Bioeconomics of Spiny Lobster Farming in Indonesia

Elizabeth H. Petersen

University of Western Australia and Advanced Choice Economic Pty Ltd
Email: Liz.Petersen@tpg.com.au

Clive Jones

Department of Agriculture, Fisheries and Forestry, Northern Fisheries Centre
Email: Clive.Jones@daff.qld.gov.au

Bayu Priyambodo

Marine Aquaculture Development Center, Lombok, Indonesia
Email: Bayu_Lombokmadc@yahoo.com

ABSTRACT

Spiny lobster puerulus settlements have recently been found in bays in Lombok, Indonesia, leading to the development of lobster grow-out culture in adjacent areas. This research suggests that lobster farming in Indonesia is a viable alternative livelihood for Indonesian fishers. Currently, returns to investment are modest and largely dependent on the price and availability of lobster seed and credit. Farmers are harvesting the lobsters as soon as they reach marketable size (100 grams) to minimize potential mortality and generate income as soon as possible. This research suggests there are significant benefits from delaying harvest until the lobsters are larger (approximately 300 grams) to benefit from higher yields. The profitability of the industry is not expected to be significantly impacted by large increases in fuel prices, although a disease epidemic would be devastating. Feeds are dominantly low-value finfish, the majority of which is caught by the farmer. There are significant economic benefits to be realized from the use of pelleted diets (especially if they are functional feeds) and farmers indicated that they would be willing to try them if they were available. Early adoption of pellets by this nascent industry is likely to prevent significant negative environmental impacts as the industry develops.

Keywords: lobster, aquaculture, indonesia, bioeconomics, industry development, grow out, Panulirus
JEL Classification: Q12, Q120

INTRODUCTION

Spiny lobster is a highly prized crustacean, with a strong and increasing demand throughout Asia, Europe, and America (Hart 2009), mainly due to their size and excellent meat (Davidson and Jaine 2006). Almost all spiny lobster production is from capture fisheries, where capture rates are at or over their maximum sustainable yield (Phillips 2000, 2005). Sea cage culture of spiny lobster (dominated by *Panulirus ornatus*, a tropical species) commenced in Vietnam in 1992. The industry expanded rapidly until the mid-2000s in response to strong export demand, resulting in high prices. Production declined rapidly within two years thereafter due to milky disease, but has almost fully recovered; current annual production had been estimated at approximately 1,600 tons (t) from approximately 38,000 cages, and valued at USD 80 million (Tuan 2011). The Vietnamese industry relies on wild-caught puerulus, commonly referred to as lobster seed. Hatchery technology for *P. ornatus* has been developed in Australia and is currently being commercialized (Jones 2010). Grow-out production of lobster in Indonesia began recently with the discovery of spiny lobster puerulus settlements within bays in Lombok, linked with an understanding of the potential for spiny lobster grow-out from the Vietnamese experience. Lobster farming in Indonesia is still in its infancy, having started in the early 2000s only. Investigations are being undertaken to discover the locations of puerulus settlements along the vast Indonesian coastlines. This paper resulted from an Australian-funded research on Indonesian lobster aquaculture. The intention was to conduct preliminary bioeconomic analysis of spiny lobster grow-out culture in Indonesia at this early stage of the industry to determine sensitivity factors of economic feasibility and to comment on implications for the industry's growth in the long term (including potential for adoption of manufactured diets). To the authors' knowledge, only three studies on the economic feasibility of lobster culture have been published anywhere in the world. Jeffs and Hooker (2000) considered land-based experimental grow-out of spiny lobsters in New Zealand and concluded that the economic feasibility of these systems relies on reducing infrastructure and operating costs, perhaps through seacage culture or sea ranching (Phillips 2000). Petersen and Phuong (2010) analyzed the bioeconomics and perceived constraints to development of tropical spiny lobster culture in Vietnam and concluded that these systems are profitably although relatively highly capital intensive and risky compared with other seafood culture systems in that country. The same authors presented a second paper on spiny lobster culture in Vietnam, focusing on the potentials of improved diets (i.e., manufactured diets) to improve the bioeconomics of these systems (Petersen and Phuong 2011).

With lobster farming in Indonesia being a nascent industry, reliable data on the industry's production and value are not yet available. From discussions with puerulus collectors and grow-out farmers for this project, the total lobster production from grow-out farming in Lombok was estimated at approximately 60 t per year, valued at about IDR 20 billion (USD 2 million) per year.[1] The dominant species is the scalloped or spiny sand lobster (*P. homarus*), known locally as Pasir. The grow-out period for this species is 8–10 months; it grows from approximately 13–120 grams (g). The lobsters are harvested as soon as they reach marketable size, even though they mature at approximately 300–500 g (after which its growth rate slows significantly) and can grow to 1 kilogram (kg) in size (Jones 2011).

There is increasing pressure worldwide to increase the sustainability of aquaculture diets. In many countries and for many aquaculture species, current diets are dominated by the low-value finfish (trash fish). Problems associated with these diets include relatively low growth rates (compared with manufactured diets), localized pollution, water quality degradation, transmission of parasites and diseases, short storage life, rapid decline of nutritional quality if stored for too long, and unstable

1 A currency conversion rate of USD 1 = IDR 8,675 is used throughout the paper, reflecting financial conditions at the time of data collection in April 2011.

supply (depending on the season) (Son 2010). Manufactured diets do not suffer many of these problems and provide the option of adding other dietary supplements that have features like immune system enhancement or pigments to improve product quality. Feeds with these extra non-nutritional benefits have been termed "functional feeds," meaning they provide benefits other than nutritional ones (Trichet 2010). These feeds may have the ability to improve the fish's state of well-being, thus, reducing the risk of disease through specialized formulations of individual feed ingredients.

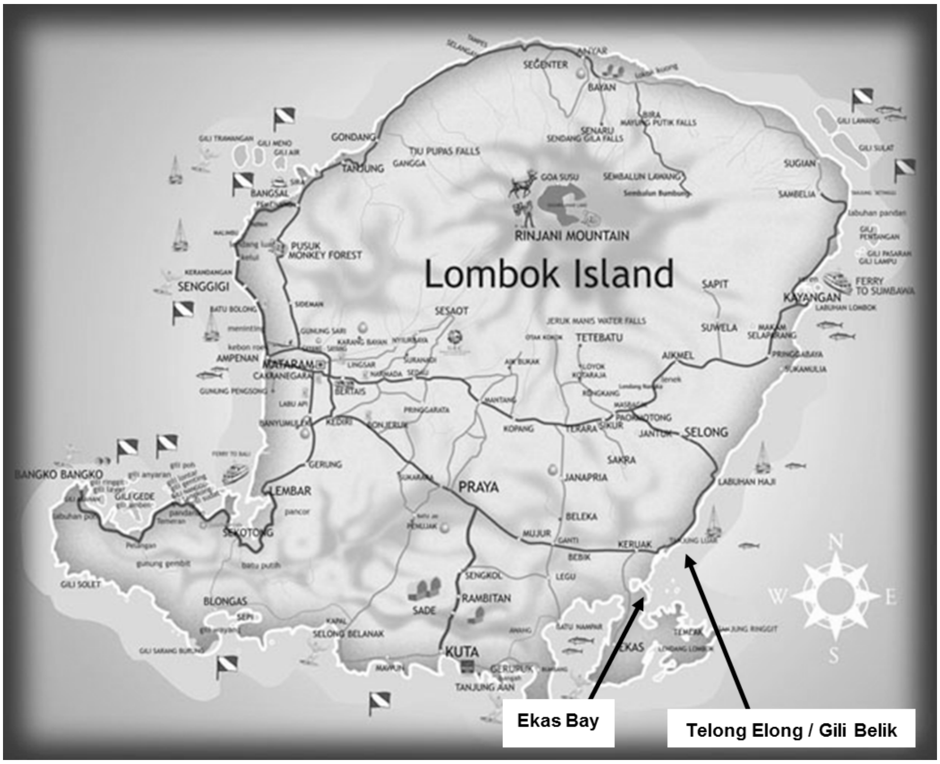
METHODOLOGY

Indonesia has approximately 1,000 lobster grow-out farmers. Key informant interviews were conducted in April 2011 in 11 lobster households at the two main grow-out regions in Lombok—Telong Elong/Gili Belik (5 households) and Ekas Bay (6 households) (Figure 1). Very little lobster grow-out is conducted elsewhere in the country, although there is significant potential for it to develop as other puerulus settlements are discovered. Locating these settlements is a separate objective of the lobster aquaculture project.

The questionnaire contained 44 questions seeking biological, economic, and husbandry information associated with stocking, harvest, equipment requirements, feeding, labor, credit, other household farming operations, and other sources of household income. It was administered via face-to-face interview between the lobster farmers and the researchers, with one researcher acting as the interpreter.

The data generated in the surveys were used in the bioeconomic model. The model interrelates a biological model of fish growth with an economic model of costs and returns

Figure 1. Location of the main lobster grow-out regions on Lombok Island, and the location of the key-informant interviews



to generate an annual enterprise gross margin (where all establishment, maintenance, and capital replacement costs were annualized). The bioeconomic model was used in the bioeconomic analysis.

The data generated in the surveys were used in the bioeconomic model. The model interrelates a biological model of fish growth with an economic model of costs and returns to generate an annual enterprise gross margin (where all establishment, maintenance, and capital replacement costs were annualized). The bioeconomic model was used in the bioeconomic analysis.

Biological Model

The biological model measures the lobster's biomass gain over a number of grow-out phases, b_i, where i = 1 to x, depending on how often a farmer varies cage size, stocking densities, and feeding rates throughout the lobster's growth. The biomass gain from each of these phases is summed to measure total biomass gain at harvest, b_H, as per Equation (1):

$$b_H = \sum_{i=1}^{x} b_i \tag{1}$$

Biomass gain in phase i is measured by dividing the quantity of feed during growth phase, i, with the feed conversion ratio, FCR_i, (wet weight) of the feed during growth phase, i, as per Equation (2).

$$b_i = \frac{qF_i}{FCR_i} \tag{2}$$

As lobsters grow, the stocking rate and feed regime (quantity, quality, and price) can be varied. Currently, Indonesian farmers usually vary the stocking rate and feeding regime at two different growth phases. Phase 1 nurses the juveniles from 13 g to 30 g over two months. The second phase is longer (6–7 months), during which lobsters grow from 30 g to 120 g at a slower rate and larger feed requirements.

The biological component of the model generates the individual lobster weight at harvest, which is fed into the economic model. Such data enable the analysis of different feeding regimes (using different quantities of feeds with different FCRs and prices) on fish growth, up to an actual or optimal harvest size.

Economic Model

The annual enterprise gross margin is a simple net revenue function as shown in Equation (3):

$$NR = TR - TC \tag{3}$$

where: *NR* = annualized net revenue (IDR)
TR = annualized total revenue (IDR)
TC = annualized total costs (IDR)

Total revenue is a function of individual lobster harvest weight and price as shown in Equation (4):

$$TR = W_H * P_H \tag{4}$$

where: *WH* = total weight of production (kg)
PH = price of harvested lobster, which is dependent on individual weight (IDR/kg).

Total costs are a function of restocking costs and a number of miscellaneous fixed and variable costs as shown in Equation (5). The fixed costs include labor, cage, and other capital and contingency costs. The variable costs are seed, feed, and interest costs. While costs are incurred over an 8–10 month period only, there is only one crop per year, hence costs are shown on an annual basis. This allows the calculation of the annual gross margin (IDR/year).

Table 1. General household information

	Telong Elong or Gili Belik	Ekas Bay
Average years of experience in lobster farming	4.0 (2.5–7.0)	4.0 (2.0–6.0)
Average number of members in the household	4.4 (3.0–6.0)	4.3 (3.0–5.0)
Average number of male members in the household	3.0 (1.0–6.0)	2.5 (2.0–4.0)

Note: Minimum and maximum levels recorded in parentheses in this and subsequent tables unless stated otherwise

$$TC = C_S + \Sigma C_{Fi} + C_L + \Sigma C_{Ci} + C_O + C_I + C_M \quad (5)$$

where: TC = total costs
C_S = seed costs
C_{Fi} = feed costs (grow-out phase i=1,2)
C_L = labor costs
C_{Ci} = cage costs (grow-out phase i=1,2)
C_O = other capital costs
C_I = interest costs
C_M= contingency costs for miscellaneous purchases

Annual seed costs, C_S, are a function of stocking and cage parameters as shown in Equation (6)

$$C_S = SR * S_C * N_C * P_S \quad (6)$$

where, SR = stocking rate (individuals/m^3/crop); S_C = average size of nursery cages (m^3/cage); N_C = number of cages; P_S = price of seed (IDR/individual).

Annual feed costs are a function of quantity and price of feed for each growth phase as shown in Equation (7):

$$C_F = \sum_{i=1}^{2} Q_{Fi} * P_{Fi} \quad (7)$$

where: Q_{Fi}= quantity of feed (grow-out phase i=1,2) and P_{Fi} = price of feed (grow-out phase i=1,2).

For the annual enterprise gross margin, cage and other capital costs are annualized by dividing the costs by the number of years to replacement.

RESULTS, ANALYSIS, AND DISCUSSION

This section presents results, analysis, and discussion of the key informant interviews. It is divided into eight sub-sections; general household information, puerulus collection and nursing, grow-out stocking and harvest information, cage and other equipment information, feed information, other inputs to production, bioeconomic analysis, and effect of improved feeding regimes on return to investment. Generally, average data are presented, with the minimum and maximum levels recorded in parentheses.

General Household Information

Lobster farming in Lombok provides a valuable income source on an island where income is mostly generated from tourism and agriculture (dominated by rice and livestock production). Table 1 presents the general household information. Households had an average of 4 years of experience in lobster farming. Household size was 4.3 members on the average, with just over half of the members being male.

All respondents indicated that lobster grow-out was a monoculture and their primary source of income. Telong Elong/Gili Belik (T/GB) farmers were also fishers, generating a net revenue of IDR 6.8 million/year (USD 780/year). Ekas Bay farmers also farmed seaweed, generating on average a net revenue of IDR 7.1 million/year (USD 820/year). On the average, the lobster grow-out farmers in T/GB were breaking even while those in Ekas Bay were earning a profit of approximately IDR 15.5 million/year (USD 1,800/year). This is discussed further in the next section.

Puerulus Collection and Nursing

The spiny lobster aquaculture industry relies on wild capture of swimming puerulus or recently settled juveniles by local fishers. In 2001 at the start of the lobster grow-out industry, only about 3 people were collecting puerulus. At the time of the study, there were more than 200 collectors, each gathering about 15,000 puerulus/year.

To capture the puerulus, collectors lower traps into the water. They used cement bags folded into a bow-tie shape as traps. One cement bag can be used to make 20 bow-ties. These traps are usually fastened to nets that are hung from nursery cages on floating frames. A puerulus fisher may have up to 450 traps at a time. The nets are raised morning and afternoon and the collected puerulus are placed into the nursery cages. The collectors then sell a portion (approximately 65%) for about IDR 4,500/piece (Table 2). The remaining portion is fed on low-value fish (sardines) caught by the farmer for approximately 3 months, after which they are sold as juveniles (weighing approximately 2–4 g) at about IDR 9,000/juvenile. A downward trend in puerulus and juvenile prices had been noted as supply had increased due to the discovery of more local sources.

The estimated annual costs of puerulus collection and nursing are provided in Table 3. Total annual cost was calculated to be IDR 16.5 million/year (USD 1,900/year). Assuming the collectors caught 15,000 puerulus/year and sold 65 percent of the catch (nursing 35% with a 50% mortality rate), the gross revenue is approximately IDR 68 million/year (USD 7,800/year). Net revenue (gross revenue minus gross costs) is approximately IDR 51 million/year (USD 5,900/year), with a benefit cost ratio (BCR) of 4.1:1 (meaning, for every rupiah spent, the collector/nursery farmer gains 4.1 rupiah in return annually). Return to investment is high and could be even higher with higher seed yields given that most (93%) of the costs are fixed; variable costs make up 7 percent only of the total costs. For example, some farmers caught up to 70,000 puerulus/year, resulting in a BCR of approximately 19:1.

Grow-Out Stocking and Harvest

The survey respondents identified two distinct grow-out phases, which are distinguished by the lobsters' movement to cages with different sizes, stocking densities, and feeding regimes. The initial stocking density in Ekas Bay (24 lobsters/m^3) was significantly higher than Telong Elong's (7 lobsters/m^3). This reflects the significantly higher number of seed stocked in Ekas Bay (averaging 1,500) than in T/GB (averaging 520). Most seed were stocked once a year in January. T/GB farmers indicated the desire to purchase more seed if

Table 2. Price received for puerulus and juveniles (IDR/piece)

Year	Puerulus	Juveniles (approximately 3 g)
2011	4,500	9,000
2010	3,500	8,500
2009	3,000	8,000
2008	3,000	5,500
2007	2,500	5,000
2006	2,000	5,000
2005	1,300	4,500

Table 3. Approximate puerulus collection and nursing costs, Awang, Lombok Island

	Number Required	Cost per Unit (IDR)	Time to Replacement (years)	Annualized Total Cost (IDR/year)
Labor				10,500,000
Cages	12	275,000	2	1,650,000
Fishing net	1	1,000,000	1	1,000,000
Boat engine	1	2,200,000	3	733,000
House	1	2,500,000	5	500,000
Boat	1	1,700,000	4	425,000
Torches	2	150,000	1	300,000
Cement bags (traps)	23	1,000	0.16	135,000
Anchoring line	25	30,000	6	125,000
Fishing nets for attaching traps	20	6,500	2	65,000
Line to hold frame together	5	30,000	4	37,500
Styrofoam floats	5	53,000	10	26,500
Bamboo lengths for cage frame	12	15,000	10	18,000
Other items	1	120,000	1	120,000
Contingency (5%)				910,000
Total				16,545,000

it was available. The price of seed averaged IDR 8,200/seed in T/GB and IDR 3,700/seed in Ekas Bay. The price in Ekas Bay is lower than in T/GB because the former is near the collection areas in Awang while in the case of T/GB, the seed still has to be transported. On the other hand, the price of seed in both areas was very low compared with that in Vietnam (IDR 45,000–70,000/seed or USD 5–8/seed) where demand for seed is stronger.

On average, phase 1 of the grow-out is 2 months, where seed grows to approximately 13-30 g. Phase 2 takes longer—6–7 months, during which the lobsters grow at a slower rate but are fed at a higher rate. The length of both grow-out phases combined is approximately 8–10 months, with an average harvest size of 115–140 g per lobster. *P. homarus* can grow up to 1 kg in size. It matures at approximately 300–500 g, after which its growth rate slows significantly (Jones 2011).

The average survival rate from stocking to harvest was about 70 percent. The harvest price received by farmers was IDR 350,000/kg (USD 40/kg) in T/GB and IDR 320,000/kg (USD 37/kg) in Ekas Bay. The benefit cost analysis for grow-out farming is presented in the next section.

Cages and Other Equipment

The number and size of cages used for lobster farming depend on the phase of production (Table 4). The cost of each cage ranged from IDR 124,000–350,000 (USD 14–40); ; they last for 2–4 years. The average annualized cost of other equipment for T/GB totaled IDR 5.0 million, mostly due to the cost of the boat, engine, and lights. For Ekas Bay, it totaled IDR 3.5 million, due largely to the cost of boat, engine, and fishing net.

Table 4. Cage information

	Telong Elong/Gili Belik		Ekas Bay	
	Grow-out Phase 1	Grow-out Phase 2	Grow-out Phase 1	Grow-out Phase 2
Average number of cages per household	4 (2–8)	4 (2–8)	3 (2–4)	7 (5–11)
Average cage length (m)	2.7	2.7	2.7	2.8
Average cage width (m)	2.6	2.6	2.8	2.8
Average cage depth/height (m)	2.6	2.6	2.8	2.8
Average size of cage (m^3)	19 (16–27)	19 (16–27)	21 (8–27)	24 (8– 27)
Average cost of cage purchase (million IDR/cage)	348,000	348,000	124,000	350,000
Average time to replacement (years)	2	2	2	4

Feeds

Farmers fed the lobsters on low-value finfish. Surveyed farmers in T/GB and Ekas Bay indicated that they purchased approximately 40 percent and 13 percent, respectively, of the finfish feed; the rest they caught by themselves at minimal cost. The price of low-value finfish was approximately IDR 5,000/kg in T/GB and IDR 4,000/kg in Ekas Bay. One T/GB farmer also used golden snail, which they bought from local farmers who harvest it from nearby paddy fields. The golden snail cost approximately IDR 3,000/kg and is combined with finfish at a ratio of 50:50.

T/GB farmers were unable to estimate the actual quantity of feeds used on a daily rate or for the total crop cycle. Ekas Bay farmers likewise did not measure the feed quantity, but were able to provide estimates, which were 1 g/lobster/day for lobsters less than 13 g and 7 g/lobster/day for lobsters greater than 13 g. With the average lobster sold at 116 g, the feed conversion ratio (FCR) (quantity of food eaten divided by weight gain) was calculated to be 11.5.

Farmers were asked to rate their perceptions on adaptability of lobsters to manufactured feeds (such as pelleted diets) on a scale of 1 to 5, where 1 is easily adaptable and 5 is not adaptable. All farmers indicated that the lobsters would easily adapt to manufactured diets. Thirty-six percent of them expected the manufactured diets to be more expensive than current diets; the remaining 64 percent indicated no notion on the matter. Farmers in T/GB believed manufactured feeds would lead to faster growth rates, while Ekas Bay farmers indicated no knowledge of the relative effect of manufactured diets on growth rates. All farmers indicated that manufactured diets were not available to them but that they would be willing to use them if available.

The growth in demand for low-value finfish feed is expected to increase with the development of lobster farming, putting pressure on local supply of finfish. Hence, adoption of pelletized lobster feeds at an early stage in the industry's development is important. Jones et al. (2007) argues that the current low-value finfish diet is not ideal—some nutritional deficiencies are likely, as evidenced by the pale pigmentation of the mature lobsters. Therefore, using other species of molluscs and crustaceans to supplement the finfish diet may be necessary. Using a manufactured diet that combines local essential ingredients could also reduce the reliance on low-value finfish as well as improve lobster quality. Adoption of manufactured diets early in the development of the industry has other benefits. For instance, compared with low-value finfish, pelletized diets would reduce local pollution and water quality degradation since a smaller mass of feed would be used but with greater efficiency). Moreover, they have a longer storage life and are potentially a more stable supply because their availability would not be dependent on seasonal factors (Petersen and Glencross 2012).

However, a specially-formulated pelletized feed for spiny lobsters is not yet commercially available, although it is a subject of ongoing research. Inadequate knowledge of the nutritional requirements of particular species of spiny lobsters is clearly a fundamental reason. Nevertheless, significant progress has been made in the past decade to better define the nutritional requirements for growing lobsters (Williams 2007; Williams and Irvin 2009; Barclay et al. 2006).

Other Production Inputs

Eighty percent of the surveyed households in T/GB and 50 percent in Ekas Bay had borrowed money to run their lobster operations. The amount borrowed averaged approximately IDR 5 million/crop (about 20% of the total cost requirement) at an interest rate of 11 percent/month. The main source of credit was the AgriBank (30% of the respondents who borrowed money).

Except for one, all the respondents indicated that two of their household members —husband and wife team—worked daily on the lobster operation throughout the year. The other respondents used hired labor at a cost of IDR 30,000/day (USD 3/day). All respondents also indicated using fuel at an average rate of 1.6 liters (l) per day at IDR 6,000/l.

Bioeconomic Analysis

A bioeconomic analysis was done using the data presented in the previous sections. Table 5 summarizes all costs incurred in the lobster grow-out enterprise. Total costs were similar across T/GB and Ekas Bay—IDR 20–23 million/crop (USD 2,300–2,700/crop). They were spread relatively evenly across capital costs, interest, seed, and variable costs. At this stage, labor costs were not included in the model, although a sensitivity analysis on this is presented later in this section. The combined cost of feed and cages was very small (less than 10% of total cost). Although the total costs were similar across the two locations, cost per production unit was significantly higher in T/GB (IDR 381,000/kg, USD 44/kg) than Ekas Bay (IDR 192,000/kg, USD 22/kg); this is because most costs were fixed and production was significantly smaller in T/GB than in Ekas Bay (51 kg/crop vs. 120 kg/crop).

Revenue statistics and BCR are presented in Table 6. Total revenue was significantly higher in Ekas Bay than in T/GB, reflecting significantly higher production in the former (harvest price was stable across the regions). Given the data, the average farmer in T/GB lost approximately IDR 1.6 million/crop (USD 180/crop). These farmers could not have continued lobster farming these past 4 years sustaining such losses if not for the fact that they were also fishers. If the significant capital costs of a boat, boat engine, and fishing net are removed from the analysis (assuming they are entirely attributable to the fishing enterprise), then the net revenue would be IDR 0.46 million/crop (USD 53/crop), with BCR of 1.03. When asked if they had any suggestions or recommendations for the fisheries authorities or management institutions to help improve their grow-out operations, all except one respondent from T/GB indicated they would like access to cheaper credit so they can buy more seed. Hence, the farmer's ability to purchase more seed and increase productivity pose as dominant constraints to the profitability of T/GB operations.

The price of seed was significantly lower in Ekas Bay (IDR 3,700/seed) than in T/GB (IDR

Table 5. Cost structure

	Telong Elong/Gili Belik	Ekas Bay
Percentage of total costs (%)	100	100
Seed	22	24
Feed	5[a]	3
Cages	4	2
Other capital items	25	23
Other variable items	17	17
Interest	22	25
Contingency	5	5
Total cost (million IDR/crop)	19.7	23.1
Total cost (USD/crop)	2,270	2,660
Cost/kg production (IDR/crop)	381,000	192,000
Cost/kg production (USD/crop)	44	22

Note: [a] Estimated based on Ekas Bay feeding rates

Table 6. Revenue statistics and the benefit cost ratio

Annual statistics	Telong Elong/Gili Belik	Ekas Bay
Total revenue (million IDR/crop)	18.1 (2,090)	38.5 (4,440)
Net revenue (million IDR/crop)	–1.60 (–190)	15.5 (1,780)
Benefit cost ratio	0.92	1.67

Note: Numbers in parenthesis are USD/crop

8,200/seed), hence farmers in Ekas Bay stocked significantly more seed at similar cost than T/GB farmers. As most costs were fixed, this directly translated to significantly higher returns and a profitable grow-out enterprise. The BCR for Ekas Bay farmers was 1.67, indicating that for every rupiah spent, the farmers gained 1.67 rupiah, or a 67 percent return on investment. This return on investment rate was similar to grow-out lobster culture in Vietnam (Petersen and Phuong 2010).

The analysis so far assumed no labor costs. That is, these farmers do not have other income generating opportunities for their time. This may not be the case, as evidenced by alternative enterprises discussed at the start of this section. Assuming a labor cost of IDR 30,000/day (wage per person paid by a farmer respondent for hired labor) and that only one household member is paid, the BCR for Ekas Bay would be 1.15. When both household members are paid, the BCR decreases to 0.87. Hence, the profits of Ekas Bay grow-out operations were equivalent to earning wages of approximately 1.5 people.

A sensitivity analysis was done on key model parameters to determine the impact of low and high levels of key parameters on return on investment (BCR). The first sensitivity analysis used likely changes in parameter levels, rather than a standard percentage change, to determine the impact of realistic low and high parameters levels, given existing market and biological conditions. The second sensitivity analysis considered parameter values that could occur under extreme conditions. These extreme conditions are:

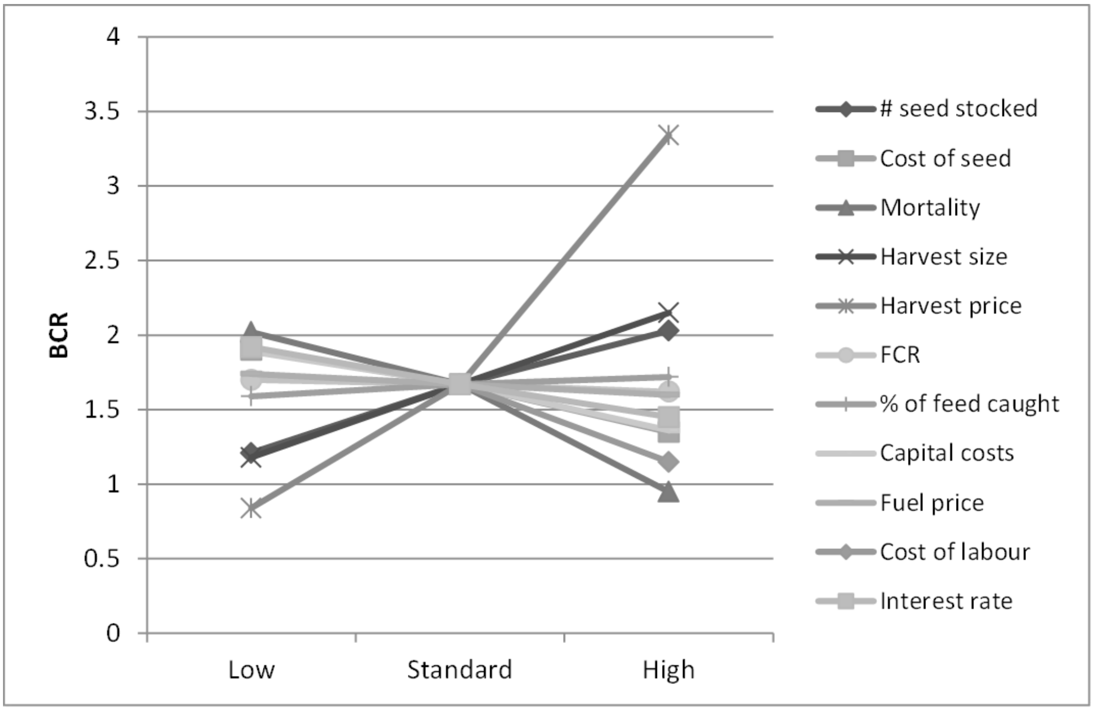
- An extremely low interest rate, reflecting current credit conditions elsewhere in Asia (i.e., Vietnam)
- An extremely low level of feed caught if they run out of time to fish or if fish supply is depleted

Table 7. Parameter levels used in the sensitivity analysis (excluding FCR)

Assumption Description	Extreme Low Level	Low Level	Standard Level	High Level	Extreme High Level
Number of seed stocked		1,000	1,500	2,000	
Cost of seed (IDR)		1,850	3,700	7,400	100,000
Mortality (%/crop)		15	31	61	80
Size of harvested lobster (kg)		0.080	0.116	0.150	0.300[a]
Harvest price (thousand IDR)		160	320	640	
FCR		5.8	11.5	23	
% of feed caught	0	65	87	100	
Capital costs (million IDR/crop)		2.7	5.3	10.6	
Fuel price (IDR/l)		4,500	6,000	7,500	12,000
Cost of labour (million IDR/worker/year)		0	0	21	
Interest rate (%/month)	2.0	6.0	12.5	20.0	

Note: a With current growth rate, a lobster is likely to reach this weight after 21 months and hence a farmer harvests every 2nd year rather than annually.

Figure 2. First sensitivity analysis showing the effect on the BCR of realistic changes on key model parameters



- An extremely high cost of seed, reflecting current conditions in Vietnam
- An extremely high mortality due to a disease epidemic
- An extremely high fuel price
- An extremely large harvest size (waiting until the lobster matures before harvesting).

Table 7 provides the parameter levels used in the two sensitivity analysis. Figure 2 presents the results of the first sensitivity analysis, showing that realistic changes in market, management, or biological conditions are not expected to have a significant impact on the BCR of most parameters. The BCR is reduced to less than 1 (where the farm becomes unprofitable) when harvest price is low and mortality rate is high. It increases to greater than 2 with low mortality or high seed stock and harvest size, and to a much larger extent with high harvest price.

Figure 3 presents the effects of extreme conditions on the BCR (second sensitivity analysis). It indicates that even if a farmer buys all his/her feed or experiences an extremely high fuel price, the BCR is not significantly affected. However, extremely high mortality or seed cost significantly decreases the BCR, while extremely low interest rate or extremely high harvest size significantly increases it. In the latter case, the modeling suggests that it is optimal for a farmer to wait until the lobster matures at 300 g (approximately 21 months) before harvesting (the current practice is to harvest as soon as the lobster reaches 120 g, which takes 8–10 months only). After this time, growth rates are significantly diminished, reducing the marginal benefits of higher harvest weights.

Figure 3. Second sensitivity analysis showing the effect on the BCR of extreme changes on key model parameters

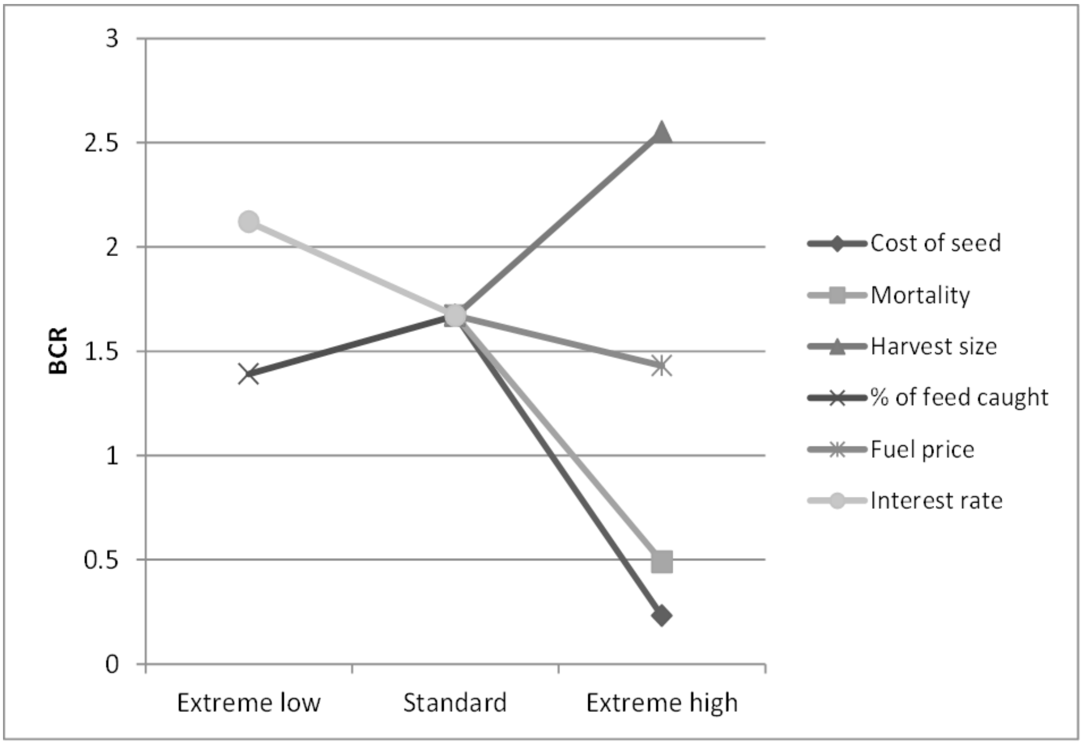


Table 8. Benefit cost ratio (BCR) with different feeding regimes under standard conditions

FCR	Feed cost (IDR/kg, USD/kg in parenthesis)							
	2,200 (0.25)	**3,900 (0.45)**	**6,500 (0.75)**	**8,700 (1.00)**	**17,300 (2.00)**	**26,000 (3.00)**	**34,700 (4.00)**	**43,300 (5.00)**
1	2.26	2.25	2.25	2.24	2.23	2.21	2.19	2.18
2	2.19	2.18	2.17	2.16	2.13	2.10	2.07	2.04
3	2.12	2.11	2.10	2.09	2.04	**2.00**	1.96	1.92
4	2.06	2.05	2.03	2.02	1.96	1.91	1.86	1.81
5	2.00	1.99	1.97	1.95	1.89	1.83	1.77	1.72
6	1.95	1.93	1.91	1.89	1.82	1.75	1.69	1.63
7	1.90	1.88	1.85	1.83	1.75	1.68	1.61	1.55
8	1.85	1.83	1.80	1.78	1.69	1.62	1.55	1.48
9	1.80	1.78	1.75	1.73	1.64	1.56	1.48	1.42
10	1.76	1.74	1.70	1.68	1.59	1.50	1.43	1.36
11	1.71	1.69	1.66	1.63	1.54	1.45	1.37	1.30
12	1.69	1.67	1.63	1.61	1.50	1.41	1.33	1.26

Effect of Improved Feeding Regimes on Return on Investment

Table 8 shows the BCRs for a number of feeding regimes (different FCRs and feed costs). The shaded cells indicate BCRs higher than the standard situation of 1.67. Hence, a farmer would have a higher return on investment using feeds with prices and FCRs corresponding to the shaded cells. Although a manufactured diet formulated specifically for lobsters is not available yet, Petersen and Glencross (2012) estimated that this kind of diet would likely cost approximately USD 3/kg and have an FCR of approximately 3. If the current systems would use feeds with these characteristics, the BCR would increase to 2.0:1. If the feed is also a functional feed, the benefits are expected to be higher. For example, if the functionality of the feed results in a 20 percent reduction in mortality, then the expected BCR would increase from 2.0:1 to 2.5:1. These results suggest that, on economic terms, a farmer would be better off using pelleted diets instead of the low-value finfish currently employed.

CONCLUSIONS

Lobster is a highly-prized crustacean with a strong and growing demand, especially in Asia. Most lobster production is from capture fisheries, where capture rates are at or over their maximum sustainable yield. Grow-out culture of lobsters has been successful in Vietnam due to an abundance of puerulus settlements along its vast coastline. Recently, puerulus settlements have been found in bays in Lombok, Indonesia, and grow-out culture of lobster has commenced in adjacent bays. This paper presented the results of a preliminary bioeconomic analysis of lobster grow-out in Indonesia, with the aim of determining the current factors affecting economic feasibility and to comment on the growth potential of the industry in the long term.

Results of the analysis showed that grow-out farming has been conducted in earnest for about 7 years. Puerulus collection is a lucrative industry, with average returns to a collector of approximately IDR 51 million/year (USD 5,900/year) and a return on investment of approximately 4.1:1. Grow-out aquaculture of lobster, on the other hand, is not so lucrative, with farmers in the Telong Elong/Gili Belik region just breaking even and farmers in Ekas Bay earning approximately IDR 16 million/year (USD 1,780/year) with returns to investment of 1.67:1. The greater profitability of lobster farming in Ekas Bay compared with Telong Elong/Gili Belik is a result of the former's higher seed stocking level, which was almost three times that of the latter. The price of seed in Ekas Bay, which was near the collection areas, was less than half that in Telong Elong/Gili Belik.

The dominant constraints to the development of the lobster grow-out industry in Indonesia are the price and availability of seed and credit. The price of seed was observed to be decreasing rapidly due to discoveries of new puerulus settlements and increase in the number of puerulus collectors. However, if the demand continues to increase, this may put upward pressure on seed prices, as has been the Vietnamese experience. Further, credit costs were extremely high (10–13% per month), which means the farmers were repaying the lender double what they borrowed. All except one farmer said they would like access to cheaper credit so they can buy more seed for their operations.

A sensitivity analysis on key model parameters shows that lobster farming in Indonesia is not highly sensitive to realistic changes in market or management conditions. Mortality and harvest price are the key parameters affecting economic feasibility. With demand for lobster growing, it is likely that harvest prices will increase in the medium term. A potential fuel price spike is not expected to have a significant impact on profitability of the industry. However, a disease epidemic, like the milky disease epidemic in Vietnam a few years ago, would be devastating to the industry.

Delaying harvest until the lobsters are much larger was observed to significantly benefit the farmers. Currently, farmers harvest the lobsters as soon as they are of marketable size to reduce the risk of mortality and to generate income as soon as possible. However, as the industry develops, it is likely that the farmers will have the capacity to grow their lobsters to a larger size to benefit from higher yields. This aspect needs further research.

Farmers fed the lobster largely on low-value finfish, the majority of which they catch themselves at minimal cost. Although manufactured diets are not available to the Indonesian grow-out farmers yet, the farmers generally indicated willingness to try them. A scenario analysis on a range of potential improved diets indicated that manufactured diets are likely to significantly improve returns on investment for the farmers, possibly increasing the BCR to 2:1 or even higher if the diets are also functional feeds. It is envisage that introducing the farmers to pellets early in the industry's development would reduce the environmental impact of lobster grow-out. This area would benefit from further research.

Extending the bioeconomic model developed for this analysis into an optimization model and modeling the interaction between stocking density and growth rates, especially with the introduction of hatchery-produced seed to the market, would allow further analysis of optimal stocking rates and harvest size. This knowledge has the potential to improve the profitability and livelihoods of lobster grow-out farmers in Indonesia.

ACKNOWLEDGMENT

The authors sincerely thank the Australian Centre for International Agricultural Research (ACIAR) for funding the project (SMAR/2008/021), of which this research is a part.

REFERENCES

Barclay, M.C., S.J. Irvin, K.C. Williams, and D.M. Smith. 2006. "Comparison of Diets for the Tropical Spiny Lobster *Panulirus ornatus*: Astaxanthin Supplemented Feeds and Mussel Flesh." *Aquaculture Nutrition* 12 (2): 117–125.

Davidson, A., and T. Jaine. 2006. *The Oxford Companion to Food*. Oxford: Oxford University Press.

Hart, G. 2009. "Assessing the South-East Asian Tropical Lobster Supply and Major Market Demands." *ACIAR Final Report (FR-2009-06)*. Canberra: Australian Centre for International Agricultural Research (ACIAR).

Jeffs, A., and S. Hooker. 2000. "Economic Feasibility of Aquaculture of Spiny Lobsters *Jasus edwardsii* in Temperate Waters." *Journal of the World Aquaculture Society* 31 (1): 30–42.

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.

———. 2011. Cultured Aquatic Species Information Program: Panulirus homarus. Food and Agriculture Organization of the United Nations. Rome, Italy.

Jones, C.M., M. Suastika, F. Sukadi, and A. Surahman. 2007. "Improving Lobster Grow-out and Nutrition in Nusa Tenggara Barat – a Feasibility Study." *ACIAR-SADI Final Report*. ACIAR.

Petersen, E.H., and B. Glencross. 2012. "Bioeconomic Analysis of Improved Diets for Marine Aquaculture in Vietnam." *Advanced Choice Economics Discussion Paper* 2. Perth: Advanced Choice Economics Pty Ltd.

Petersen, E.H., and T.H. Phuong. 2010. "Tropical Spiny Lobster (*Panulirus ornatus*) Farming in Vietnam—Bioeconomics and Perceived Constraints to Development." *Aquaculture Research* 41 (10): e634–e642.

Petersen, E.H., and T.H. Phuong. 2011. "Bioeconomic Analysis of Improved Diets for Lobster (*Panulirus ornatus*) Culture in Vietnam." *Journal of the World Aquaculture Society* 42 (1): 1–11.

Phillips, B.F. 2000. "Perspectives." In *Spiny Lobsters: Fisheries and Culture* (2nd ed.), edited by B.F. Phillips and J. Kittaka, 667–672. London: Blackwell Science Ltd.

———. 2005. "Lobsters: The Search for Knowledge Continues (and Why We Need to Know!)." *New Zealand Journal of Marine and Freshwater Research* 39 (2): 231–241.

Son, V.M. 2010. "Techniques on Cobia Culture." Slideshow available at http://www.slideshare.net/ridzaludin/tilapia-and-cobia-culture-trong-and-son.

Trichet, V.V. 2010. "Nutrition and Immunity: An Update." *Aquaculture Research* 41 (3): 356–372.

Tuan, L.A. 2011. "Spiny Lobster Aquaculture in Vietnam: Constraints and Opportunities." Paper presented at the Ninth International Workshop on Lobster Biology and Management, Norway, Bergen, June 19–24.

Williams, K.C. 2007. "Nutritional Requirements and Feeds Development for Post-larval Spiny Lobster: A Review." *Aquaculture* 263 (1):1–14.

William, K.C., and S. Irvin. 2009. "*Panulirus ornatus* Lobster Feed Development: from Trash Fish to Formulated Feeds." *ACIAR Proceeding No. 132,* 98–109. Australian Centre for International Agricultural Research, Canberra.