ECONOMIC ANALYSIS OF THE ENVIRONMENTAL IMPACT ON MARINE CAGE LOBSTER AQUACULTURE IN VIETNAM

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ABSTRACT

In Vietnam, marine cage lobster aquaculture has been expanding significantly over the last years. Besides the economic contribution for locals living in the coastal areas in Central of Vietnam, this industry has created some problems that are relating to the marine environmental protection where trash fish feed is predominant. This paper investigates the environmental impact on cage marine lobster aquaculture in Vietnam by using the Change of Productivity method in which nitrogen releasing from lobster cage is considered as the seawater quality parameter. And the usage of a mathematics function in this study is Mass Balance Model to calculate the total nitrogen loading volume in an every single crop in three provinces. This approach indicates the reverse relationship between lobster productivity (kg/m2) and volume of nitrogen releasing in a household unit. Additionally, the lobster productivity diminishes gradually if the number of cages increases in specific area. On the other hand, the estimation of the environmental effect uses the 'Treatment Cost' calculation for this waste has been done. However, this figure is lower than comparing that of the Change of Productivity method without considering the environmental carrying capacity. To give a strong recommendation to both local authorities, marine environmental management Departments and policy makers having a better consideration to the environmental and economic balance, the analysis of Cost – Benefit is presented in this study. This analysis shows that marine lobster aquaculture industry in Vietnam is profitable. However, because there is yet marine lobster food processing industry, the lack of awareness in environmental conservation from lobster farmers as well as the open-access sea in Vietnam that have been generating increasingly the marine water pollution . Therefore, in order to have a sustainability in cage marine lobster aquaculture development in Vietnam, it is vital for the local authorities and any other organizations to promote the development of high quality feed from food industry, to have technical training programs and raise up the awareness of the community in environmental protection as well as to plan strategic schemes to the entire region especially in the farming areas. Finally, setting up the environmental protection regulations to whose responsibility in a certain sea area is essential task to the government.

KEY WORDS: Marine cage lobster aquaculture, environmental impact, environmental quality, environment cost, change of productivity, treatment cost, optimal input level

Chapter 1 INTRODUCTION

1.1 Study site

1.1.1 The importance of lobster aquaculture in Vietnam

Vietnam, with a total coastline of 3,260km and an Exclusive Economic Zone (EEZ) of more than 1 million square km, has a great potential for aquaculture development (Heen K., L.T. Tuan, 2007). Marine aquaculture is playing an important role in Vietnam economy particularly in seafood supply to domestic and overseas market whereas the fishing industry is shrinking. With more than 4,000 islands, lagoons and bays giving an ideal protection against the waves and wind that are particularly strong and dangerous during the winter monsoon, the coastal zone in Vietnam is biologically sustainable geography for sea cage culture development.

Marine cage lobster aquaculture is an important industry in Vietnam particularly in the Mid-south coastal region. Over the last years, this industry is developing that is creating jobs and better livelihood to the locals and contributes to economic development of these provinces. Specifically in 2007, the total lobster cages in the region is about 52,696 covering 11,529 ha of sea area, with the number of 7,040 household participation and creating 15,000 jobs and bringing 2,000 tons of lobster valued at over 40 million US dollar. Now caged-cultured lobster is a seawater speciality in many countries over the world, becomes favorite, rich in protein and nice smell seafood, and gets high-valued export contributing a valuable item for Vietnam economy.

Table 1. Marine Lobster Culture in Vietnam

Province	Number of culturing regions	Total culturing area (ha)	Number of cages	Juveniles (piece)	Average profit/cage
Binh Dinh	2	52	1,680	67,700	3,571
Phu Yen	13	6,715	28,038	267,136	11,669
Khanh Hoa	23	4,223	22,173	131,405	10,116
Ninh Thuan	2	320	187	26,430	3,750
Binh Thuan	1	20	618	20,700	9,346
Total	**41**	**11,529**	**52,696**	**513,371**	

Source: Ministry of Agriculture and Forestry, 2007

1.1.2 Geography features

Vietnam location is in tropical and monsoon Asian area, Lobster is only located in the Central with 7 identified species that belong to Palinuridae. The allocation area crossing 8 latitudes passing 14 provinces from Deo Ngang Pass in Quang Binh to Ky Van Headland in Ba Ria-Vung Tau. This allocation distributes on the ecological variety of marine ecological system; it is high valued and economic aquaculture product. Lobster's inhabitation in natural rocky and coral reefs in the seawater and living in flock in the bottom ocean stream; they mainly stay in the cage during the daytime and become active at night. Depending on its body growth in their life and species, this kind of crustacean can be found at some different sea depth levels. In its mature period, lobster usually lives at the depth of 20m from the sea surface, at the period of post larva or juvenile, lobster lives at the coral and rocky reefs at the depth of from 2m – 10m under the sea surface. Lobster inhabits at the clean, light wave, windless areas with the salty level of 30 – $36^{o}/_{oo}$ and temperature of $25\text{-}30^{o}C$. Therefore, at some bays in Khanh Hoa-Phu Yen-Ninh Thuan, Binh Thuan are the most suitable biological inhibition areas for the lobster aquaculture.

Sea-cage lobster farms firstly cultured in Vietnam in 1992 in Khanh Hoa province and then quickly be expanded to other provinces in Central of Vietnam. So far, there are 41 lobster cultured regions in Vietnam located in Khanh Hoa, Phu Yen, Ninh Thuan, Binh Dinh, and Binh Thuan provinces. In which, Khanh Hoa and Phu Yen are the two leading provinces in marine lobster culturing which account 23 regions and 13 regions respectively. Here are the maps describing the lobster cultured regions in different provinces in Vietnam from the census survey done by Ministry of Agriculture and Rural Development (MARD) in 2007.

Number of cultured regions: 41
Total area: 11,529 ha
Number of household: 7,040
Working labors: 15,000
Floats: 2,883
Cages: 52,696
Revenue: about 65 millions USD

Figure 1: Major lobster culture areas in Vietnam
Source: Heen K., Le A.T., 2008

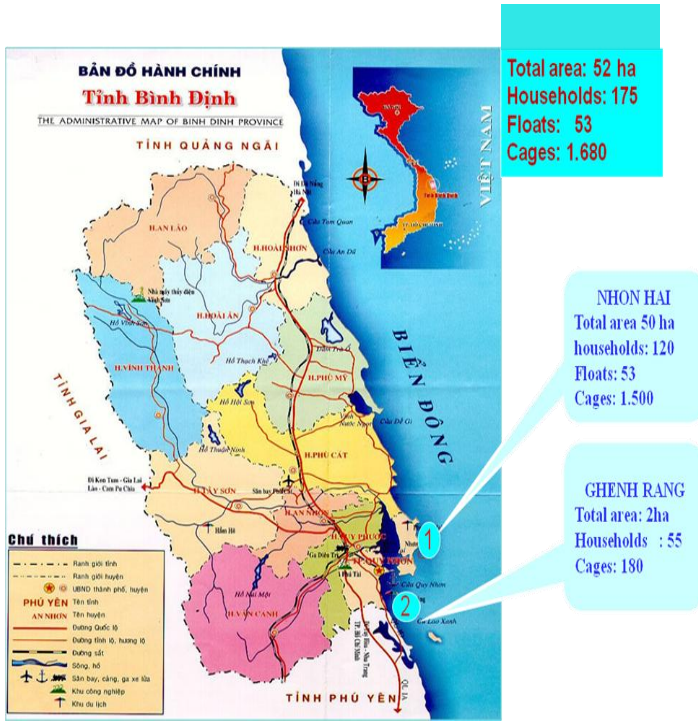


Figure 2: The distribution of lobster cages in Binh Dinh Provinces

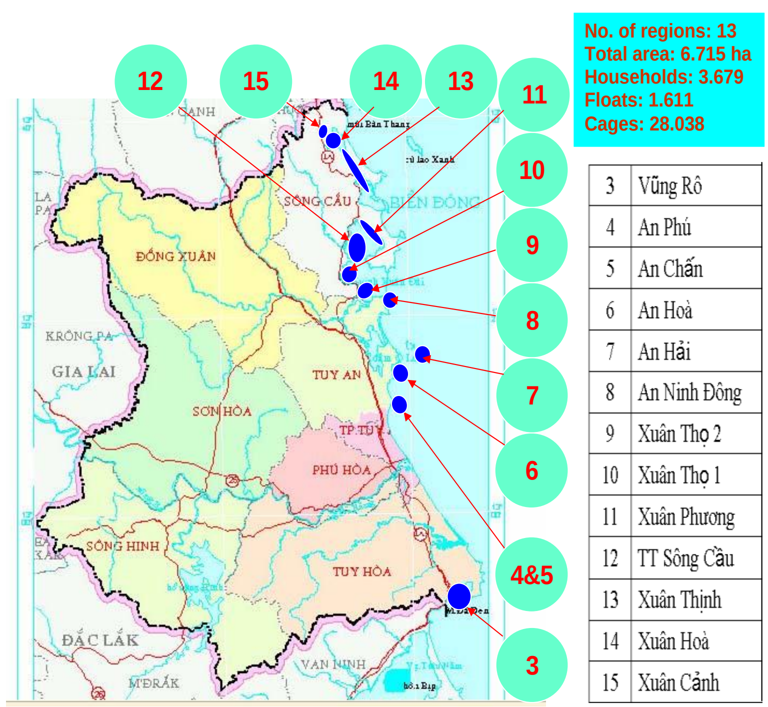
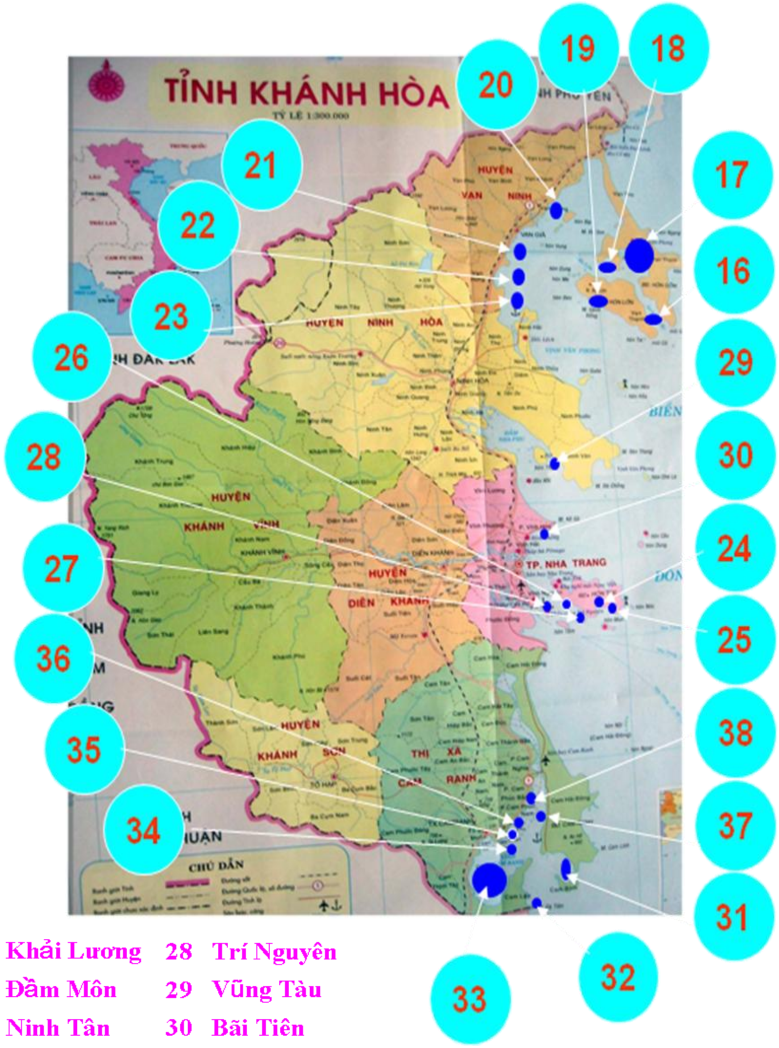


Figure 3: Allocation of marine lobster cages in Phu Yen Province

Source: Ministry of Agriculture and Rural Development, 2007



16	Khải Lương	28	Trí Nguyên
17	Đầm Môn	29	Vũng Tàu
18	Ninh Tân	30	Bãi Tiên
19	Ninh Đảo	31	Bình Ba
20	Điệp Sơn	32	Bình Hưng
21	Xuân Tự	33	Cam Lập
22	Hà Già	34	Cam Linh
23	Xuân Vinh	35	Cam Thuận
24	Đầm Bấy	36	Cam Phú
25	Bích Đầm	37	Cam Phúc Nam
26	Vũng Ngán	38	Cam Phúc Bắc
27	Hòn Một		

No. of regions: 23

Total area: 4.423 ha

Households: 3.121

Figure 4: Allocation of marine lobster cages in Khanh Hoa Province

Source: Ministry of Agriculture and Rural Development, 2007

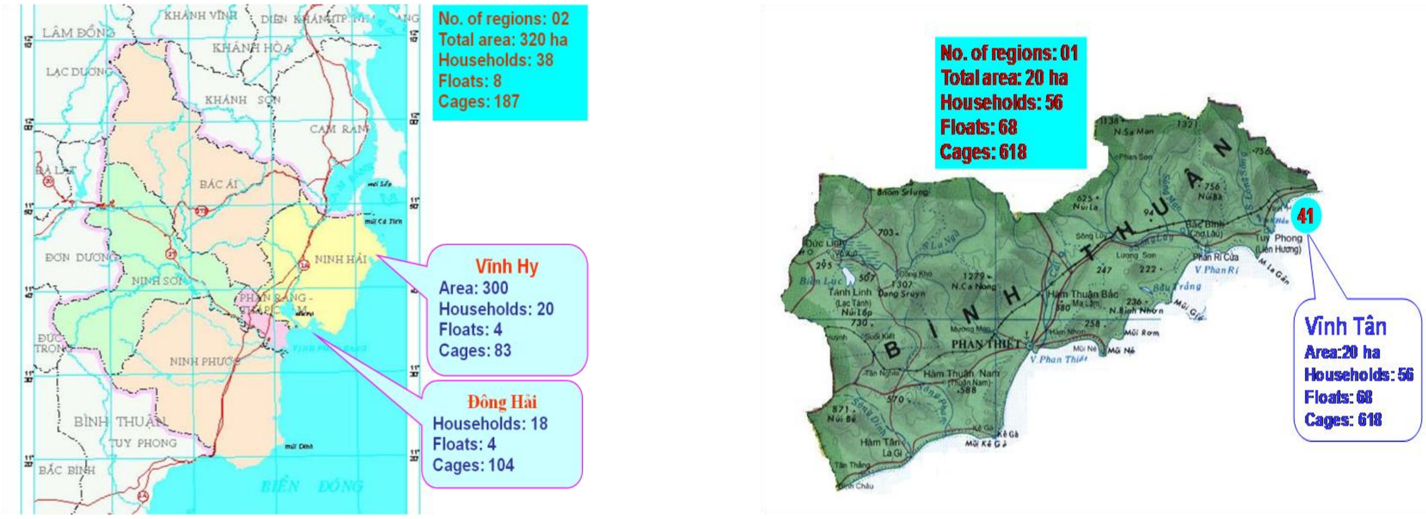


Figure 5: The distribution of marine lobster cages in Ninh Thuan and Binh Thuan Provinces

Source: Ministry of Agriculture and Rural Development, 2007

1.1.3 Cultured species

Among seven identified species[1] in Vietnam, there are three species with rapid growth rate, large size, bright color, and high export-value. These are Panulirus ornatus, P. hormarus, and P. stimpsoni. P. longipes is also cultured, but in small quantities (Heen K., Le A.T., 2007).

Table 2: Characteristics of Different Lobster Species in Vietnam

Species	**Growth rate**	**Market size**	**Price USD/kg**
Panulirus ornatus (spiny lobster)	Fast (>1kg/18 cultured month)	Large	36 – 44
Panulirus homarus (green lobster)	Medium (0,35 – 0,40 kg/18 cultured month)	Medium	20 – 24
Panulirus polypagus (bamboo lobster), Panulirus longipes (red lobster)	Slow (0,25 – 0,35 kg/18 cultured month)	Small	15 – 18

Source: Ministry of Agriculture and Rural Development, 2007.

[1] Will be presented in the appendix

However, two major cultured species in Vietnam up to now are Panulirus ornatus or spiny lobster (tôm hùm bông) and P. hormarus or green lobster (tôm hùm xanh) accounting for more than 90%. The table 2 indicates the superior features of Panulirus ornatus with faster growth rate and higher price comparing to these of P. hormarus, P. polypagus or bamboo lobster and P. longipes or red lobster. Consequently, spiny lobster is the most preferable farming species in Vietnam so far.

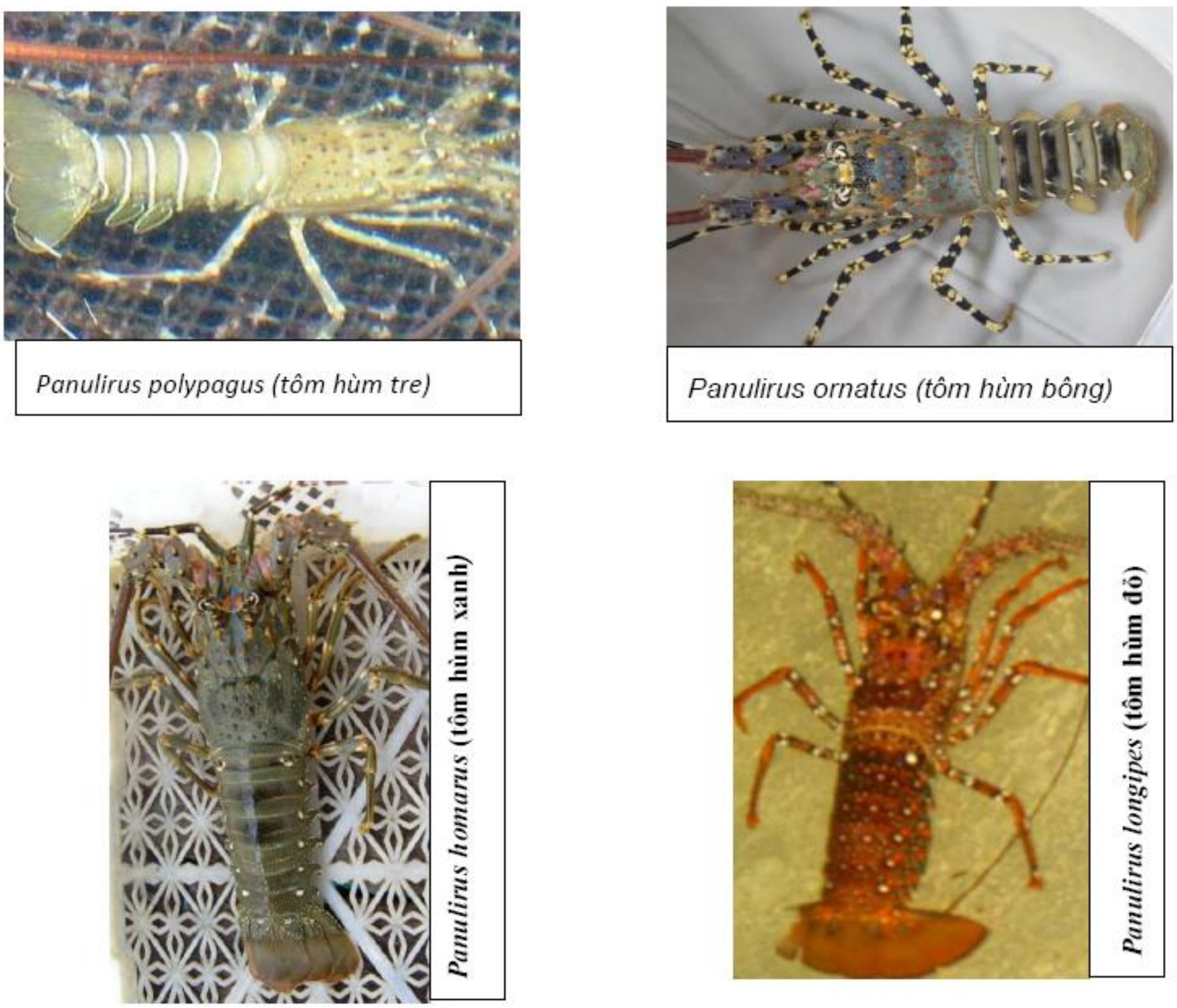


Figure 6: Lobster Species in Vietnam

Source: L.A. Tuan, 2007 and own picture

1.1.4 Nutrient features

In Vietnam, lobsters are fed with fresh whole or chopped fish and shellfish. The most commonly used species for feeding lobster are lizardfish (Saurida spp); red big eye (Priacanthus spp); pony fish (Leiognathus spp); pomfret; nails, oysters, and cockles; small swimming crabs, other crabs, and shrimps (Lai V.H., Le A.T.,2008). Juvenile lobsters are fed by the chopped fish and shellfish with 3-4 times/day. While with adult lobsters, we do not need to chop the fish or shellfish and the feeding times are decreased as 1-2 times/day depending on the locations. At night, the farmers usually give more feed for them because lobsters are strongly active in the evening.

Famers normally buy the trash fish feed at the fish port then transport to the lobster cage by boat. Some of them buy the feed from middleman cage gate. The payment for these feed is done by day or month with the average price ranges from 4,000 VND to 25,000VND/kg approximately US$0.23 to US$1.67 per kg[2].

1.1.5 Growing process

Like other kind of crustaceans, lobster's growth is observed through changing the crust. When it is adult, the cycle of crust changing is longer than that of the young ones. Lobster's size and weight increase much higher after replacing the crust. It take time much longer than comparing to other species in the crust changing cycle therefore the growth rate of lobster is lower than that of other species. In addition, in the crust changing period, lobster usually eat less than normally, therefore, the farmer should reduce the feeding quantity in these days in order to decrease the waste feed.

1.1.6 Reproductive features

Wild lobsters do the generative role every time of year, however, the main reproductive season is from August to September. It takes 10 to 12 months to become the juvenile from post larva. In Vietnam, we have not been successful in producing lobster seed (hatchery), therefore, the main lobster seed resources come from wild seed. Depleting in wild seed resources and unsustainably in exploiting are the challenges when lobster farms is developed at the higher scale.

[2] Exchange rate is 17,500VND/1US$

1.1.7 Culture technology

Sea-cage is the method for culturing lobster in Vietnam thus far. There are three main cage types depending on the culture area and the financial capacity of the famers.

Floating cage: The bag of the floating cage is normally supported by a frame with buoys and commonly located in waters with a depth of 10–20 m. Although the initial investment for this kind of cage is high because of the frame construction, the sustainability of these cages is high with the using time up to 6 – 10 years. This lobster cage is popularly used in the Nha Trang Bay and Van Phong Bay in Khanh Hoa Province (Heen K. & Le A. T., 2007).

Figure 7: Floating cages

Wooden fixed cage: The framework is made of salt-resistant wood. Wooden stakes with 10–15 cm diameter and 4–5 m length are embedded every 2 meters so as to create a rectangular or square shape. The bottom area of a farm is normally 20–40 square meters, but may be as large as 200–400 square meters. The cage size also varies. Each cage normally has a cover. The cage may be on- or off-bottom. A fixed off-bottom cage is about 0.5 m above the seabed. A fixed on-bottom cage is lined with a layer of sand. This kind of cage is suitable for sheltered bays and behind islands where there is shelter from big waves and typhoons. This cage is commonly used in the Van Phong bay in Khanh Hoa province.

Figure 8: Wooden fixed cages

Source: L.A. Tuan, 2007

Submerged cage: The framework is made of iron with a diameter of 15–16 mm. The bottom shape is rectangular or square with an area normally between 1 and 16 square metres. The height is 1.0–1.5 m. The cage has a cover and a feeding pipe. This kind of cage is common for nursing juveniles in Nha Phu lagoon, and for grow-out farming in the Cam Ranh Bay in Khanh Hoa, in Ninh Thuan, and Phu Yen provinces. It is very flexible for moving from this area to another area when the storm or bad weather happened.

Figure 9: Submerged cages

The materials for making cages, such as wood, iron, net, etc., are available in Vietnam. The marine cages are often of a small size suitable for a family-scale operation. That is why the number of cages has increased significantly in recent years. While individual developments may have no significant impact on the environment or society. A large number of developments, however, may have significant impacts on the wider social and economic environment, and on each other (Heen K. & Le A. T., 2007)

1.1.8 Juveniles

Lobster culture industry in Vietnam bases on the wild-catch seed. Generally, fishermen exploit the juveniles by using purse seines, traps, and diving. Farmers catch juveniles for their own commercial culture or buy it from the middle man with the price as 120,000-250,000VND/individual (*Panulirus ornatus)*. Normally, after being caught, the larva is cultured in the nursery cages until it obtains the size of 5-10g per juvenile for 30-40days. And then, it will be moved to the grow-out cages or sold to other farmers. The total catch of juveniles has increased from 500,000 animals in 1999 to 2,500,000 animals in 2003. The estimated figure for 2004-2005 catches were similar to those of 2003, but for the period of 2005-2006 and 2006-2007, the total catch was approximately two and one billion animals respectively (Lai V.H, Le A.T, 2008). These numbers indicate, recent years, the number of juveniles from wild catch has decreasing as the consequence of the depletion of wild seed resource and higher pressure of demand on juveniles.

1.1.9 Chemical use

According to some scientists in Research Institute of Aquaculture No.3 in Nha Trang City, so far, there are three effective pharmacies used in lobster grow-out process: Doxycylin antibiotics, Formlin and Vitamin C. However, when going to the field trip, the study has seen that, currently, lobster famers use several kinds of antibiotics and vitamin relying their experiences and market supply. Because lobster diseases are the critical problem in aquaculture industry and affect significantly on the local economy as well as the living standard of local residents, many organizations are concentrating on researching the pharmacies to resist or prevent these diseases. Therefore, the chemical market for lobster diseases is going to expanded and diverse. We hope that, in the next time, the products more effective will be invented and transferred to lobster farmers in order to prevent disease outbreak.

1.1.10 Value chain of lobster in Vietnam

There are five stakeholders participating in the value chain of lobster in Vietnam so far.

L1: Lobster catchers: at this link, fisherman catch the lobster seed from the sea then sell them to the middleman with price ranging to 2-3US$/individual when the lobsters were born 2-10days.

L2: Middleman person or seed merchant: they collect and buy lobster from fisherman then sell them to nursery growers where lobster kept for 1-3 days.

L3: Nursery grower: lobsters were bought at price ranging to 4-5US$ then it will be grown for 30 – 45 days. In this period, the value-added product is around 5-10g and the sold to lobster farmers with price of US$.8- US$.12/individual.

L4: Grow-out farmer: value-added is about 0.65-1kg for 10-20 months and then sell to the middle man with price of US$20- US$50/individual.

L5: Vietnamese exporters or marketers: lobsters are collected from grow-out farmers for exporting to China, Taiwan, Hongkong, Japan accounting more than 80% of total production with price range to S$40- US$70 /kg.

1.2 Problem statement and research objective

1.2.1 Problem statement

Considered as a profitable industry, it has developed quickly recent years, cage marine lobster culture in Vietnam has created several jobs, income, and development in culture techniques for local residents as well as contributed significantly on economic development of coastal Provinces. Currently, trash fish is dominantly used as feed in Vietnam lobster aquaculture and wild seed is the only resources for seeding which in turn have high rates of mortality and uncertain development (Vo V.N, 2004).

Beside advantages mentioned in part 1.1.1, this industry has caused a number of problems, especially environmental pollution and disease outspread. There is evidence that marine cage lobster aquaculture is generating a detrimental effect on coastal environments such as using of trash fish and shellfish as feed can easily lead to degradation of surrounding water and sediment quality, especially in sheltered areas with little water flow and tidal flushing, particularly where aquaculture development is close to or above carrying capacity (IUCN Vietnam Program, 2003). In addition, the high waste feed dues to trash fish feed is dominant is discarding directly to the sea that contributes to marine pollution. Le A.T, 2003 showed that, lobster feed and domestic sewage accounted for 59-80% and 30-12% of the nutrient inputs in Xuan Tu lagoon, Van Ninh, Khanh Hoa respectively, and this contribution of the lobster feed tends to increase over the time. Moreover, there is not a planned framework or supported program for developing this industry from the government. Lobster is being farmed spontaneously where sea area is open-access; marine environment pollution is not responsibility of lobster farmers.

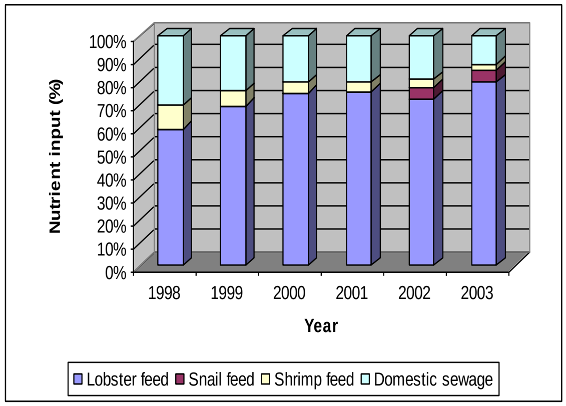


Figure 10: Contributive percentages of different waste resources in Xuan Tu
*Source***:** Le A. T, 2003,

Consequently, lobster productivity has been decreasing overtime because of the seawater pollution (Mr. Cu, individual discussion). Basing on the information from the presentation of Dr. Hung and Dr.Tuan at Tropical Spiny Lobster Aquaculture Symposium (9-10 Dec. 2008, Nha Trang Vietnam), the lobster productivity had decreased gradually since 2001-2006, and rapidly in 2007 at 30 kg/cage (Fig.10). This might imply that the quality of farming water and lobster seed had become worse a long time before the milky disease outbreak occurred.

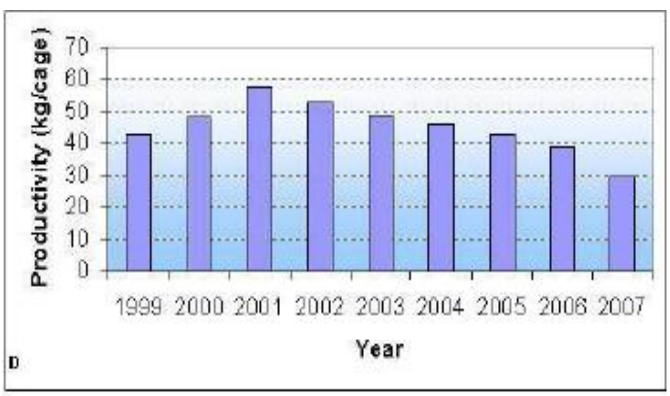


Figure 11: Lobster productivity in Vietnam from 1999 to 2007 by kg/cage

Source: Lai V .H., Le A. T., 2008

In addition, because of the breaking of milky disease, the survival of lobster decrease markedly (the dead rate about 80-90%). Hence, farmers have used some chemicals and antibiotics in order to protect their lobster. Consequently, the lobster's growth rate is decreasing. Mr. Huong from Research Institute of Aquaculture No. 3, who I met in the brief field trip on 20 Nov.2008 in Vung Ngan islet said: the previous years, it took 20 months for cultivating the lobster weighted 1kg, but this year, after using the disease protected chemicals and antibiotics, 20 months pasted now, but the lobster's weight is just 0.8kg. He also said that the disease may be caused by the water pollution. Moreover, in the past, lobster diseases rarely occurred. Recently, however, culturing in poorer quality water (due to rapid increase in number of cages) have resulted in some diseases in cultured lobsters in the lagoon (Le A.T., 2003). On ther other hand, polluted water promotes the development of disease bomming.

From these information we can see that, marine lobster culture is significantly contributing on developing the economis of coastal provinces. It has generated a great deal of interest in recent years, due to the referability in market place, the high retail value, and the great potential in future development, it may represent for aquaculture in Vietnam. However, environmental impacts is one of chellences of this industry in recent years when the numbers of lobster cages are going up. Feeding by trash fish, crab, shrimp, and shells causes a huge wastes creating surrounding water pollution. This water degradation affects not only ocean ecosystem but also has significantly affected on the productivity of cultured lobster itself.

1.2.2 Research objectives

The general objective of the study is to estimate the environmental impact on marine cage lobster aquaculture by the view of economics. Specifically, the paper tries to:

- Calculate the quantity of wastes releasing from caged marine lobster farms by measuring nitrogen and phosphorous volumes mixing in surrounding environment in a certain harvest using the Mass – Balance Model.

- Estimate these waste effects on marine environment by using Production Function approach (Change of Productivity) to see how these wastes counteract on the productivity of lobster. Additionally, this paper also focuses on calculation this environmental effect by the Treatment Costs method. The calculation of the entirely environmental effects on caged marine lobster culture by the view of economics will be presented.

- On the other hand, the paper also indicates that some possible causes of marine water pollution from lobster culture industry.

- And the profitability estimation of marine lobster aquaculture by using the Cost-Benefit Analysis (CBA) (including environmental cost) is one part in this paper giving supportive information to Government and policy makers, Local Authorities Departments and others whom may concern.

- Finally, there are some suggestions given to hold a point of view of sustainable lobster aquaculture development in Vietnam.

Chapter 2 RESEARCH METHODOLOGY AND RELATED LITERATURE

2.1 Research methodolygy

2.1.1 Effects of environment conditions on aquaculture

Although aquaculture is a source of risk for environmental degradation, environment factors also impact on culturing operation. Regarding to the following growth rate equation in fisheries (the paper starts by the simple model of individual growth and natural mortality in fisheries based on the logistic type natural growth equation):

$$F(X) = rX\,(1-X/K) \qquad \textit{(Eq. 1)}$$

Where:

- r is the maximum relative growth rate or intrinsic growth rate assumed to be fixed (each species has different intrinsic growth rate.
- K is the carrying capacity depending mainly on the natural environment of the stock
- X is the stock level

From this equation, we can demonstrate that the natural growth rate of a species depends on the stock level. If the stock level is higher than the carrying capacity, the growth rate of that species will be negative and positive when the stock level is lower than carrying capacity. Therefore, to approach the positively growth rate in the animal, we need to culture with the density is lower than the carrying capacity and it archives the maximum growth rate at r when stock level is zero (Flaaten, 2008).

Hence, our duty is to figure out in which stock level producing the maximum sustainable yield (MSY). Basing on the mathematic method, the first derivativeness of (1) equals to zero equivalently to $F'(X) = r - 2rX/K = 0$ or $X_{MSY} = K/2$.

Additionally, aquaculture can influence the physical or chemical environment in its vicinity, and this may affect directly or indirectly, as well as positively or negatively on fish-populations through K (Mikkelsen, 2007).

2.1.2 Cost – benefit analysis

Cost – benefit analysis (CBA) is used to estimate the profitability of marine lobster cage farming. It's a tool that decision-makers use to choose among alternative courses of action and in deciding whether a proposed project should go ahead or not. Cost-benefit analysis is undertaken to weigh the costs of proceeding with a project against the benefits that would arise from it

Efficient farm is evaluated through average costs and revenue of household lobster culturing. Costs include cost of fix costs (initial investment) and variable costs (cost of production for one crop). The fix costs include: cost of cage construction, guarding house, expenditures for tools and equipments. Variable costs are intermediate costs and labor for guarding and harvesting; intermediate means payments for post- larvae, feed, chemicals, antibiotic (if any), fuel or electricity, cage cleaning etc. Revenue is the total money receivable from selling lobster.

We know that to do CBA we calculate the Net Present Value (NPV):

$$\text{NPV} = \sum_{t=0}^{t=T} \frac{NB_t}{(1+r)^t} \qquad \textit{(Eq. 2)}$$

And that the project should go ahead if NPV >0. Net benefit is the excess of benefits over costs in each period and we can write

$$\text{NPV} = \sum_{t=0}^{t=T} \frac{B_t - C_t}{(1+r)^t} \qquad \textit{(Eq. 3)}$$

With B is benefits and C is costs. In environmental economics, environmental cost and benefit must be included.

2.1.3 Environmental impact assessement (EIA)

Traditionally, efficience assessement of a project, planing or activity had not concluded the environmental cost explained by environmental impacts, or damages of that project. Therefore, cost of producing product is the key item to determine the product's selling price. Since the mid-1980s there has been a growing interest in placing monetary values on environmental impacts and combining these values into overall project analysis work. Then cost of product includes not only the private cost but also the environmental cost TC = PC +EC

Economic analysis the environmental impact of project would take the environment value into consideration, project cost including environmental effect, and gear towards seeking the economic values (of both costs and benefits) of the environmental impacts (EIA for developing countries in Asia, 1997). Environmental impact assessment is one way to ensure that major development decisions take account of, and where possible mitigate, environmental impacts. Where the goals of economic growth and environmental protection conflict governments attempt to reach a decision by weighing the environmental damage that might occur due to a proposed project against the benefits that might accrue. (Sharon Beder, 1997).

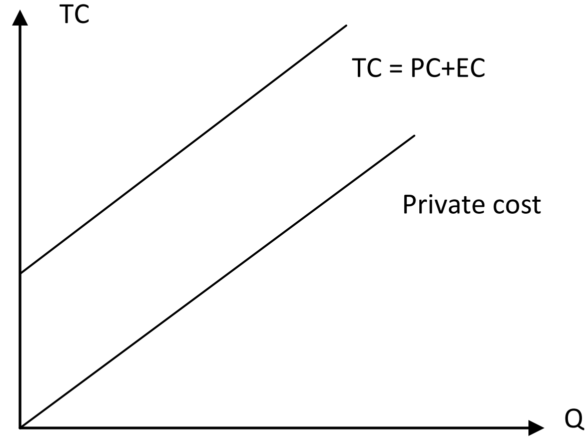


Figure 12: Total cost of production process

In additon, FAO, 2007, “Comparative Assessment of the Environmental Costs of Aquaculture and other Food Production Sectors” indicates: the environmental impacts can lead to environmental costs that can be incorporated into the analysis of the financial benefits or losses of the activity to which they are related. Environmental economists classify such costs as follows:

- Private costs (cost of producing product);
- External costs (primarily to the environmental cost) including the cost of abatement and residual damages after control measures are in place;
- User costs (where future uses are compromised); and
- Rehabilitation costs.

Therefore:

Environment impact = External cost

This paper just intends to estimate the external costs as the impact of marine lobster aquaculture on environment in Vietnam.

2.1.5 Production function method

To estimate the environmental cost (cost of the damage to the activity itself), the research intend to use the Production Function approach as follow description

- Production function based techniques: examining the relationship between environmental inputs in to a productive system and the resulting output. Input – output relationships such as this are termed production functions (P. Wattage, 2002).

- The basis for this method is the production function: $Q_i = f(K_i, L_i, Env_i)$

Where K (cappital) and L (labour) have the usual meanings, Env is some environmental indicators (water quality).

If we know the algebraic form of the production function and parameter values, we could use that information to map some change in water quality, ΔEnv, into a change in harvest, ΔQ, for constant levels of other input factors such as L and K. if we could then convert ΔQ into a monetary measure (unit price of Q based on the market), we would have valued the environmental quality change as it affects production (Perman R., et. al, 2003).

By the other word, a production function can be specified in terms of several inputs - e.g. labor (L), capital (K) and the environment (Env) - and a single output (Q). The idea can be applied to marine lobster aquaculture , where we may suppose that a key environmental variable affecting production is water quality - higher levels of water quality being associated with increased in lobster production per square meter and vice versa. Provided the relationship is known or can be estimated, any policy designed to raise water quality can then be evaluated through its impact on lobster harvest for any given level of labor and capital. If the price of the lobster is known, the change in harvest can in turn be translated into a monetary measure to find out the impact of water quality improvement in marine on the value of the lobster cage aquaculture. With regard to the effect on production, this is an outline description of what is often called the Dose-Response Valuation technique (P. Wattage, 2002).

2.1.5 Cobb-Douglas function

Constructed on this theory, the study is going to determine the general production function of marine lobster culture as the Cobb-Douglas function because Cobb-Douglas function follows the discriminating marginal productivity as the general production function composed. The lobster production function is written as the below Cobb-Douglas form:

$$Y = X_1^{\alpha 1} X_2^{\alpha 2} \ldots X_k^{\alpha k} \qquad \textit{(Eq. 4)}$$

Using a general log-log specification, the above equation could be written as:

$$\ln(Y) = \alpha_1 \ln(X_1) + \alpha_2 \ln(X_2) + \ldots + \alpha_k \ln(X_k) \qquad \textit{(Eq. 5)}$$

In this case, the production function of lobster culture is expected to depend on the following variables:

$$Ln(Q_i) = \alpha_1 + \alpha_2 \ln(FQ_i) + \alpha_3 \ln(SD_i) + \alpha_4 \ln(CT_i) + \alpha_5 \ln(Exp_i) + \alpha_6 \ln(Edu_i) + \alpha_7 \ln(Anti_i) + \alpha_8 \ln(EC_i) + \alpha_9 \ln(Env_i) + \text{Dummy variables} \qquad \textit{(Eq. 6)}$$

Where: i = 1… n: observations in the sample;

- $Ln(Q_i)$ is the log value of harvested lobster quantity/m^2

- $\ln(FQ_i)$, $\ln(SD_i)$, $\ln(CT_i)$, $\ln(Exp_i)$, $\ln(Edu_i)$, $\ln(Anti_i)$, $\ln(EC_i)$, $\ln(Env_i)$ are respectively the log values of feeding quantity kg/m^2), stocking density (number of seed/ m^2), cultured time (month), experience of the farmer (years), education of the farmer (level), cost of antibiotic use (thousand VND/m^2), environmental cleaning (thousand VND/m^2), and environmental quality (nitrogent or phosphorous quantity wasted of feed/ m^2).

To make clear on determining these varibales, we need to explain carefully the unit calculation of these variables:

- Harvested lobster quantity per one square meter is chosen as the proxy varibale of the output in this model. The productivity variable is chosen instead of the revenue variable to avoid the change in price at different time. We choose the quantity of lobter per one square meter because in reality there are different size of lobster cages such as 3x3x1.5, 2x2x1.5, 1.5x1.5x1.5, hence every sizes will be standardized to the square meter. This variable will be counted resulting from survival rate multiply with the harvested weight.

- FQi: the feeding volume that household i had used for one square meter of lobster farming measured by kg. Although farmers use different kinds of fresh fishes such as trash fish, shellfish, crab or shrimp, relying on the analysis result about the ingredients of the lobster feed from Thai N.C., et al., 2007 indicated that: there is not much different in the amount of nitrogen and phosphorous ingredients among trash feed types. Therefore, this paper will not distinguish in feed kinds used in lobster farming. We just consider the significance of total amount of used feed /m^2 with an expectation: when the amount of feed/ m^2 increases, the lobster productivity will increase and conversely.

- SD_i: Stocking density is the number of juveniles per square meter at the commercial culture stage which is reported by the household i.

- Cultured time (CT_i) indicates the number of months of culturing presented by the household i with the expectation: the longer in culturing time, the higher in weight of harvested lobster.

- Farmer's experience (Exp_i) is explained by the numbers of year that the farmer had done in lobster culture reported by the farmer. We expect that the higher in productivity indicates the longer in culturing experience.

- Farmer's education (Edu_i) variable is the binary category variable classified into 4 categories of $EDU1_i$, $EDU2_i$, $EDU3_i$ and $EDU4_i$ expresses for the education of the farmer below primary level, secondary level, high level and post high level. With 4 categories, we can use quantitative variable for this variable by coding as 1, 2, 3, 4 if education level of farmer is non-educated, secondary, high school and graduated level, respectively. It is expected that the higher in education, the upper in lobster productivity.

- Antibiotic use ($Anti_i$) is determined by the amount of money using for antibiotics/m^2 of a crop. Although, so far, the farmers in different area use different kind of chemical, the main ingredients and level of each ingredients are different (strong, medium or weak). Therefore, we intend to stadardize these information into amount of money to advoid the missing on measure units.

- Environmental cleaning (EC_i) variable is the cost that household i needs for spend in order to remove the wastes surrounding the cage in a crop. This cost is counted through the working hours multiply with the cost of a working hour. Some farmers do the cage cleaning one time for a crop; others clean the cage several times. The paper expect, the more times in cage cleaning, the higher in lobster productivity.

- Environment quality (Env_i): the amount of notrigent or phosphorous wasted from feed measured as kg/m2/crop. The paper chooses nitrogen and phosphorous wastes representable for environemtal opllution parameters in marine culture because nutrient pollution, particularly nitrogen pollution, is primary cause of environmental degradation in marine water (Boesch et al., 2001). Therefore, nitrogen and phosphorous are the water quality parameters considered in this study.

- Location variable: is the parameter to determine the whether there is difference in lobster productivity among three provinces. Firstly, the paper determines the different effect of three main categories on lobster productivity by combining slope and intercept dummy variable:

+ With the consideration of lobster productivity depends on several variables explained above. It is common test that whether this productivity depends other variables have not mentioned in the model such on location feature as well as the difference in lobster productivity generated by the difference in variables mentioned in model by each region.

Where the dummy variable D is used to pick up the location effect:

$$D_1 = \begin{cases} 1\ if\ property\ is\ in\ Khanh\ Hoa\ Province \\ \quad 0\ if\ property\ is\ not\ in\ this\ Province \end{cases}$$

$$D_2 = \begin{cases} 1\ if\ property\ is\ in\ Phu\ Yen\ Province \\ 0\ if\ property\ is\ not\ in\ this\ province \end{cases}$$

Other property (base case) is lobster farmers in Ninh Thuan Provice.

The first model is applied in Nha Trang with the DUMMY1 variable. In this model, not only are we able to explore which independent variables have influences on lobster productivity, but also accurately test and explore influences of these variables in Nha Trang as compared with those in other provinces. Similarly, the second model is run with lobster cage in Phu Yen by using variable of DUMMY2 to capture and exactly test the deference of factors affecting lobster productivity in Phu Yen comparing with that in other provinces.

Therefore, the production function of lobster cage in Phu Yen at site 1 is expressed in the following equation:

$Ln(Q_i) = \alpha_1 + \alpha_2\ DUMMY1_i + \alpha_3 ln(FQ_i) + \alpha_4 DUMMY1_i{*}\ ln(FQ_i) + \alpha_5 ln(SD_i) + \alpha_6 DUMMY1_i{*}\ ln(SD_i) + \alpha_7 ln(CT_i) + \alpha_8 DUMMY1_i{*}\ ln(CT_i) + \alpha_9 ln(ST_i) + \alpha_{10} DUMMY1_i{*}ln(ST_i) + \alpha_{11} ln(Exp_i) + \alpha_{12} DUMMY1_i{*}ln(Exp_i) + \alpha_{13} ln(Edu_i) + \alpha_{14} DUMMY1_i{*}ln(Edu_i) + \alpha_{15}\ ln(Anti_i) + DUMMY1_i{*}\ ln(Anti_i) + \alpha_{16}\ ln(EC_i) + \alpha_{17} DUMMY1_i{*}\ ln(EC_i) + \alpha_{18} ln(Env_i) + \alpha_{19} DUMMY1_i{*}ln(Env_i)$ *(Eq. 7)*

And the production function for lobster cage in Nha Trang is shown in the following equation:

$Ln(Q_i) = \alpha_1 + \alpha_2\ DUMMY2_i + \alpha_3 ln(FQ_i) + \alpha_4 DUMMY2_i{*}\ ln(FQ_i) + \alpha_5 ln(SD_i) + \alpha_6 DUMMY2_i{*}\ ln(SD_i) + \alpha_7 ln(CT_i) + \alpha_8 DUMMY2_i{*}\ ln(CT_i) + \alpha_9 ln(ST_i) + \alpha_{10} DUMMY2_i{*}ln(ST_i) + \alpha_{11} ln(Exp_i) + \alpha_{12} DUMMY2_i{*}ln(Exp_i) + \alpha_{13} ln(Edu_i) + \alpha_{14} DUMMY2_i{*}ln(Edu_i) + \alpha_{15}\ ln(Anti_i) + DUMMY2_i{*}\ ln(Anti_i) + \alpha_{16}\ ln(EC_i) + \alpha_{17} DUMMY2_i{*}\ ln(EC_i) + \alpha_{18} ln(Env_i) + \alpha_{19} DUMMY2_i{*}ln(Env_i)$ *(Eq. 8)*

Where Ninh Thuan is the reference case. Based on these models, the effect of above factors on productivity of lobster cage will be estimated

2.1.6 Optimal level of input factors

From the result of production function estimation, the optimal level of each input factor in order to maximize profit is verified:

$MPV_i = P_i$ *(Eq. 9)*

And $MPV_i = MP_i * P_0$ *(Eq. 10)*

Where

+ MPV_i is marginal value of product (it means that if we increase one unit of input i then the fish value raises as MPV)

+P_i: market price of input i

+ MP_i is marginal product (indicating the fish production increases when increasing one unit input i)

+ P_0: market price of output (lobster)

$$X_{i\ optimal} = a*P_0*\overline{Y}/P_i \qquad \textit{(Eq.11)}$$

Where + a is elasticity of Y by X_i (given from estimated result of production function)

+ $\overline{Y}$ is average productivity

+ P_0: price of output (lobster)

+ P_i: market price of input i

If the optimal level of each input factor is higher than that of the current investment, the paper intends to recommend increasing that input level in order to archive the economic efficiency and conversely (Nguyen S. H, 2009).

2.1.7 Nitrogent loading estimation

The paper applied the Nutrient-Budget Balance or Mass Balance Model to assess the relationships between feed nutrients input, nutrient retention in the cultured fish, and nutrient release to the environemtn in the relation to a given production tonnage. Particularly, this item is calculated basing on the research of Thai N.C., et al., 2007 done in Van Phong and Nha Trang bays. The way to estimate the waste N and P from lobster cage based on the Mass Balance Equation developed by Wallin & Hankanson (1991) as folowing:

$$L = P \text{ x } (F_c \text{ x } C_{feed} – C_{fish}) \qquad \textit{(Eq. 12)}$$

Where:

+ L is amount of N/P wastes into marine environment (kg/m^2)

+ P is the total amount of lobster production (kg/ m^2)

+ F_c is the food conversion ratio (different in households)

+ C_{feed}: nutrigent level in feed (%)

+ C_{fish}: nutrigent level in lobster (%) } based on the previous study.

The loadings of nitrogen and phosphorous from cage lobster farming mainly depend on the nutrient content in the diet (expressed by Feed), feed conversion rate (expressed by FCR) and the nutrient in the harvested fish (expressed by Lobster). This equation will be estimated through prevous study with C_{feed} and C_{fish} available as:

Table 3: Bio-chemical Ingredients of Feed Used for Lobster and Lobster's Meat

Items	N (%)	P (%)	C (%)
Crab	1.403	0.002	2.660
Shellfish	1.440	0.001	8.655
Trashfish	1.169	0.001	1.735
Average	1.337	0.001	4.350
Lobster	3.580		

Source: Thai N.C., 2005

However, there is not available information related the P contributed in the lobster from above table, the study could not determine the phosphorous waste without doing the experiment of phosphorous analysis of lobster meat. Hence, the nitrogen waste will be preventative for water quality parameter in this research. From equation (1), we would estimate the total amount of nitrogen leased to environment from lobster cage farms in Vietnam. Basing on this information, combining the treatment cost of a unit of nitrogen from previous studies, we will estimate the external cost of marine cage lobster aquaculture.

In addition, paper will combine the environmental factor in lobster production model with the current pollution level, how much the environment pollution affect on the productivity of lobster aquaculture will be estimated. The monetary values of this environmental effect can be counted by taking the change in lobster productivity multiply with the market price of this product.

2.1.8 Replacement cost

To estimate the environmental cost of marine lobster cage farming, the paper also counts this cost by the Replacement Cost (Treatment Cost) in order to compare with the result of Change of Productiivty. The basic premise of the Replacement-Cost approach is that the costs incurred in replacing productive assets damaged by a project can be measured. These costs can be interpreted as an estimate of the benefits presumed to flow from measures taken to prevent that damage from occurring. The rationale for this technique is similar to that for preventive expenditures except that the replacement costs are not a subjective valuation of the potential damages. Rather they are the true costs of replacement if damage had actually occurred. The approach may thus be interpreted as an "accounting procedure" used to work out whether it is more efficient to let damage happen and then to repair it or to prevent it from happening in the first place. It estimates the upper limit of the value of the damage but does not really measure the benefits of environmental protection per se.

The assumptions implicit in this type of analysis are:

1. The magnitude of damage is measurable;

2. The replacement costs are calculable and are not greater than the value of the productive resources destroyed, and therefore it is economically efficient to make the replacement; and

3. There are no secondary benefits associated with the expenditures.

(Source: EIA for developing countries, 1997)

2.1.9 Some water quality parameters

- *Phosphorous*: a nutrient found in all living things is a mineral in nature. Both plants and animals have phosphorus in their bodies. Phosphorus enters the water from a number of places. It is found when human and animal wastes are flushed into waterways, either from poorly treated sewage, broken pipes or runoff. High levels of phosphorus are more serious in lakes and ponds.

- *Nitrogen*: is one of the most common elements in the world that all living plants and animals need it to build proteins. Nitrogen can be found in fertilizers and in human or farm animal wastes. Therefore, seawater and groundwater can become polluted by nitrogen in the wastewater.

In marine cage culture, the nitrogen and phosphorus releases directly into the environment through the unconsumed feed (trash fish) and faecal production. It has been estimated that some 75% to 85% of C, 40% to 80% of N and 65% to 73% of P input into a marine fish culture system will be lost into the environment, contributing to water and sediment pollution. Consequently

Feed waste is the single most important pollution source in aquaculture (Jim C.W. Chu, Regional Workshop on Seafarming and Grouper Aquaculture)

- *Marine pollution*: entry into the oecean of chemicals, particals, industrial, agricultural, aquacultural, and residental wastes, or the spread of invasive orgaisms. The Joint Group of Experts on the Sientific Aspects of Marine Polltion (GESAMP) defines marine polltion as “the introduction by man, directly or indirectly, of substances or energy into the marine environment, resulting in such deleterious effects as harm to living resource, harzards to human health, hindrance to marine activities including fisheries, impairment of quality for use of sea water, and reduction of amennities. In which, organic carbon enrichment related to elavated to nutrient inputs, particualrly nitrogen and phosphorus is one of the contaminants of affecting water quality (Michael J. Kennish, Pratical Handbook of Estuarine and Marine Pollution)

- *Eutrophication*: an increase in chemical nutrients compounds containing nitrogen and phosphorus in an ecosystem, and may occur in land or in water that cause lacking of oxygen, severe reductions in water quality, fish, and other animal pollutions

2.2 Data collection

2.2.1 Data forms

Primary data was collected through personal interviews. The respondents were household members who are working on lobster farms. At the beginning, the paper intend to collect the number of HH based on the number of lobster farmers in each province and financial source. Recently, there is insignificant difference between Khanh Hoa and Phu Yen province to answer the question which province is larger in lobster farming amount and scale. To make the significance in statistic, hence, the study has intended to collect 50 HHs in each province. In addition, Ninh Thuan is considered as the new and small scale province in lobster farming, thus, 30 HHs will be interviewed is the goal of the research.

Finally, randoomly sampled collection is the method used to collect each household in each province for this paper.

Cross section form: data collected over sample units in a particular time period for example, lobster prodution by household during crop 2007 or feeding quantity by cage in a crop.

- Consequently, the survey was conducted by directly interview through questionare with the lobster farmers in different areas with different pollution levels. Because in marine area, in the same region, the environmental quality is usually similar, so it's difficult to recognize the environment effect. Therefore, I intend to interview the farmers not only in Nha Trang Bay but also in Phu Yen and Ninh Thuan Provinces, the three larggest provinces in marine lobster culture in Vietnam. A survey of 130 households was implemented in three provinces in order to obtain information associated with lobster production including cage characteristics, farming location, feed types, farming technology, post larvae density, costs and revenues of lobster farming production. Household data includes labour force of the family, experience in lobster farming, income resources of each member and educational level of household members.

- However, Phu Yen is the first interviewing implemented area, therefore, 15 beginning interviews with several mistakes in questionnaire design and information collection are considered as invaluable respondents. Hence, the sample size in Phu Yen had reduced from 50 to 35 HHs. In addition, there were 5 in-valued respondents in Khanh Hoa and Ninh Thuan provinces. Consequently, the paper has been done with 110 reliable respondents instead of 130 samples in three provinces.

Secondary data was collected from previous studies and available reports of the local management agencies. The data includes the overall and socio- economic characteristics of the area, the area and productivity of losbter culturing and number of households involving in lobster production in each province. These information was obtained from Department of Agriculture and Rural Development, Department of Scientic Technology and Environment in Khanh Hoa, Phu Yen and Ninh Thuan provinces. Local management agencies which are the People's Committee of Song Cau, Xuan Thinh District in Phu Yen; Cam Ranh Town, Xuan Tu Districts in Khanh Hoa; Vinh Hi District in Ninh Thuan supporting lobter farming related documents about study sites.

2.2.2 Sampling

Target respondents of the study were lobser cage culture operators. The study area consists of some commues of three provinces in Khanh Hoa, Phu Yen, and Ninh Thuan. Random sampling method is used to collect the HH in each province in this study based on the certain number of HHs in each province has been determined.

Random sampling: A samples of n observation on one or more variables, denoted x1, x2, …, xn is a random sample if the n observations are drawn independently from the sample population, or probability dstributions, f(xi, θ). The sample may be univariate if xi is a single random variable or multivariate if each observation contains several variables. A random sample of observations, denoted [x1, x2, …, xn] or {xi}I=1,…n, is said to be independent, identically distributed, which we denote i.i.d. the vector θ contains one or more unknown parameters (William . Greene, 2003).

Among 110 valid households interviewed were selected randomly based on the local statistics by local staffs of Department of Agriculture and Rural Development and local people communities. In Khanh Hoa, there were 45 households participated in the interview among 3,212 ones involving in lobster cage culture. In Phu Yen, 37 households were selected from 3,679 ones. In Ninh Thuan, the number of respondents was 28 over 38 households culturing lobster.

Table 4: Sample and Population of Lobster Farming Households (HH) in Three Provinces

	Sample size	**Population**	**Percentage (%)**
Total			
No. of cage	2,869	50,598	5.67
No. of HH	110	6,848	1.61
Khanh Hoa			
No. of cage	1,824	22,173	8.23
No. of HH	45	3,121	1.44
Phu Yen			
No. of cage	817	28,038	2.91
No. of HH	37	3,679	1.01
Ninh Thuan			
No. of cage	128	187	68.45
No. of HH	28	38	73.68

Source: Own survey and local agencies' data

* Note: The paper aims to archive the statistical significance in sampling (around 30 samples in each region) of the respondents without strongly considering on presentative sample in term of number for each province because of the following reasons:

- It takes time to meet and interview one lobster farmer. As the feature of marine cage lobster farming, at the daytime, most lobster farmers work on their cages in the sea. Hence, to meet them, I must rent the mini boat with driver to go to each cage, it takes around 30 minutes to 2 houses from inland to their farming place. Moreover, at the cage, most respondents works and answer simontaneously, hence, I usually spent 2 – 3 housed in interviwing each HH. On the other hand, in the sea area, I ought to use mini boat to move from this household to another household.

- It's expensive for one field trip. It costs around 700 thousands VND for renting a mini boat to go around lobster farms for one day. With the limited budget, I could not expect to do more samples.

2.3 Related literature

2.3.1 Environmental impacts of marine aquaculture operation

Being an essentially open system, cages are usually characterized by high degree of interaction with environment and cage systems are highly to produce large bulk of wastes that are released directly into the environment (Islam M. S. 2004). Especially, floating cages marine aquaculture operations directly release wastes and uneaten food directly into the marine environment, which impacts both on water quality and benthos. Therefore, like other forms of animal production, marine aquaculture can lead to the environment degradation. Generally, the main environmental effects of marine aquaculture can be divided into five categories: 1) biological pollution, 2) fish for fish feeds, 3) organic pollution and eutrophication, 4) chemical pollution, and 5) habitat modification. Additionally, marine aquaculture will create the loss of marine habitat, chemical pollution, drugs, such as antibiotics, increased presence of algae in the water, and fish fecal waste pollution.

In addition, unlike other species farming where pelleted feed is used, trash fish is the predominant caged lobster feed. Therefore, food wastage and organic and nutrient loadings are several times higher when trash fish is used comparing with fish farms where pelleted feed used. The use of trash fish also generates food wastes of much smaller particle size and hence may facilitate a wider dispersion and greater impact upon a much larger area (R. S. S. Wu, K. S. Lam, et al. 1993). Generally, aquaculture effects on the environment by several ways. Nevertheless, with intensive aquaculture, there are four specific types of environmental impact named hypernutrification, benthic enrichment, biochemical oxygen demand, and bacterial changes (this list excludes other more general impact such as those associated with the use of chemical and the general question of interaction with natural populations (William Silvert, 1992).

In technical point of view, there are several studies related to investigate the impacts of mariculture on environment particularly on water quality, coastal ecosystems, sediments beneath culture installations, biodiversity of the farming areas. To support for the theory used in this paper, in this part, we reference some typical results done from previous studies indicating the effects of marine fish farming activities on the environment as different perspectives.

From the paper "***Nitrogen and Phosphorus Budget in Coastal and Marine Cage Aquaculture and Impacts of Effluent Loading on Ecosystem: Review and Analysis Towards Model Development***" written by Md. Shahidul Islam in 2004, the potential organic and nutrient wastes of marine cage aquaculture have been estimated. It shows that, nitrogen loading in fish cages ranged from 47.3kg to 320.6kg per ton of fish produced in different experimental systems using different species as well as different types of diets. In Asia countries, especially, where trash fish is the predominant diet of caged fishes, the nitrogen loading reached as 320.6 kg/ton. Therefore, if the annual global production of fish from cage aquaculture is of 10,000 tons, the annual global Nitrogen loading released to marine environment is of 1,325 tons Nitrogen. Moreover, the paper indicated that the waste foods and faeces are going to affect the marine ecosystem. Particularly, the higher level of nutrients caused the higher phytoplankton density near fish culture zones, organic enrichment of the ecosystem, changes in sediment chemistry and the ecology of benthic organisms. However, these the effects of effluents resulting from cage and other forms of aquaculture activities depend primarily on the annual fish production, area, depth of the water??lake, water residence time, feeding regimes and methods.

The paper "***Assessing Environmental Impacts of Finfish Aquaculture in Marine Waters***" (William Silvert, 1992) has determined the environmental impacts of marine finfish aquaculture in terms of oxygen depletion, benthic deposition, and eutrophication at different scales and different points of time. By another word, these effects are classified as internal, local, and regional impacts. Internally, cage finfish culture impacts on particular farm itself and its immediate environment such as oxygen depletion by the fish within the boundaries of a single fish farm. Locally, these impacts are occurred nearby farms and wild populations within distances on the order of a kilometer. This effect derived by the faecal matter and unconsumed pellets on the seafloor under the cage impact on both the farms and the environment. Regional impacts involve an entire inlets or larger water body with space scales of many kilometers and time scales ranging from a single tidal cycle to an entire season. Like eutrophication which potentially lead to increase frequency of toxic algal blooms.

The paper**: "*Environmental Impact of the Marine Aquaculture in Gulluk Bay, Turkey*" (**Demirak et al., 2006) stated that the environmental impact of marine aquaculture is primarily a function of feed composition and feed conversion, feacal waste generation, organic and inorganic fertilizers, limiting materials, algicides and herbicides, disinfectants, antibiotics, inducing agents, osmoregulators, piscicides, probiotics etc. And then it assesses and compares on a macro scale in the concentration gradient of nutrients and chlorophyll between cage stations and reference stations. Consequently, to produce one ton of live weight fish, the organic wastes, nitrogen, and phosphorous were 2,500kg, 60kg, and 10kg respectively.

The paper "***A Review of the Environmental Effects and Alternative Production Strategies of Marine Aquaculture in Chile***" by Alejandro H. Buschmann, Daniel A. Lopez & Alberto Medina, 1995 indicated that aquaculture activities might have effect on the environment in a variety of ways. It can affect the quality of sediments beneath culture installations and produce variations in the composition of the water column, which include increased nutrient levels, turbidity, organic matter, and reduced oxygen concentrations, conductivity levels and pH that can lead to enhanced sediment metabolism, sulphate reduction and high ammonium efflux and sulphide accumulation. These affect levels are varying relying on the distance from culture center and natural characteristics of culture sites. Moreover, feeding methods and food quality also affect the waste loading. The particular number has been mentioned, there are 7,800kg of N and 950kg of P per day to produce 100 tons of salmon. Therefore, in 1994, the total production of salmon in Chile was 80,000 ton producing 6,240 tons of N and 760 tons of P. However, the valuable result of this paper is the estimation of the cost of Chilean aquaculture industry by expenditure incurred by waste treatments. In Sweden, expenditure amounts to UD$6.4-12.8/kg N and US$2.6-3.8/kg P. these values were transferred into Chilean case where cost of 1kg trout and salmon is in the range US$3.1-3.5, prices increased by 15-57% depending on the N and P contents of the food administered to the fish. Therefore, the prices of trout and salmon fluctuated in 1992 around US$5.5 and US$6.0 respectively. Higher FCR value mean higher quantities of feed required to produce a given quantity of fish. Higher nutrient loading are therefore associated with higher FCR values (Islam M. S., 2004)

2.3.2 Effects of environment on aquaculture

As we know, there are several researches related to the environmental impacts of fish aquaculture. Nevertheless, how are fish growth rate and fish biomass affected by different environmental conditions also the important topic for many researchers. Like other animals, fish is directly affected by the environmental states such as water quality, nutrient level, stocking density. In this part, the paper is going to mention two studies discussing the assessment of environmental effects on fish growth rate.

The paper "***A Simple Regression Model to Assess Environmental Effects on Fish Growth***" (M. J. Maceina, 1992) used the multiple-regression model to evaluate the relationships between annular fish growth and environmental variables. The model had been run based on collecting empirical length-at-age data or by computing back-calculated lengths of a 7-year investigation in In Lake Conroe (8100 ha), Texas. In which, aquatic macrophyte covergage, threadfin shad biomass, and age-1 density of black crappie were considered as the environmental variables. The general model had presented as:

$$TLINC = \mathbf{b_0} - b_1 AGE \pm b_2 (I/AGE)*ENV \qquad \textit{(Eq. 13)}$$

Where: TLINC is the mean annular growth increments in length, AGE is fish age, and ENV is environmental variable.

Consequently, for all year classes, the relationship between mean length increments and age of black crappie was negative and environmental impacts on growth will be reduced as fish grow older.

Another paper "***Effects of Tilapia Stocking Densities on Fish Growth and Water Quality in Tanks***" (A.H. Al-Harbi and A.Q. Siddiqui, 2000) had investigated the effects of feed input and stocking density of hybrid tilapia (Oreochromis niloticus x O. aureus) on growth and water quality. The study had done at laboratory level by replicated changing in feed input and tilapia stocking density. As a result, the feed consumption significantly decreased with increasing density of tilapia. And the maximum increase in fish biomass was found at the lowest stocking density and decreased with increasing density because of better feed utilization and unstressed conditions at low stocking levels. Therefore, higher stocking density negatively affects the feeding rates and percentage increase in biomass.

Chapter 3 RESULT INTERPRETATION

3.1 Socio-economic and demographic characteristics of the sample

3.1.1 Household (HH)

The household size of surveyed data is fluctuant around from 2 to 8 persons in three provinces. There is not significant difference in HH size among three regions with an average of 4.7persons/HH. In which, Phu Yen has the largest in HH size as 5.3 persons.HH and number of persons per household in Khanh Hoa is lowest as 4.4 persons. They are considered as the common family in Vietnam currently when normally the family size in Vietnam ranges 4 – 5 persons/HH (General Statistic Office, 2008).

Household income is one of indicators to assess the living standard of a population. The surveyed data shows the cross revenue of lobster farming per HH in three provinces is very high with the annually average income as $US 32,602 per year. In which, some HHs got the highest income level as more than $US167,000/year and some of others got the lowest income level as US$ 3,000/year. We can say that, Lobster aquaculture in the high gross revenue industry, simultaneously requiring high investment on feeding, cage preparation, anti-biotic use, boats. From general information given by respondents, this total investment usually account for 65-70% of total revenue except mentioning on survival rate in culturing process. Therefore, it is the high profitable industry but most poor people could not get into due to lacking of invested money.

Table 5: HH size and HH gross revenue from lobster farming of surveyed respondents in three provinces

	Household size (number of persons)			Annually HH gross income ($US)		
	Max	Average	Min	Max	Average	Min
Average	8	4.7	1.9	167,619	31,602	3,000
Ninh Thuan	7	4.6	2	42,429	15,758	3,000
Phu Yen	8	5.3	1	148,114	44,982	4,535
Khanh Hoa	9	4.4	2	167,619	29,519	3,291

Source: Own survey

Education level of lobster farmers is seen as the factor affecting on the lobster productivity. Education level directly impacts on the ability to acknowledge and apply culturing technologies, hence, it effects indirectly on the lobster productivity. Surveyed data shows most lobster farmers educated at secondary, high school and lower level which account of 98% in total, especially, there are 5% lobster farmer have not educated or trained. Meanwhile, the famers educated as vocational training and university just account 2% in total. Most of the household leaders had attained a low level of education giving the evident to explain the low in lobster productivity.

Farmer’s experience in lobster culturing is regarded as factor affecting on farming productivity. Generally, we expect that, farming experience support farmers to avoid and reduce the losses of risks as well as save inputs in farming. However, with the natural disaster such as flood, storm or drought, culturing experience is not the expression variable. On average, the surveyed respondents have experienced in lobster farming as 8.3 years. In which, famers in Nha Trang got the highest experience of 10 years and farmers in Ninh Thuan got the lowest experience by 6 years. It is appropriate with the general picture in three regions where Nha Trang is the first province in lobster culturing whereas Ninh Thuan has just developed this industry recently.

Lobster farmer’s occupation or substitute job is also the feature to see the importance and potential development of lobster culturing currently and in the future to locals. Most HH income relies on the lobster farms when 56% of surveyed household stated that every member in their family is only working on lobster culturing. There is 21% of household working on other jobs together with lobster culturing such as government staff, do business, worker, motorbike preparation, motorbike driver. Additionally, 23% of respondents do fishing and lobster farming simultaneously. Therefore, marine cage lobster farming is the main income resource of most farmers surveyed; this aspect must be regarded by policy makers and local authorities in planning and developing the lobster aquaculture industry in these regions.

Table 6: General Characteristics about Lobster Farmers in the Surveyed Areas

	Lobster farmer's education			Experience in lobster farming (years)	Occupation		
	Secondary school and lower	High school	Vocational training/ University		Lobster culture only	Lobster culture &fishing	Lobster culture &others
Average	73%	25%	2%	8.33	56%	23%	21%
Ninh Thuan	61%	34%	5%	6	66%	21%	13%
Phu Yen	77%	23%	0	9	61%	13%	26%
Khanh Hoa	80%	18%	2%	10	40%	36%	24%

Source: Own survey with un-weighted average

3.1.2 Lobster farm characteristics

- Lobster seed

100% of respondents chose to culture spiny lobster because of high profit and high efficiency due to the high value, good market price, high productivity, and market referable. However, the culturing period of spiny lobster is so long usually lasting around 20 months and requiring high investment. Therefore, some farmers have combined culturing spiny lobster with red lobster, rock lobster, green lobster in order to reduce the risks because these species are more defensible with diseases, higher in growth rate. In addition, the farming period of these species is shorter than that of spiny lobster by 10-12 months, thus, farmers could harvest "shorter investment (red lobster, rock lobster, green lobster) to culture longer culturing species (spiny lobster)".

On the other hand, origin of lobster seed also affect on its productivity. Some laboratory studies presented as Tropical Spiny Lobster Aquaculture Symposium 9-10 December 2008, Nha Trang, Vietnam indicated that lobster seed is very sensitive and stressed with the transferring distance, hence, the further in transportation time, the lower in survival rate in farming process. Therefore, determination the seed source is very important task of all farmers. Unfortunately, most respondents said that they bought post larva from middleman without considering source of this seed accounting 87% of HH surveyed, 11% of household bought the post larva from fisherman in the same region and 4% of lobster famers had bought the seed from other provinces such as Binh Dinh, Da Nang, Binh Thuan,...

- Culturing cage

Lobsters are farmed in different types of cage depending on its location such as in Ninh Thuan 100% of household use only floating cage whereas in Phu Yen both floating cages and submerged cages are applied. Generally, submerged and floating cages are more referable recently because of its flexibility. Famers could move these cages from off-shore to in-shore during the unstable weather or from polluted water/disease area to the cleaner/without disease area.

The cage size in three regions is not significant different with average size is of 11.4m^2 (length x largeness). This paper does not distinguish the different in the height of lobster cage because most cages are designed similarly in the height commonly ranging from 1.5 to 2 meters.

Finally, number of cages per HH clarifies the culturing scale affecting the lobster productivity through the culturing techniques, investment, and economic scale. Ninh Thuan is regarded as the smallest scale as 10 cages/HH and Phu Yen is considered as the largest in scale with 26 cages/HH. As average, the number of cages per HH is of 16 cages.

Table 7: Lobster Cage Information of Surveyed Households

	Total No. of cages	Cages /HH (average)	Cage type			Cage size (m^2)
			Floating cage	Wooden fixed cage	Submerged cage	
Sample	1,693	16	53%	6%	41%	11.4
Ninh Thuan	217	10	100%	0	0	14.4
Phu Yen	797	26	27%	0	73%	9.4
Khanh Hoa	679	18	32%	18%	50%	10.5

Source: Own survey

Generally, after buying the post larva from middleman, lobster seeds were nursing average 86 days in the nursing cages with the stocking density is of 328 species/cage. When lobsters weighted 100-150g with the survival rate is of 78%, they are moved to the commercial cages with the density about 100 – 150 species per cage until harvested (own survey).

- Culturing period

The time for lobster culturing is not significantly different among three provinces with the average time for a crop was 16 months. However, there was difference in the culturing time within one region because of the seed size and feeding regime. Hence, some lobsters were farmed for only ten months; others were farmed for 21 months.

Table 8: Months for lobster culturing in three regions

	Culture period (months)		
	Max	Average	Min
Ninh Thuan	20	17	10
Phu Yen	21	17	10
Khanh Hoa	21	15	10
Sample	21	16	10

Source: Own survey

- Feeding

Trash fishes are dominant feed for lobster in these areas including mini crabs, shrimps, fish, and other shells. The distribution of these types in lobster feed is presented in the following figure:

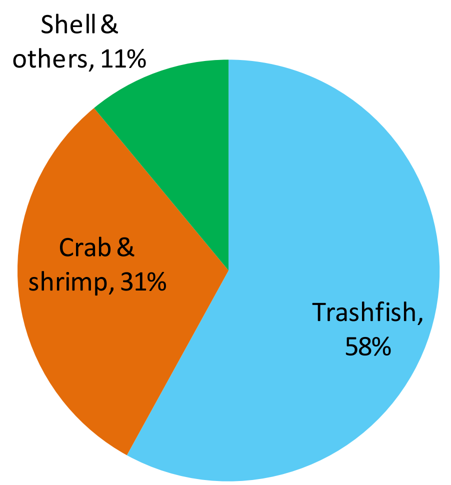


Figure 13: The distribution of feed ingredients was used for lobster culturing

Source: Own survey

Calculating for a crop, amount of trash fish used are highest. However, different type of fish is used in different development period. Such as, at the nursing period, shrimp and crab are referable because of the high nutrient ingredients that support lobsters grow quickly. However, the price of this feed is so high from 25 to 35 thousands VND/kg depending on the seasons. After nursing period, so, trash fishes are mainly used because it's much cheaper as 11 – 12 thousands VND/kg (Own survey). Sometime, there is not enough trash fish because of the weather, shells and others like soil worm is applied. The study has not gone to discuss the feed quality of each fish type because it's so difficult to get this information from farmers when it relies on the weather, seeding season, fish market and culturing place. Therefore, sometime because of the rare fishes in the market due to storm or flood, they must use the stale fishes that strongly affect on water quality. And in the fishing season, the fishes are variety, fresh and good quality fishes are fed.

- Feed conversion ratio (FCR)

Feed conversion ratio is the indicator to evaluate the feed efficiency as well as the feeding proficiency. Currently, lobster aquaculture in Vietnam fully relies on the trash fishes; hence, the feed conversion ratio is much higher comparing to the pellet feed because of high water ingredients and low concentration of nutrients. In this paper, the FCR of lobster culture is estimated basing on the reported information from farmers. Generally, the average FCR in three provinces is 31.84, it means that in order to produce one kg of lobster, the needed fresh fish is 31.84kg. However, this ratio is significantly different among HHs, there is the highest level in FCR as 84.4 in Phu Yen province where trash feed used as inefficient, conversely, some HHs in Khanh Hoa province get the FCR as 6.5 indicating the high productivity in feeding regime. These results in FCR is much higher comparing with the FCR = 18 given from laboratory study related determining the nitrogen loading from lobster farm in Xuan Tu – Van Phong Bay, Nha Trang done by T.N.Chien in 2005.

Table 9: Feed conversion ratio of lobster farming in three provinces

	Feed Conversion Ratio (FCR)		
	Max	Average	Min
Ninh Thuan	36	27.5	18.7
Phu Yen	84.4	42.4	15.2
Khanh Hoa	63	27.7	6.5
Sample	84.4	31.8	6.5

Source: Own survey

- Labor sources

Lobster farming is not the strictly taking-care needed species; therefore, lobster culturing does not need much labor force. Labor force for lobster farming mainly belongs to family members. Normally, there are two persons per HH working in the farm at 1-25 lobster –cage scale. Hence, in the early morning, the wife must goes to the fish market for buying feed then come back to clean and prepare the feed for 4 – 5 hours. At 9 – 10 am, the husband brings feed to culturing place then does feeding and cleans the cages by removing the wasted feed from previous day out of the cage; it takes 3 – 4 hours. Some HH have more than 25 cages, they will hire one or two workers for feed preparation, feeding, and guarding in the evening, so the number of labors has not considered as the factor influence on lobster productivity.

- Loan and interest

Lobster culturing requires high investment, thus 82/110 households had a loan of fund from government banks or local credit agencies. The years by 2006, it was easy for lobster farmers to borrow money from government at suitable interest around 1.5 – 2%/year. Recently, however, because of disease outbreak and other natural disaster, this resource has been limited thus farmers must access to the legal/illegal local credit organizations or individual with high interest (around 5 – 15%/year) in order to continue their farming. On average, 79/110 HH have been loaned with the average volume of each HH was 54million VND for a lobster crop. In which the highest borrowed amount archives at 250 million VND and the lowest borrowed level was 10million VND. Khanh Hoa and Phu Yen are two provinces where the number of HH has been loaned around 75 to 76% in total surveyed HH while this ratio in Ninh Thuan was little lower of 61%. Generally, loan source is very important for lobster farming, therefore, to help the farmers develop their farm, it is necessary to set up the specific credit budget for lobster farmers from the government.

Table 10: Amount of money borrowed by lobster farmers for a crop

Province	No. HH borrowed	Proportion of total surveyed HH (%)	Money had been lent (million VND)		
			Max	Average	Min
Ninh Thuan	17	61	100	25	10
Phu Yen	28	76	250	89	10
Khanh Hoa	34	75	200	48	10
Sample	79	72	250	54	10

Source: Own survey

- Market

Vietnam lobster is mainly used to export to other countries such as China, Taiwan, and Japan. The domestic consumption just accounts for less than 10% and just available at the luxury restaurants. The domestic market is distributed by the middleman. 100% of respondents said that, they sold lobster for middleman and the price was given by middleman also. Usually, farmers contact with the buyers to ask the price, and middleman will come to harvest and weight lobster at the cage or farmers bring lobster to the inland for selling.

- Farmer's environmental knowledge

The question related to whether lobster cage culture caused the seawater pollution or not as well as what are factors impact on sea water quality. 57/110 HH indicate that lobster cage farming is affecting on water pollution because of the feed waste, stale fishes used, anti-biotic use, high stocking density, lobster's faeces, and sediment when doing culture for long time at one place regardless on environmental conservation. Because of the open-access sea, lobster farmers easily move to the new places after generating the pollution in the current area. Additionally, the responsibility in marine environment protection is not clear, if someone is aware of in preserving their surrounding environment, once some others are generating environment dirty, in the marine environment, they are affected similarly. Therefore, there is not any encouragement for whom farming friendly with the environment. On the other hand, 53/110 of respondents are not aware of their duty for the current wastes, so said that seawater pollution is because of industrial wastes, regulation of water flow, natural weather so on.

3.2 Profitability of marine cage lobster operation

3.2.1 Cost of lobster production

- Investment costs consist of cage preparation, boat, diving equiptment, light and electricity, guarding cottage.

+ All most of the lobster farmers have the individual boat for moving and trasfering lobster feed from landward to offshore with the distance around 3 – 15 sea kilomers. The average investment for one boat is 12.86 millions VND, in which some farmers bought the new one, the price may be of 35millions VND/boat and others bought the second-use with the lower price is 750 thousands VND. The using period are varying, in general, the depreciation time for a boat is 12 years.

+ Cage preparation: the cage for grow-out period with the average size is 11.4m^2, the average cost of one cage is 2.73 millions VND and must be replace the new one after around 7 years (dipreciated time). Besdes the main cages for culturing, most households have the replacement cages (or backup cages) to trasfer lobster in short time for cleaning cages.

+ Diving equiptments are the tools that the farmers use every day to dive to the bottom of the cages for looking after lobsters, feeding, and removing feed waste. Generally, every household has one diving tool costing about 2.67millions VND for 5 years-used period.

+ Because lobster is mainly cultured in offshore so far to their house, therefore, every farms has been built the guarding cottage to stay for guarding the lobster cages. The average cost for constructing a cottage is 6.2 millions VND for 5-years-used period.

+ Finally, the lights and electricity are needed for staying at the guarding cotatge as normal 711 thousands VND/year.

- **Production costs** include cost of post larva, feed, antibiotic use, daily fuel, equiptment correcting, labor, loan's interest, cage cleaning,…in which the equiptment correcting are regarded to the correcting costs of boat, diving tool, cost of replacing nets covering the cage. Detail of each item is presented in table 17

- **Environmental cost**: the detail will be presented in part 3.7. Through this part, the effect of water quality on lobster productivity is estimated. Hence, based on the reality of nitrogen pollution per househole, how much does it affect on lobster productivity. Relied on lobster market price, this effect could be convert into monetary value . However, this cost had happed and affected on reducing the lobster productivity in each cage. Hence, in the Cost – Benefit Analysis of lobster farm, this cost will become the benefit because without this pollution due to nitrogent loads from lobster cage, the lobster productivity will be higher. By other word, it is the benefit that the lobster farmers reveive when the seawater quality is improved.

Finally, to simplyfy in Cost – Benefit Analysis, every costs with the used time more than one crop will be depriciated by straight line as year then multiply with the crop time (average culture time for one crop was 16 months approximating 1.3 years) (table 8).

3.2.2 Revenue

Revenue from lobster farm is estimated through market price multiplies with output. The market price of lobster is varying depeding on the season and imported market as reported by the farmers. For a crop 2007, the average price of lobster was 949,000VND/kg (collected information from respondents' selling price). This lobster market price looks relative higher than normally because the survey had done in the end of 2008, be affected by the disease outbreak in 2006-2007, the lobster production had reduded significantly whereas market demand on lobster is increasing that endorses the lobster price to the highest level. In addition, the average lobster production per cage was 57kg containing about 65 lobster species, so,the average weight of one lobster was 0.86kg. Total benefit and total costs are estimated as in the table below.

Table 11: Benefit and costs of a lobster cage per one crop (1.3 years)

Benefit	Production (kg)	Market price (1,000VND)	Total (1,000VND)
Revenue	**57**	**949**	**54,093**
Costs	Total cost(1,000VND)	Depriciated time (year)	Cost/cage/crop (1,000VND)
Cage preparation	2,730	7	390
Boat	12,860	12	1,071
Diving equiptment	140	5	28
Guarding cottage	1,600	5	320
Light and elasticity	711	1	924
Juveniles	13,216		13,216
Feed	20,000		20,000
Antibiotic use	200		200
Daily fuel	689		689
Equiptment correcting	266		266
Labor (home & hired)	5,942		5,942
Loan's interest	120		120
Cage cleaning	300		300
Total cost			**43,466**
Profit			**10,627**

Source: Own survey

**Note*: labor cost has been calculated based on the cost for hiring labor and cost of family labor. In which , the opportunity cost of family members working on lobster farming based on the hiring cost in each area annually about 14,500 thousands VND/year (approximately US$830/year).

Now we would recalculate the cost by group in which the initial investment, depreciate cost, and cost for a crop investment for one lobster cage are presented as the following table:

Table 12: Cost, Revenue, NPV, IRR by Crop Production

Items	Unit	Value
Total revenue for one cage/crop	Thousand VND	54,093
Initial investment	Thousand VND	17,330
Investment for a crop	Thousand VND	41,657
Depreciated cost for a crop	Thousand VND	1,809
Interest rate used for working capital	%/crop	10
Profit/crop	Thousand VND	10,627
NPV	Thousand VND	34,250
IRR	%	43

Source: Own survey

Above table is calculated with these assumptions:

- The imputed interest on the working capital of the total investment based on the market interest as 10% for a crop (1.3year).

- The production cycle is 10 crops equivalent to 13 years. It is chosen based on the longest using period of the equipment for 12 years of a boat with expectation, at that time, all invested equipments depreciated completely.

- Although each item in cash flow would occur in different time, the study assumes all cash flows arise at the end of each year.

Consequently, the Net Present Value of the production cycle is 34,250 thousands VND. It implies, cage marine lobster aquaculture in Vietnam is the profitable project. In addition, IRR value is very high as 43%, four times higher than the interest rate of working capital is seen as the opportunity cost of capital. Obviously, cage marine lobster aquaculture in Vietnam is considered as a very attractive investment industry. Therefore, in the future, the pressure on this industry will be much higher.

Finally, as mentioned above, the environmental pollution seen as the nitrogen waste had caused reduction in lobster productivity. Therefore, without this effect, the profit per lobster cage will be higher.

3.3 Difficulties in marine cage lobster operation

This question had been given to the lobster farmers with the purpose of determining the challenges that famers are facing and supporting information for policy makers. The question related to the seed quality, seed supply, technology information, weather, loan, feed sources, feed cost, labor force, government regulation, and environmental regulation.

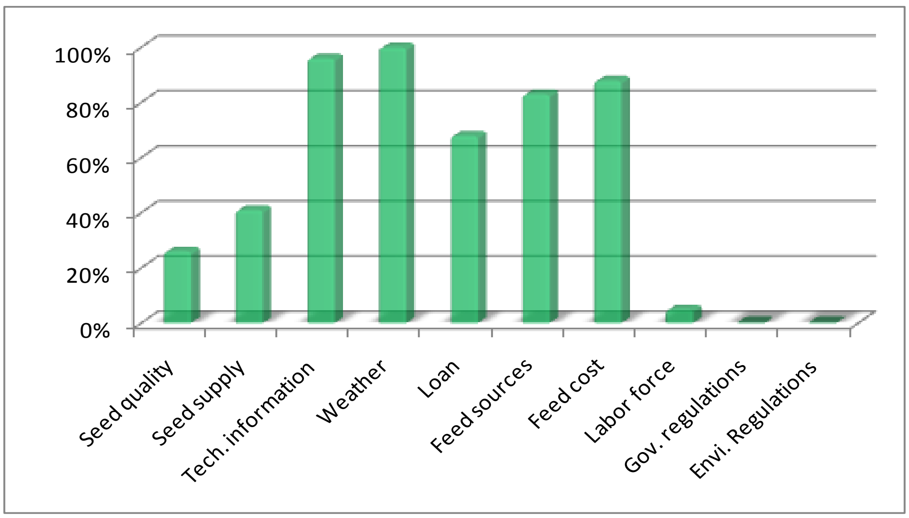


Figure 14: Percentage of difficulties of lobster farming in surveyed households

- Fortunately, no one faces with the challenges in government regulations or environmental regulations. Currently, HH are freely to enter sea area for culturing, without paying any entrance fees, and liberally move from one place to another.

- Labor force is not the difficulty at present because most HH could culture by themselves thus they do not hire much labor except the harvesting season. However, in the coastal areas, the labor force is abundant; it is easy to the labor in the harvesting time.

- 100% of respondents indicated weather is their issue such as raining, storm will change the salt level in sea water that make the lobster died because lobster could not survive in the fresh water. Recently, the weather changes irregularly that strongly impacts on their production.

- Technology information is also the most challengeable to farmers because most farmers do lobster culture relying on their own experiences. So far, there is not any official training course on lobster culturing skills for farmer, thus, they farm by themselves or their neighbors' sharing experiences. The information on disease prevention and bio-chemical use has not directly transferred to the farmers; they found this information from friends or middleman or based on the production's instruction. Additionally, market information and lobster price have not been the responsibility of any person, instead of that, farmer access this information through middleman and accepted selling price from local middleman mainly depend on the export markets.

- Feed source and feed cost are the next challences to the lobster farmers. Lobster is the gobbled species, hence, everyday to feed the current lobster cages, a large a mount of trash fish had used. That creates the stressure on the fishing industry. Especially, when the fishing in Vietnam is going to shrink that conversely affect on the feed source for lobster. Therefore, the lobster farmers are difficult in buying trash fish if the weather is not good or in the off-fishing seasons. Consequently, at that time the fish price is pushed up irregularly, some time out of the farmer's efforts.

Finally, 40% and 26% of HH are difficult in juvenile source and juvenile quality respectively. In the long view, they are also the challenges of Vietnam lobster industry when the lobster seed is basing on the wild catch. With the fast expandability in this industry, the demand for lobster seed increases whereas the we do not ensure the natural resource of lobster seed. In the seeding season, some famers with large scale could not buy enough juveniles although they tried to buy from other provinces. Moreover, now, there is not any office or government agencies are responsible for controlling the juvenile supply as well as checking seed quality. Therefore, the seed quality was normally evaluated by the relation or loyalty between farmer and middleman or friend. Hences, some farmers had been lost a lot of money because of the poor or un-qualified lobster seed. Its also the potential for disease outbreak.

3.4 Simple biological model of marine cage lobster in Vietnam

Above information indicates that the lobster productivity in these provinces has decreased gradually by time. One more time, in this part, the simple biological model for lobster culture is shown by stock size (number of cage, NoC) and productivity (kg/cage) using time series data provided by local offices collected from 1992 to 2008 in Van Ninh- Khanh Hoa and from 1994 to 2008 in Ninh Thuan. At the beginning, there were only two lobster cages, the productivity had reached at 150kg/cage. And then, when the number of cages increased, the lobster productivity had also decreased because of the stocking density at that time under the environment carrying capacity. The lobster quantity per cage was at the peak of 200kg/cage when the number of cages in the region is of 35.

However, when the number of cage in this region enlarged to 75 and higher, the productivity has reduced gradually. From this point, it could be stated that, the number of cages has risen higher than the carrying capacity of the environment. Especially, in 2006 and 2007, the number of cages turned up 7,200, the productivity had gone down rapidly to 44 and 48kg/cage respectively.

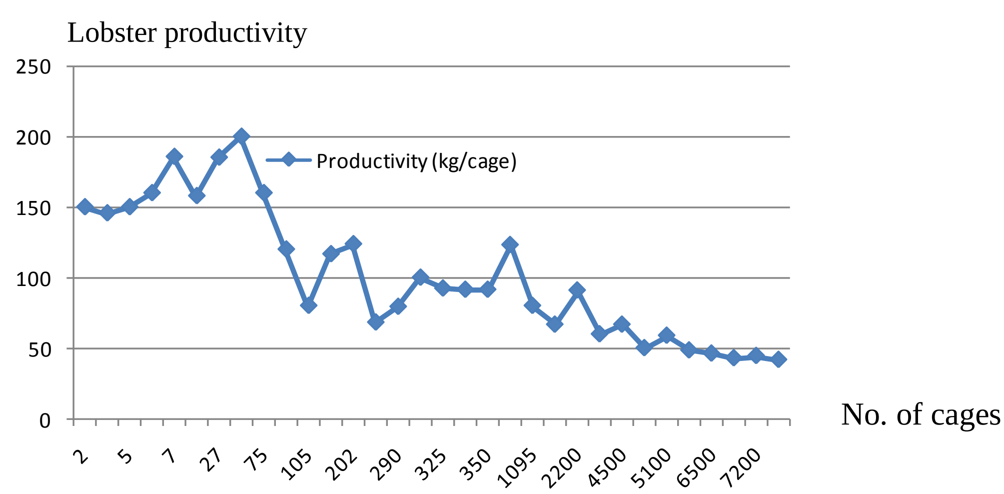


Figure 15: Relation between No. of cage and productivity

Source: Department of Agriculture and Rural Development in KhanhHoa and Ninh Thuan

Although in some cases the diminishing rule of lobster productivity by number of cages had not approved. It could be understood as there are other factors impacting on the lobster productivity because the coefficient of determination, or $R^2 = 0.80$ revealing that 80% of variation in lobster productivity is explained by the variation of number of cage and 20% explained by other factors.

By running the OLS directly between two variable lnQ and lnNoC in order to show the logistic model with 32 observations, the result is presented as following:

$$\ln Q = 5.5 - 0.17 \ln NoC \quad (R^2 = 0.80) \qquad \textit{(Eq. 14)}$$

Where: Q is the productivity (kg/cage) and NoC is the number of cage

These data can be plotted as figure:

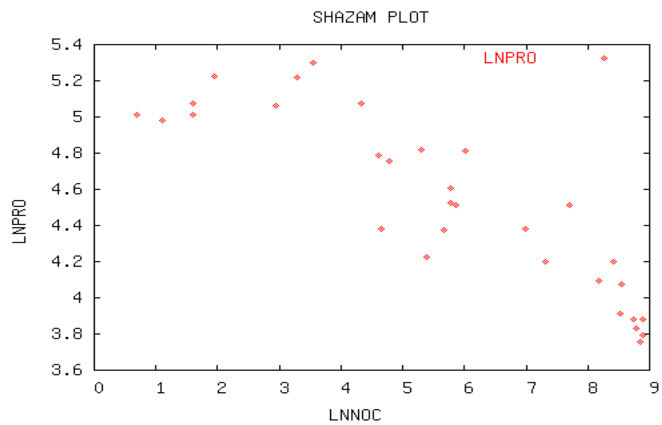


Figure 16: Plotting the relationship between lnPro and lnNoC of lobster culture from 1992-2007
Source: Department of Agriculture and Rural Development in Khanh Hoa and Ninh Thuan.

$$(14) \Leftrightarrow \quad Q = e^{5.5}/NoC^{0.17} \quad \Leftrightarrow \quad Q = \frac{245}{NoC^{0.17}} \qquad \textit{(Eq. 15)}$$

Therefore, Fig. 16 is the combination between equation (15) and available data.

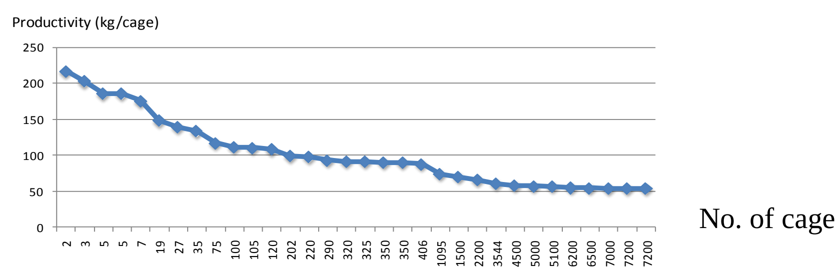


Figure 17: Relationship between No. of cage and the productivity in studies regions

Three above figures imply that, if the number of cages in certain area is under the environmental carrying capacity, the lobster productivity will decrease. However, when number of cages over the carrying capacity of environment, at from that time, if we increase the number of cage, the lobster quantity per cage will decline gradually. By other word, when marine area is not expanded, the density of cages per certain area increase due to the raising in number of cages. It impacts on the water quality, the feed competition, marine nutrient sources. Consequently, the amount of lobster per cage is decreasing when the cage density (number of cage per certain area) increases.

3.5 Wastes loading from cage lobster aquaculture

In this study, Nitrogen and phosphorous are considered as the parameters representative for marine water quality. Hence, the next step is going to estimate the N and P loading from cage lobster aquaculture. To estimate these wastes, the information related on N, P content in trash fish and in lobster must be determined. However, because lacking of the data related to the P content in lobster, the paper just focuses on estimating the nitrogen loading.

The nitrogen content of trash fish in Vietnam is very low. The average nitrogen content in trash fish feed is 1.337% and the measured nitrogen content in the harvested lobster is 3.580% (T.N.Chien, 2005). The average trash fish conversion ratio (FCR) is very high, given in Table 9 is 31.8. It means that we must invest 31.8 kg of trash fish feed in order to harvest 1kg marine cage lobster.

Combining the formula to estimate the wastes loadings of Wallin & Hankanson (1991) (Eq. 12) and available data, the total nitrogen wasted into the marine environment from trash fish feed marine lobster cage aquaculture in three provinces in 2007 crop was calculated. The result shows, in order to produce one ton of lobster, the nitrogen loadings in to the environment will be 389kg. wholly, in 2007 crop, the total lobster production in three provinces was 1,792tons, and so the total nitrogen loading into marine environment was 803 tons.

Table 13: Nitrogen loading from marine cage lobster operation in three province in 2007

	Khanh Hoa	Phu Yen	Ninh Thuan	Total
FCR	33.3	42.4	27.5	
Total lobster production (ton)	1,200	580	12	1,792
Nitrogen loadings (ton/crop)	491	308	4	803

Source: Own survey

This figure is higher than that of the study done in Van Phong Bay in 2005 by Thai.N.C. . he had showed the nitrogen loading into marine environment was of 205 tons when one ton of lobster produced. However, he had stated with that amount of nitrogen loading, it was 5.5 times higher than that of Vietnam marine pollution standard after measure the environment carrying capacity. Therefore, absolutely this paper can say that the current nitrogen leasing volume is much higher than that of Vietnam marine pollution standard. It implies this loading level out of environmental carrying capacity.

Finally, to know exactly how many percentage of 803 tons released nitrogen really created the marine water pollution in these areas, we ought to estimate the environmental carrying capacity of each province. Nevetheless, there was not available data related to the water depth, the water flow and water exchange in these study sites. For that reson, the paper just brings to a close at nitrogent loading consideration.

3.6 Marine cage lobster production function

In this part, the paper is going to determine the contribution of different factors affecting on lobster productivity including the environment variable. At the beginning, the model was set up in expressing the lobster productivity depend on the feeding quantity, stocking density, culture time, farmer's experience, farmer's education, anti-biotic use, and environmental parameter. After correcting the multi-collinear and heterokadasticity errors in the econometric model, the result is described as the following table as the production regression result regardless on location dummy variable:

Table 14: Production regression result without dummy variables among three provinces

Variables	Description	Coefficient	P-value
$ln(FQ_i)$*	Feeding quantity used	0.31117	0.001
$ln(SD_i)$*	Lobster stocking density	0.66138	0.000
LNCT	Culture time for a crop	-0.20061	0.219
$ln(Exp_i)$	Farmer’s experience	-0.32965E-01	0.471
$ln(Edu_i)$***	Farmer’s education	0.11533	0.055
$ln(Anti_i)$	Cost of anti-biotic used	0.66120E-02	0.839
(EC_i)	Cost for environmental cleaning	0.16939E-01	0.339
$ln(Env_i)$	Environmental parameter	-0.90451E-01	0.152
Ln(NoC)	Number of cage per household	0.59738E-01	0.289
Constant		-0.42988	0.435

Source: Survey data and authors’ calculation

Note: * significant at 1%; ** significant at 5%, *** significant at 10%

In which, R^2 = 45%. It indicates that, 45% the variance of lobster productivity is explained by the variation of above variables.

Statistically, the model let us know that there are just feeding quantity and stocking density, two significant variables at 1%. In addition, education variable is significant at 10%.

Therefore, we can state that, there is positive relationship between lobster productivity and feeding quantity as well as stocking density. Particularly, when the feeding quantity increases 1%, the productivity of lobster goes up as 0.31%. Similarly, if we increase the stocking density to 1%, the lobster productivity will rise at 0.66%. Finally, farmer’s education is also the statistical significant variable affecting on lobster productivity. It follows what we had expected, the higher in education, the better in lobster productivity. Specifically, if the education level of lobster operator increases 1%, the productivity will go up 0.115%.

Unfortunately, the environmental parameter, the key factor expected to impact on lobster productivity, is not significant in statistic aspect in this model. It shows, amount of nitrogen waste in each household does not significantly affect on the lobster productivity of each farmer.

This result follows what we had predicted in the cage of marine cage aquaculture: the individual effect of waste from cage culture on its productivity is not visible in the case of marine culture because of the spillover effect. In the same location in the sea, the pollution impact is almost the same due to the flow of seawater and natural water exchange. Hence, although the amount of wasted nitrogen in some households is much higher than that of other households, in one location, these wastes will be overspilled and mixed each other composing the equivalent seawater quality level. Consequently, it generates the similar pressure on every lobsters farmed in this region. In other word, it is not obvious to see the different effects of water quality on marine lobster productivity in the same region. That is the reason why the environmental variable in this model is not significant.

The next step, therefore, we test the different in location expressed by dummy variable for three location Khanh Hoa, Phu Yen and Ninh Thuan in above model with the aim of clarifying whether nitrogen loading getting the regional effect or not. The result of model now is much better comparing the first model shown as following:

Table 15: Production regression result with dummy variables among three provinces

Variables	**Description**	**Coefficient**	**P-value**
$ln(FQ_i)$*	Feeding quantity used	0.34621	0.000
$ln(SD_i)$*	Lobster stocking density	0.43926	0.000
LNCT	Culture time for a crop	-0.20652	0.161
$ln(Exp_i)$	Farmer's experience	-0.86578E-03	0.984
$ln(Edu_i)$***	Farmer's education	0.92513E-01	0.098
$ln(Anti_i)$	Cost of anti-biotic used	0.19311E-01	0.505
(EC_i)	Cost for environmental cleaning	0.24352E-01	0.137
$ln(Env_i)$**	Environmental parameter	-0.13744	0.018
Ln(NoC)**	Number of cage per household	0.13535	0.011
LD1**	Dummy variable for Phu Yen location	-0.14856	0.013
LD2*	Dummy variable for Khanh Hoa location	-0.25640	0.000
Constant		-0.17172	0.731

Source: Survey data and authors' calculation

Note: * significant at 1%; ** significant at 5%, *** significant at 10%

R^2 = 57% implies 57% of lobster productivity variation is clarified by the variation of above variables. Hence, there is 43% variation of lobster productivity could not be explained by variables in the model.

Similarly, feeding quantity and stocking density are two statistically significant variables at 1%. However, the coefficient parameter of these variables is different of that in the first one. Specifically, the lobster productivity will increase 0.346% when raising 1% in feeding quantity. And if increasing the stocking density of 1%, the lobster productivity moves up 0.439%.

Two dummy variables are significant in statistical view making us think about the differences among three provinces. As mentioned, Ninh Thuan is the reference case, the negative value of D1 and D2 imply that the lobster productivity in Nha Trang and Phu Yen lower than that of in Ninh Thuan. By other word, lobster productivity in Ninh Thuan province is highest. Comparing to Ninh Thuan case, lobster productivity in Phu Yen is lower 0.148unit than that in Ninh Thuan, and productivity in Khanh Hoa is lowest with 0.256unit lower than that in Ninh Thuan or productivity in Khanh Hoa is lowest.

It is familiar with what we had though in qualitative aspect. Where Nha Trang is the first province to culture lobster since 1992 with highest in number of cage and total production as well as highest in nitrogen loading (Table 13), hence, the productivity is strongest effect by environment pollution. Meanwhile, the number of cage, total production and nitrogen waste from lobster cage in Phu Yen is lower than those in Nha Trang, that's why the lobster productivity in Phu Yen higher than that in Nha Trang. Comparably, Ninh Thuan is considered as the new province in lobster culture recently with small scale as well as low nitrogen loading, therefore, the productivity in this area is highest. The significance of dummy location variable indicates that different in lobster productivity among three provinces. Obviously, at the regional level, environment quality is different causing lobster productivity among three provinces diverse.

Moreover, when adding dummy location variable to this model, the environment variable becomes significant at 5%. It shows, the nitrogen waste from each household negatively affects on the lobster productivity. Particularly, if we increase 1% of nitrogen waste in each HH, the productivity of lobster will decrease as 0.14%. Although there is not significant correlation between dummy location variable and environment variable, the implication of regional effect has supported to see clearly the impact of seawater quality on marine cage lobster productivity.

Similarly, the number of cage variable is significant at 5% after adding the dummy variable. It means that, the lobster productivity will go up at 0.135% if the number of cages increases 1%. It infers the lobster productivity is increasing by scale.

To clarify whether the difference in lobster productivity among three provinces caused by environmental and other parameters mentioned in this model or not, the final step is to test the contribution of independent variables for this difference by slope dummy variable with three locations. The general model is described as following:

$$Ln(Q_i) = \alpha_1 + \alpha_2 ln(FQ_i) + \alpha_3 DUMMY1_i * ln(FQ_i) + \alpha_4 DUMMY2_i * ln(FQ_i) + \alpha_5 ln(SD_i) + \alpha_6 DUMMY1_i * ln(SD_i) + \alpha_7 DUMMY2_i * ln(SD_i) + \alpha_8 ln(CT_i) + \alpha_9 DUMMY1_i * ln(CT_i) + \alpha_{10} DUMMY2_i * ln(CT_i) + \alpha_{11} ln(Exp_i) + \alpha_{12} DUMMY1_i * ln(Exp_i) + \alpha_{13} DUMMY2_i * ln(Exp_i) + \alpha_{14} ln(Edu_i) + \alpha_{15} DUMMY1_i * ln(Edu_i) + \alpha_{16} DUMMY2_i * ln(Edu_i) + \alpha_{17} ln(Anti_i) + \alpha_{18} DUMMY1_i * ln(Anti_i) + \alpha_{19} DUMMY2_i * ln(Anti_i) + \alpha_{20} ln(EC_i) + \alpha_{21} DUMMY1_i * ln(EC_i) + \alpha_{22} DUMMY2_i * ln(EC_i) + \alpha_{23} ln(Env_i) + \alpha_{24} DUMMY1_i * ln(Env_i) + \alpha_{25} DUMMY2_i * ln(Env_i) + \alpha_{26} ln(NoC) + \alpha_{27} DUMMY1_i * ln(NoC) + \alpha_{28} DUMMY1_i ln(NoC) + \alpha_{29} DUMMY2_i ln(NoC) \qquad \textit{(Eq. 16)}$$

The paper have checked variable by variable to see the differences of each parameter in three locations with the following result: R^2 = 61%, although after adding several variables, the significant of the model is not improved much.

The result expresses there is the differences in feeding quantity, stocking density, farmer's experience, farmer's education, anti-biotic use, nitrogen waste, and number of cage between Nha Trang and other provinces. In addition, there is significant difference in culture time between Phu Yen Province and others. By that the culture time of lobster in Phu Yen shorter than that of in other provinces. Moreover, the amount of nitrogen waste in Nha Trang is higher than that of in other province with significant at 1%. It is the hint to point out the environmental parameter affecting on the lobster productivity at the regional level. In the same way, the lobster productivity in Nha Trang is lowest with the highest in nitrogen waste.

Table 16: Production regression result without cross effect of dummy variables among three provinces

Variables	Description	Coefficient	P-value
$\ln(FQ_i)$*	Feeding quantity used	0.77804	0.002
$\ln(SD_i)$	Lobster stocking density	0.19754	0.359
LNCT	Culture time for a crop	0.31657	0.233
$\ln(Exp_i)$	Farmer’s experience	-0.16686E-01	0.755
$\ln(Edu_i)$	Farmer’s education	-0.64940E-01	0.541
$\ln(Anti_i)$	Cost of anti-biotic used	-0.24241E-01	0.663
(EC_i)	Cost for environmental cleaning	0.58553E-03	0.982
$\ln(Env_i)$*	Environmental parameter	-0.46603	0.006
Ln(NoC)*	Number of cage per household	0.43321	0.007
LD1xlnFQ	Interaction of dummy variable and log feeding quantity	0.28310	0.356
LD2xlnFQ*	Interaction of dummy variable and log feeding quantity	-0.80859	0.001
LD1xlnSD	Interaction of dummy variable and log stocking density	0.33169	0.377
LD2xlnSD***	Interaction of dummy variable and log stocking density	0.46083	0.072
LD1xlnCT*	Interaction of dummy variable and log culture time	-1.2087	0.002
LD2xlnCT	Interaction of dummy variable and log culture time	0.26687E-01	0.917
LD1xlnExp**	Interaction of dummy variable and log farmer’s experience	0.35136	0.038
LD2xlnExp*	Interaction of dummy variable and log farmer’s experience	-0.21985	0.005
LD1xlnEdu	Interaction of dummy variable and log farmer’s education	0.53104E-01	0.730
LD2xlnEdu**	Interaction of dummy variable and log farmer’s education	0.30039	0.018
LD1xlnAnti	Interaction of dummy variable and log anti-biotic use	0.23106E-01	0.782
LD2xlnAnti***	Interaction of dummy variable and log anti-biotic use	0.11332	0.080
LD1xlnEC	Interaction of dummy variable and log environment cleaning	0.56600E-01	0.239
LD2xlnEC	Interaction of dummy variable and log environment cleaning	-0.11586E-01	0.741
LD1xlnEnv	Interaction of dummy variable and log environment parameter	0.10798	0.568
LD2xlnEnv*	Interaction of dummy variable and log environment parameter	0.96119	0.000
LD1xlnNoC	Interaction of dummy variable and log number of cage	-0.19274	0.288
LD2xlnNoC*	Interaction of dummy variable and log number of cage	-0.88776	0.000
Constant		-1.8051	0.000

Source: Survey data and authors’ calculation

Note: * significant at 1%; ** significant at 5%, *** significant at 10%

The environmental variable in this model are more valuable with the significance at 1% due to support of some slope dummy variables. However, several slope dummy variables has made the model is so complicated and not trust in explanation. For example, the result shows the significant difference in number of cage in Nha Trang comparing to that in Ninh Thuan. Particularly, number of cage per household in Nha Trang is lower than 0.89 unit that in Ninh Than. However, coming back to the data source, on average, the number of cage per household in Nha Trang is highest. Therefore, comparing the results of three above model, the second model (table 15) is seen as the best, so from now, every calculation related to production function will be based on this model.

3.7 Environmental effect of marine cage lobster culture

The main task of this paper is to assess the environmental impact on marine lobster cage aquaculture when the nitrogen waste is regarded as the pollution parameter which mainly comes from unconsumed feed. In part 3.5, we had estimate the total nitrogen loading of lobster cage into marine environment in three provinces is 803 tons for a crop. In order to calculate the environmental cost of this waste to the environment, the Change of Productivity method and the expenditure incurred by waste treatment approach as mentioned in the theory methodology part have been used.

With the Change of Productivity method, we would use the result from above production function to estimate the environmental cost of marine cage lobster culture industry. There are several factors having a effect on the lobster productivity including the environmental factor. Therefore, in order to only assess the effect of environmental parameter on the productivity, we must assume and control other factors are un-change (constant), the productivity of lobster is affected by environmental factor expressed as:

$$Q = \alpha_T Env^k \qquad \textit{(Eq. 17)}$$

As mentioned above, the econometric model 2 is used to estimate the environmental effect on marine cage lobster aquaculture. Other variables are replaced as the average value from surveyed data. The result in table 15 indicates that, the environmental parameter and lobster productivity in three regions are different; therefore, we are going to estimate separately the effect of environmental on lobster productivity in Ninh Thuan, Phu Yen, Khanh Hoa respectively.

Based on the result of model 2 in Table 15, the lobster production function in Ninh Thuan could be re-written as:

LnQ = -0.17172 + 0.34621lnFQ + 0.43926lnSD – 0.20652lnCT – 0.86578E-03lnExp + 0.92513E-01lnEdu + 0.19311E-01lnAnti + 0.24352E-01lnEC – 0.13744lnEnv +0.13535lnNoC (*Eq. 18*)

Control other variables in this equation constant by replacing the average value from surveyed data, (Eq. 18) ⇔ lnQ = 0.88 – 0.13744lnEnv

⇔ $Q = e^{0.88*} Env^{\alpha_N}$ or $Q = 2.41 Env^{-0.13744}$ (*Eq. 19*)

The scenario based on the surveyed data, if the nitrogen loadings for a square meter in Ninh Thuan is ranging from 0.93kg – 2.8kg for a crop that makes the lobster productivity loss from 2.43 – 2.09kg /m^2.

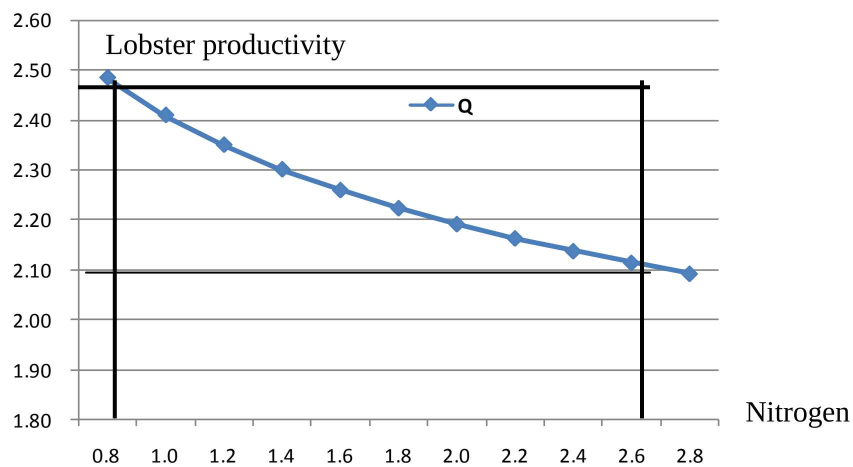


Figure 18: Relationship between nitrogen loading and lobster productivity

Similarly, the lobster productivity function in Phu Yen could be re-written as:

LnQ = -0.32028 + 0.34621lnFQ + 0.43926lnSD – 0.20652lnCT – 0.86578E-03lnExp + 0.92513E-01lnEdu + 0.19311E-01lnAnti + 0.24352E-01lnEC – 0.13744lnEnv +0.13535lnNoC (*Eq. 20*)

Control other variables in this equation constant by replacing the average value from surveyed data, (Eq. 20) ⇔ lnQ = 0.73 – 0.13744lnEnv

$\Leftrightarrow$ Q = $e^{0.73*} Env^{\alpha_N}$ $\Leftrightarrow$ Q = $2.08Env^{-0.13744}$ (*Eq. 21*)

The scenario based on the surveyed data in Phu Yen, where the nitrogen loadings for a square meter in Ninh Thuan is ranging from 0.89kg – 5.59kg for a crop that makes the lobster productivity loss from 2.1 – 1.6kg /m^2.

Finally, the production function in Khanh Hoa:

LnQ = - 0.57668 + 0.34621lnFQ + 0.43926lnSD – 0.20652lnCT – 0.86578E-03lnExp + 0.92513E-01lnEdu + 0.19311E-01lnAnti + 0.24352E-01lnEC – 0.13744lnEnv +0.13535lnNoC (*Eq. 22*)

Control other variables in this equation constant by replacing the average value from surveyed data, (Eq. 22) $\Leftrightarrow$ lnQ = 0.48 – 0.13744lnEnv

$\Leftrightarrow$ Q = $e^{0.48*} Env^{\alpha_N}$ or Q = $1.61Env^{-0.13744}$ (*Eq. 23*)

The scenario based on the surveyed data in Khanh Hoa, where the nitrogen loadings for a square meter in Khanh Hoa is ranging from 0.43kg – 5.59kg for a crop that makes the lobster productivity loss from 1.8 – 1.2kg /m2.

Consequently, with the current nitrogen loadings level in three regions, on average it makes the lobster productivity lost of 0.34kg/m^2, 0.5kg/m^2, and 0.6kg/m^2 in Ninh Thuan, Phu Yen, Khanh Hoa, respectively. If the average size of lobster cage in three regions is 11.4m^2 (own survey), the total lobster lost for a crop due to water pollution will be 3.8kg/cage in Ninh Thuan, 5.7kg/cage in Phu Yen, and 6.8kg/cage in Khanh Hoa. Relying on lobster market price of 949,000VND/kg, the monetary value of this loss will be 3.6millionVND/cage in Ninh Thuan, 5.4millionVND/cage in Phu Yen, and 6.45millionVND/cage in Khanh Hoa.

In 2007 crop, there were 187 lobster cages in Ninh Thuan Province, the total environmental effect on lobster productivity is estimated approximately 673.2millionVND for a crop. Similarly, total number of lobster cages in Phu Yen was 28,038; hence, the total lobster loss because of nitrogen waste is 151,405millionsVND. And with the total of 22,173 lobster cages in Khanh Hoa, the value of losing in lobster production because on environmental pollution is 143,015millionsVND for one crop. Totally, the losing lobster value as a result of sea water pollution because of marine cage lobster aquaculture in three provinces is 295,093.2millionVND approximately US$16,863,468 for a crop in 2007.

However, as mentioned above, there is another way to calculate this effect by treatment cost. In order to calculate the cost to the marine cage lobster aquaculture industry, we need information regarding expenditure incurred by waste treatments. Particularly, in paper we require the information expenditure incurred by nitrogen treatment. However, to date, there is yet information or evaluation is available in Vietnam related to the marine waste treatment cost or techniques. For this reason, the study considers the costs in developed countries and assess to what extent the Vietnam lobster aquaculture industry would be in a position to meet such costs.

If relying on the study "*A Review of the Environmental Effects and Alternative Production Strategies of Marine Aquaculture in Chile*", in Sweden and Chile, the expenditure amounts for waste treatment of one kg nitrogen is US$6.4-12.8. Combining with the total nitrogen waste leasing from lobster cages into marine environment in three provinces in Vietnam in 2007 crop was 803 tons. Hence, the total treatment cost for these wastes will be US$ 5,139,000 – 10,278,400 per crop. These numbers is lower than that of based on the Change of Productivity method without calculation of the environmental carrying capacity.

In reality, the nitrogen leasing from lobster cages could be absorbed by natural environment and other ocean animals and plants. Hence, to estimate exactly the environmental effect on marine lobster cage due to nitrogen waste, it's necessary to calculate the environment carrying capacity and interaction among marine faunas and plants. The paper has estimated the treatment cost for total nitrogen loadings without measuring the nitrogen waste absorbed by environment. Obviously, the nitrogen waste has been distributed and absorbed by others in marine environment, thus its effect on lobster productivity has been lessen. However, in the Change of Productivity method, the market price of lobster at the surveyed time was much higher than normally. Currently, the lobster price has decreased to 450,000VND/kg, less than a half comparing 949,000VND/kg at the time data collected. That is the reason for the environmental effect value in the Change of Productivity calculation is higher than that of the Treatment Cost method. In addition, because there is not available data related to marine nitrogen treatment cost in Vietnam or other countries in Asia, thus the expenditure nitrogen treatment had been used from developed countries like Sweden and Chile where living standard and Gross Domestic

Product (GDP) are much higher, and technology more developed than that in Vietnam. For that reason, the result from Treatment Expenditure is different with that of the Change on Productivity and considered as the reference.

3.8 Estimated some optimal input level of marine cage lobster farm

Basing on the equation for estimating the optimal input level in aquaculture presented in the theory part, the paper is going to apply this equation in marine cage lobster farming. Relying the above production function model, there are three main parameters that affect on the lobster productivity and significant in statistical aspect including feeding quantity, stocking density, and number of cages. Therefore, whether current level of these variables is optimal in economic point of view or not, this part will clarify this puzzlement. However, to estimate the optimal level for one input item, we must do the assumption of other factors are constant.

Table 17: Comparison the estimated optimal level and current investment of some input level

Item	Unit	Optimal level	Current level	Δ
Feeding quantity	Kg/m^2	114	155	– 41
Stocking density	No. of lobster seed/m^2	10	8	+ 2
Number of cage	Cages/household	7	19	– 12

Source: Own survey

- ***Feeding quantity***: the estimated optimal level in order to archive the highest profit is 114kg/m^2/crop comparing to the current level of 155kg/m^2/crop. It indicates that farmers are using feeding quantity much higher than the optimal level. Hence, to peak at the optimal level in feeding quantity, the farmer should reduce 41kg/m^2/crop of the feeding quantity at the time of doing survey.

- ***Stocking density***: the result in the table shows that the stocking density of lobster per m^2 in order to get the highest profit is of 10. Meanwhile, currently, farmers have stocked as 8 species per square meter. Therefore, to get the highest profit in economic view, the farmers should increase two more species per m^2 in the stocking density

- ***Number of cage***: the optimal level in this case is 7 cages/household much lower than that current investment. It may be explained by the high interest payment for loans because most households with the high level in number of cages do not have enough money for investment when lobster aquaculture is the industry required high investment. Therefore, most of them had borrowed money from the government banks or legal/illegal credit agencies or individuals in that area with the high interest. Additionally, may be due to the limited labor force in each household, they do not manage all cages perfectly, thus, when the number of cage increase, the productivity has decreased.

Nevertheless, this calculation only considers the in the economic aspect when other factors are assumed unchanged. Specifically, these numbers are strictly constructed from the production function with the certain scale of production, environmental pollution or water quality specified. Therefore, the result is trust with the surveyed data, however, in the other cases; the general formulation could be applied. In reality, we may consider other social factors such as local employment for farmers, water quality, economics of scale, as well as the changing in the market price of inputs and outputs. This is the first step in illustrating this optimal formula in the static conditions. In the further researches, it is needed to consider the optimal level in the dynamic conditions and interactions among other factors.

Chapter 4 DISCUSSION AND CONCLUSION

4.1 General discussion

The Mass Balance model has been appied to measure the nitrogen loadings to environment from lobter cage. The result shows, on order to produce 1 ton lobster, the nitrogen loadings in to the environment will be 389kg. hence, with crop in 2007, the total nitrogen quantity releasing into marine environment from lobster cages in three provinces was 803 tons when the total production was of 1,792 tons. It's a huge amount of nitrogen waste that contributes on sea pollution currently in the central Provinces of Vietnam. The exploited results also imply that amount of nitrogen waste of lobster cage mainly coming from un-eaten feed is much higher than the currently required standard on marine environment in Vietnam (T.N.Chien, 2005). This waste is going to lease directly to the marine environment contribiting on the water pollution. Therefore, to control the huge nitrogen loadings on marine environment in order to avoid the seawater pollution, it's the priority in promoting the cooperation among government, local authorities, and lobster farmers.

The aim of this study is to estimate the environmental impact on marine cage lobster aquaculture by using the Change of Productivity. The production function calculation has indicated that the nitrogen loading is generating the negative impact on lobster productivity. Although this effect is not easily to fugure out at the household level, it is clearly seen at the regional view after adding the location dummy variable of three province to the econometric model. Particularly, for one percent increase in nitrogen waste per square meter, the lobster productivity per m^2 will decreases by 0.13744% where other factors are assumed unchanged. The statistic significance of location dummy variable in the model implies that there is a difference in lobster productivity among three regions. Specifically, lobster productivity in Khanh Hoa is lowest, whereas, in Ninh Thuan, lobster productivity is better than comparing to that of in Khanh Hoa and Phu Yen. The difference in this productivity may due to the difference in seawater quality, geography features, and some other factors mentioned in the model. In addtion, feeding quantity, stocking density, farmer's education level, and number of cage per household are variables affecting on lobster productivity. However, all variable metioned in model explained only 57% the variation of productivity, it is one of the limitations of this paper.

Moreover, based on lobster production function, the total environmental impact is calculated as US$16,863,468 comparing the total national export values of lobster in 2007 was around 40 million US$, this amount accounts for 42.16% the total exported value. Hence, environemtal parameter has significant effect on lobtster producvity.

Additionally, the secondary data including number of cage and total production from 1994 to 2007 provided by Khanh Hoa and Ninh Thuan Department of Agriculture and Rural Development also shows the negative relation between lobster productivity and cage density. Clearly, when the number of cages in specific area increase, the amount of lobster per cage reduces with the stocking density higher than the environmetal carrying capacity. This outcome could be explained that, the nitrogen waste from lobster cage is high , thus the cage density in certain area raises following the higher pollution level that influence on lobster growth rate, survival rate, and disease outbreak. Consequently, the prodcutivity is going to lessen.

Further more, marine cage lobster pollution mainly dues to using of trash fish feed. Like other countries in Asia, trash fish feed is predominant in lobster aquaculture in Vietnam because of lacking the pellet feeds. As we know, trash fish feed is the main factor creating marine polltion through aquaculture. Therefore, the pollicies related to reducing the trash fish feed use, inovating culture techniques in order to reduce the nutrients loadings as well as eventing the artifical feed are very useful currently. Also, trash fish feed use generates the conflict between aquaculture and fishing industries. It makes the pressure on the fishing industry go to un-sustainable fishing. Therefore, more research about the interaction between lobster aquaculture industry and fihsing industry is necessary in order to set up the appropriate development stratergy for each region.

The estimated optimal inputs level is the foundation for lobster farmers in culturing process, especially, currently there is not any technical instruction for marine lobster farming. To archive the highest benefit in economic point of view, the suggetsted feeding quantity per one square meter is 114kg lower than the feed level that farmers used 155kg/m^2. Therefore, as an economist, famers may reduce the feeding quantity in order to save money and cut down the nitrogen waste. The result of Cost – Benefit analysis for one lobster cage in a crop infers that marine lobster cage culture is the high profitable industry. It helps to poverty alleviation in the provinces in the Cetral of Vietnam. However, at present, there is not any particular program for developing this industry, it is producing spontaneously by famers in the coastal areas. Hence, to promote this industry develop efficiently, the government should figure out the detail plaining for each province.

Relying on the study's results, the paper is going to present some specific suggestions:

- In order to move sustainablely the future development of marine lobster cage farming activities, it is the urgent task to keep the cage density and pollution loadings under the environmental carrying capacity. The detailed technical guides including stocking density, feeding regime, environmental cleaning,… could be issued and distributed to the lobster farmers. Composing the planing frames, strategies and sullutions for lobster culturing in each teritory is necessory for sustainable development. To the current polluted areas, it is necessary to establish the temporary geographical zones where no farming licenses are issued until the water quality improved.

- To manage the aquaculture environment, the government could carry out scientific and rational planing; regulation aimed at protecting the aquaculture activities as well as set up the pollution discharge monitoring and reporting system from lobster cages to marine environment to ensure that the marine lobster cage production does not exceed the carrying capacity of the environment.

- Related to trash fish feed issue. Firstly, it is urgent need for the development of high quality artifical feed and efficient culturing technology in trash fish feed areas in order to reduce the waste generation. In addition, the un-eaten feed must be removed completely out of the marine environment. At present, most farmers has collected the trash fish feed remained under the cages, and then drop it to the sea surrounding the farming areas. Thus, this waste not only affects on themselves but also influences on their neighbors. For that reason, the lobster farmers must be asked to bring these wastes into the inland and treat by group, so that the marine pollution by un-consumed trash fish feed will be prevented.

The use of chemical substances in lobster aquaculture is small in comparison with other species aquaculture. However, various chemical and biological products are applied to cage/water cleaning or incorporated in lobster feeds to improve the disease prevention recently. The increased use of antibiotics and pesticides in lobster farming has also raised concerns about the possible effects of their release into adjacent habitats, natural ecosystems, water pollution and human health. Therefore, regulations, rules for using quantity, using method and allowable chemicals or fertilizers could be made clear to avoid the farmer's overusing contributing on environmental, ecosystem conservation.

Presently, marine lobster cage farming in Vietnam is the monoculture. With the aim of reducing the environmental impacts as well as raising the economic efficiency, we could apply the co-culture between lobster and green mussels, groupers, sea cucumbers, barramundis. Because each of them has the different habitat and feeding regime, therefore, with the polyculture, would improve not only the environmental quality but also the economic proficiency. The nitrogen concentration in the policulture cage was of 0.02% whereas in the monoculture cage, this indicator was 0.06%. The number of microorganisms in the cage bottom of monoculture was 6,266,667 CFU/ml comparing to 4,366,667 CFU/ml in the policulture bottom cage. Besides of that, the number of microorganism species and Vibrio the monoculture cage is higher than that of the policulture cage. On the other hand, the economic efficiency in the policulture model is higher than that of monoculture twice (N.L.A.Huy, 2004). Obviously, the environmental quality in the policulture has improved significantly and economic efficiency of this model has touched.

Finally, several studies has indicated the environmental impacts of marine lobster cage aquaculture especially where trash fish feed is dominant. However, most households farming the lobster cages in the study sites have not revealed these effects. 53/110 respondents said that their farm has not impact on the marine environment because they have contributed mini part on the large sea area, the present water pollution may dues to domestic and industrial wastes, or dischargers from other farms and other regions. Conversely, 57/110 respondents thought, their activities are contributing on the water pollution through feed waste, high cage density, chemical or antibiotic uses, farmer's behavior and acknowledge. For that reason, besides organizing the training the farmer knowledge about technical lobster farming skills, the information and knowledge related to protecting, cleaning, and preserving the marine environment outside and inside of their farm must be explained for the farmers. To enhance the sustainable lobster production in Vietnam, in the near future, each lobster farmer must be asked to responsible for their farming region.

In summary, the marine cage lobster aquaculture in Vietnam develop sustainably if and only if there is the cooperation among government, local authorities, lobster farmers, businessman and scientists. With the typical feature of spillover influence of marine environment, the managers not only focus on local regulations as household administration but also figure out the macro policies as regional level.

4.2 Conclusion

Marine cage lobster aquaculture is emphasizing its role in Vietnam economy especially the central Provinces. In 2000, it had generated the total value of 19 million US$ and archived around 40 million US$ in 2007. The sea areas in Khanh Hoa, Phu Yen, Binh Dinh, Ninh Thuan, and Binh Thuan are potential places in developing lobser farming because of its geograhpy features and natural conditions. Spiny lobster is the most popular species cultured along these provices because of high economic value, high productivity, and most preferable product. However, this industry is dealing with the marine environmental pollution due to fast development and trash fish feed use.

The FCR-based nitrogen loading analysis using Mass Balance method to measure nitrogen leasing to marine environment from lobster cage. For crop 2007, lasting 16 months, the total nitrogen waste from marine lobster cage aquaculture in three provinces including Khanh Hoa, Phu Yen, and Ninh Thuan was 803 tons when the total lobster production was 1,792 tons. This waste was created by un-consumed feed following inefficient feeding regime and less awareness on marine environment conservation of lobster farmers.

The measured nitrogen loading is one of inputs involving on lobster productivity. By applying the Change of Productivity method, the environmental impact on marine cage lobster culture has been measured in the view point of economics. In which, nitrogen loading is considered as the seawater quality parameter. The econometric model expresses the negative relation between amount of nitrogen loading per household per crop and the productivity. Consequently, the current nitrogen loading volume made reduction of 3.8kg lobster/cage/crop in Ninh Thuan, 5.7kg lobster/cage/crop in Phu Yen, and 6.8kg lobster/cage/crop in Khanh Hoa. This result follows what we had expected when lobster productivity in Khanh Hoa is lowest because it is the marine lobster culture originated in this province with high in cage density and large in cage numbers. Conversely, productivity in Ninh Thuan is highest because of better environmental quality when the lobster culture has been developed in this province recently with low in cage density and lower in amount of lobster cages. On average, the environmental pollution due to the feed waste has made the total lobster production reduce by 295,093.2 millionVND approximately US$16,863,468 for a crop in 2007 in three provinces. This result is higher than comparing to the number given by using Treatment Cost method.

In addition, the logistic model expressing the relation between number of cages and productivity by time series data in Khanh Hoa and Ninh Thuan since 1994 is supplemental information for statement of the number of cages in certain area increase making the productivity fall down. Or when the number of lobster cage over the environmental carrying capacity, if we continue enlarging the number of cages in the same area, the lobster quantity per cage will decrease.

The econometric model has also indicated other factors impacting on lobster productivity in statistical significance including feeding quantity, stocking density, farmer's education, number of cage. In which, all of them get the positive effect with lobster productivity. On the other hand, the paper has determined the optimal input level of feeding quantity, stocking density and number of cage. The optimal feeding level for a square meter of lobster is 114kg/cage, the optimal stocking density is 10 juveniles/m^2 and the optimal number of case is 7 cages/household.

Finally, Cost – Benefit analysis of marine lobster cage including the environmental cost has been done. Like other studies' result, marine lobster culture in Vietnam is considered as the high profitable industry. Specially, one lobster cage with the average size is 11.4m^2, the stocking density is 100 juveniles has generates the benefit for a crop was of 10,627 thousand VND. The value of NPV for lobster farming investment for a production cycle of 10 crops equivalent to 13 years is 34,250millionsVND and IRR value equals 43%. If combining with the environmental cost has made the lobster productivity decrease, the total benefit without environmental pollution will be higher. The value of NPV and IRR imply that marine cage lobster aquaculture in Vietnam is an attractive industry; in the next time the higher pressure will occur. Therefore, all above results are the supplemental information for policy makers, managers to figure out the sustainable development schemes for marine cage lobster culture in Vietnam in the balance of economic and environmental considerations.

4.3 Further research suggestion

The nitrogen loading preventative parameter is just solely used in this paper for marine water pollution measure due to lacking of reliable data related other kinds of loading wastes. However, it is better to be aware of different factors that have other impact on the marine water pollution from lobster cage such as phosphor, dissolved oxygen, dissolved organic carbon, sediment oxygen demand. Hence, further researches on these parameters are needed too.

To archive the absolute calculation on environmental impact of marine lobster cage aquaculture, it is necessary to estimate the marine environment carrying capacity. It deeply relates to the environment technology and not available data, thus, the paper has not done this part. The further studies about this content are recommended in order to describe the environmental impacts more accurately.

Furthermore, the loading wastes from lobster cage aquaculture not only do impact on the lobster productivity itself but also affect on the marine ecosystems as well as other animal life. With the limited in time, budget, and data, the paper has not taken into account of these effects. To archive the accurate result of environmental impact assessment, the future studies could consider these missing values.

The relationship between water pollution and disease outbreak in lobster recently has not mentioned is also the limited of this paper. Additionally, the paper has not distinguished the distribution of waste resources affecting on lobster productivity at present such as waste from industrial zones, domestic wastes, as well as the natural disasters. Another limited of this paper is that, the interaction between location dummy variables of three provinces and the nitrogen loading or environmental quality had not explained. Finally, it is the first paper doing in this area in Vietnam in economic point of view; data based on the household survey without time budget for re-test. Therefore, to ensure every number mentioned in this paper, the further researches for testing these numbers are very important. All above limitations of the paper are also the recommendation for future researches in this field.

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Appendixes

1. Questionnaire

Master graduated thesis

QUESTIONNAIRE FOR LOBSTER FARMERS

Part 1: Information about lobster farming operation

1. How many years have you practiced in lobster grow-out aquaculture? ____________ years

2. How many year have you cultured the lobster at current area? ____________________ years

3. Why did you move the lobster cages to another place? (details) __________________________

4. What kinds of lobster species did you culture in the last crop?

a. Spiny lobster b. Red lobster c. Rock lobster d. Green lobster e. Other (specify)

5. Why do you choose this kind of lobster?____

6. Type of culture cage?

a. Floating cage b. Wooden fixed cage c. Submerged cage d. Other (specify)

7. How large water area did you culture in the last crop? __________________________ m^2

8. Are you asked to pay for the sea water use or other environmental fees when culturing at sea?

a. Yes b. No

8.1 If yes, what is it? (please specify) ____

8.2 How much do you pay for crop or year? ____

8.3 Who collect that fee? ____

9. How many cages do you have (culture and replacement)? _______________________ cages

10. Did you culture the nursery? ___________________Yes/No If No go on the No. 13

11. If yes, how many nursery cages had you got? _____________________________________

Cage size	Cost of cage purchase	Length of time before each cage needs replacing (years)	Stocking rate (individuals/ cage)	Cost of fingerlings (VND/individual)	Survival rate (% of purchased fingerlings that survive until harvest)
1					
2					
3					

12. How many days did you culture for nursery period? ______________Days

13. How is the feeding practice at this period?

Cage size	Description of ingredients	Cost of feed (VND/kg)	Quantity fed (kg/cage/day)
Size1:	Trash fish %		
	Shellfish %		
	Crab or shrimp %		
	Other %		
Size2:	Trash fish %		
	Shellfish %		
	Crab or shrimp %		
	Other %		

Part 2: At the grow-out lobster culture period

14. What is the average length of your grow-out period?______________________ months

15. In which month do you usually stock the fingerlings? ______________________________

16. In which month do you usually harvest the lobsters?_______________________________

17. Please indicate in the table below the number and sizes of cages used for commercial period:

	Size of cage	Number of cages of that size	Cost of cage purchase (VND/cage)	Length of time before each cage needs replacing (years)
1				
2				
3				

18. How many cages did you culture? ____

19. How many cages for back-up? ____

20. What is the average weight and/or length of fingerlings at stocking? _____ g, ________ cm

21. Please indicate in the table below stocking rates, cost and survival rates of fingerlings

Cage size	Stocking rate (individuals/cage)	Cost of fingerlings (VND/individual)	Survival rate (% of purchased fingerlings that survive until harvest)
1			
2			
3			
4			
5			

22. Where do you buy the lobster seed?

a. Wild catch b. Buy from middle man as local seed c. Buy from middle man from other provinces d. From nursery culture

23. Where do you buy the feed for lobster grow-out?

a. Middle man at cage b. Land-market c. Other (please specific)

24. Please indicate in the table below your current feeding practices

Cage size	Description of ingredients		Cost of feed (VND/kg)	Quantity fed (kg/cage/day)		
				Period 1 (from….. month to …..month)	Period 2 (from….. month to …..month)	Period 3 (from….. month to …..month)
Size1:	Trash fish	%				
No. of cage size 1:	Shellfish	%				
	Crab or shrimp	%				
	Other	%				
Size2:	Trash fish	%				
No. of cage size 2:	Shellfish	%				
	Crab or shrimp	%				
	Other	%				

25. Please indicate in the table below the other capital requirements of your lobster operation (HH)

	Capital item (e.g. boats, diving, electricity, equipment preparation, cottage etc)	Number (quantity) of each item	Cost of purchase (VND/item)	Length of time before item needs replacing (years)
1	Boat			
2	Diving equipments			
3	Electricity/light			
4	Equipment preparation			
5	Cottage			
6	Others			
7				

26. Please indicate in the table below the number of members of your household currently working on the lobster growout operation?

Household member	Gender (M or F)	% of their work-time spent on the lobster operation (0-100%, where 100% is approximately a 40-hour week)
1		
2		
3		

27. How many people do you hire to work on lobster operation? ____________________________

28. Approximately how many full-time workers is this equivalent to? ________________________

29. What is the cost of hiring this labor? ______________________________ VND/worker/month

30. On average, how much credit do you borrow for each crop? _________________ VND/crop

31. What is the average interest rate for this borrowed money?__________%/month or %/year or %/crop

32. Please indicate in the table below any other costs that have not been specified above (i.e. costs other than capital, fingerling purchase, feeding, labor and interest)

Cost type (please describe)	(A) cost per unit (VND/unit/crop)	(B) number of units required per crop	(C) total cost per crop (A*B=C)

33. What is the average individual lobster weight at harvest: ___________________________ kg

34. What is the average price received for the harvest lobster ______________________ VND/kg

35. Do you have any quality, food safety and/or environmental protection requirements that you must adhere?

36. If yes, please describe them: ____

____

37. Where (who) do you usually sell the lobster? ____

38. Who decide the selling price? ____

39. Have you cleaned the lobster cage? Yes/No

If yes, how often have you clean the cage/crop? ____________________________________ times

40. How do you clean the cage? (specify) ____

____

How long does it take for one cleaning time? ________________________________ hours

41. Do you take the feed waste out of the culturing places or through it directly to the sea water?

____

42. Have you ever been in dealing with the lobster diseases? Yes/No

If yes, what kind of the disease? (specify)____

	Diseases								
	1	2	3	4	5	6	7	8	9
Crop (year)									
How's age of lobster									
Death rate (%)									
Damages (productivity)									
How did you solve									

1. Trắng râu *2. Black gill* *3. Đóng sun,hầu* *4. Phồng mang*

5. Long đầu *6. Đầu to* *7. Shell necrosis* *8. Red body* *9.Milky disease*

43. In your experiences, what are the factors to cause these diseases? ____________________

____

44. Are any of the following issues constraining your lobster growout operations?

a. Access to sufficient quantities of fingerlings? _____________________________ Yes/No

If yes, please specify: ____

b. Access of fingerlings of high enough quality? _____________________________ Yes/No

If yes, please specify: ____

c. Access of good information about technology improvements in lobster farming? ___ Yes/No

If yes, please specify: ____

d. Seasonal/climate/weather constraints? ___________________________________ Yes/No

If yes, please specify: ____

e. Leasing fees and other taxes or charges? ________________________________ Yes/No

If yes, please specify: ____

f.Insufficient access to credit ? Yes/No

If yes, please specify: ____

g. Ability to pay back interest costs? Yes/No

If yes, please specify: ____

h. Access to good quality feed? ____ Yes/No

If yes, please specify: ____

i. Cost of good quality feed?____ Yes/No

If yes, please specify: ____

j. Access to farm labor? ____ Yes/No

If yes, please specify: ____

k. Cost of farm labor? ____ Yes/No

if yes, please specify: ____

i. Government regulations or policies? ___________________________________ Yes/No

If yes, please specify: ____

m. Constraints to allocation of land and/or marine area? ______________________ Yes/No

if yes, please specify: ____

n. quality, food safety and/or environmental protection requirements? ____________ Yes/No

if yes, please specify: ____

45. Are there any issues not listed above that are constraining your lobster growout operations? Yes/No

If yes, please specify: ____

____

46. What is you plan for next lobster culturing?

a. Un-change b. Increase the cages c. Decrease the cages d. Others (specify)

47. What are your other suggestions? ____

____

____

Part 2: Pharmacy, chemical used in lobster culturing process

48. Did you use chemical for cleaning the cage bottom? Yes/No

If yes, what are they?

a. CaO b. $CaCO_3$ c. Dolomite– CaMg $(CO_3)_2$, d. Other (specify)

b. Antibiotics: Yes/No

	Antibiotics	Bath (h)	Feed mixing (g/kg feed)	Times/month	Period (month)	Cost (VND/time)
1						
2						
3						
4						
5						

c. Chemicals: Yes/No

	Chemicals	Bath (h)	Feed mixing (g/kg feed)	Times/month	Period (month)	Cost (VND/time)
1	Formol					
2	Chlorine					
3	$KmnO_4$ (thuốc tím)					
4						

d. Vitamines: Yes/No

	Vitamine	Bath (h)	Feed mixing (g/kg feed)	Times/month	Period (month)	Cost (VND/time)
1	Vitamin B					
2	Vitamin C					
3	Synthetic Vitamin					
4						

49. Where do you usually buy these products? ____

50. How can you use these products?

a. based on experience b. author's instructor c. agent's advice d. others

51. How much does it cost for chemicals and pharmacy/crop?

Part 3: Information about farmer's environmental knowledge

52. Do you think your lobster culture generate the environmental pollution? Yes/No

If yes, please explain in the detail why? ____

____

53. What do other factors impact on the water quality around your culturing place? ________________

____

54. In your experience, what should yourself do to avoid the environmental pollution as doing lobster culture? ____

____

55. How to improve the water quality in this area? ____

Part 4: Information about the household

56. Name of household head: ____

57. Age of household head: ____

Phone number:

58. Gender of household head: Male [ ] Female [ ]

59. Educational level of household head:

a. No formal education b. Primary school c. Secondary school d. High school
e. Vocational level and University degree g. Other (please specific)

60: Address: ____

Telephone number: ____

61. How many members in your household? ________ Male ________ Female ________

62. What are the main occupations of household head? ______________________

63. How many percentages do your main occupations generate in household income? ______ %

64. Do you have any supplementary occupation(s)? Yes No

65. If yes, please rank them by importance:

(1) ______________________________ % of HH income ____________

(2) ______________________________ % of HH income ____________

(3) ______________________________ % of HH income ____________

* **Note**: only interview the HH head who are working lobster culture

Thank you very much for your answers.

Date:

Interviewer:

Respondent:

2. Seven indentified lobster species in Vietnam

No.	Scientific name	Local name in English	Local name in Vietnamese
1	*Panulirus ornatus*	Spiny lobster	Tôm Hùm Bông, Sao
2	*Panulirus homarus*	Rock/blue lobster	Tôm Hùm Đá/Xanh
3	*Panulirus longipes*	Red lobster	Tôm Hùm Đỏ
4	*Panulirus stimpsoni*	Gravel lobster	Tôm Hùm Sỏi
5	*Panulirus penicillatus*	God lobster	Tôm Hùm Ma
6	*Panulirus versicolour*	Lotus lobster	Tôm Hùm Sen
7	*Panulirus polyphagus*	Bamboo lobster	Tôm Hùm Bùn

Latin name lobster: *Homarus americanus* . *locusta*

Lobster species classification:

Phylum Arthropoda

Class Crustacea

Order Decapoda

Pleocyemata

Palinura

Palinuroidea

Family Palinuridae

Genus Homarus

Species Panulirus Palinurus

Jasus Justitia

Palinutrus Linuparus

Puerulus Projasus