CHAPTER 3

LITERATURE REVIEW AND THE RESEARCH SITE

The chapter is devoted to reviewing the characteristics and essential requirements of shrimp; shrimp aquacultural systems; system's performance; the studies related to shrimp, stochastic frontiers and technical efficiency (TE). In addition, this chapter will describe the research site.

3.1 Characteristics of shrimp

The shrimp species under consideration is *Penaeus monodon* Fabricius. According to Holthuis (1980), their characteristics are as follows;

a. Synonymy**:** *Penaeus carinatus*, *Penaeus tahitensis*, *Penaeus semisulcatus exsulcatus*, *Penaeus coeruleus, Penaeus bubulus, Penaeus monodon monodon*. In older literature often confused with *P. semisulcatus*.

b. FAO (Food and Agriculture Organization) name: Giant Tiger prawn.

c. Local names: Tôm sú (Vietnam), Tiger prawn (S. and E. Africa), Kamba, Kamba ndogo (Swahili language, Kenya), Kalri (Pakistan), Jinga (Bombay, India), Kara chemmeen (Kerala, India), Yera (Madras, India), Bagda chingri (Calcutta, India), Ushi-ebi (Japan), Grass shrimp (Taiwan), Ghost prawn (Hong Kong), Sugpo, Jumbo tiger shrimp (Philippines), Udang windu, Udang pantjet (Indonesia), Jumbo Tiger prawn, Giant Tiger prawn, Black Tiger prawn, Blue Tiger prawn, Leader prawn, Panda prawn (Australia).

d. Distribution: Indo-West Pacific: East and South East Africa and Pakistan to Japan, the Malay Archipelago and northern Australia.

e. Habitat: Depth 0 to 110 meters. Bottom mud, sand. Estuarine (juveniles) and marine (adults).

f. Size: Maximum total length 336 mm.

g. Weight: 60 to 130gram.

3.2 The life cycle of Black Tiger shrimp-*Penaeus monodon*

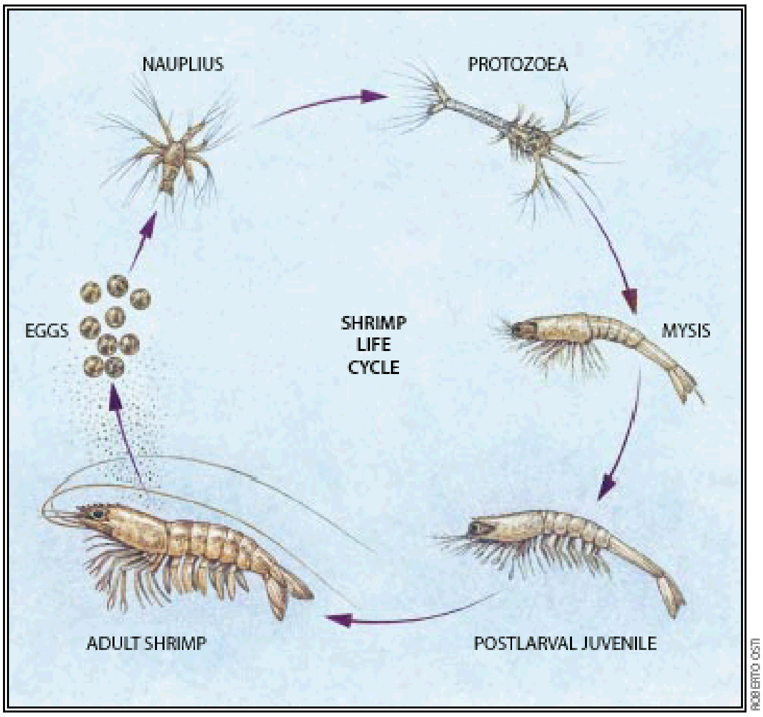
The life cycle of the shrimp (Figure 3.1) begins with the spawning of gravid females. Females may produce 50,000 to 1,000,000 eggs, depending on such variables as temperature, species, size, wild or captive, and number of times previously spawned (Rosenberry, 1999 *cited by* Russett, 2001). From egg to maturity, shrimp undergoes a number of dramatic metamorphoses.

Eggs: Shrimp eggs are thought to sink to the bottom at the time of spawning. Egg diameter is less than 1/64 inch. Most spawning is believed to occur in high salinity oceanic waters. 30 to 40 minutes after fertilization, the cell divides into two cells and these gradually increase in number and develop. Within 13 to 18 hours the eggs hatch. There are several stages of larval development as follows:

First larval stage (Nauplius): This is the first stage after hatching. A *nauplius* resembles a spider, with three pairs of appendages. Larvae of this stage molt at least six times and each molting means an increase in size. They take 36 to 40 hours to develop to the second stage. Normally larvae of the first stage require no food since they obtain nourishment from their yolk sacs.

Second larval stage (Protozoea): The larvae become elongated and the head and body can be clearly distinguished. At this stage, there are three developmental steps. Larvae at each step are different in appearance. During the first step, the eyes look like little knobs on the head. Then in the second step, the eyes protrude from the head and have a stalk. Finally, in the third step, larvae develop a telson. Larvae at this stage molt three times. It takes them about 4 to 5 days to develop to the third stage. When the yolk sac is absorbed larvae start feeding on diatoms.

Third larval stage (Mysis): Larvae become more or less like fry in appearance but they swim differently: their head points downward and the body moves rapidly up and down. Larvae at this stage are also divided into three development stages. Firstly, they have no swimming legs. Secondly, first segments of swimming legs are visible. Thirdly, swimming legs have grown fully. The larvae have then reached the post larvae stage and feed on aquatic plants and animals.



Source: Boy and Clay, 1998.

Figure 3.1. Life cycle of shrimp

Post larval stage: Larvae at this stage look very similar to fry. Their organs are almost completely developed and continue to develop gradually until the larvae reach the fry stage. At this stage they swim parallel to the water surface. They are kept in the hatching ponds for about 22 to 30 days or until they reach 1 to 2 centimeters in length and 0.02 to 0.05g in weight. Larvae of this size are transferred to the rearing ponds.

Adults: Adults may be 5 to 8 inches in length. Adults are usually found in the ocean, but in dry years may delay migration until cold weather occurs. Spawning females are characterized by brightly colored ovaries that can be seen under the shell on the upper side of the body. Adults may be found near the beaches out to 5 or 6 miles from shore. Some species are known to migrate hundreds of miles along the coast. The life cycle of giant tiger shrimp has then been completed.

3.3 Basic and essential requirements of shrimp

Shrimp species are very sensitive to the environment. Hence, shrimp aquaculture must create living conditions which are appropriate and suitable for the biological characteristics of shrimp in order to help the development of shrimp in ponds. In a suitable environment, shrimp productivity and value will be increased. The following are the main biological and environmental factors related to shrimp life.

Temperature: Shrimp are cold-blooded species so their bodies' temperature changes together with the environmental temperature. The most suitable temperature for the development of Black Tiger shrimp is in the range of 28ºC to 30ºC. If the environmental temperature is over 30ºC, shrimp will develop better; they are, however, prone to disease, especially MBV (*monodon baculovirus*) disease. If the temperature is below 13ºC or over 35ºC, shrimp will stop eating feed and if this situation lasts for long time shrimp will die.

Salinity: The demand for salinity by shrimp is different from species to species and time point to time point in the shrimp life cycle. Shrimp can tolerate fluctuations of salinity from 3‰ to 45 ‰. The best salinity for shrimp is from 18‰ to 20‰.

pH: The pH of the pond water is important, since it has direct and indirect effects on the shrimp and plankton. The pH scale represents the acidity of solutions, including pond water. Solutions with a pH less than 7 are acid and those higher than 7 are basic. Seawater and brackish water normally have a pH of between 7.8 and 8.2, this is the optimal pH range for the culture of *Penaeus monodon*.

Dissolved oxygen: The amount of dissolved oxygen (DO) is the most crucial factor attributing to the success of both marine and aquatic animal farming businesses, including Black Tiger prawn aquaculture. The effects of low oxygen depend on the level of oxygen present, the length of time and the frequency of exposure to low concentrations. Low oxygen levels may only occur for a short period during a day, however, the effects on the shrimp can persist after the oxygen levels have been restored, often resulting in low growth.

At levels of 4 mg/l, shrimp continue to eat, but they will not utilize their feed efficiently. Such levels may also harm the shrimp, leading to increased disease. The reduction in the Feed Conversion Ratio (FCR) and increased incidence of disease will reduce profitability. If oxygen levels drop even further (2 to 3 mg/l), shrimp will stop eating and become weakened. Even lower oxygen concentrations can result in the death of shrimp due to suffocation (typically < 2 mg/l); however, this is not a problem when there are aerators in shrimp ponds and oxygen-producing phytoplankton is present. Low oxygen levels are common problems in shrimp ponds where stocking density is high and less aeration equipment is utilized.

Turbidity: Turbidity is the optical property of a water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. In simple terms, turbidity answers the question “How cloudy is the water?”.

Aquatic animals cannot see very well in turbid water and so may have difficulty finding food. On the other hand, turbid water may make it easier for aquatic animals to hide from predators. Turbidity in the range of 30 to 40 cm is good for Black Tiger shrimp (Tangtrongpiros, 2001).

Alkalinity: The alkalinity of water is a measure of the combined concentrations of carbonate and bicarbonate. Carbonate and bicarbonate have an important effect on the water, through their ability to minimize pH fluctuations. Natural seawater always has high alkalinity, indicating a plentiful supply of carbonate and bicarbonate. In shrimp ponds, alkalinity can be undesirable low for a number of reasons: low salinity pond water, acidic pond soils, low water exchange and dense phytoplankton blooms.

Alkalinity is not a pollutant. It is a total measure of the substances in water that have acid-neutralizing ability. Alkalinity is important for fish and aquatic life as it protects or buffers against pH changes and makes water less vulnerable to acid rain. The desirable range of total alkalinity for fish culture is 75-200 ppm even though good pond productivity can be achieved as low as 20 ppm (Hill, no date).

In general, water quality parameters should be maintained at levels suitable for optimal growth, and they should never reach lethal level (often described as LC_{50} in scientific literature). The following table contains the recommended levels and maximum fluctuations for optimal growth.

Table 3.1 Recommended water parameters for successful culture of *P. monodon*

Water parameters	Optimum level	Comments
pH	7.5 to 8.3	Daily fluctuation < 0.5
Salinity	10 to 30 ppt	Daily fluctuation < 5 ppt
Dissolved oxygen	5 to 6 ppm	Not less than 4 ppm
Alkalinity	> 80 ppm (as $CaCO_3$)	Dependent on pH fluctuation
Secchi disc	30 to50 cm	
H_2S	< 0.03 ppm	More toxic at low pH
Unionized ammonia	< 0.1 ppm	More toxic at high pH and temperature

Source: Charatchakool et al., 1998.

Note: ppm = parts per million. ppt = parts per thousand.

3.4 Shrimp aquacultural systems

In Thua Thien Hue there exist four shrimp aquacultural systems (i) traditional extensive, (ii) improved extensive, (iii) semi-intensive and (iv) intensive shrimp. There has been no official document for defining and categorizing them in Thua Thien Hue Department of Fisheries in general and in Phu Vang Department of Statistics and Agriculture in particular. However, the names of the four types of shrimp aquacultural systems still exist in the documents of those departments. Before defining the shrimp aquacultural systems for the study, it is necessary to explore the shrimp aquacultural systems and their definitions around the world and in Vietnam.

3.4.1 Shrimp aquacultural systems in the world

When considering the definitions of shrimp aquacultural systems in the world, it should be noticed that shrimp aquacultural systems are divided in to three main sub-systems: extensive, semi-intensive and intensive. However, different authors and different countries will have their own different definitions. For instance, the shrimp aquacultural systems in Asia, in the Philippines are presented in Tables 3.2 and 3.3.

The shrimp aquacultural system in Thailand has three levels of intensity: extensive, semi-intensive, and intensive. Beginning with the extensive system of more than three decades ago, parts of this system were later modified into the semi-intensive system in 1980, and further developed into the intensive system, which was introduced in 1987. The characteristics of these cultural systems are summarized in Table 3.4.

Table 3.2 Shrimp aquacultural systems in Asia

Management aspects	Extensive	Semi-intensive	Intensive
Feed	Natural	Natural and supplemental	Formulated high protein
Water management	Tidal	Tidal and pumping	Pumping and aeration
Pond size (ha)	2 – 20	1 – 5	0.1 – 1.0
Density (post larvae/m^2)	0.1 – 1.0	1 – 5	5 – ≥ 25
Production (ton/ha/year)	0.1 – 0.5	0.5 – 4.0	4.0 – ≥ 15.0

Source: Primavera, 1991.

Table 3.3 The characteristics of shrimp aquacultural systems in the Philippines

Characteristics	Traditional	Extensive	Semi-intensive	Intensive
Stocking (1,000PLs/ha)	10	10 - 30	30 - 100	100 - 300
Yield (ton/ha/year)	0.1 – 0.5	0.6 – 1.5	2 - 6	7 - 15
Development and first year operating costs (1,000 pesos/ha/year)	252	350	628	1,645

Source: Primavera, 1991.

Table 3.4 The characteristics of shrimp aquacultural systems in Thailand

Indicators	Extensive	Semi-intensive	Intensive
Pond size (ha)	>5	1 - 2	≤ 1
Feed	Natural	Natural and supplemental	Processed feed
Density (PLs/m^2)	<5	5 - 15	≥ 20
Aeration	Natural	Water exchange or aerators	Intensive aeration
Yield(tons/ha/year)	0.15 or less	0.6 to 1.8 or more	6.0 –10.0 /crop
Evalation (MSL)	0 - + 1.4	0 - + 1.4	> +2

Source: Menasveta, 1998.

Note: Note: PLs = post larvae. MSL = meter above sea level.

3.4.2 Shrimp aquacultural systems in Vietnam

In Vietnam, according to the Ministry of Fisheries (2000) the definitions of SSAS and ISAS are as follows:

Semi-intensive shrimp are aquacultured by artificial seed and mainly by processed feed. Pond area is from 0.5 to 1.5 ha. Pond deep water level is from 1.2 to 1.5 meters. Stocking density is from 10 to 25 post larvae per square meter. Shrimp yield is about 1 to 3 tons/ha/year.

Intensive shrimp aquaculture is an aquacultural system that has very high yield and high investment in infrastructure and aquacultural techniques. ISAS also requires the aquaculturists to have a relatively high knowledge of shrimp aquaculture. It is entirely based on artificial seed and processed feed. Pond areas are from 0.5 to 1.0 ha. In ISAS, reservoirs (water reserved ponds) are needed with about 30% of the total cultural pond area. The deep water level of cultural pond is from 1.5 to 2.0 meters. Stocking density is from 25 to 40 post larvae per square meter and shrimp yield reaches 3 tons/ha/crop or more.

According to the Department of Fisheries of Khanh Hoa province (1995), one of the main shrimp aquacultural provinces of Vietnam, the definitions of the aquacultural systems are:

Extensive culture: This system tries to use natural advantages so it is completely dependent on nature regarding fry, feed, and water. The management is very simple. Depending on the commitment of aquaculturists contributing to the production, the system can be divided into:

Traditional extensive culture: In this system, fry is from nature and shrimp are fed with natural feed. The management of the system is very simple. A lot of species might be cultured together such as seaweed, shrimp, fish, and crab, etc. As a result, the yield is very low and reaches 50 to 100 kg/ha/year or the highest yield of 150 to 200 kg/ha/year.

Improved extensive culture: Mainly shrimp are cultured with a pond area of 0.2 to 2.0 ha. Stocking density is about 2 to 3 post larvae per square meter. With a higher density, supplement food or fertilizer is needed. 1 or 2 crops of shrimp are harvested per year. Yield ranges from 200 to 500 kg/ha/year, sometimes reaching 1,000 kg/ha/year.

Semi-intensive culture: This is an aquacultural system in which shrimp aquacultural advances are applied. The system solves the shortcomings of extensive culture. Aquaculturists actively influence shrimp aquacultural activities such as stocking density and testing seed quality, feeding shrimp appropriately according to their development stage, and preventing and treating diseases, etc. However, the pond environment is not perfectly controlled, for instance water quality and water supply.

This system has a potential average yield of 10 tons/ha/year. However, in Central Vietnam, the average yield is 2.0 to 3.0 ton/ha/year with the stocking density from 5 to 10 post larvae per square meter (Department of Fisheries of Khanh Hoa, 1995).

Intensive culture: Aquaculturists are active in supplying seed quantity and quality, feed, etc., appropriate to the development stages of the shrimp. Likewise, pond environment and diseases are perfectly controlled by aquaculturists. This system requires high investment in infrastructures, such as electricity, aerators, communications and security etc. Every activity must be harmonized and streamlined within this shrimp cultural system. Stocking density is often greater than 15 post larvae per square meter and yield reaches 5 to 10 tons/ha/year.

3.5 System performance and performance criteria

To evaluate and compare the systems' performance, the selection of system performance criteria is crucial. It would be an error to evaluate both systems according to a criterion that is relevant to only the first system and not the latter and vice versa. In order to accurately select the appropriate performance criteria, a literature review needs to be carried out.

Economic performance is a complex, multi-dimensional concept, about which there is no agreed definition. Some literature reviews are set out below, but the list is not exhaustive, and the division of the criteria is inevitably arbitrary.

According to Turner and Taylor (1998) farm comparisons are usually made by calculating some measures of performance as follows:

a. Profitability: Profitability consists of net farm income per hectare (the reward to the farmer for his own manual labor, management and interest on tenant-type capital invested in the farm whether it is borrowed or not), management and investment income per hectare (the reward to management, both paid and unpaid, and the return on tenant-type capital invested in the farm whether it is borrowed or not), profit per hectare, and percentage return on tenant's capital invested.

b. Overheads: Overheads are analyzed under the following headings: (i) total overheads per hectare, (ii) rent and rates per hectare, (iii) labor costs per hectare, (iv) machinery costs per hectare, and (v) miscellaneous costs per hectare.

c. Output: Output includes physical and financial performance such as total gross output per hectare, gross output per £100 labor costs, gross output per £100 machinery costs, and gross output per £100 labor and machinery costs.

d. Inputs: Finally, variable inputs are analyzed (including physical and financial performance).

The system performance suggested by McConnell and Dillon (1997) includes eight properties of a system: profitability, productivity, stability, sustainability, flexibility, time dispersion, diversity, and complementarily and environmental compatibility.

According to Thanassoulis (2001), the measurement of performance we typically use reflects our estimate of a unit's potential for resource conversion or for output augmentation. Thus to measure performance we need to estimate the input and output levels at which a unit could have operated if efficient. A simple and commonly used method for measuring the performance of an operating unit is that of performance indicators. A performance indicator is typically a ratio of some output to input pertaining to the unit being assessed.

In cases where multiple performance indicators pertain we have no unique benchmark of minimum input to output ratio to be used for measuring the performance of each operating unit. In a multi-input and multi-output context, performance indicators of the ratio variety do not capture how the multiple input affect simultaneously the multiple outputs of the transformation process carried out by the unit being assessed. Ratio style performance indicators can only capture in full a transformation process when a single resource and a single output are involved. Once we move to more realistic contexts which involve multiple inputs and/or multiple outputs we need a modelling approach to measuring performance.

The modelling approach to measuring comparative performance attempts to arrive at a fuller understanding, i.e. a model, of the production process operated by the units being assessed rather than simply compute indexes of their comparative performance. There are two types of modelling methods of comparative performance measurement. They are parametric and the non-parametric methods.

3.6 Technical efficiency (TE) and measurement

3.6.1 Production frontier estimation

To examine TE for the semi-intensive and intensive shrimp aquacultural systems, production frontiers need to be estimated.

The theoretical definition of a production function expressing the maximum amount of output obtainable from a given input bundle with fixed technology has been accepted for many decades (Aigner, Lovell and Schmidt, 1977). And for almost as long, econometricians have been estimating *average* production functions.

In microeconomic theory, a production function is defined in terms of the maximum output that can be produced from a specified set of inputs, given the existing technology available to the firms involved. However, up until the late 1960's, most empirical studies used traditional least-squares methods to estimate production functions. Hence the estimated functions could be more appropriately described as *response* (or average) functions (Battese, 1992).

The stochastic frontier production function of Kumbhakar and Lovell (2000) is concerned with the development of a modified econometric approach to the estimation of productive efficiency. They called it *Stochastic Frontier Analysis* because they are concerned with the estimation of frontiers, which envelop data, rather than with functions, which intersect data.

The way in which econometricians look at production frontiers has undergone substantial modification. The earliest work on frontiers assumed what we would call a deterministic frontier. This idea was developed by Farrell (1957), Farrell and Fieldhouse (1962) and Afriat (1972), and tested by Aigner and Chu (1968), Seitz (1971), Richmond (1974), Førsund and Jansen (1977), and others. Deterministic frontiers have some statistical problems, which are considered in section 3.6.2 of this chapter. Consequently, this leads to the development of probabilistic production frontiers by Timmer (1971). In this approach a deterministic frontier is computed by mathematical programming techniques, after which supporting data points are discarded and a new deterministic frontier is computed. The process continues until the computed frontier stabilizes (Schmidt and Lovell, 1979).

Finally, Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) have sought to ameliorate the problems associated with both deterministic and probabilistic production frontiers by specifying a stochastic production frontier.

The strong and weak points of each modification will be considered in the following part.

3.6.2 Strong and weak points of frontiers

According to Schmidt and Lovell (1979) the recent interest in the formulation and estimation of production frontiers has centered on three problems. First, it is the production frontier rather than fitted "average" function that corresponds to the theoretical notion of a production function. Second, there has been some interest in examining the nature of the relationship between the production frontier and the fitted "average" function. Finally, and most importantly, production frontiers have implications for the TE of production. Although under certain conditions a fitted "average" function permits a ranking of observations by TE, it provides no quantitative information on TI in the sample.

Considering deterministic frontiers, Schmidt and Lovell (1979) wrote: Apart from all conceptual questions of whether the frontier is really ought to be deterministic, there are severe statistical problems with deterministic frontiers. In some cases, although some disturbance must implicitly be assumed, no assumptions are made about its properties; as a result, the parameters are not estimated in any statistical sense, but are merely "computed" via mathematical programming techniques. In other cases, a one-sided (non-positive) disturbance has explicitly been assumed, of some particular form (e.g., gamma). Finally, deterministic frontiers are extremely sensitive to outliers.

In addition, according to the two authors, the appearance of the probabilistic frontier approach with the previous characteristics thus solves the outlier problem by discarding outliers from the sample. Moreover, since it is computed rather than estimated, hypothesis testing is impossible. As a result, papers by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) have sought to ameliorate the problems associated with both deterministic and probabilistic production frontiers by specifying a stochastic production frontier. From an economic standpoint this technique permits firms to be technically inefficient relative to their own frontier presumably captures the effects of exogenous shocks, favorable and unfavorable, beyond the control of the firms. The statistical specification is that the disturbance term is made up of two parts: a symmetric (normal) component capturing randomness outside the control of the firm; and a one-sided (non-positive) component capturing randomness under the control of the firm (i.e., inefficiency). Estimation of the frontier is then a statistical problem, and the usual types of statistical inference are possible (Schmidt and Lovell, 1979).

Finally, these two authors concluded although a stochastic production frontier is a useful construct, there is one serious limitation in the information it contains. A production process can be inefficient in two ways, only one of which can be detected by an estimated production frontier. It can be technically inefficient, in the sense that it fails to produce maximum output from a given inputs bundles; TI results in an equiproportionate over-utilization of all inputs. It can also be allocatively inefficient in the sense that the marginal revenue product of an input might not be equal to the marginal cost of that input; allocative inefficiency results in utilization of inputs in the wrong proportions, given input prices. Since estimation of production frontiers is carried out with observations on output and inputs only, such an exercise cannot provide evidence bearing on the matter of allocative inefficiency, and hence cannot be used to draw inferences about total, or economic, inefficiency.

3.7 Studies related to shrimp aquaculture, production frontier and technical efficiency

The studies review covers two parts. The first part focuses on the research and studies related to shrimp aquaculture and the second part discusses the research and studies related to production frontier and technical efficiency.

3.7.1 Studies related to shrimp aquaculture

Savitri (1989) analyzed the economic aspects of intensive Giant Tiger prawn culture in Samutsongkram, Thailand employing the Cobb- Douglas function and cost and return analysis. The study revealed that three variables (feed, seed, and fuel expenditures) were significantly related to shrimp outputs. The variable feed, which had highest elasticity, was considered as the most important factor determining the quantity of shrimp produced. Other variables like area, labor, reservoirs, experience and education have been reported to have no significant effects on shrimp production.

Hung (2000) surveyed 150 shrimp farms consisting of two shrimp aquacultural systems, improved extensive and semi-intensive, in Phu Vang district, Thua Thien Hue, Vietnam. The research findings showed that (1) By applying descriptive statistics, in cost shares, the cost of fry accounted for the highest percentage (47.4%), followed by cost of feed (34.9)%, cost of pond cleaning (11.3%), etc. (2) The economic efficiency of the semi-intensive shrimp farms was higher than that of improved extensive shrimp farms when analyzed using the budgeting analysis method. (3) Based on the Cobb-Douglas function, it was found that all the variables included in the function (cost of pond cleaning, feed, density, labor, method of farming (dummy), and location of the farm) were statistically significant.

3.7.2 Studies related to production frontiers and technical efficiency (TE)

So far, there has been no research found related to shrimp aquaculture in which stochastic production frontier and TE are applied. This research employs these methods. Hence, the following are some studies on other products in which either or both stochastic production frontier and TE are employed.

Paudyal (1996) attempted to measure the TE and to find the sources of inefficiency of fish farmers in Nepal. He applied a two-stage approach to measure TE. In the first stage, the general Cobb-Douglas production function was employed to estimate the efficient production frontier of the fish farmers using a linear programming technique. The coefficients of labor, capital, feed and pond area were significant. The Farrell TE index, the ratio of actual output to the potential output, was employed with the potential and actual outputs receiving from the linear programming technique. The TE Farrell index for all fish farms was found to be 0.77 with the range of TE index of farms from 0.52 to 1.00. In the second stage, to find the sources of inefficiency, a multiple regression model using Tobit estimation technique was employed with inefficiency in percentage as a dependent variable and pond area, years of experience in fish culture, literacy (dummy variable), age of the head of fish farm and number of workable persons in the family as independent variables. It was found that the farmers operating in a small pond area are relatively more efficient than the farmers operating in a large pond area. Similarly, literature, experiences and younger farmers were found to be relatively more efficient than illiterate, inexperienced and older fish farmers, respectively.

Sriboonchitta and Wiboonpongse (2001) employed transcendental logarithmic (translog) and Cobb-Douglas stochastic production functions using maximum likelihood method by Frontier 4.1 computer program to find the effects of production inputs, TI and other factors on jasmine and nonjasmine rice in production year 1999/2000 in Thailand. After employing the two production functions, the most suitable production model selected was then used to estimate the production frontiers for jasmine and nonjasmine rice simultaneously with the inefficiency equations. Finally, the Cobb-Douglas frontier was selected for policy implications. The results showed that the crucial factors influencing jasmine rice yield were chemical fertilizer, labor, irrigation, severe drought and neck blast, whereas those for the nonjasmine rice were the same except for labor and neck blast. The factors affecting the TI for nonjasmine rice in a negative relationship were male labor to total labor ratio and experience reflected by age while the labor influenced in a positive direction. For jasmine rice, there was only one variable, that influenced the TI significantly, i.e. male-labor ratio to total labor ratio.

Seyoum *et al.* (1998) investigated the TE of two samples of maize producers in eastern Ethiopia, one involving farmers within the Sasakawa-Global 2000 project and the other involving farmers outside this program. The study used Cobb-Douglas stochastic production frontiers with cross-sectional data obtained for the 1995/1996 agricultural year. TI effects were assumed to be functions of the age and education of the farmers, together with the time spent by extension advisors in assisting farmers in their agricultural production operations. The empirical results indicated that farmers within the SG 2000 project were more technically efficient than farmers outside the project, relative to their respective technologies. The mean frontier output of maize for farmers within the SG 2000 project was significantly greater than that for the farmers outside the project.

Tzouvelekas *et al.* (2001) analyzed empirically the TE of organic and conventional olive-growing farms using a stochastic production frontier methodology and a translog functional specification. The samples used here consist respectively of 84 organic and 87 conventional, olive growing farms located in four different counties of Greece (namely, the counties of Messinia, Achaea, Corfu and Heraklion). The dependent variable in the production frontier model was (organic or conventional) olive-oil production measured in kilograms. The aggregate inputs included as explanatory variables were: (a) farm's total land devoted to olive-tree cultivation, measured in stremmas; (b) total labor (i.e. both hired and family labor) used in olive-farming, measured in hours; (c) the total amount of chemical fertilizers and pesticides applied in olive production, measured in Drachmas (in organic farms this refers to organic fertilizers and means of biological weed and pest control) and; (d) other cost expenses (consisting of fuel and electricity, depreciation, fixed and current assets interest, and other miscellaneous expenses) measured in Drachmas. The variables in the inefficiency model include: (a) the share of family in total labor expenses; (b) the farm size measured in stremmas; (c) the stock of capital inputs (including machinery, inventories and buildings) expressed in Drachmas; and (d) four regional dummies in order to capture the general environmental conditions in each particular county of Greece (i.e. soil quality, weather). The parameters of both the stochastic frontier and the inefficiency effects model were consistently estimated by maximum likelihood (ML) procedure using the frontier 4.1 computer program (Coelli, 1996). Findings indicated that the organic olive-growing farms examined exhibit a higher degree of

TE than do conventional olive-growing farms. Reasons might include lower profit margins and restrictions on inputs permitted, thus forcing organic farmers to be more cautious with input use. However, both input- and output-oriented TE scores are still relatively low for both types of olive-farming. Thus there was considerable scope for cost reducing and farm income improvement in both farming modes. This could prove crucial for the long-run viability and the future course of the sector.

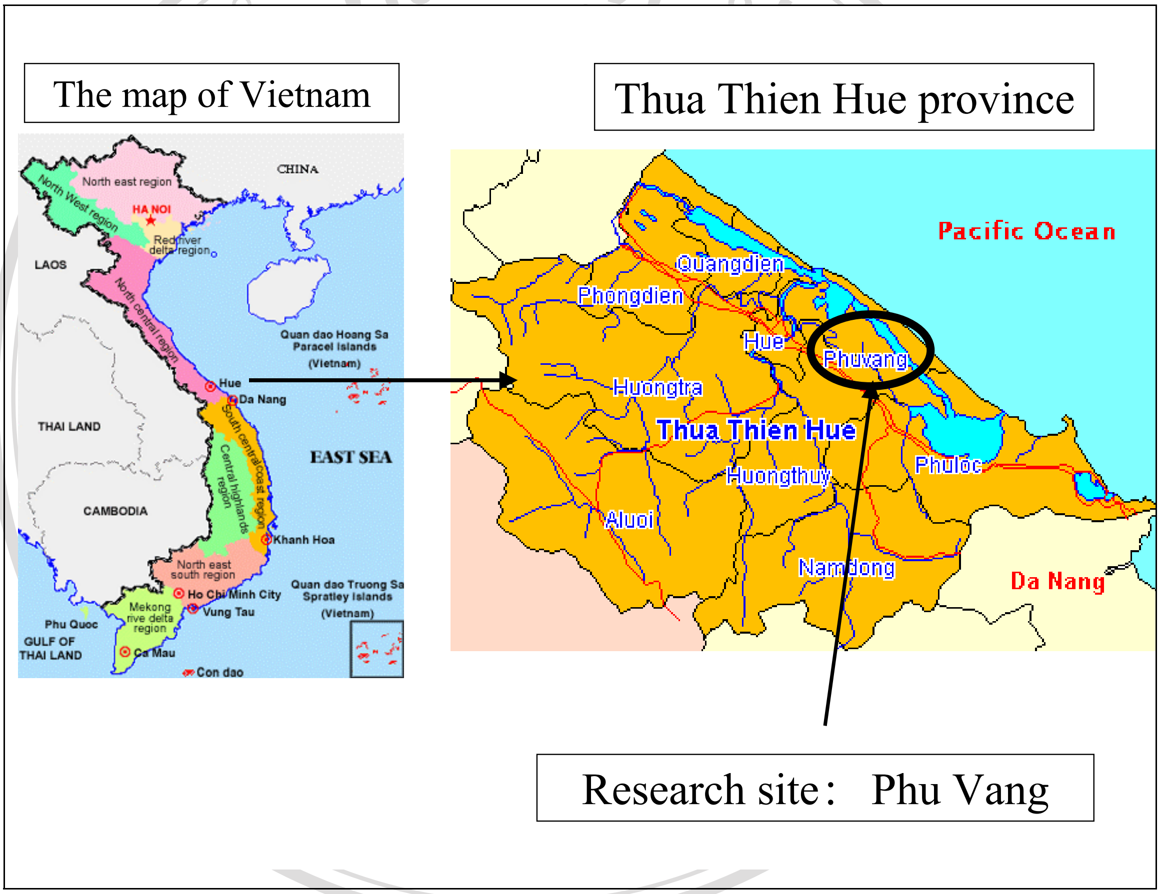
Iinuma *et al.* (1999) employed stochastic production frontier analysis conducting in conjunction with a TI model to examine the productive performance and its determinants in carp pond culture in Peninsula Malaysia. The database used for the study consisted of 94 farms (52 intensive/semi-intensive farms and 42 extensive farms). The production frontier involved six input variables, including seed, seed ratio, feed, feed ratio, labor and other inputs. Similarly, the TI model included five farm-specific variables, namely culture intensity, ownership, carp farming as a primary activity, pond area and pond age. The results of the study revealed that (1) All coefficients in the stochastic production frontier are estimated to be positive and significant, except for the coefficient for feed ratio. (2) The results from the TI model indicated that the various farm specific factors mentioned above contribute significantly to the level of and variations in the TI of carp pond culture in Peninsula Malaysia. On average, the intensive/semi-intensive culture system is found to be more technically efficient than the extensive system. In addition, the mean TE for sample carp farms was estimated to be 42%. Finally, because the intensive/semi-intensive system is found to be more technically efficient than the extensive system, efforts should be made to promote the intensive/semi-intensive carp culture.

3.8 Research site description

3.8.1 Location of the research site

Phu Vang is a coastal district of Thua Thien Hue province with a 40-kilometer coastal border. In the east it faces one of the largest lagoons in Southeast Asian known as Tam Giang, which stretches from the top to the end of the district coastal border

(Figure 3.2). The latitude of Phu Vang district is from 16°19'35" to 16°34'35" and the longitude is from 107°34'35" to 107°51'15". It is bordered by Huong Tra district in the north, Phu Loc district and Huong Thuy district in the south, East sea in the east, and Hue city in the west (Department of Agriculture and Statistics of Phu Vang, 2002).



Source: UNDP Vietnam.

Figure 3.2 The research site

As being a large district of Thua Thien Hue province, Phu Vang is located at the south-east of Hue city, the capital city of Thua Thien Hue province. The national road No. 49 goes through the district and connects Hue city with the communes of Phu Vang. The provincial road No. 10 connecting the capital city with the remote communes of the district has been upgraded. In addition, there is a seaport and it is being upgraded in order to receive large and high capacity ships. Those crucial infrastructures will help support the economic growth and social development of the district.

Phu Vang has 21 communes (Phu Xuan, Phu My, Phu An, Phu Da, Phu Thuan, Phu Dien, Phu Thanh, Phu Hai, Phu Mau, Phu Duong, Phu Thuong, Phu Ho, Phu Luong, Phu Tan, Vinh An, Vinh Thanh, Vinh Xuan, Vinh Ha, Vinh Phu, Vinh Thai, and Thuan An); of which there are 13 communes relating to shrimp aquaculture: Phu Xuan, Phu An , Phu My, Phu Da, Phu Dien, Phu Thuan, Phu Hai, Vinh An, Vinh Thanh, Vinh Xuan, Vinh Ha, Vinh Phu, and Thuan An. These communes belong to the Phu Vang lagoon region that is a combination of delta, sea, and coast. The above descriptions form an abundant and diversified ecological region which is appropriate for fresh, blackish, and saltwater species. Consequently, on one hand Phu Vang has the potential and advantages for fishery and aquaculture in general, and for shrimp aquaculture in particular. On the other hand, it is located near the capital city of the province, has the national seaport, national road and provincial road going through, thus it can take advantage of these for its economic growth and social development.

3.8.2 Climate

Phu Vang has a mixed tropical and monsoon climate and is influenced by the mixed climate of oceans and continents. Phu Vang is also the climate border of the North and the South with the dividing frontier, Hai Van pass. Because of this, Phu Vang has the climate of the two regions, the North and the South, and has one of the highest rainfall levels in Vietnam.

The yearly average temperature is about 25°C, the maximum temperature is 41°C and the minimum temperature is 8,8°C. June, July, August and September are the hot and sunny months. This time has the highest total sunshine hours and the lowest rainfall and humidity. As a result, droughts often occur and the salinity in the lagoon and in saltwater also increases. The rainy season often lasts from September to December. Heavy rains are concentrated in November. The rainy season also combines with cold wind, which makes it cold and rainy, leading to a decrease in salinity in sea and lagoon water. Storms also coincide with the rainy season and cause floods.

Phu Vang is influenced by two main kinds of wind, hot monsoon and cold monsoon. The hot monsoon often comes in May and lasts until September. The main wind directions are south, east and south-west, with average speed from 1.3 to 1.6 m/s. The cold monsoon blows from October until April, mainly in north-west, west and north-east directions. The average speed of this wind is higher than that of the hot monsoon, reaching 1.6 to 1.9 m/s. When combined with a cold atmosphere, its speed is up to 17–18 m/s, with a maximum speed of 20 m/s.

Storms often occur from July to November, but are mainly concentrated in August, September and October. Storm frequency in September is about 37%. The speed of storm wind is 20 m/s, and sometimes reaches 40 m/s.

Besides the damage caused by strong winds, storms often carry heavy rains and these are concentrated in a short period. Consequently, there are floods together with storms, causing yet further damage. There occur around 5 to 10 floods a year in Thua Thien Hue.

These descriptions of climate indicate harsh weather in Phu Vang. This weather greatly influences Phu Vang's natural environment and the lagoon ecological environment as well.

3.8.3 The lagoon and its features

Water and the hydrological cycle play a very crucial role in aquaculture. They are among the most important factors which decide the success or failure of aquaculture. Four shrimp aquacultural systems in Phu Vang depend on the lagoon water. Phu Vang lagoon belongs to the lagoon system of Thua Thien Hue province. Hence, the characteristics of Phu Vang lagoon can be deduced from those of Thua Thien Hue lagoon.

The average depth of Thua Thien Hue lagoon is 2 meters; however, at 7.0 meters, the deepest place is Thuan An estuary. The average length of the lagoon is 2 kilometers, the narrowest place is 0.6 kilometer, and the largest place is about 10 kilometers. According to Phap (No date), the lagoon's bottom topography can be categorized into two types. First, it has valley or basin shape. Second, the lagoon's bottom decreases from northwest to southeast with the depth at the northwest bottom from 1.0 to 1.5 meters and at the southeast bottom from 3.0 to 3.5 meters. Accordingly, the bottom topography of Phu Vang lagoon provides potential opportunity for aquaculture, since these types of bottom topography are easy for aquacultural practices and activities.

Water in the lagoon exchanges with water from the sea by the tide. The water level in the lagoon does not seem to change in the dry season, but often changes in the rainy or flood season. Consequently, the environment of the lagoon is easily polluted in the dry season, causing disadvantages for species that exist in the lagoon. Moreover, the wind speed is slow; thus, the distribution and provision of food for species in the lagoon is very poor, especially in the dry season. To be brief, much food is available for species in the lagoon in the rainy season but less in the dry one.

The pH of the lagoon is rather high and normally ranges between 6.21 and 8.28. The pH varies in the same direction as the salinity. Salinity ranges between 10‰ and 26‰. In the rainy season or when big floods occur, salinity in the region decreases significantly (0‰-6‰). However, in dry season, it increases greatly. Water becoming fresh in the rainy season and salty in the dry season is, hence, a common feature of Thua Thien Hue and Phu Vang lagoon. This is one of the profound problems of the lagoon environment, especially in the dry season, since it causes severe damage to farms and the fishery economy.

Dissolved oxygen in the lagoon water varies between 6.78 and 9.93 mg/l. This entity also varies according to season. It is high in the rainy months and low in the sunny ones. In general, dissolved oxygen in the lagoon water is suitable for aquacultural purposes and other aquatic purposes as well.

3.8.4 Population and labor force

Table 3.5 reflects the population and labor force of the district. The number of shrimp households made up the majority of aquacultural households in 2001 (97.2%). This shows that shrimp was widely farmed in the district as compared with other aquatic species. In recent years, shrimp has become the main fishery species raised in Phu Vang. More and more households have stopped farming rice or other agricultural products and turned to raising shrimp; since shrimp aquaculture can bring higher income for farms as compared with other agricultural products.

In 2001, the female population (50.3%) was higher than the male population (49.7%). This trend was also true for the labor force. Labor force accounted for 45.8% (79,272 labors as compared with 173,126 people). This is considered as a huge labor force for Phu Vang. The number of laborers per household is 2.4 persons, while the number of persons per household is 5.3. This means that on average one laborer has to work to feed more than 2 members of the family.

Table 3.5 Population and labor force of Phu Vang district in 2001

Indicators	Unit	Quantity	%
1. No. of aquacultural household	Household	1,683	100.0
In which No. of shrimp household	Household	1,635	97.2
2. Total population	Person	173,126	100.0
Male	Person	86,016	49.7
Female	Person	87,110	50.3
3. Total labor force	Person	79,272	100.0
Male	Person	38,321	48.3
Female	Person	40,951	51.7
4. No. of person(s)/household	Person	5.3	
5. No. of labor(s)/household	Person	2.4	

Source: Phu Vang Department of Agriculture and Statistics, 2002