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Final Report

project

Improving lobster grow-out and nutrition in Nusa Tenggara Barat – a feasibility study

ACIAR-SADI research report

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Australia Indonesia Partnership
Kemitraan Australia Indonesia

ACIAR's participation in the Australia–Indonesian Partnership

The Australia–Indonesia Partnership (AIP) supports Indonesia's reconstruction and development efforts, both in and beyond tsunami-affected areas. Assistance will involve long-term sustained cooperation focused on economic and social development.

As part of the AIP, the Smallholder Agribusiness Development Initiative (SADI) aims to improve incomes and productivity for farmers and agribusiness, in response to market opportunities, in four eastern provinces—East Nusa Tenggara, West Nusa Tenggara, South East Sulawesi and South Sulawesi.

ACIAR's commitment to SADI focuses on supporting market-driven adaptive research, improving the transfer of knowledge and developing the capacity of key institutional stakeholders. This commitment will overcome constraints and barriers that prevent smallholders and agribusinesses successfully engaging with the market.

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Foreword

The Australia-Indonesia Partnership (AIP), comprising $500 million in grants and $500 million in highly concessional loans over five years, was announced in January 2005. The partnership supports Indonesia's reconstruction and development efforts, both in and beyond tsunami-affected areas. Assistance involves long-term sustained cooperation focused on economic and social development projects and Indonesia's programs of reform and democratisation.

ACIAR is committed to the partnership through the management of a component of the Smallholder Agribusiness Development Initiative (SADI), which aims to improve rural sector productivity and growth in four Eastern provinces—East Nusa Tenggara, West Nusa Tenggara, South East Sulawesi and South Sulawesi.

This initiative will improve incomes and productivity for farmers and agribusiness in response to market opportunities, through a process that is underpinned by improved adaptive research and development capacity.

ACIAR's role in the initiative is to strengthen province-based agricultural research and development capacity that is market and client-driven and effectively transfers improved knowledge to end-users. A key part of this approach is delivered through market driven adaptive projects which are priorities for smallholders, farmer groups, agribusiness, government and other supporting agencies.

This report forms part of ACIAR's contribution to the Australia-Indonesia Partnership, through an in-depth analysis of an important smallholder industry sector within Eastern Indonesia. The report makes recommendations to support the future development of the industry within the framework of the Smallholder Agribusiness Development Initiative and will be used extensively in ACIAR's future commitment to the Australia-Indonesia Partnership.

I trust this report is able to make a value contribution to this important partnership.

Peter Core
Chief Executive Officer

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1 Acknowledgments

The project team would like to thank the community groups and exporters who made a significant contribution, through their industry insights, to the feasibility study and this report.

2 Executive summary

This report is a result of a rapid assessment of the lobster aquaculture industry of Nusa Tenggarra Barat (NTB).

Three villages were visited in NTB at which lobster aquaculture has been established. Development of the industry has arisen as a by-product of grouper and seaweed culture which both involve floating rafts (Figure 1), moored in protected coastal areas. Juvenile lobsters were settling on the floats and cages of the existing aquaculture facilities, and were captured and cultured to a marketable size. This development began in 2000 and has now expanded to encompass several villages and around 100 cages.

Two species are cultured, the sand lobster, *Panulirus homarus* known locally as pasir, and the pearl lobster, *P. ornatus* known locally as mutiara. The relative abundance of the seed captured dictates the proportion of each species produced, and is in the order of 3 to 1 in favour of *P. homarus*. Both species are highly marketable, although the price currently received for *P. ornatus* is lower than it may otherwise be because harvest size is relatively small (<500g). *P. homarus* at a harvest size of 200 to 300g receives a price of Rp150,000 per kg to the farmer, while *P. ornatus* fetches Rp130,000 per kg.

The cage specifications and method of culture are simple and effective (Figure 1), and very similar to that of Vietnam where a very successful lobster aquaculture industry is well established. Cages are made from synthetic mesh (fish net) of mesh size up to 15mm, in cubic shape from 3.5m^3 to 64m^3 and suspended from a floating frame supported on plastic or steel drum floats.

Figure 1: Floating rafts for lobster culture

Lobster seed collected includes both the swimming post-larval stage known as the puerulus, and more advanced juveniles which are found attached to substrates. Both were

initially collected as by-product from other fishing activity, but are increasingly targeted with specific apparatus and techniques to maximise catch. Methods include use of fish traps, shelter traps, netting and manual collection from existing cage structures. Number of seed collected across the entire industry is unknown but not likely to exceed 250,000. Given the small scale of the industry, limited capture effort applied and extent of the coastline, the capacity to increase the seed catch is significant.

Pueruli are stocked to smaller cages with finer mesh net, and cultured for about 2 to 4 weeks until the lobsters are pigmented and around 2cm in total length. Survival through this phase is low, less than 50% attributed primarily to cannibalism. Juveniles are cultured in larger cages at densities of up to 20 per m^3 until they reach around 100g. A final growout phase at densities of up to 10 per m^3 is managed until lobsters reach market size. Overall survival from seed to market size is around 20 to 40%.

Lobsters are fed trash fish which is a by-product of normal fishing activities. The fish is roughly chopped and fed fresh to the lobsters each morning after the fishing catch has been sorted. The nature of fishing results in the trash fish consisting almost entirely of small fish species with very little of mollusc or crustacean species. This may be impacting negatively on growth rate and shell colour of the harvested lobsters.

Marketable lobsters are sold to middlemen who transport them in small quantities (20 to 50kg) from the village to Mataram and then onto exporters in Bali. Price paid to farmers is around Rp150,000 for 250-300g *P. homarus* and Rp130,000 for 300g to 500g *P. ornatus*.

Exporters pay a lower price for farmed lobster than for wild caught. This is primarily because supply volume is small and inconsistent, and farmed lobsters are considered to be pale in colour and of weak vigour, which impacts significantly on their suitability for live transport to markets in Taiwan and China. Market demand for lobster is significant and increasing. Prices paid to exporters are very attractive; for *P. ornatus* over Rp350,000 per kg (for large lobsters above 1kg) and for *P. homarus* Rp250,000 to 300,000. Slipper lobsters, and particularly *Scyllarides squammosus*, also fetch high export price. Exporters would readily accept increased supply of aquacultured lobsters of the high value species.

NTB is advantaged in having already established a small lobster aquaculture industry, in having a long coastline with many suitable sites adjacent to existing villages, and in having identified a source of lobster seed that has capacity for expansion.

Primary constraints to expansion of the industry are lack of seed supply and knowledge of best practice farming methods. There is great interest in hatchery technology to supply the seed, although for spiny lobsters this may never be economic because of the prolonged larval life. The prospect of hatchery supplied seed for alternative lobsters species, such as slipper lobster, may be an appropriate alternative strategy to support the development of the industry.

Figure 2: Lombok Island in Nusa Tenggarra Barat (NTB), showing location of villages in the southeast, where lobster aquaculture is developed, and the Marine Aquaculture Development Centre (MADC) in the southwest.

3 Introduction

The concept benefits from a current ACIAR project 'Sustainable tropical spiny lobster aquaculture in Vietnam and Australia (FIS/2001/058), which seeks to improve the efficacy and sustainability of a relatively new lobster aquaculture industry in central south Vietnam. This industry in Vietnam now generates in excess of 2,000 tonnes of lobster per annum, and provides a useful model for Indonesia.

The global demand for lobster is growing by approximately 15% p.a. The increased demand is being driven by the international market, particularly China, which for Indonesia is being serviced by trading locations in Bali and Surabaya. This demand is most significant for the tropical rock lobster, *Panulirus ornatus*, known in Indonesia as Pearl lobster, and this species is also the basis of the successful lobster aquaculture industry of Vietnam.

The proximity to high value markets and trading areas, clean ocean resources that are available and skilled human resources are part of the comparative advantage of NTB. In addition, it is possible, depending on coastal conditions, lobster production cages will not require major capital investment, increasing the accessibility of lobster production to the smallholder.

Culture Species and Species for export

The lobsters which are common for culture are lobster pasir (sand lobster or *Panulirus polyphagus*) and lobster mutiara (pearl lobster, *P. ornatus*). Sand lobster is a dominant species and its population 3 to 9 times greater than pearl lobster. Since the exporters collected the lobster both from culture and the wild, there are 8 species of lobster are identified for export, including Lobster Pasir (*P. polyphagus*), Lobster Mutiara (*P. ornatus*), Lobster Pakistan, Lobster Kipas (Slipper lobster) Merah, Lobster Kipas Orange, Lobster Kipas Hitam, Lobster Bambu, and Lobster Batu (*P. versicolor*).

Locations

Lobster culture sites are mostly found in East Lombok and Mid Lombok Districts. Villages of Batu Nampar and Teelong Elong in East Lombok District and Village of Grupuk in Mid Lombok District are the most common villages where the lobster seed collection and its

grow out are located. There are 634 lobster floating cages in East Lombok District where 200 cages of which are located in Teelong Elong and 30 cages of which in Batu Nampar. There are 64 lobster cages which are operated in Grupuk Village. Oceanographical condition where the water current from north of Alas Strait bring the larval stage and young lobster to the area might explain the abundance of lobster seeds.

Seed

Seeds are collected from the waters close to where the floating cages for lobster are located. Seed are collected by several means. The puerulus stage of lobsters which are still transparent are mostly collected from shelters made of netting, which is hung onto the raft. Bagan-light fishing is also common for catching the puerulus stage lobster. Up to ten seeds might be collected from the shelters, and 20 to 100 seeds from bagan per night. The fingerlings (6-8 cm seeds) are caught by bagan- traditional light fishing, karakad oros - beach seines, and divers. In Teelong Elong Village, the farmers mostly collect the seeds which are frequently found attached to the raft floats or the cage nets. According to farmers, November is a good season for puerulus or young seed of lobster and May or June good season for young lobster (6-8 cm each)..

The price of puerulus seed is Rp 1500 each, and that of 2-3 cm seed is Rp 2500 and of 6-8 cm seed is Rp 5000 each while the young lobster (25 g) is Rp 7000 each. Puerulus and young seeds are packed in plastic bag with water and oxygen for transportation whilst young lobsters are transported by dry method.

The constraints in seed production are:

- High mortality rates both for the puerulus and young seed reared in the cages
- Low production of seed caught from the wild.

Grow-out

Floating net cages are the only common method used for growing out. One unit rafts usually has 4 cages of 2m x 2m x 2m or 3m x 3m x 3m. The bagan-traditional fishing light is commonly set near the cages. The function of bagan is for collecting fish as feed and trading. The density of lobster in 3m x3m x 3m cages is 600 lobsters. Low economical value fish are used as feed. Food Conversion Ratio is 12 to 1, but survival rate is still low or up to 60%. It takes one year to grow sand lobster (*P. polyphagus*) from 2 cm seed until 150 gr, but take only 8 – 9 months for 2 cm pearl lobster (*P. ornatus*) to grow until that size. The cost of bagan constuction is Rp 10 million and that one raft with four cages including seeds is Rp 3.8 million.

Constraints in lobster grow out period are:

- Low survival rate
- Feed depends on low value fish which is seasonal.

Marketing

Lobsters harvested from the cages are put in water of 21°C in tank for about 2 hours before dry packing for delivery. Denpasar, Bali is a common destination for lobster from NTB. There are four exporters of lobster in Bali: CV Duta Bahari; Mina Sari Sedana; Mina Kencana and Pulo Mas who collect the lobsters both from culture and the wild. Each exporter holds lobster in their facilities for 1-2 days before exporting lobster in a dry method. Cooling facility are used by one exporter to keep water temperature in holding tank between 19°C and 26°C. There are 2 – 3 middlemen who get the benefit from cultured or captured lobster between farmer and exporter level.

Taiwan, China and Hong Kong are the destination for lobster exported from Denpasar, Bali. CV Duta Bahari export approximately 1- 2 ton of lobster per day.

The price of lobster is Rp 160,000 per kg for sand lobster, Rp 140,000 per kg for pearl lobster and Rp 120,000 per kg for other species. Special price of 1 – 2.5 kg Pearl Lobster is US $ 37 per kg.

Constraints in marketing of lobster are:

- Lobster collected from culture is usually weak and less coloured. This situation made the price of cultured lobster less than that from the wild
- Production of cultured lobster is still low (5 – 22 ton per month)
- Taiwan accused that Indonesian Lobster contains Nitrofurazon even though there is no evident that the drugs are used in lobster culture during this feasibility study.

4 Lobster Exports

The exporters of Bali (Figure 3) operate in the same manner as lobster exporters in Australia. They purchase live lobsters from the fishers and then pack them and send them to export markets. The bulk of their product is wild caught and is supplied from a several hundred km radius of Bali. Some product is road transported from various fishing ports around Bali, some is delivered directly by fishing boats and some air or sea (ferry) transported from further a-field. There is very little aquaculture product from NTB, and it is seasonal. Because the price received by the exporters falls during the period when Australia supplies the market (March through September), the NTB farmers tend to hold back product until after this period.

Considerable export of lobsters also occurs from Surabaya and possibly other locations. Capacity and volumes sold from these other destinations were not determined.

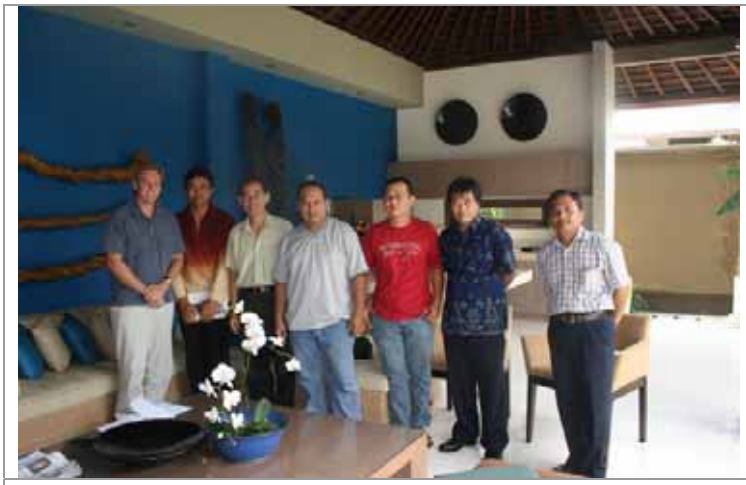

Figure 3: Lobster exporters in Bali

4.1 Lobster species exported

Species marketed include all those endemic to the Indonesian archipelago (Table 1) encompass both spiny and slipper lobsters.

Table 1: Species marketed, endemic to the Indonesian archipelago

Indonesian name	Common name	Generic name
Spiny Lobster		
Mutiara	Pearl lobster	*Panulirus ornatus*
Pasir	Sand lobster	*P. homarus*
Batik	Red lobster	*P. longipes femoristriga*
Pakistani		*P. polyphagus*
Bamboo		*P. versicolor*
Batu	Black lobster	*P. penicillatus*
Kipas	**Slipper lobsters**	
Kipas Mera	Red slipper lobster	*Scyllarides squammosus*
Kipas Hitam	Black slipper lobster	*Parribacus antarcticus*
Kipas Tanduk	?	*?*
Kipas	Brown slipper lobster	*Thenus spp*

The pearl lobster, *P. ornatus (Figure 4)*, is the most valuable species ($US 37 /kg), although its volume appears to be relatively small, suggesting possible over-fishing. Although it has the highest value, this only applies to lobsters over 1kg and up to 2.5 kg. Small pearl lobsters fetch a low price (< Rp200,000 /kg). The bamboo lobster (*P. versicolor*) is the second most valuable and appears to be in better supply. Sand lobsters (*P. homarus*) fetch the best price (up to Rp300,000 /kg) for small individuals (100 to 250g), but overall are the third most valuable. The others are of generally lesser value because of lower volume, lower price per kg or a combination of both. The sand lobster (Figure 7) was often referred to by the exporters as *P. polyphagus*, but close inspection has confirmed that it is *P. homarus*. Although all lobsters are sold live, *P. ornatus* is marketed as a sashimi product to be served uncooked, while bamboo and sand lobsters are sold for cooking. Sand lobsters are reputedly of excellent culinary quality, having sweet and tender flesh.

The red slipper lobster, Kipas mera, *Scyllarides squammosus* (Figure 5) is also a high value species (IDR 250,000 /kg), although its supply volume is relatively low.

Figure 4: Pearl lobster, *Panulirus ornatus*, Mutiara

Figure 5: Red slipper lobster, Kipas mera, *Scyllarides squammosus*

Figure 6: Black slipper lobster, *Parribacus antarcticus*

Figure 7: Pasir, *P. homarus*, sand lobster

Figure 8: Batik lobster, *P. longipes*

4.2 Export Markets

Export is to a number of markets, although they are all south-east Asian. It appears that Hong Kong and Taiwan are the primary market destinations, although some product is also sold directly to northern China, Singapore and Japan.

Total volumes sold were not known, but are likely to be no more than 2,500 tonnes per annum from the 5 export companies. This estimate is based on the scale and holding capacity of the facilities inspected. Each facility is of a similar specification and has a through-put of product of approximately 1.5 tonnes per day.

Exporters claim fishery supply is consistent from year to year. However, given absence of any resource management, and ready market demand for all sizes, the fishing pressure must be high, and likelihood of over-fishing extreme. This may also impact on broodstock capacity to supply seed for the aquaculture sector.

4.3 Export Holding / Packing Facilities

Facilities are relatively simple and effective in their specification. They consist of a holding building (Figure 10) furnished with concrete and fibreglass tanks (Figure 9) containing seawater with aeration. Seawater is exchanged daily at a rate of 25 to 50% with clean seawater trucked to the site. Within the building water is recirculated through simple biological trickle filters (over coral rubble) and sand filters. The capacity of the filters is unknown and likely to provide only modest removal of solid wastes and soluble nitrogenous compounds (ammonia/ammonium, nitrites and nitrates). Nevertheless, the system works and with periodic water replacement, the bulk of lobsters appear to be in healthy state. Water temperature is held at 18-19°C to cool lobsters prior to packing, reducing their metabolic rate and extending their capacity to endure the period of transport out of water. Total capacity of the facility was around 2.5 tonnes.

Figure 9: Holding tanks

Figure 10: Live lobster holding facility of Duta Bahari

Lobsters are sorted by species and sizes into separate tanks and/or containers (plastic baskets) within tanks. During this process, unhealthy, moribund and dead lobsters are separated to a reject tank, as are lobsters with heavily damaged antennae or those missing more than 3 walking legs. These rejects are sold live to local markets. Dead and moribund lobsters are frozen for later sale.

Turn around time for lobsters in the facility is a maximum of 2 days, that is every lobster will be packed and shipped (or otherwise sold) within 2 days of arrival. Lobsters of particular species and size grade are weighed in lots appropriate to the packing box (standard styrofoam fish box). For Taiwan the box holds approximately 12 to 13kg of product, while for Hong Kong and China, a 20kg box is used. Boxes are individually numbered and the details of its contents are recorded on a manifest. The lobsters are then rolled in wood shavings (to retain moisture) (Figure 11) and individually wrapped in newspaper, before placing in the box (Figure 12). To assist in maintaining a cool internal temperature in each box, frozen 500ml bottles of water are also placed in each box; two to a 12kg box and 4 to a 20kg box. Once all lobsters have been stacked in the box, its lid is secured with masking tape, and a shipping label applied. Approximately 25 people work at each facility to process up to 1.5 tonnes per day. The facilities also handle some other products including fingerling fish (milk fish) and live groupers.

Figure 11: Rolling lobsters in wood shavings

Figure 12: Export airfreight boxes. 12kg box for Taiwan (right) & 20kg box for China (left)

4.4 Lobster Supply

Most of the lobsters are supplied from the wild fishery. For the Balinese exporters, the supply primarily comes from waters within a 200km radius of Bali. Lobsters caught in local

Balinese waters are generally road transported from various ports to Denpasar. Some fishermen and/or suppliers are contracted to particular exporters, while others will supply to any on the basis of negotiated price.

Supplies from outside Bali, may be shipped by fishing boat (Figure 13), or as freight by ferry or plane. Air supplies tend to go to Surabaya for which more regular and greater capacity flights are available.

An individual lobster fishing boat was visited, which had just returned to port after 1 month fishing. It was a 15m wooden vessel with a crew of 15 men. They use hookah (compressed air supplied from surface) to dive for the lobsters in waters down to 25m depth. A noose attached to a pole is used to catch the lobsters. In this respect, the fishing method is very similar to that of the Torres Strait fishery in Australia. The vessel holds the live lobsters in its open bilge (Figure 14), in which several tonnes of water are maintained. This water is continually replaced by pumping. The capacity of the vessel is 1 tonne of lobsters. Lobsters are not sorted in any way onboard, but left to roam freely through the hold. On arrival to port, the lobsters are collected by hand and placed in 30kg styrofoam boxes (Figure 15) for road transport to the holding / packing facility (Figure 16).

Supply of aquaculture product comes primarily from NTB, but is of small and seasonal volume. It is transported by air freight to Bali, although this is expensive and of limited capacity because of the small aircraft and number of flights. From NTB, air freight may be more profitable to Surabaya which is serviced by larger planes more regularly.

There appears to be generally three steps in the supply. Fishermen or lobster farmer, one (but sometimes more) middlemen involved in supply chain through to exporter. Profit margin at each step is very low, possibly as low as $US1 per kg, according to exporters.

Figure 13: Lobster fishing boat

Figure 14: Lobsters being loaded from hold of boat

Figure 15: Transport to packing facility

Figure 16: Weighing sorted lobsters prior to packing

4.5 Other Issues

For the Taiwan market there have been recent claims that lobsters from Indonesia are contaminated with antibiotic (Nitrofurazone). Taiwanese health department has made submissions to Indonesian Department of Commerce on this issue, and this was reported in a newspaper article (Media 19/4/2007). Exporters are adamant they do not use any chemical treatments in the holding facilities. They claim there is no reason because the stock are held for a maximum of 2 days, there is a low incidence (<15%) of health issues and mortality, and when these do occur the lobsters are separated and used for supply to local markets, where they achieve higher prices than for export. It is unlikely that contamination would occur in the wild, however, the fishing boats may use antibiotic to prolong the survival of lobsters on-board.

4.6 Export development issues

- Currently very small volume of product from lobster farms (<20 tonnes per annum)
- Product is consistently pale in colour and weak in vigour, giving them comparatively low value relative to fishery caught product. Both these issues can be managed through improved husbandry and nutrition
- If supply were to increase, exporters could market year-round, although price would fluctuate in accordance with seasonal supplies from elsewhere, and particularly from Australia's wild fishery (March through September)
- *P. ornatus* would be the most attractive aquaculture species, but others (particularly bamboo, sand and red slipper lobsters) would also be attractive to exporters
- The likely over-fishing of wild stocks may have a significant impact on broodstock numbers, reproductive capacity and therefore supply of seed
- Expansion of lobster aquaculture in Indonesia is initially dependent on supply of wild caught seed, however, if hatchery supplied seed were pursued, there may be merit in examining species other than *P. ornatus* which have larval characteristics more amenable to culture. For example, *Scyllarides squammosus* (red slipper lobster) is of relatively high value, and is likely to have a significantly abbreviated larval life, as per other species of this family (Scyllaridae). The technical capacity to produce it therefore would be far less onerous and more achievable.

5 Current Lobster Aquaculture

Lobster culture in NTB was first established in 2000 as a by-product of seaweed and grouper culture which had been in operation since the 1990's. Swimming puerulus (i.e. first post-larval stage of the lobster) and juvenile lobster were often observed settling on the floats, cages and other materials associated with seaweed and grouper culture. They were captured by hand and retained in separate cages, in which they grew well, and thus was borne lobster aquaculture.

Most of the lobster aquaculture appears to occur in combination with other species, primarily grouper (*Cromileptes* spp.) and seaweed.

5.1 Cage Facilities

There was considerable variation in raft and cage specification, reflecting the novelty of the industry and its developmental stage. In many respects, the cage structures are similar to those of Vietnam.

All cages were supported on floating rafts 100m or more off the beach. The materials used varied from less sophisticated structures fabricated from bamboo to more well engineered platforms made from milled timber. Floats consisted of plastic or steel drums, and at Teelong Elong, the drums were covered in canvas, presumably to prevent corrosion. The rafts varied in dimension, and generally were in the range of 10m x 10m up to 25 x 25m. Rectangular cages were hung within the raft in a grid pattern of varying specification. Cages varied from small (1.5 x 1.5 x 1.5m) up to large (4 x 4 x 4m), depending on species (grouper or lobster) and size of stock, i.e smaller cages for juveniles and larger for growout. Cage nets used to hold the lobsters are cubic in shape, made of nylon fishing net materials generally of a fine mesh size, less than 12mm. Larger cages tend to be fabricated from larger mesh size, although none was larger than 20mm. This is in contrast with Vietnam where mesh size for lobster growout is quite large (up to 40mm).

Nearly all rafts had a hut for equipment and housing personnel working there. These varied from very flimsy thatched frames to quite elegant little rooms with proper doors and windows.

5.2 Species Cultured

The species of lobsters cultured is a direct product of the seed caught, and it appears that two lobster species are prevalent. The mutiara (*Panulirus ornatus*) and the pasir (*P. homarus*) (Figures 17 and 18). Very small numbers of bamboo *P. versicolor* and batik *P. longipes* lobsters were observed.

The species available is fortuitous, as they represent two of the more valuable lobsters for marketing. Availability of the two species was in the proportion of approximately 3 to 1, in favour of pasir. The proportion may vary from one location to another, but pasir is the more abundant throughout the areas visited.

Figure 17: Market size Pasir, P. homarus with eggs, indicating maturity

Figure 18: Pasir P. homarus at 300g

5.3 Seed Collection

There seems to be some development of a separate seed collecting sector, although presently, most seed is captured by the lobster farmers and used directly in their own growout cages. The methods vary and can be separated into those targeting the swimming puerulus stage and those for larger juveniles.

For puerulus many are collected as a by-product of a light trap used for catching fish (Figure 20). These traps, known as bagang, are common along the coastline and consist of a bamboo frame structure secured to the sea floor by posts or moorings, and supporting a rectangular net which is lowered by rope to the sea floor. They are deployed at night, and a lamp is lit over the trap to attract fish. The lamp may be powered by kerosene, oil or electricity supplied from a small petrol generator. The trap is raised 4 times through the night to retrieve fish, and puerulus are often caught as well. Many of the fish are for direct human consumption, but the trash fish are all used for feed for the lobster (and grouper) aquaculture. Now that lobster aquaculture is developing, there is more attention paid to finding puerulus within the bagang catch, although it is apparent that villagers in many areas where the bagang is used are not involved in aquaculture and not aware of the puerulus. This latent capacity could be developed very quickly.

Figure 19: Village of Batu Nampur

Figure 20: Seed collecting raft

There is also considerable use of shelter traps for swimming pueruli (Figure 21). These consist of bundles of mesh material hung into the water from the rafts, and onto which the pueruli settle. These are generally inspected every second or third day, and a raft with 25 to 50 bundles, may generate up to 100 pueruli at a time. This figure is likely to be an exception, and the average catch per retrieval is more likely around 20. A small number of pueruli are also caught as they settle on the cages and floats of the rafts. These are collected by hand has they are observed.

Figure 21: Puerulus shelter trap, suspended off raft

Availability of pueruli is seasonal and there appears to be a peak in catch rate during November and December. This is in accordance with Vietnam puerulus seasonality but in contrast with Australia for which peak recruitment occurs in July to September. This suggests that the source of seed, that is the breeding stock generating the larvae, is located north of Indonesia where summer breeding occurs around June and July.

It was apparent that catches are relatively higher over periods of new moon (i.e. dark moon), which again is in accordance with the known catch rates in Vietnam.

Juvenile lobsters are collected in much smaller numbers, but are more valuable as they are more robust and likely to survive. There doesn't appear to be any targeted catching method, and they are taken as a byproduct of other fishing activity, particularly seine netting in the shallows off the beach. Some juveniles are also observed on the floats and cages of the rafts and are collected as they're observed.

As the industry has developed, knowledge of the puerulus and juvenile stages has increased, and in some areas, the seed are collected for subsequent sale to lobster farmers. In addition, some farmers collect more than their facility can accommodate, and they on sell them to other farmers. Current price is IDR 1,500 per puerulus and up to IDR 10,000 per juvenile depending on size. It is worthy of note that current price for pueruli of *P. ornatus* in Vietnam is $US12 (IDR 120,000).

The current practices for seed collection indicate that it is sparse and not well targeted. There is significant capacity to increase seed volume available through increased effort (gear and areas) and improved techniques, through transfer of technology from Vietnam.

5.4 Growout Methods

Lobster growout appears to involve periodic grading, generally into 3 stages. A nursery phase from puerulus to 2cm juvenile, a juvenile phase from 2cm total length to 50 to 100g,

and growout phase to market size which appears to be 200 to 300g for pasir and 300 to 500g for mutiara. Pasir, *P. homarus* matures at a size of 200 to 300g, so the targeted growout size is appropriate. Growth slows significantly beyond 300g, and further growout would be unprofitable. Furthermore, pasir fetches a maximum price of around Rp150,000 per kg at 200 to 300g. In contrast, mutiara doesn't mature until a size well in excess of 1kg, at which size it will receive its maximum price. However, they are harvested at a maximum size of 500g and attract a lower price (Rp130,000 per kg) than pasir. There is clearly capacity to increase farmers income by educating them about the value in growing mutiara to 1kg plus.

The puerulus phase is characterised by its short duration 2 to 4 weeks and high mortality. There is no particular husbandry applied to this stage. The pueruli are housed in smaller cages, generally 3.5m^3, stocked at up to 100 per cage (28 per m^3), and fed finely chopped trash fish.

Juveniles are transferred to larger cages, up to 9m^3, (Figures 22 and 23) at densities of up to 20 per m^3 and fed trash fish. In turn, the larger juveniles at around 100g are transferred to larger cages for growth through to market size at densities up to 10 per m^3.

Figure 22: Simple cage raft

Figure 23: Cage rafts at village of Grupuk

Some seaweed may be placed in the cages to provide refuge (Figure 24), although it is unlikely to be very effective, and indeed may be consumed by the lobsters. Its effectiveness, if any, would be most significant for the puerulus to juvenile phase. Shading over the cages was common, provided through palm frond thatch or synthetic shadecloth material.

Figure 24: Seaweed culture at Batu Nampur

5.5 Feeding

Feeding of the lobsters is entirely with trash fish caught as a byproduct of other fishing activity (Figure 26), and particularly from the bagang (Figure 25). Although none of this material was observed directly, it is understood to consist almost entirely of small fish, and almost no mollusc or crustacean species.

Food material is very fresh, as there is no delay in its provision from catch to use. It is roughly chopped and fed each morning after the night's fishing activity is completed. Based on the broad estimates discussed, it seems likely that the food conversion ratio is around 12 to 15:1 (i.e. 12 to 15kg of trash fish to raise each kilogram of lobster).

Because relatively fine mesh netting material is used in the cages, a significant proportion of uneaten food remains in the cage, unable to fall though the mesh. In all cages observed, from 10am through 5pm, there was a large amount of waste material. This is not conducive to good hygiene or growth, and larger mesh sizes may be beneficial.

The current trash fish diet is not ideal, and there is likely to be some nutritional deficiency in the practice, as evidenced by the pale pigmentation of the grown-out lobsters. There may be opportunity to catch additional species of molluscs and crustaceans specifically to supplement the fish currently used. A more comprehensive assessment of the trash fish composition will be required, and then recommendations could be generated as to other materials that should be added to the diet. This might also include the prospect of locally manufactured diet using the trash fish and other fresh materials, along with specific essential ingredients such as binders and vitamin/mineral premix that could be transported to site.

Figure 25: Bagang, fish trap

Figure 26: Grouper culture at Grupuk

5.6 Productivity

It proved difficult to extract a clear and consistent account of survival through the various stages. Nevertheless, it is clear that mortality during the puerulus phase is very high, and is primarily attributable to cannibalism. This is in accordance with the experience in both Vietnam and Australia, and is no surprise. Survival of lobsters from puerulus to 2cm juvenile (Figure 27) is likely to be in the order of 40 to 50%. Survival through the juveniles phase (Figure 28) is likely to be in the order of 60 to 90%.

Figure 27: Small juvenile

Figure 28: Puerulus (centre) & pigmented juveniles

Although the growout phase should be the most stable, there were varying accounts of survival from the various people interviewed, from very high (>90%) to quite poor (< 50%). The proven track record of lobster growout suggests that growout survival consistently above 90% should be achievable with improved husbandry and nutrition.

Figure 29: Cage net lifted to reveal juvenile lobster

Growth rates, for 2cm juvenile to market size (Figure 30) were declared to be in the order of 6 months for pasir to 200g, and 8 months for mutiara to 350g, although with considerable variation in accounts. It was apparent that pasir initially grows faster than mutiara, perhaps through to 100g, but then the mutiara growth rate increases while that of pasir slows.

Figure 30: Market size Pasir, P. homarus ready for harvest

It is difficult to estimate overall production or yield per unit given the high variance in information concerning number of seed available, survival, growth rates, harvest size and number of cages dedicated to lobster rather than grouper. On average it seems 100kg of marketable lobsters are produced per average cage (3 x 3 x 3m) per year. The total number of cages in which lobster are grown may be in the order of 100, and so total annual production is likely to be around 10 tonnes.

6 Capacity for Research and Development

The facilities at the Marine Aquaculture Development Centre are of good quality and significant capacity, servicing research, development and industry support activities for a variety of species including pearl, abalone, sea cucumber, shrimp, lobster and grouper.

Land based facilities include a number of separate buildings housing tanks of various number and dimension suitable for accommodating a wide variety of work. In addition, a large scale raft facility is positioned 200m offshore, housing more than 25 large cages, of similar specification to the east NTB aquaculture industry. There are lobsters housed in this facility, although the nature of the research on them was unclear. It is evident that the human and physical resources are available to accommodate lobster aquaculture development activities immediately.

7 Conclusions

7.1 Comparative Advantages

- Proximity to high value markets (Hong Kong and Taipei) for live product
- Clean ocean with significant space for expansion
- Skilled human resources from established industry
- Low capital cost for establishing cage facilities
- Likelihood of a significant, under-exploited seed resource.

7.2 Constraints

Primary constraints to the further development of the lobster aquaculture industry include:

- Seed supply limited by amount of effort and gear used
- Availability of proven technology (cf. Vietnam) for both seed collection and for growout
- Food supplied to lobsters is less than ideal, and its volume from current fishing practices may not sustain a large scale industry
- Focus on lesser valued *P. homarus* rather than *P. ornatus* due to seed supply available
- Marketing of sub-premium sized *P. ornatus*
- No immediate prospects of hatchery technology to supply seed.

7.3 Opportunities

- Suitable growout sites along a significant length of coastline that are currently not or under developed, i.e. significant room for expansion
- Volume of seed collected could be significantly expanded immediately through increased effort and more effective technologies available from Vietnam
- Increasing market demand for live lobsters, particularly large *P. ornatus*
- Development of hatchery technology for slipper lobsters (cf spiny lobsters) that have better commercial prospects because of more simple biology.

8 Recommendations

- Technology be transferred from Vietnam to Indonesia, on
  - seed collecting technology of swimming puerulus. key issues: locations (i.e. north flowing water, enclosed bays), timing (dark moon), equipment (floating nets, lights, boats)
  - collecting technology of settled juveniles. key issues: locations, equipment (netting, timber and coral rocks with drilled holes)
  - growout husbandry
  - feed manufacture
  - Involving NTB farmers travelling to Vietnam to inspect first-hand
  - trialling of methods in NTB through MADC
  - workshops / extension activities
- Extension program be established in NTB
  - to all users of the bagang to realise the value of the puerulus and capture them where possible for sale to lobster farmers
  - to educate existing lobster farming villages, and new villages as to best practice methods for seed collection and lobster growout
  - for improved lobster nutrition, including development of feed manufacturing capacity
  - to educate on best species and value of larger harvest size (*P. ornatus*)
- Research program be established in NTB encompassing the following activities
  - seed collection census
  - seed collection technology development
  - assessment of seed collection locations
  - cage specification improvement (mesh size, shelters, shading etc)
  - improved handling and husbandry, particularly for puerulus stage to increase survival
  - nutrition profile of existing feed practice
  - feed manufacture, particularly for village-based capacity

- Research program be established in Australia on hatchery production of suitable species, eg slipper lobsters (particularly *Scyllarides*). This would be the primary activity for the Australian benefit.