development permits and approvals
- Support the production of a quality product at a size, weight and price, which satisfy market demand, and

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<sup>51</sup> Qld Government Department of Primary Industry and Fisheries, June 2004, *An Ecological Assessment of Queensland's East Coast Tropical Rock Lobster Fishery*, collated by Joanne Atfield, pp. 25-6.

- Improve grow-out rates and production cycles, which underpin continuing improvements in the economics of farming spiny lobster in Australia.

In addition, significant levels of grant funding are expected to be available through the Wungul Environmental Foundation. The Foundation has been established with philanthropic funds to assist ATSI people establish enterprises that are environmentally sustainable and that conserve cultural and natural resources on country. The Foundation is based in Cairns.

The key threat is nutrient discharge into the GBR Marine Park World Heritage Area, which may affect the ability to obtain a Marine Parks Permit. This is manageable through:

- The economic opportunity afforded by establishment of a sustainable industry that offers training and employment opportunities for the Yarrabah community where, otherwise, there are limited commercial activities, and
- DEEDI’s ongoing R&D program that has already reduced nutrient discharge levels since development of this Business case.

The SWOT does not canvas aspects of the commercial facility, given the need to reassess market opportunities and to take account of advances in economics post the Pilot Project.

**Figure 10: SWOT analysis**

STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> <li>● Facility built and managed to strict Australian standards, with minimal impact on the environment and robust disease control</li> <li>● Application of best practice farming techniques, incl. quality control of product</li> <li>● Sustainable access to seed supply &amp; feeds</li> <li>● Technical support and extension services from leading DEEDI scientists</li> <li>● Ownership by Traditional Owners</li> </ul>	<ul style="list-style-type: none"> <li>● Proximity to GBRMP World Heritage Area</li> <li>● High start-up costs</li> <li>● Limited production capacity</li> <li>● High production costs</li> <li>● Limited management capacity</li> </ul>
OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> <li>● Involvement at cutting edge of science technology, incl. ongoing R&amp;D</li> <li>● Training &amp; employment of local ATSI community people</li> <li>● Production of a quality product at a size/weight &amp; price to satisfy market demand</li> <li>● Grant funding potentially available from an Aboriginal foundation</li> </ul>	<ul style="list-style-type: none"> <li>● Inability to attract establishment funding and/or on-going support</li> <li>● Occurrence of natural disasters</li> <li>● Poor site security</li> </ul>

## 6.5 Operations

### Grow-out system

The aquaculture facility for conducting the Pilot Project will involve a tank-based recirculation system, designed and managed to meet Australia’s strict regulatory requirements, as per Part 5—Permits and Approvals. A schematic of the proposed system is contained in Part 3—Project details.

### Tanks

The recirculation system has 11 tanks, as follows:

Tank details	Nursery	Grow-out Phase 1	Grow-out Phase 2	Grow-out Phase 3
Average tank height (m)	1	1	1	1
Average tank width (m)	3	3	3	3
Average tank depth (m)	1	2	2	2
Average tank size (m <sup>3</sup> )	3	6	6	6
Number of tanks	3	2	2	4
<b>Total aquaculture volume (m<sup>3</sup>)</b>	<b>9</b>	<b>12</b>	<b>12</b>	<b>24</b>

To achieve optimal stocking densities, spiny lobster will be moved through each grow-out phase to avoid overcrowding.

### Production process

The production process comprises:

1. Receipt of juveniles—sourced from DEEDI’s hatchery
2. Juveniles stock in nursery tanks—to a weight of 113 grams
3. Grow-out to commercial size—to a weight of 1+ kg weight
4. Harvesting and processing—on-site
5. Dispatch to commercial wholesaler—as live product.

### Seed stock and stocking densities

Seed information	Nursery	Grow-out Phase 1	Grow-out Phase 2	Grow-out Phase 3
Stocking density (#/m <sup>3</sup> )	60	31.5	28.4	12.8
Stocking rate (#/tank)	180	189		
No. lobsters stocked (#/crop)	540	378		
Stocking biomass (kg/crop)	3.0			
Size of stocked individual (g/individual)	5.5	122.6	314.6	628.6
Survival rate (%)	70	90	90	90
Total no. surviving individuals	378	340	306	276
Price of seed	10			
Cost of seed	5,400			

## Feed

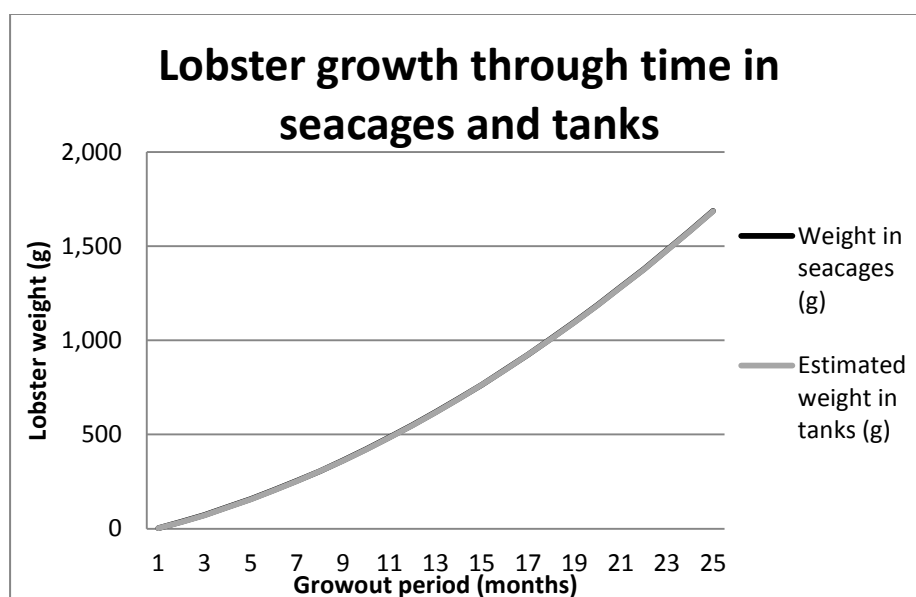
	Feed conversion ratio	Quantity of food eaten	Quantity of food eaten	Quantity	Feed cost \$	Total feeding cost
	g food eaten/g weight gain	g/lobster/phase	kg/phase/crop	% body weight	AUD/kg	AUD/crop
Nursery	5.0	585	221	10.0	5.00	1,107
Grow-out 1	3.5	672	229	3.2	3.50	800
Grow-out 2	3.5	1,099	337	2.4	3.00	1,010
Grow-out 3	3.5	1,670	460	1.9	3.00	1,381
<b>Total</b>		<b>4,027</b>	<b>1,247</b>			<b>4,297</b>

## Grow-out rates

The total grow-out period is estimated to be around 18 months, from three grams to a marketable size of 1+ kg. This is based on receipt of juvenile spiny lobsters at approximately 5.5 months old at a weight of three grams.

The grow-out rate has been calculated on data collected from DEEDI hatchery experiments at the Northern Fisheries Centre and grow-out rates of lobsters in Vietnam using sea cages. The grow-out rates are virtually identical, as shown in the following table.

Figure 11: Estimated grow-out rate



## Production levels

Production is expected to be 202 kg per year, i.e. 303 kg over 18 months. Six crops are expected to be produced over the ten-year period.

## Staff

Three staff are required to operate the facility. These include: a facility manager and two aquaculture technicians. Annual wages are in Australian industry rates, as follows:

- Manager, at \$90,000, and
- Aquaculture technicians, at \$80,000 (2 x \$40,000).

Staff will receive a minimum Certificate III in Aquaculture (Seafood). The training costs will be borne by a Government-funded training program.

## Repairs and maintenance

\$5,000 per annum.

## Price

The farm-gate price is estimated at \$75 per 1 kg live animal.

## 6.6 Financial analysis

### Limitations

The major limitation of preparing the Business Case is the provision of data for a ten-year period. Production levels during this period are for a facility at the scale of the Pilot Project, i.e. no data is included for a commercial scale facility for years four to ten following the Pilot Project.

Other limitations include the following:

- This is the first time that economic modeling of spiny lobster grow-out has been attempted for Australia
- Economic modeling is based on the Vietnam experience of growing out wild caught spiny lobsters in sea cages, with a different feeding regime based on trash fish, and
- Further R&D is taking place to collect more primary data on nutrient discharge using formulated dietary needs, both of which will improve the business case.

At DEEDI's request, the Business Case does not include costs associated with permit and approvals that are contained in Part 5 – Permits and Approvals of this Report. These costs would be in addition to the economic analysis.

### Assumptions

Tank-based recirculation system

11 tanks with total capacity of 57m<sup>3</sup>

Tank replacement period of 25 years

Juvenile stock weight of 113 grams per individual

Sale weight of 1+ kg

Seed stock cost of \$5,400 per crop

Feed cost of \$4,297 per crop



Food conversion rate (gr food eaten/gr weight gain): 5 for nursery; and, 3.5 per grow-out phase

Grow-out period of 18 months

Six crops over 10 years

Total wages of \$170,000 per annum

Cost of repairs & maintenance estimated at \$5,000 per annum

Sale price estimated at \$75 per 1kg live animal

No application of GST

Full depreciation of equipment over 10 years

**START UP**

<b>Start-up capital</b>	<b>Item</b>	<b>Cost</b>
Utilities	Phone/Internet	\$ 300
Advertising & promotion	Office signage	\$ 900
<b>Sub-total</b>		<b>\$ 1,200</b>
<b>Capital expenses (assets)</b>		
Pumps & filters		\$ 28,663
Reservoir		\$ 13,000
Tanks		\$ 58,100
Feeding equipment	Fridge	\$ 2,000
	Freezer	\$ 2,000
Back-up generator		\$ 10,000
Shed & buildings (incl. construction)		\$ 80,000
Water quality meter (multiprobe)		\$ 4,500
Palintest		\$ 1,500
Miscellaneous consumables		\$ 1,000
Office furniture	Table & chairs	\$ 500
	Computer	\$ 1,500
	Computer desk	\$ 300
	Computer chair	\$ 300
	Printer	\$ 600
Motor vehicles	Ute	\$ 25,000
<b>Sub-total</b>		<b>\$ 228,963</b>
<b>Security &amp; Collateral for Loan</b>		<b>\$ 0</b>
<b>Owners investment</b>		<b>\$ 0</b>
<b>Total loan required for start-up</b>		<b>\$ 230,163</b>

## PROFIT AND LOSS, YEARS 1-10

SALES	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Product	\$ -	\$ 22,740	\$ 22,740	\$ -	\$ 22,740	\$ 22,740	\$ -	\$ 22,740	\$ 22,740	\$ -
Owners investment	\$ 1	\$ -	\$ -	\$ 1	\$ -	\$ -	\$ 1	\$ -	\$ -	\$ 1
<b>Total sales</b>	<b>\$ 1</b>	<b>\$ 22,740</b>	<b>\$ 22,740</b>	<b>\$ 1</b>	<b>\$ 22,740</b>	<b>\$ 22,740</b>	<b>\$ 1</b>	<b>\$ 22,740</b>	<b>\$ 22,740</b>	<b>\$ 1</b>
<b>OPERATING COSTS</b>										
<i>Fixed costs</i>										
Labour	\$ 170,000	\$ 170,000	\$ 170,000	\$ 170,000	\$ 170,000	\$ 170,000	\$ 170,000	\$ 170,000	\$ 170,000	\$ 170,000
Lease of land	\$ 2,250	\$ 2,250	\$ 2,250	\$ 2,250	\$ 2,250	\$ 2,250	\$ 2,250	\$ 2,250	\$ 2,250	\$ 2,250
Loan repayment	\$ 10,439	\$ 10,439	\$ 10,439	\$ 10,439	\$ 10,439	\$ 10,439	\$ 10,439	\$ 10,439	\$ 10,439	\$ 10,439
Insurances	\$ 4,000	\$ 4,000	\$ 4,000	\$ 4,000	\$ 4,000	\$ 4,000	\$ 4,000	\$ 4,000	\$ 4,000	\$ 4,000
Professional (accounting)	\$ 3,500	\$ 3,500	\$ 3,500	\$ 3,500	\$ 3,500	\$ 3,500	\$ 3,500	\$ 3,500	\$ 3,500	\$ 3,500
Repairs & maintenance	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000
Telephone/Internet	\$ 65	\$ 65	\$ 65	\$ 65	\$ 65	\$ 65	\$ 65	\$ 65	\$ 65	\$ 65
Electricity	\$ 8,000	\$ 8,000	\$ 8,000	\$ 8,000	\$ 8,000	\$ 8,000	\$ 8,000	\$ 8,000	\$ 8,000	\$ 8,000
<b>Sub-total</b>	<b>\$ 203,254</b>	<b>\$ 203,254</b>	<b>\$ 203,254</b>	<b>\$ 203,254</b>	<b>\$ 203,254</b>	<b>\$ 203,254</b>	<b>\$ 203,254</b>	<b>\$ 203,254</b>	<b>\$ 203,254</b>	<b>\$ 203,254</b>
<i>Variable costs</i>										
Seed stock	\$ 5,400	\$ 5,400	\$ -	\$ 5,400	\$ 5,400	\$ -	\$ 5,400	\$ 5,400	\$ 5,400	\$ -
Feed	\$ 4,297	\$ 4,297	\$ -	\$ 4,297	\$ 4,297	\$ -	\$ 4,297	\$ 4,297	\$ 4,297	\$ -
Fuel	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000	\$ 5,000
Printing & stationary	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600
Office consumables	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600	\$ 600
<b>Sub-total</b>	<b>\$ 15,897</b>	<b>\$ 15,897</b>	<b>\$ 6,200</b>	<b>\$ 15,897</b>	<b>\$ 15,897</b>	<b>\$ 6,200</b>	<b>\$ 15,897</b>	<b>\$ 15,897</b>	<b>\$ 15,897</b>	<b>\$ 6,200</b>
<b>Total operating costs</b>	<b>\$ 219,151</b>	<b>\$ 219,151</b>	<b>\$ 209,454</b>	<b>\$ 219,151</b>	<b>\$ 219,151</b>	<b>\$ 209,454</b>	<b>\$ 219,151</b>	<b>\$ 219,151</b>	<b>\$ 219,151</b>	<b>\$ 209,454</b>
<b>Gross profit (Sales less Operating)</b>	<b>-\$ 219,150</b>	<b>-\$ 196,411</b>	<b>-\$ 186,714</b>	<b>-\$ 219,150</b>	<b>-\$ 196,411</b>	<b>-\$ 186,714</b>	<b>-\$ 219,150</b>	<b>-\$ 196,411</b>	<b>-\$ 196,411</b>	<b>-\$ 209,453</b>
<b>Less depreciation</b>	<b>\$ 22,896</b>	<b>\$ 22,896</b>	<b>\$ 22,896</b>	<b>\$ 22,896</b>	<b>\$ 22,896</b>	<b>\$ 22,896</b>	<b>\$ 22,896</b>	<b>\$ 22,896</b>	<b>\$ 22,896</b>	<b>\$ 22,896</b>
<b>Profit before tax</b>	<b>-\$ 242,046</b>	<b>-\$ 219,307</b>	<b>-\$ 209,610</b>	<b>-\$ 242,046</b>	<b>-\$ 219,307</b>	<b>-\$ 209,610</b>	<b>-\$ 242,046</b>	<b>-\$ 219,307</b>	<b>-\$ 219,307</b>	<b>-\$ 232,349</b>
<b>Tax @ 30%</b>	<b>\$ -</b>	<b>\$ -</b>	<b>\$ -</b>	<b>\$ -</b>	<b>\$ -</b>	<b>\$ -</b>	<b>\$ -</b>	<b>\$ -</b>	<b>\$ -</b>	<b>\$ -</b>
<b>Net profit</b>	<b>-\$ 242,046</b>	<b>-\$ 219,307</b>	<b>-\$ 209,610</b>	<b>-\$ 242,046</b>	<b>-\$ 219,307</b>	<b>-\$ 209,610</b>	<b>-\$ 242,046</b>	<b>-\$ 219,307</b>	<b>-\$ 219,307</b>	<b>-\$ 232,349</b>
<b>% of revenue</b>	<b>-24204600%</b>	<b>-964%</b>	<b>-922%</b>	<b>-24204600%</b>	<b>-964%</b>	<b>-922%</b>	<b>-24204600%</b>	<b>-964%</b>	<b>-964%</b>	<b>-23234900%</b>

## PROJECTED CASH FLOW - TEN YEARS

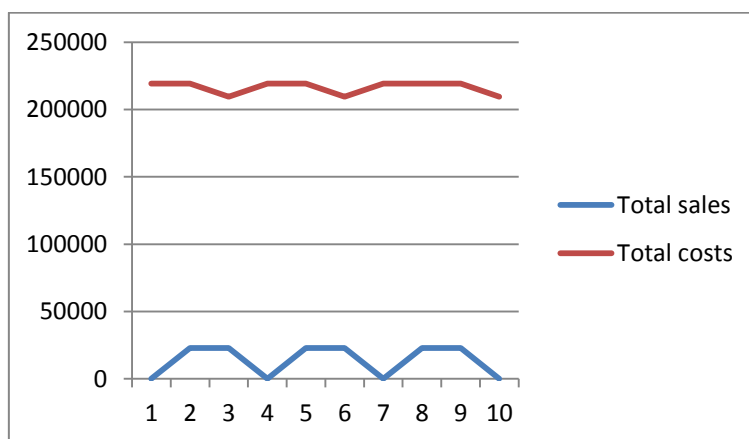
Cash flow	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Net profit after tax	-\$ 246,046	-\$ 219,307	-\$ 209,610	-\$ 242,046	-\$ 219,307	-\$ 209,610	-\$ 242,046	-\$ 219,307	-\$ 219,307	-\$ 232,349
Add depreciation	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896
Less loan principle	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896	\$ 22,896
Add loan funds received	\$ 228,963	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Less start-up capital expenditure	\$ 228,963	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
<b>Net cash flow</b>	<b>-\$ 246,046</b>	<b>-\$ 219,307</b>	<b>-\$ 209,610</b>	<b>-\$ 242,046</b>	<b>-\$ 219,307</b>	<b>-\$ 209,610</b>	<b>-\$ 242,046</b>	<b>-\$ 219,307</b>	<b>-\$ 219,307</b>	<b>-\$ 232,349</b>
Operating cash balance	\$ 10	-\$ 246,036	-\$ 465,343	-\$ 674,953	-\$ 916,999	-\$ 1,136,306	-\$ 1,345,916	-\$ 1,587,962	-\$ 1,807,269	-\$ 2,026,576
<b>Closing cash balance</b>	<b>-\$ 246,036</b>	<b>-\$ 465,343</b>	<b>-\$ 674,953</b>	<b>-\$ 916,999</b>	<b>-\$ 1,136,306</b>	<b>-\$ 1,345,916</b>	<b>-\$ 1,587,962</b>	<b>-\$ 1,807,269</b>	<b>-\$ 2,026,576</b>	<b>-\$ 2,258,925</b>

Balance sheet	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
<b>Assets</b>											
Cash	\$ 228,973	-\$ 246,036	-\$ 465,343	-\$ 674,953	-\$ 916,999	-\$ 1,136,306	-\$ 1,345,916	-\$ 1,587,962	-\$ 1,807,269	-\$ 2,026,576	-\$ 2,258,925
Fixed assets	\$ -	\$ 228,963	\$ 206,067	\$ 183,171	\$ 137,379	\$ 68,691	-\$ 22,893	-\$ 137,373	-\$ 274,749	-\$ 435,021	-\$ 618,189
Less accumulated depreciation	\$ -	\$ 22,896	\$ 45,792	\$ 68,688	\$ 91,584	\$ 114,480	\$ 137,376	\$ 160,272	\$ 183,168	\$ 206,064	\$ 228,960
<b>Total assets</b>	<b>\$ 228,973</b>	<b>-\$ 39,969</b>	<b>-\$ 305,068</b>	<b>-\$ 560,470</b>	<b>-\$ 871,204</b>	<b>-\$ 1,182,095</b>	<b>-\$ 1,506,185</b>	<b>-\$ 1,885,607</b>	<b>-\$ 2,265,186</b>	<b>-\$ 2,667,661</b>	<b>-\$ 3,106,074</b>
<b>Liabilities</b>											
Loan	\$ 228,963	\$ 206,067	\$ 183,171	\$ 160,275	\$ 137,379	\$ 114,483	\$ 91,587	\$ 68,691	\$ 45,795	\$ 22,899	\$ 3
<b>Total liabilities</b>	<b>\$ 228,963</b>	<b>\$ 206,067</b>	<b>\$ 183,171</b>	<b>\$ 160,275</b>	<b>\$ 137,379</b>	<b>\$ 114,483</b>	<b>\$ 91,587</b>	<b>\$ 68,691</b>	<b>\$ 45,795</b>	<b>\$ 22,899</b>	<b>\$ 3</b>
<b>Net assets</b>	<b>\$ 10</b>	<b>-\$ 246,036</b>	<b>-\$ 488,239</b>	<b>-\$ 720,745</b>	<b>-\$ 1,008,583</b>	<b>-\$ 1,296,578</b>	<b>-\$ 1,597,772</b>	<b>-\$ 1,954,298</b>	<b>-\$ 2,310,981</b>	<b>-\$ 2,690,560</b>	<b>-\$ 3,106,077</b>
<b>Shareholder equity</b>											
Issued capital	\$ 10	\$ 10	\$ 10	\$ 10	\$ 10	\$ 10	\$ 10	\$ 10	\$ 10	\$ 10	\$ 10
Retained profits	\$ -	-\$ 246,046	-\$ 488,249	-\$ 720,755	-\$ 1,008,593	-\$ 1,296,588	-\$ 1,597,782	-\$ 1,954,308	-\$ 2,310,991	-\$ 2,690,570	-\$ 3,106,087
<b>Total shareholder equity</b>	<b>\$ 10</b>	<b>-\$ 246,036</b>	<b>-\$ 488,239</b>	<b>-\$ 720,745</b>	<b>-\$ 1,008,583</b>	<b>-\$ 1,296,578</b>	<b>-\$ 1,597,772</b>	<b>-\$ 1,954,298</b>	<b>-\$ 2,310,981</b>	<b>-\$ 2,690,560</b>	<b>-\$ 3,106,077</b>

### 6.7 Conclusion

The Business Case does not support pursuing the establishment of the Pilot Project at Yarrabah at this point in time. The financial analysis shows that a break-even point will never be achieved, due to the small level of sales relative to costs. The stocking densities, grow-out rates, number of production cycles and farm-gate unit price of spiny lobster will need to improve significantly to achieve annual profit margins.

**Figure 12: Production sales versus costs**



The Business Case, however, was underpinned by an 18 month grow-out period to meet GBRMPA's requirement for a business case that supports a commercial facility as a condition of assessment for a Marine Parks Permit. This does not reflect the purpose of the Pilot Project, which was expected to involve:

- Only a six-month grow-out period, which is based on the purchase of spiny lobster at minimum legal size rather than grow-out over 18 months from hatchery-produced seed, and
- A further three years of R&D, which is needed to obtain the biometric data required to develop a business case for a commercial facility.

The key strength of pursuing the Pilot Project is the socio-economic benefits to Yarrabah and other ATSI communities across northern Australia. This will remain the case and justifies a review of how to take the Pilot Project forward without the constraints imposed by permit and approval requirements, including utilisation of less expensive grow-out technology such as sea cages.

ATSI communities are in a position to source the funds needed to establish environmentally sustainable enterprises.

## ATTACHMENT A: Wetlands of HES, Demonstrating compliance with overall outcomes

**Table 1 – Demonstrating compliance with development outcomes**

Development outcome (DO)	Acceptable outcomes (AO)
Development is located outside the HES wetland	AO1.1
Development avoids adverse effects on the wetland	AO2.1–2.3, AO3.1, AO4.1–4.3, AO5.1, AO5.8, AO6.1, AO7.1, AO8.1, AO9.1, AO10.1 and AO11.1–11.2.
Development minimises adverse effects on the wetland and an environmental offset is provided for any remaining impacts.	AO3.2–3.3, AO5.2–5.7, AO6.2, AO7.2, AO8.2–8.4, AO9.2–9.3, AO10.2–10.4 and AO11.1–11.2.
Where there is a development commitment	All of the above to the greatest extent practicable without compromising the intrinsic characteristics of the development.

## 4.0 Code provisions

Specific outcomes (SO)	Acceptable outcomes (AO)
<b>Development positioning</b>	
SO1 Development is not carried out in a HES wetland.	<p>AO1.1 Development is located outside:</p> <ul style="list-style-type: none"> <li>a) the mapped boundary of a HES wetland in a Great Barrier Reef wetland protection area; or</li> <li>b) an alternative mapped boundary of the HES wetland—               <ul style="list-style-type: none"> <li>(1) submitted as part of the development application; and</li> <li>(2) supported by a detailed assessment and site analysis of the wetland to delineate its extent in accordance with the Queensland Wetland Definition and Delineation Guidelines (2010); and</li> <li>(3) that the alternative assessment manager or concurrence agency agrees is a more accurate representation of the boundary.</li> </ul> </li> </ul>
SO2 An adequate buffer to a HES wetland is provided.	<p><b>To avoid adverse effects:</b></p> <p>AO2.1 A buffer surrounding a HES wetland in a Great Barrier Reef wetland protection area is provided and has a minimum width of:</p> <ul style="list-style-type: none"> <li>a) 200 metres where a HES wetland is located outside an urban area or</li> <li>b) 50 metres where a HES wetland is located within an urban area.</li> </ul> <p>OR</p> <p>AO2.2 An alternative buffer is provided, the width of which is supported by an evaluation of the values, functioning and threats to the wetland.</p> <p>AND</p> <p>AO2.3 A buffer surrounding a wetland of ecological significance is maintained.</p> <p><b>Note:</b> DERM should be contacted for information on maintaining a wetland buffer and the process for determining an alternative buffer width.</p>



Specific outcomes (SO)	Acceptable outcomes (AO)
<b>Hydrology</b>	
<p>SO3 The existing surface water hydrological regime of the Great Barrier Reef wetland protection area (including the HES wetland) is maintained or enhanced.</p> <p><b>Note:</b> The hydrological regime of surface waters includes:</p> <ul style="list-style-type: none"> <li>• peak flows</li> <li>• volume of flows</li> <li>• duration of flows</li> <li>• frequency of flows</li> <li>• seasonality of flows</li> <li>• water depth (seasonal average)</li> <li>• wetting and drying cycle.</li> </ul>	<p><b>To avoid adverse effects:</b></p> <p>AO3.1 Development does not change the existing surface water hydrological regime of a HES wetland, including through channelisation, redirection or interruption of flows.</p> <p><b>Note:</b> An assessment of the extent of change must take into account the natural variability of the hydrological regime of the wetland.</p> <p><b>To minimise adverse effects:</b></p> <p>AO3.2 If AO3.1 does not apply, the extent of the change is minimised to ensure the wetland values and functioning are protected. The change is minimised if, at least:</p> <ol style="list-style-type: none"> <li>a) there is no change to the reference duration high-flow and low-flow duration frequency curves, low-flow spells frequency curve and mean annual flow to and from the wetland; and</li> <li>b) any relevant stream flows into the wetland comply with relevant environmental flow objectives (EFOs) of the applicable water resource plan for the area; and</li> <li>c) for development resulting in an increase to the velocity or volume of stormwater flows into the HES wetland – the collection and reuse of stormwater occurs in accordance with (a) and (b).</li> </ol> <p><b>Note:</b> Reference durations for wetland types are available in the SPP guideline.</p> <p>OR</p> <p>AO3.3 If neither AO3.1 nor AO3.2 apply, the following apply in relation to the development:</p> <ol style="list-style-type: none"> <li>a) a net ecological benefit and improvement to the values and functioning of the wetland; and</li> <li>b) development is limited to rehabilitating the existing hydrological regime or restoring the natural hydrological regime of the wetland to enhance the ecological functions and biodiversity values of the wetland.</li> </ol> <p><b>Note:</b> Refer to the Wetland Rehabilitation Guidelines for the Great Barrier Reef Catchment (2008).</p>
<p>SO4 The existing groundwater hydrological regime of the Great Barrier Reef wetland protection area (including the HES wetland) is protected or enhanced.</p>	<p><b>To avoid adverse effects:</b></p> <p>AO4.1 The water table and hydrostatic pressure within the Great Barrier Reef wetland protection area is not lowered or raised outside the bounds of variability under existing conditions.</p> <p>OR</p> <p>AO4.2 The water table and hydrostatic pressure in the Great Barrier Reef wetland protection area is returned to its natural state.</p> <p>AND</p> <p>AO4.3 Development does not result in the ingress of saline water into freshwater aquifers.</p>

Specific outcomes (SO)	Acceptable outcomes (AO)
<b>Water quality – stormwater</b>	
<p>SO5 During construction and operation of development:</p> <ul style="list-style-type: none"> <li>• a wetland is not used for stormwater treatment</li> <li>• the buffer and water quality values of a HES wetland are protected from stormwater impacts.</li> </ul> <p>Note: Best practice stormwater management is available in the following guidelines:</p> <ul style="list-style-type: none"> <li>• for urban areas: Queensland Best Practice Environmental Management Guidelines – Urban Stormwater</li> <li>• for outside urban areas: Wetland Management Handbook: Farm Management Systems guidelines for managing wetlands in intensive agriculture.</li> </ul>	<p><b>In an urban area</b></p> <p><b>To avoid adverse effects:</b></p> <p>AO5.1 Development does not result in any measurable change to the quantity or quality of stormwater entering the HES wetland during construction or operation.</p> <p><b>To minimise adverse effects:</b></p> <p>AO5.2 Stormwater quality is managed in accordance with best practice environmental management for erosion and sediment control.</p> <p>AND</p> <p>AO5.3 During construction, development incorporates erosion and sediment control measures to achieve best practice design objectives.</p> <p>Note: An erosion and sediment control plan should be prepared by a suitably qualified person to demonstrate compliance with acceptable outcomes AO5.2 and AO5.3.</p> <p>AND</p> <p>AO5.4 During construction, release of sediment-laden stormwater is avoided for the nominated design storm, and minimised if the design storm is exceeded, consistent with the erosion and sediment control plan, including the following best practice:</p> <ul style="list-style-type: none"> <li>• stormwater runoff during any construction works is diverted or bypassed around the HES wetland; and</li> <li>• all stormwater runoff saved for dewatering flow from site catchments achieves a maximum concentration of 50 mg/L of total suspended solids; and</li> <li>• all drainage lines, diversion and collection drains and bank, chutes and outlets are able to safely carry peak flow in accordance with the Queensland Best Practice Environmental Management Guidelines – Urban Stormwater.</li> </ul> <p>AND</p> <p>AO5.5 During construction, erosion and sediment control practices including approved proprietary products are designed, installed, constructed, maintained and monitored in accordance with local conditions and recommendations by suitably qualified persons/professionals<sup>14</sup>.</p> <p>AND</p> <p>AO5.6 During operation, stormwater discharges are treated in accordance with best practice load reduction design objectives before stormwater flow enters the buffer area of the wetland. Stormwater treatment should address pollutants including, but not limited to:</p> <ul style="list-style-type: none"> <li>• total suspended solids</li> <li>• total phosphorus</li> <li>• total nitrogen</li> <li>• gross pollutants &gt;5 mm.</li> </ul> <p>AND</p> <p>AO5.7 During operation, development incorporates stormwater flow control measures to achieve best practice design objectives.</p>

Specific outcomes (SO)	Acceptable outcomes (AO)				
	<p><b>Other than in an urban area</b></p> <p>To avoid adverse effects:</p> <p>AO5.8 Development does not result in any measurable change to the quantity or quality of stormwater entering the HES wetland during construction or operation.</p>				
<b>Ecological values</b>					
<b>Vegetation and land degradation</b>					
<p>SO6 Development involving the clearing of vegetation protects the biodiversity, ecological values and processes, and hydrological functioning of a HES wetland, including:</p> <ul style="list-style-type: none"> <li>• water quality values</li> <li>• aquatic habitat values;</li> <li>• terrestrial habitat values</li> <li>• usage of the site by native wetland fauna species or communities, including threatened or near threatened species, and species of regional and local significance.</li> </ul>	<p>To avoid adverse effects:</p> <p>AO6.1 Vegetation clearing undertaken as a consequence of development does not occur:</p> <ul style="list-style-type: none"> <li>• in a HES wetland; or</li> <li>• in a buffer area under specific outcome SO2.</li> </ul> <p><b>In an urban area</b></p> <p>To minimise adverse effects:</p> <p>AO6.2 Development is undertaken outside of the HES wetland and buffer, so as to minimise the extent of vegetation clearing required.</p>				
<p>SO7 Development avoids land degradation in a Great Barrier Reef wetland protection area, including:</p> <ul style="list-style-type: none"> <li>• mass movement, gully erosion, rill erosion, sheet erosion, tunnel erosion, stream bank erosion, wind erosion, or scalding</li> <li>• loss or modification of chemical, physical or biological properties or functions of soils.</li> </ul>	<p>To avoid adverse effects:</p> <p>AO7.1 Development in the Great Barrier Reef wetland protection area does not occur on landforms that are particularly vulnerable to soil loss, such as steep slopes.</p> <p>To minimise adverse effects:</p> <p>AO7.2 Mechanical clearing of vegetation within a Great Barrier Reef wetland protection area is located outside of the HES wetland and buffer, and occurs only in accordance with the following:</p>				
	Soil stability class	South-east Queensland bioregion	Coastal bioregions	Western bioregions	Brigalow Belt & New England Tablelands
		On a slope less than—			
	Very stable	15 %	-	-	15 %
	Stable	12 %	32 %	10 %	12 %
	Unstable	8 %	10 %	3 %	8 %
	Very unstable	5 %	1 %	1 %	5 %

Specific outcomes (SO)	Acceptable outcomes (AO)
<b>Ecological corridors</b>	
<p>SO8 Existing ecological corridors are protected or enhanced and have dimensions and characteristics that will:</p> <ul style="list-style-type: none"> <li>• effectively link habitats on and/or adjacent to the site</li> <li>• facilitate the effective movement of terrestrial and aquatic fauna accessing and/or using the site as habitat.</li> </ul>	<p><b>To avoid adverse effects:</b></p> <p>AO8.1 Development does not occur within an existing ecological corridor.</p> <p><b>To minimise adverse effects:</b></p> <p>AO8.2 If an ecological corridor is required to facilitate fauna movement, access or use of the HES wetland, the ecological corridor has a minimum width of 100 metres, and is provided and maintained in accordance with the Wetland Rehabilitation Guidelines for the Great Barrier Reef Catchment (2008) or other relevant guidelines.</p> <p>OR</p> <p>AO8.3 The width of the ecological corridor is sufficient to facilitate fauna movement, access or use of the HES wetland and is provided and maintained in accordance with the Wetland Rehabilitation Guidelines for the Great Barrier Reef Catchment (2008), or other relevant guidelines.<sup>15</sup></p> <p>AND</p> <p>AO8.4 Unimpeded movement of fauna associated with and/or likely to use the HES wetland as part of their normal life cycle is facilitated within and through the Great Barrier Reef wetland protection area, particularly along identified ecological corridors by:</p> <ul style="list-style-type: none"> <li>• ensuring that development (e.g. roads, pedestrian access, in-stream structures, etc), both during construction and operation, does not create barriers to the movement of fauna along or within ecological corridors; and</li> <li>• providing wildlife movement infrastructure where necessary and directing fauna to locations where wildlife movement infrastructure has been provided to enable fauna to safely negotiate a development area; and</li> <li>• separating fauna from potential hazards (e.g. through fencing).</li> </ul>
<b>Pest and invasive species</b>	
<p>SO9 Development does not result in pest management impacts that pose a risk to the ecological values and processes of a HES wetland.</p>	<p><b>To avoid adverse effects:</b></p> <p>AO9.1 Development does not result in the introduction of any non-native fauna or pest species.</p> <p><b>To minimise adverse effects:</b></p> <p>AO9.2 Exclusion fencing is provided in appropriate locations to manage the threat of pest species to the HES wetland, and to prevent stock from carrying weeds/exotics into the HES wetland</p> <p>AND</p> <p>AO9.3 The exclusion fencing does not result in a barrier or hazard to the movement of wetland fauna.</p>



Specific outcomes (SO)	Acceptable outcomes (AO)
<b>Noise, light and visual disturbance</b>	
<p>SO10 During construction and operation of development wetland fauna values are protected from impacts associated with noise, light or visual disturbance.</p>	<p><b>To avoid adverse effects:</b></p> <p>AO10.1 Development does not result in any measurable impact on wetland fauna values from noise, light or visual disturbance during construction or operation.</p> <p><b>To minimise adverse effects:</b></p> <p>AO10.2 Lighting is managed to ensure it does not have an adverse effect on the wetland fauna values of a HES wetland, in accordance with expert ecological advice.</p> <p>AND</p> <p>AO10.3 Noise is managed to ensure it does not have an adverse effect on the wetland fauna values of a HES wetland, in accordance with expert ecological advice.</p> <p>AND</p> <p>AO10.4 Visual disturbance is controlled to ensure it does not have an adverse effect on the wetland fauna values of a HES wetland, in accordance with expert ecological advice. Visual disturbance may be controlled through exclusion of activities in certain areas (e.g. line of sight buffers, exclusion fencing, etc), and the use of visual screens or similar during sensitive periods, such as breeding periods and roosting periods.</p>
<b>Operational management, maintenance and monitoring issues</b>	
<p>SO11 Ongoing management, maintenance and monitoring is undertaken to ensure adverse effects on hydrology, water quality and ecological processes of a HES wetland are avoided or minimised during construction and operation of the development.</p>	<p><b>To avoid or minimise adverse effects:</b></p> <p>AO11.1 Construction and operations related to the development are carried out in accordance with an operational management plan where appropriate. The plan can form an amendment to an existing approved management plan for the site.</p> <p>AND</p> <p>AO11.2A Performance bond and agreement is lodged, where appropriate, with the concurrence agency or alternative assessment manager to ensure the approved management, maintenance or monitoring program is implemented.</p>
<b>Environmental offsets in urban areas</b>	
<p>SO12 For development in an urban area where it is not possible to avoid adverse effects on HES wetlands, development:</p> <p>a) minimises adverse effects and;</p> <p>b) an environmental offset<sup>16</sup> is provided for any remaining environmental impacts on the HES wetland.</p>	
<p><b>Note:</b> An environmental offset to compensate the loss of environmental values caused by the development is consistent with the policy principle of the Qld Government Environmental Offsets Policy 2008 and corresponding specific issue offsets policy.</p>	

## ATTACHMENT B: Regional Management Code for Bioregions, Part P, AS P.4—S

Part P: Requirements for clearing for public safety and infrastructure

- a) Public safety and infrastructure includes clearing that is:
- b) for establishing a necessary fence, firebreak, road or vehicular track, or for constructing necessary built infrastructure, if there is no suitable alternative site for the fence, firebreak, road, track or infrastructure; or
- c) a natural and ordinary consequence of other assessable development for which a development approval as defined under the Integrated Planning Act 1997 (IPA) was given, or a development application as defined under IPA was made, before 16 May 2003; or to ensure public safety.

<b>Performance requirement</b>	
<b>PR P.1: Limits to clearing for public safety and infrastructure</b>	
To regulate the clearing of vegetation in a way that conserves remnant vegetation that are regional ecosystems, does not cause land degradation, prevents the loss of biodiversity and maintains ecological processes—subject to the limitations required to meet PR P.2 to PR P.10—clearing is limited to the extent that is necessary—	
<ul style="list-style-type: none"> <li>a) for establishing a necessary fence, firebreak, road or vehicular track, or for constructing necessary built infrastructure, if there is no suitable alternative site for the fence, firebreak, road, track or infrastructure; or</li> <li>b) as a natural and ordinary consequence of other assessable development for which a development approval as defined under the IPA was given, or a development application as defined under IPA was made, before 16 May 2003; or</li> <li>c) to ensure public safety.</li> </ul>	
<b>Performance requirement</b>	<b>Acceptable solution</b> <i>(applicants can propose an alternative solution to meet the performance requirement)</i>
<b>PR P.2: Wetlands</b>	<b>AS P.2</b>
To regulate the clearing of vegetation in a way that prevents the loss of biodiversity and maintains ecological processes—assessable vegetation associated with any natural significant wetland and/or natural wetland is protected to maintain—	P.2.1 Clearing does not occur—
<ul style="list-style-type: none"> <li>a) water quality by filtering sediments, nutrients and other pollutants; and</li> <li>b) aquatic habitat; and</li> <li>c) terrestrial habitat.</li> </ul>	<ul style="list-style-type: none"> <li>a) in any natural wetland; and</li> <li>b) within 100 metres from any natural wetland; and</li> <li>c) in any natural significant wetland; and</li> <li>d) within 200 metres from any natural significant wetland.</li> </ul>
	AND
	P.2.2
	Where clearing is for a significant community project, maintain the current extent of assessable vegetation associated with any natural significant wetland and/or natural wetland to provide—
	<ul style="list-style-type: none"> <li>a) water quality by filtering sediments, nutrients and</li> <li>b) aquatic habitat; and</li> <li>c) terrestrial habitat.</li> </ul>

<p><b>PR P.3: Watercourses</b></p> <p>To regulate the clearing of vegetation in a way that does not cause land degradation, prevents the loss of biodiversity and maintains ecological processes— assessable vegetation associated with any watercourse is protected to maintain—</p> <ul style="list-style-type: none"> <li>a) bank stability by protecting against bank erosion; and</li> <li>b) water quality by filtering sediments, nutrients and other pollutants; and</li> <li>c) aquatic habitat; and</li> <li>d) terrestrial habitat.</li> </ul>	<p><b>AS P.3</b></p> <p>P.3.1 Clearing does not occur—</p> <ul style="list-style-type: none"> <li>a) in any watercourse; and</li> <li>b) within the relevant distance stipulated in Table 1, of each high bank of each watercourse.</li> </ul> <p>AND</p> <p>P.3.2 Where clearing is for a significant community project, maintain the current extent of assessable vegetation associated with any watercourse to provide—</p> <ul style="list-style-type: none"> <li>a) bank stability by protecting against bank erosion; and</li> <li>b) water quality by filtering sediments, nutrients and other pollutants; and</li> <li>c) aquatic habitat; and</li> <li>d) terrestrial habitat.</li> </ul>
<p><b>PR P.4: Connectivity</b></p> <p>To regulate the clearing of vegetation in a way that prevents the loss of biodiversity and maintains ecological processes—areas of mapped remnant vegetation are retained that are—</p> <ul style="list-style-type: none"> <li>a) of sufficient size and configured in a way to maintain ecosystem functioning; and</li> <li>b) of sufficient size and configured in a way to remain in the landscape in spite of any threatening processes; and</li> <li>c) located on the lot(s) that are the subject of the application to maintain connectivity to mapped remnant vegetation on adjacent properties.</li> </ul>	<p><b>AS P.4</b></p> <p>P.4.1 Where clearing is less than—</p> <ul style="list-style-type: none"> <li>a) 10 metres wide; or</li> <li>b) 2 hectares;</li> </ul> <p>clearing does not—</p> <ul style="list-style-type: none"> <li>i) reduce the width of mapped remnant vegetation to less than 200 metres; and</li> <li>ii) occur where the width of mapped remnant vegetation is less than 200 metres;</li> </ul> <p>AND</p> <p>P.4.2 Clearing does not—</p> <ul style="list-style-type: none"> <li>a) reduce areas of contiguous mapped remnant vegetation to less than 10 hectares; and</li> <li>b) occur in areas of contiguous mapped remnant vegetation that are less than 10 hectares; and</li> <li>c) reduce the width of mapped remnant vegetation to less than 200 metres; and</li> <li>d) occur where the width of mapped remnant vegetation is less than 200 metres; and</li> <li>e) reduce the total extent of mapped remnant vegetation to less than 30%; and</li> <li>f) occur where the total extent of mapped</li> </ul>



	<p>remnant vegetation is less than 30%.</p> <p>AND</p> <p>P.4.3 Where clearing is for a significant community project, maintain the current extent of mapped remnant vegetation where the vegetation is—</p> <ul style="list-style-type: none"> <li>a) of sufficient size and configured in a way to maintain ecosystem functioning; and</li> <li>b) of sufficient size and configured in a way to remain in the landscape in spite of any threatening processes; and</li> <li>c) located on the lot(s) that are the subject of the application to maintain connectivity to mapped remnant vegetation on adjacent properties.</li> </ul>
<p><b>PR P.5: Soil erosion</b></p> <p>To regulate the clearing of vegetation in a way that does not cause land degradation and maintains ecological processes—the effect of clearing does not result in—</p> <ul style="list-style-type: none"> <li>a) mass movement, gully erosion, rill erosion, sheet erosion, tunnel erosion, stream bank erosion, wind erosion, or scalding; and</li> <li>b) any associated loss of chemical, physical or biological fertility—including, but not limited to water holding capacity, soil structure, organic matter, soil biology, and nutrients, within and/or outside the lot(s) that are the subject of the application.</li> </ul>	<p><b>AS P.5</b></p> <p>P.5.1 Mechanical clearing only occurs on—</p> <ul style="list-style-type: none"> <li>a) stable soils on a slope less than 30%; and</li> <li>b) unstable soils on a slope less than 10%; and</li> <li>c) very unstable soils on a slope less than 1%.</li> </ul>
<p><b>PR P.6: Salinity</b></p> <p>To regulate the clearing of vegetation in a way that does not cause land degradation and maintains ecological processes—clearing does not contribute to—</p> <ul style="list-style-type: none"> <li>a) waterlogging; or</li> <li>b) the salinisation of groundwater, surface water or soil.</li> </ul>	<p><b>AS P.6</b></p> <p>P.6.1 Where clearing is less than—</p> <ul style="list-style-type: none"> <li>a) 2 hectares; or</li> <li>b) 10 metres wide;</li> </ul> <p>clearing does not occur in any discharge area.</p> <p>AND</p> <p>P.6.2 Where clearing is less than—</p> <ul style="list-style-type: none"> <li>a) 5 hectares; or</li> <li>b) 50 metres wide—</li> </ul> <p>clearing does not occur—</p> <ul style="list-style-type: none"> <li>i) in any discharge area; and</li> <li>ii) within 200 metres of any discharge area.</li> </ul>

	<p>AND</p> <p>P.6.3 Clearing does not occur in areas greater than 5 hectares</p>
<p><b>PR P.7: Conserving remnant vegetation that are <i>endangered</i> regional ecosystems and of concern regional ecosystems</b></p> <p>To regulate the clearing of vegetation in a way that conserves remnant vegetation that are <i>endangered</i> regional ecosystems and <i>of concern</i> regional ecosystems—maintain the current extent of <i>endangered</i> regional ecosystems and <i>of concern</i> regional ecosystems.</p>	<p><b>AS P.7</b></p> <p>P.7.1 Clearing—</p> <ul style="list-style-type: none"> <li>a) does not occur in an <i>endangered</i> regional ecosystem or an <i>of concern</i> regional ecosystem that is listed in Table 2; and</li> <li>b) in an <i>endangered</i> regional ecosystem or an <i>of concern</i> regional ecosystem that is not listed in Table 2 only occurs where the clearing is less than 10 metres wide or 0.5 hectares.</li> </ul>
<p><b>PR P.8: Essential habitat</b></p> <p>To regulate the clearing of vegetation in a way that prevents the loss of biodiversity—maintain the current extent of essential habitat.</p>	<p><b>AS P.8</b></p> <p>P.8.1 Clearing does not occur in an area shown as essential habitat on the essential habitat map.</p>
<p><b>PR P.9: Conservation status thresholds</b></p> <p>To regulate the clearing of vegetation in a way that conserves remnant vegetation that are regional ecosystems and prevents the loss of biodiversity—maintain the current extent of regional ecosystems listed in Table 3.</p>	<p><b>AS P.9</b></p> <p>P.9.1 Clearing in a regional ecosystem listed in Table 3, does not occur unless the clearing is less than—</p> <ul style="list-style-type: none"> <li>a) 10 metres wide; or</li> <li>b) 2 hectares.</li> </ul>
<p><b>PR P.10: Acid sulfate soils</b></p> <p>To regulate the clearing of vegetation in a way that does not cause land degradation and maintains ecological processes—clearing activities do not result in disturbance of acid sulfate soils or changes to the hydrology of the location that will either—</p> <ul style="list-style-type: none"> <li>a) aerate horizons containing iron sulfides; or</li> <li>b) mobilise acid and/or metals.</li> </ul>	<p><b>AS P.10</b></p> <p>P.10.1 Clearing in land zone 1, land zone 2 or land zone 3 in areas below 5 metre Australian Height Datum—</p> <ul style="list-style-type: none"> <li>a) is carried out in accordance with an acid sulfate soils environmental management plan as outlined in the <i>State Planning Policy 2/02 Guideline: Planning and Managing Development involving Acid Sulfate Soils</i>; and</li> <li>b) follows management principles in accordance with the Soil Management Guidelines in the <i>Queensland Acid Sulfate Soil Technical Manual</i>.</li> </ul>

### **ATTACHMENT C: Great Barrier Reef Marine Park Regulations**

#### **Division 2A.4 Consideration of applications**

##### **88Q Consideration of applications — mandatory considerations**

In deciding whether or not to grant a permission in relation to an application, and whether or not to impose any conditions on the permission, the Authority must consider the following:

- (a) the potential impacts of the conduct proposed to be permitted by the permission (the proposed conduct) on the environment and on the social, cultural and heritage values of the Marine Park or a part of the Marine Park;
- (b) options for monitoring, managing and mitigating the potential impacts of the proposed conduct;
- (c) if the proposed conduct will take place in an area to which a zoning plan applies — the objectives of the zone as set out in the zoning plan;
- (d) if the proposed conduct also requires an approval or permit under the Environment Protection and Biodiversity Conservation Act 1999:
  - (i) whether the approval or permit has been, or is likely to be, granted and, if granted, the terms and conditions of it being granted; and
  - (ii) any relevant assessment documentation (within the meaning given by subsection 133 (8) of that Act) in relation to the approval or permit;
- (e) any written comments received about the application in response to the public advertisement published in accordance with regulation 88D;
- (f) any other matters relevant to the orderly and proper management of the Marine Park.

Note Subsection 7 (3) of the Great Barrier Reef Marine Park Act 1975 provides that the Authority must, in managing the Marine Park and performing its other functions, have regard to, and seek to act in a way that is consistent with, the objects of the Act, the principles of ecologically sustainable use and the protection of the world heritage values of the Great Barrier Reef World Heritage Area.

##### **88R Consideration of applications — discretionary considerations**

In deciding whether or not to grant a permission in relation to an application, and whether or not to impose any conditions on the permission, the Authority may consider the following:

- (a) the requirement in section 37AA of the Act for users of the Marine Park to take all reasonable steps to prevent or minimise harm to the environment in the Marine Park that might or will be caused by the user's use or entry;
- (b) the effect that the grant of the permission will have on public appreciation, understanding and enjoyment of the Marine Park;
- (c) the impact of the conduct proposed to be permitted under the permission in the context of other conduct in the relevant area or nearby areas, or in the Marine Park, that is being undertaken, is planned,

is in progress, or is reasonably foreseeable at the time of the Authority's consideration of the application, whether or not related to or a consequence of the proposed conduct;

- (d) any policies or guidelines issued by the Authority about the management of the Marine Park or the performance of the Authority's functions under the Act and these Regulations;
- (e) if the application for the permission relates to an undeveloped project the cost of which will be large — the capacity of the applicant to satisfactorily develop and manage the project;
- (f) if the proposed conduct also requires an approval or a permission under a law of Queensland — whether the approval or permission has been, or is likely to be, granted and, if granted, the terms and conditions of it being granted; and
- (g) any international Convention to which Australia is a signatory, or any agreement between the Commonwealth and a State or Territory, that is relevant to the application;
- (h) any relevant law of the Commonwealth, or a relevant law of Queensland as in force from time to time, or a relevant plan made under such a law, relating to the management of the environment, or an area in the Marine Park;
- (i) any relevant recovery plan, wildlife conservation plan, threat abatement plan or approved conservation advice, under the Environment Protection and Biodiversity Conservation Act 1999;
- (j) whether the applicant for the permission is a suitable person to hold such a permission, having regard to:
  - (i) the applicant's history in relation to environmental matters; and
  - (ii) if the applicant is a body corporate — the history of its executive officers in relation to environmental matters; and
  - (iii) if the applicant is a company that is a subsidiary of another company (the parent body) — the history of the parent body and its executive officers in relation to environmental matters; and
  - (iv) any charge, collected amount or penalty amount that is overdue for payment by the applicant as the holder of a chargeable permission (whether or not the permission is in force); and
  - (v) any late payment penalty that is payable by the applicant as the holder of a chargeable permission (whether or not the permission is in force); and
  - (vi) any unpaid fines or civil penalties required to be paid by the applicant in relation to a contravention of the Act or of these Regulations;
- (k) any other matters relevant to achieving the objects of the Act.

## Attachment D: Great Barrier Reef Marine Park environmental impact management tools

Table 1: Indicative level of environmental impact management tools

Assessment	Monitoring	Environmental Management Plan	Deed	Bond
Level 1	Compliance	No*	No	No
Level 2	Site Inspection	No	Yes (standard)	~\$50,000
Level 3	Site Inspection + Issue Based	Yes + Advisory Committee	Yes (standard)	~\$250,000
Level 4	Site Inspection + Issue Based + Reactive + Monitoring Consultant	Yes + Advisory Committee + Environmental Site Supervisor	Yes (specific)	~\$500,000+

Table 2: Examples of assessment levels of projects (these examples are for guidance only and are not binding on a GBRMPA delegate)

<p><b>Level 1</b> Minor Project Minimal and/or transient impact Example – small navigation marker</p>
<p><b>Level 2</b> Small project Low and/or short-term impact Example – Jetty or Pontoon (less than 15m long), small boat ramp (1 or 2 lane ramp or widen existing ramp by up to 2 lanes).</p>
<p><b>Level 3</b> Medium scale project Public interest , sensitive environment, Moderate and/or medium term impact Example – spoil disposal from maintenance dredging associated with ports</p>
<p><b>Level 4</b> Complex or large scale project Public interest, irreversible and/or major impact Example – Large marina development (over 30 berths), large capital dredge and spoil disposal</p>

### **ATTACHMENT E: Significant impact criteria**

#### **Listed threatened species and ecological communities**

##### *Extinct in the wild species*

An action is likely to have a significant impact on extinct in the wild species if there is a real chance or possibility that it will:

- Adversely affect a captive or propagated population or one recently introduced/reintroduced to the wild, or
- Interfere with the recovery of the species or its reintroduction into the wild.

##### *Critically endangered and endangered species*

An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:

- Lead to a long-term decrease in the size of a population
- Reduce the area of occupancy of the species
- Fragment an existing population into two or more populations
- Adversely affect habitat critical to the survival of a species
- Disrupt the breeding cycle of a population
- Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
- Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat
- Introduce disease that may cause the species to decline, or
- Interfere with the recovery of the species.

##### *Vulnerable species*

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

- Lead to a long-term decrease in the size of an important population of a species
- Reduce the area of occupancy of an important population
- Fragment an existing important population into two or more populations
- Adversely affect habitat critical to the survival of a species
- Disrupt the breeding cycle of an important population
- Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
- Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
- Introduce disease that may cause the species to decline, or
- Interfere substantially with the recovery of the species.

##### Critically endangered and endangered ecological communities

An action is likely to have a significant impact on a critically endangered or endangered ecological community if there is a real chance or possibility that it will:

- Reduce the extent of an ecological community

- Fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines
- Adversely affect habitat critical to the survival of an ecological community
- Modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns
- Cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting
- Cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to:
  - assisting invasive species, that are harmful to the listed ecological community, to become established, or
  - causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community, or
- Interfere with the recovery of an ecological community.

### Listed migratory species

An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:

- Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species
- Result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or
- Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

### World Heritage Properties

An action is likely to have a significant impact on the World Heritage values of a declared World Heritage property if there is a real chance or possibility that it will cause:

- One or more of the World Heritage values to be lost
- One or more of the World Heritage values to be degraded or damaged, or
- One or more of the World Heritage values to be notably altered, modified, obscured or diminished.

### National Heritage Places

An action is likely to have a significant impact on the National Heritage values of a National Heritage place if there is a real chance or possibility that it will cause:

- One or more of the National Heritage values to be lost
- One or more of the National Heritage values to be degraded or damaged, or
- One or more of the National Heritage values to be notably altered, modified, obscured or diminished.

### Great Barrier Reef Marine Park



An action is likely to have a significant impact on the environment of the Great Barrier Reef Marine Park if there is a real chance or possibility that the action will:

- Modify, destroy, fragment, isolate or disturb an important, substantial, sensitive or vulnerable area of habitat or ecosystem component such that an adverse impact on marine ecosystem health, functioning or integrity in the Great Barrier Reef Marine Park results
- Have a substantial adverse effect on a population of a species or cetacean including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution
- Result in a substantial change in air quality or water quality (including temperature) which may adversely impact on biodiversity, ecological health or integrity or social amenity or human health
- Result in a known or potential pest species being introduced or becoming established in the Great Barrier Reef Marine Park
- Result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, or social amenity or human health may be adversely affected, or
- Have a substantial adverse impact on heritage values of the Great Barrier Reef Marine Park, including damage or destruction of an historic shipwreck.