BIOECONOMIC ANALYSIS OF THE SHRIMP TRAWL FISHERY IN THE TONKIN GULF, VIETNAM

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Cover picture:

The Fisheries Harbor in Hong Gai town, Halong Bay (Tonkin Gulf), Vietnam
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Abstract

The objective of this study is to investigate the sustainability properties of the stock and management of the shrimp trawl fishery in the Tonkin Gulf, Vietnam. Surplus production models of Verhulst-Schaefer and Gompertz-Fox are applied to the shrimp trawl fishery, which is a typical tropical fishery with the characteristic properties of small scale and multi-species fisheries. There are two shrimp spawning seasons per year in the Gulf. This implies that it is appropriate to divide the time scale into a half year in accordance with the biological year of the stock. The surplus production models which are usually associated with calendar year catch and effort data, in this study are applied for a half year time interval data. Empirical data were collected from the enumerator project (ALRMV), which was supported by DANIDA and carried out in Vietnam from 2000 to 2004. The catch and effort data aggregated from the data of the project were monthly collected by the questionnaire methodology in local fishing ports. Standard reference points with and without discounting are analyzed and policy implications of the findings are indicated. Entry tax and closing seasons may be reasonable regulations for the fishery in order to achieve maximum economic and sustainable yield.

Key words: Bioeconomic analysis, shrimp trawl fishery, fisheries management, Vietnam

Dedication

This work is dedicated to my parents and my wife who has been a great supported in my endeavors. The most dedication is to my daughter, Thuy Duong and my son, Phuc Lam who represent my future.

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Abbreviation

ALMRV	Assessment of Living Marine Resources in Vietnam
DANIDA	Danish International Development Agency
IFEP	Institute of Fisheries Economic and Planning
NADAREP	National Directorate of Fisheries Resource Exploitation and Protection
RIMF	Research Institute For Marine Fisheries
MOFI	Ministry of Fishery Vietnam
CPUE	Catch per unit of effort
HP	Horse power
VND	Vietnam Dong
BT 20-45 HP	Beam trawlers with engine from 20 HP to 45 HP
OT 20-45 HP	Otter trawlers with engine from 20 HP to 45 HP
BT <20 HP	Beam trawlers with engine lower than 20 HP
OT <20 HP	Otter trawlers with engine lower than 20 HP
MSY, E_{MSY}	Maximum sustainable yield, effort at MSY
MEY, E_{MEY}	Maximum economic yield, effort at MEY
Y_{OA}, E_{OA}	Open access yield, effort at Y_{OA}

Introduction

The Tonkin Gulf is a semi-closed gulf in the Northwest of the South China Sea with total area about 126,250 km^2 (Vietnam's sea water-the Western part: 67,203 km^2 or 53.23%). It is a shallow Gulf, the average depth around 38 m and maximum depth less than 100 m. The Gulf is one of the most important fishing grounds in Vietnam's sea water. It contributes to around 16% of Vietnam's marine resources, 30% of all fishing boats and about 20% of annual total landings from marine fisheries (Chinh, 2005). The fisheries in the Gulf are small scale, multi-species and multi-gears fisheries. In 2003, there were about 26,000 fishing boats using 25 different types of gears in the Gulf; 86% of these boats had the engine lower than 45 HP (Chinh, 2005). There were 166 species of 74 different families identified by bottom trawl surveys in the offshore water of the Gulf (Son, 2001).

Shrimps are the most important commercial species in Vietnam's marine waters. In 2003, shrimp landing contributed around 17 % in monetary value of the marine capture fisheries (MOFI, 2006). There has been found 58 shrimp species, in the Western part of Tonkin Gulf, mainly belong to the family of *Penaeidae*. Most shrimp species are distributed along the coastal areas, spawning seasons are February-March (spring) and June-July (autumn)_(Son, 2003). The shrimp trawl fishery in the Tonkin Gulf has a long history of development. Before 1985, almost all fishing boats were otter trawls belonging to stated-owned enterprises and used engines of higher than 200 HP. However, due to low economic returns, they have been closed (Long, 2003). At present, shrimp trawl fleet are small scale and under private ownership. In 1997, the fleet occupied about 18% of the total fishing boats in the Gulf, the shrimp trawlers was about 9-13m in length, almost used engines of 15-30 HP and operated in the waters within 30 m depth. The fishing trip was around one or two days (Long, 2003). Shrimp landing was estimated around 11.445 tones, occupying about 4.6 % of the total catch of the Gulf's fisheries in 2003 (Chinh, 2005).

Some studies indicate that maximum sustainable yield (MSY) in the coastal areas of the Tonkin Gulf was reached since 1994 and that fishing activities give low economic returns due to overfishing (Long, 2001; Long, 2003). Catch per unit of effort (CPUE) globally declined from 1.34 to 0.34 ton/HP/year between 1985 and 1997 (Son, 2003). In addition, fisheries in the Gulf as well as other sea waters in Vietnam are argued still in the open access situation (FAO, 2005). It has been shown that it is difficult to achieve the sustainable development of the fisheries and in the long run, the stocks may be in danger. This is also valid in the shrimp fishery by trawl. The current fishing effort seems to be too high for a sustainable exploitation even though no quantitative analysis has been carried out so far.

The objective of this study is to investigate the sustainability properties of the stock and management of the shrimp trawl fishery in the Tonkin Gulf by using bio-economic analysis of historical data. The basis assumption is that the management objectives are to sustain development and to maximize economic yield. The major questions that arise in this case include:

(1) What is the sustainable harvest of selected reference points? Must the fishing effort be reduces in order to reach the reference points?

(2) Is the current management regime efficient? If not what should be the alternative regulations?

The hypothesis of the study is that, the catch by shrimp trawlers is expected too high to meet the reference points MEY (Maximum Economic Yield) and MSY (Maximum Sustainable Yield), and the shrimp catches have been declining over the studied period. It is assumed that fishery regulations are inefficient and the actual situation is close to open access.

In this study, standard surplus production models of Verhulst-Schaefer and Gompertz-Fox are used to analyze the data derived from an enumerator program (ALRMV project) which was supported by DANIDA and carried out in Vietnam from 2000-2004. The time series cover a short time span, which may involve the "one way trip" problem since the full development history of the fishery is not covered. Furthermore, simple models may not describe the full dynamics of such a complicated system.

Chapter 2 brings the reader some background information on the shrimp trawl fishery in the Tonkin Gulf. Chapter 3 presents the basics of the models used. Chapter 4 covers the data set applied - the standardization of the data for the models. Chapter 5 shows the results from the models and relevant results. The thesis results are summarized in the discussion and conclusion parts, chapter 6 and chapter 7.

Background information

1. Resource biology

For all known members of the *Penaeidae* family, the sequence of development is similar: planktonic larvae and postlarval stages, followed by juvenile and adult stages. The greatest differences are in the preferred habitat of postlarvae, juveniles and adults, whether they are predominantly estuarine, inshore or offshore. Usually, spawning takes place offshore, the depth varying with the species, and the planktonic stages migrate inshore towards the end of larval development, when the postlarvae settle on their preferred "nursery grounds" (Dall et al., 1990: 283-284). The growth of penaeids is very fast, they settle as postlarvae in different nursery habitats 3-4 weeks after the eggs are released and the growth in the juvenile phase usually takes from one to six months (Dall et al., 1990: 237, 289). The life span of most coastal penaeids is between one and two years in the tropics. In heavily fished populations of penaeus, the life span often appears to be less than 1.5 years (Dall et al., 1990: 289). The maximum size of some smaller penaeid species (*Metapenaeus* spp., *Xiphopenaeus* spp.) varies from 15-16 cm total length to 30 cm in the giant tiger shrimp (*Penaeus monodon*) (Garcia, 1988).

In the Tonkin Gulf, the *Penaeidae* family is dominant both in terms of numbers of species as well as the abundance (see table 1). However, there are some indications of overexploitation in recent years. Surveys by RIMF showed that the density of the *Penaeidae* family was dimidiated from 1975-1978 (66kg/km^2) to 2002 (32.01kg/km^2)_(Chinh, 2005). The abundance of some valuable species such as *Penaeus monodon* (giant tiger shrimp), *Penaeus merguiensis* (white/banana shrimp) has also been reduced dramatically. In 1975-1980, *Penaeus merguiensis* constituted 20-90% of the total catch and the CPUE reached 5 to 10 kg/h in the shrimp trawl fishery (Thuc & Thang, 1983). In 2003, it only made up 0.1 % of the total catch and the CPUE was lower than 0.01 kg/h in the RIMF's surveys (Thi, Ha & Kien, 2004)

There is a disagreement on the figure of shrimp stock in the Tonkin Gulf. In 2003, the biomass was estimated to be about 4,165 tones in the southwest monsoon season (4/2003) and approximately 6,687 tones in the northeast monsoon season (9/2003)_(Thi et al., 2004). The biomass was preliminary estimated around 1390 tones annually for the period of 1975 to 1978 (Son, 2003), however, it is argued to be an impossible figure because it is about eight times lower than the shrimp landing in 2003 (Chinh, 2005). The disagreement may be a consequence of different estimation methods.

Table 1 Mean CPUE of the shrimp trawl surveys in the Tonkin Gulf

Family	*CPUE (kg/h)*	
	April, 2003	***September, 2003***
Penaeidae (18 species)	1.33	1.93
Scyllaridae (3 species)	-	0.01
Solenoceridae(1 species)	0.06	0.35
Squillidae (6 species)	0.60	0.35
Total	1.99	2.64

Source: (Thi et al., 2004)

2. The fishery

2.1. Fishing grounds and fishing seasons

The *Penaeidae* family is widely distributed in the coastal areas of the Gulf. The nursery grounds of shrimp larvae and juveniles typically occur within depths of 15m, especially estuaries (Son, 2003). In the southwest monsoon (rainy) season, the main fishing period of the shrimp fishery is from April to August. In the northeast monsoon (dry) season, the main fishing period is from November to December (Son, 2003). The shrimp fishing grounds of the two seasons are showed in figure 1 (inside of the dotted line).

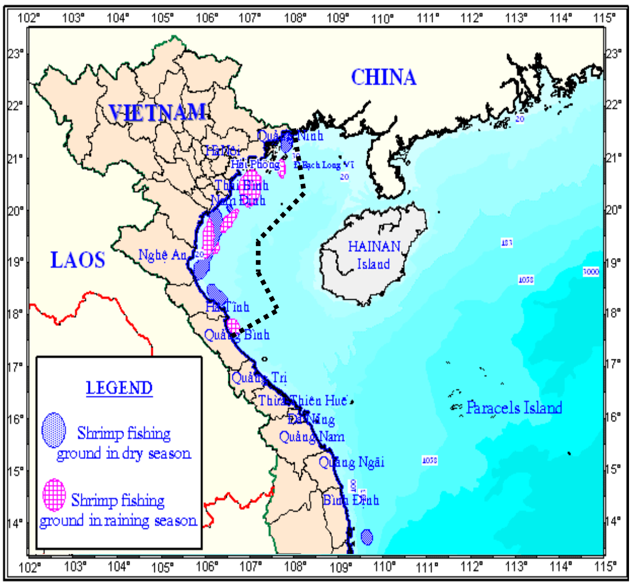

Figure 1 Shrimp fishing grounds (*penaeidae*) in the Tonkin Gulf (Son, 2004)

2.2. Fishing fleet and fishing gears

Otter trawl and beam trawl are the two main gears used in the shrimp fishery. Both otter and beam trawlers use the single boat, for horizontal opening trawls, the otter trawlers uses otter-boards while the beam trawlers use sticks or pipes. Beam trawlers often have the engine ranging from 22-90 HP, rarely up to 250 HP. A small boat tows 1 to 2 beam trawls, but larger boats can tow up to 18 beam trawls (Long et al., 2002). The net mouth is horizontally propped open by bamboo or steel pipes. Sometimes, the fishers use two skis that are joined together with the lead and head rope for slipping along the seabed easily. The fishing ground of beam trawlers are sandy-muddy bottom and shallow waters. Target species are shrimp, crab and small demersal fish. The shrimp otter trawlers often use the engine with less than 60 HP and operate within 30 m water depths (Long et al., 2002). The otter boards are rectangular and flat, and are made of wood and iron. Iron tickler chains (about 1.5-3.5 m) are used to round up the shrimp in the sand.

At present, there are few shrimp trawlers with larger engines than 45 HP in the Tonkin Gulf (below 10%). In addition, the percentage of shrimp in catch of these is also low, for example lower than 10% for the otter trawl fleet with engine 46-89 HP[1]. In this study, only trawlers with engine size less than 45 HP is used (table 2).

Table 2 Shrimp trawl fleet in 2003

Groups	Beam trawl	Otter trawl	*Total*
< 20 HP	203	1749	1952
20 HP to 45 HP	211	1808	2019
Total	**414**	**3557**	**3971**

Source: NADAREP, MOFI, 2005

2.3. The landing and the price

The landing of shrimp trawlers includes many species. Shrimps and mixed fish are the main groups. The proportion of these groups in the landing of the trawl fishery has changed over time. Otter trawlers have relatively higher productivity, but a lower proportion of shrimps in catch than beam trawlers (figure 2, 3, 4, 5).

[1] Data from the database of the ALRM project

The landing prices of the main groups also fluctuated overtime. However, shrimps are the most valuable species as the price of shrimps is about ten to thirty times the price of mixed fish and trash fish (figure 6, 7, 8, 9). Shrimp therefore is not only dominant in terms of the proportion in the landing, but even more in terms of value.

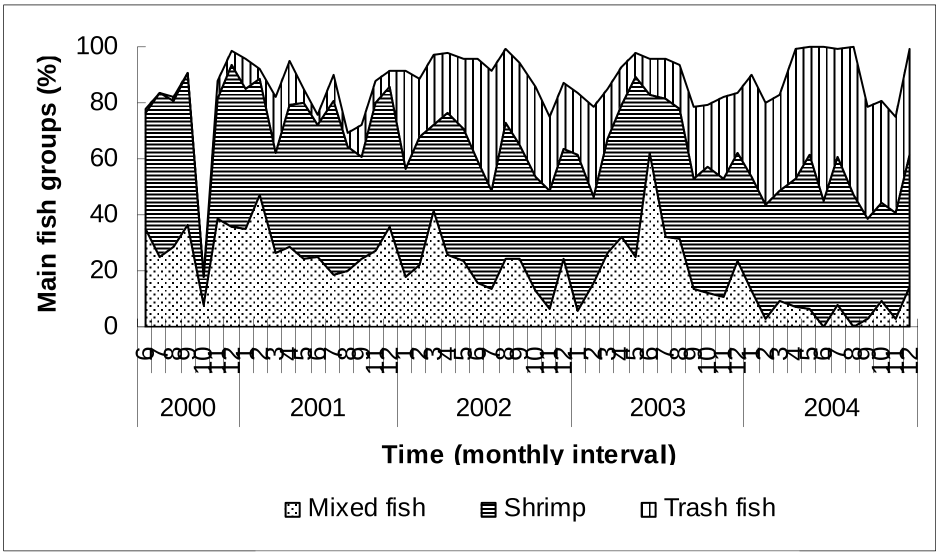

Figure 2 The proportion of main fish groups in the landing of beam trawlers 20-45 HP
(*Data from the database of the ALRMV project, 2005)*

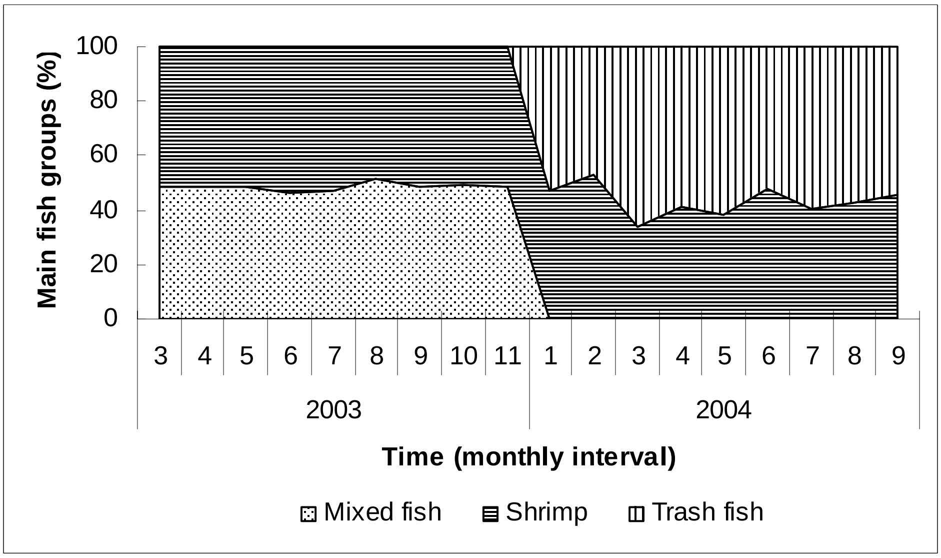

Figure 3 The proportion of main fish groups in the landing of beam trawlers <20 HP
(*Data from the database of the ALRMV project, 2005)*

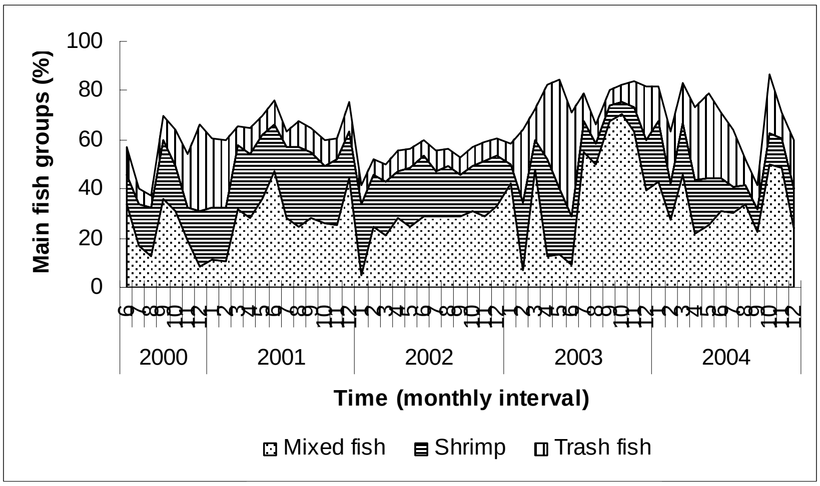

Figure 4 The proportion of main fish groups in the landing of OT 20-45
(*Data from the database of the ALRMV project, 2005)*

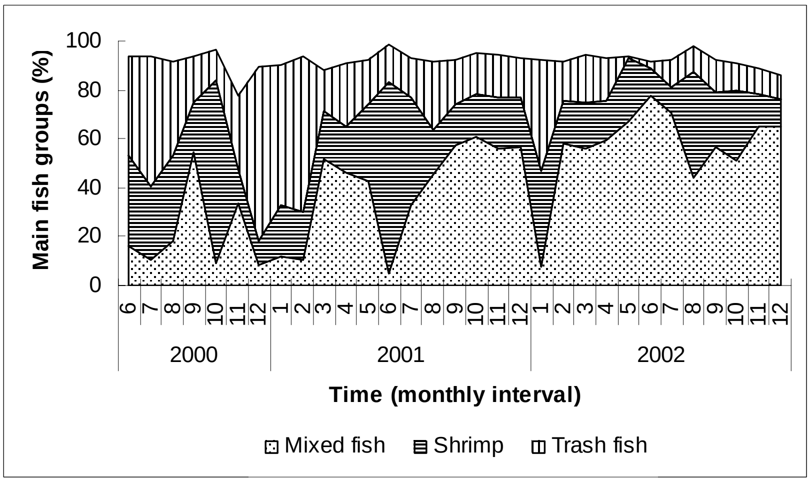

Figure 5 The proportion of main fish groups in the landing of OT <20
(*Data from the database of the ALRMV project, 2005)*

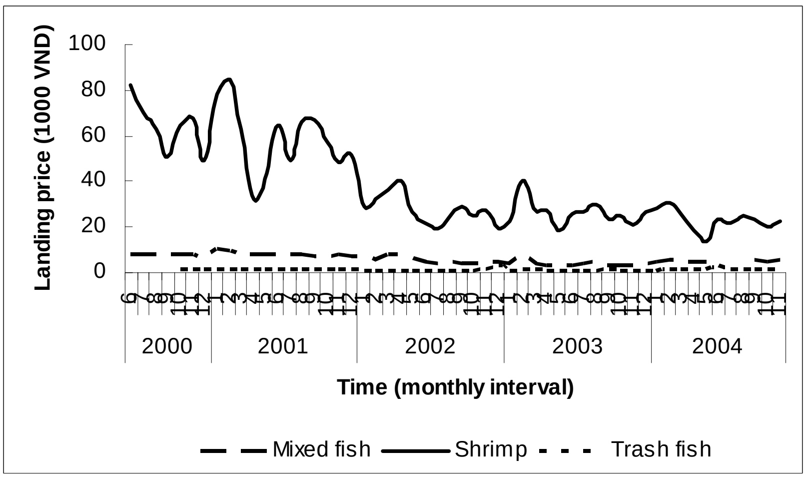

Figure 6 The landing price of main fish groups of BT 20-45
(*Data from the database of the ALRMV project, 2005)*

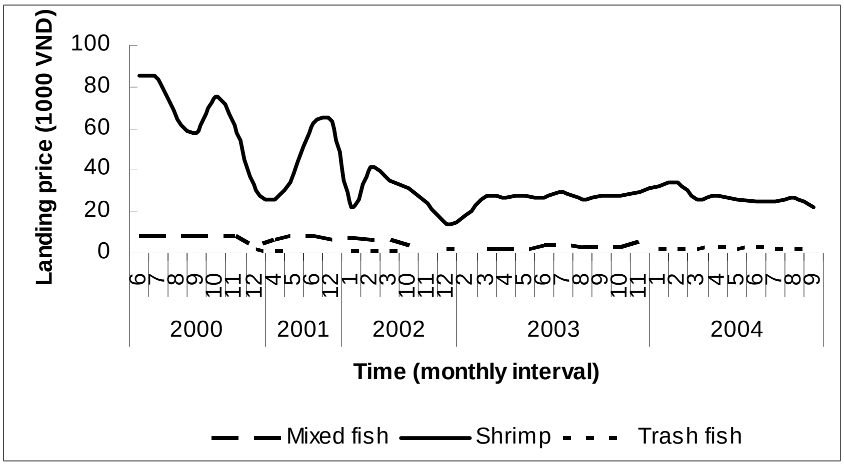

Figure 7 The landing price of main fish groups of BT <20
(*Data from the database of the ALRMV project, 2005)*

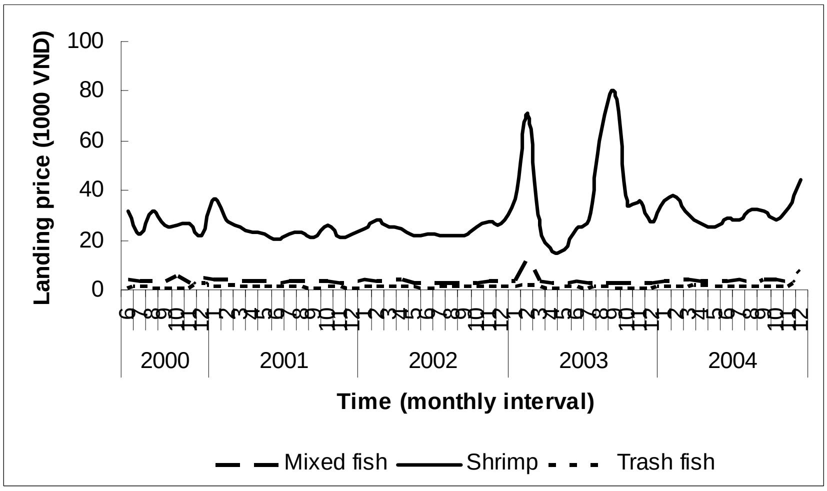

Figure 8 The landing price of main fish groups of OT 20-45
(*Data from the database of the ALRMV project, 2005)*

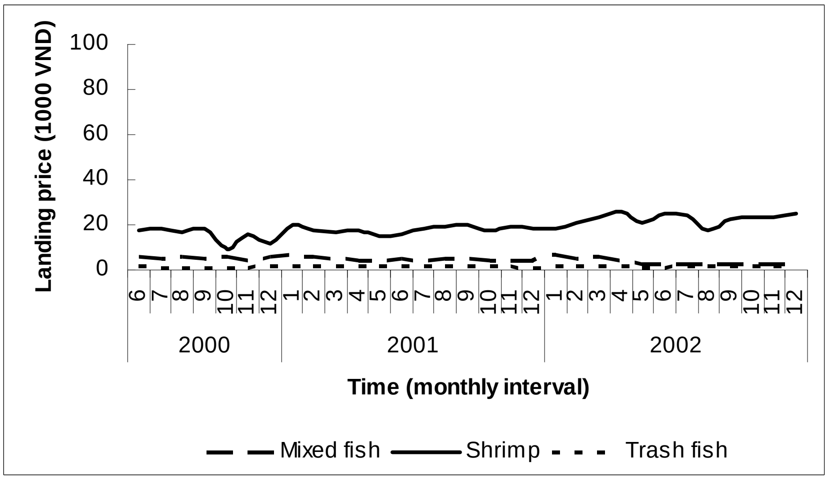

Figure 9 The landing price of main fish groups of OT <20
(*Data from the database of the ALRMV project, 2005)*

Figure 6, 7 shows that beam trawler price on shrimp catch has been reduced by about one third from 2000 to 2004. This implies that valuable shrimp species in catch of beam trawlers may have been reduced significantly.

2.4. Fishing communities

In the coastal areas, fishers are often poor and have moved from the agricultural villages or floating communities. Those who have fished from the rivers near sea have moved to fish in the sea (Hersoug et al., 2002; Thong, 1998). In 1994, the amount of fishers in Tonkin Gulf (Red rive delta) was around 46,254 persons living in 112 communities, of which 13 communes are set in town, district's capital; 56 villages in the rivulet, port; 43 villages in the beaches (Thong, 1998). These figures imply that fishing communities are very diverse and complex, which may make the top down management system impossible to operate. In practice, fishers often do not comply with national and provincial fisheries rules and regulations, and, worse, they are often not aware of them. In part, the problem results from many rules having been made as *ad hoc* decrees, some being contradiction to others (Ruddle, 1998).

2.5. Management

The fisheries law was promulgated on 01 July 2004 and was apparently intended to serve as the main instrument for national living aquatic resources management. However, a highly detailed *Circular* issued on 28 April 2000 by the Vice-Minister of Fisheries, provided instruments on many aspects of the fisheries management, including the shrimp trawl fishery. These instruments include allowable concentrations of toxic substances in waters inhabited by aquatic organisms, minimum permitted mesh sizes by gear type, prohibited species, area closures during spawning seasons and minimum size regulation.

In fact, the Government of Vietnam is in the process of making the basic legal and institutional changes necessary, in order to ensure a more market-oriented economy. As a consequence, the legal framework governing fisheries still lacks coherence. The problems of small scale and industrial fisheries management have hardly been touch-on, despite recognizing an overfishing problems (Ruddle, 1998). In the shrimp trawl fishery, the compliance of regulations is also questionable.

The license regulation is opposed to an open access system, in which a limited number of boats or boat owners are given licenses (King, 1995). In case of the shrimp trawl fishery (also other marine fisheries in Vietnam), the regulation has been applied ineffectively. Fishing licenses are imposed, but many fishermen appear to ignore them. Licenses are granted on the basis of submitting a number of supporting documents such as vessel inspection and registration papers. A small license fee, proportional to engine size is levied. In this case, a license application generally leads to a license being issued and the shrimp trawl fishery as well as other marine capture fisheries are, in fact, in the open access situation (FAO, 2005).

The minimum legal length regulation is imposed but it seems to be inefficiently in the shrimp trawl fishery. Table 3 shows some shrimp species (*Metapenaeus intermedius, Metapenaeus affinis)* were caught with equal mean length in catch, around one third of the minimum legal length. Other species (*Penaeus merguiensis)* which was abundant in 1980s had almost disappeared according to surveys in 2003.

Table 3 The length of some species in the shrimp trawl surveys in comparison with the minimum legal length

Species	The minimum legal length (mm)	The length in surveys (mm)			
		4/2003		9/2003	
		Mean length	Variance	Mean length	Variance
Metapenaeus intermedius	95	33.6	20-40	23.4	20-40
Metapenaeus affinis	95	-	-	23.4	10-30
Penaeus merguiensis	110	-	-	-	-

Source: (MOFI, 2006; Thi et al., 2004)

The basics of the model

The shrimp trawl fishery is a typical tropical fishery with all characteristic properties of small scale and multi-species tropical fisheries. In such cases, surplus production models often have shown to be an appropriate analysis tool when catch and effort data are available. This is supported by Hilborn & Walters:

> *"It is quite difficult to age many fishes, particularly tropical ones, and age-structured analysis is often not practical in these fisheries. Moreover, in the tropical fisheries, the catch consists of many species, and the catch data are difficult if not impossible to collect by species. Management regulations are also difficult to make species specific. In these cases, treating the entire catch as a biomass dynamics pool may be more appropriate than trying to look at single species dynamics"* (Hilborn & Walters, 1992:298).

Garcia (1988: 237) also argues that surplus production models might be more appropriate than other in shrimp fisheries because of short life span of species, which means that equilibrium conditions are close to exist at any time within a biological year, which starting with the main recruitment. With respect to the Tonkin Gulf, there are two shrimp spawning seasons per year (February-March and June-July). This implies that it is appropriate to divide the time scale into a half year in accordance with the biological year of the stock. Surplus production models which are generally applicable to a calendar year data, now, are applied for a half year time interval data in this study. It is assumed that the stock will reach an equilibrium situation within a period of six months. The models use steady state (equilibrium) conditions to formulate reference points and equilibrium assumptions to estimate parameters.

In this chapter, surplus production models are presented in general forms and assumptions will also be paid attention. Verhulst-Schaefer and Gompertz-Fox models are used and parameters estimated from catch and effort data.

1. Biological growth

1.1. General models

A general biological growth model of a fish stock in case of absence of harvesting and other human interference can be expressed (Eide, 1989; Pella & Tomlinson, 1969):

$$\frac{dX}{dt} = rX^{u} + sX^{m} \qquad (1)$$

Where

X stock size to be measured in terms of biomass (cohorts are implicit);

r growth rate of the stock, a positive parameter, includes recruitment and growth of individuals;

s mortality rate of the sock, a negative parameter, includes natural death of individuals (from all causes other than capture by man);

m, u positive constants.

The growth equation of Pella and Tomlinson (1969) is defined by:

$$\frac{dX}{dt} = rX\left[1 - \left(\frac{X}{K}\right)^{m-1}\right] \qquad (2)$$

Where

K the environmental carrying capacity

r in this case is called the intrinsic growth rate

This is a simplified case of the general growth equation when u = 1 and $s = -rK^{1-m}$.

1.2. Logistic growth model

The logistic growth model first proposed as a population model by P.F. Verhulst in 1838

$$\frac{dX}{dt} = rX(1 - \frac{X}{K}) \qquad (3)$$

This is a special case of the Pella and Tomlinson equation when *m* = 2. The logistic growth function is said to describe a process of feedback, or *compensation,* which controls the growth of the population as its level increases. The logistic growth curve is symmetrical round its point of inflexion. This simple model has been used widely both from a theoretical standpoint and as a convenient empirical curve (Richards, 1959).

1.3. Gompertz growth model

The Gompertz growth model proposed by Gompertz in 1825, is defined by:

$$\frac{dX}{dt} = rX \log_e\left(\frac{K}{X}\right) \qquad (4)$$

The Gompertz curve, which resembles the logistic curve in many features but is asymmetrical (inflecting at X = K/e = 0.368 K), has also been used extensively in population studies (Fox, 1970; Richards, 1959). The Gompertz model is a special case of the Pella and Tomlinson equation when $m \rightarrow 1$.

1.4. Comparison of the Logistic and Gompertz models:

The Logistic and Gompertz models are graphed in the figure 10. For a given stock size at time t = 0 and a given carrying capacity, the Gompertz model may expects a faster growth of the stock size over time than the Logistic model.

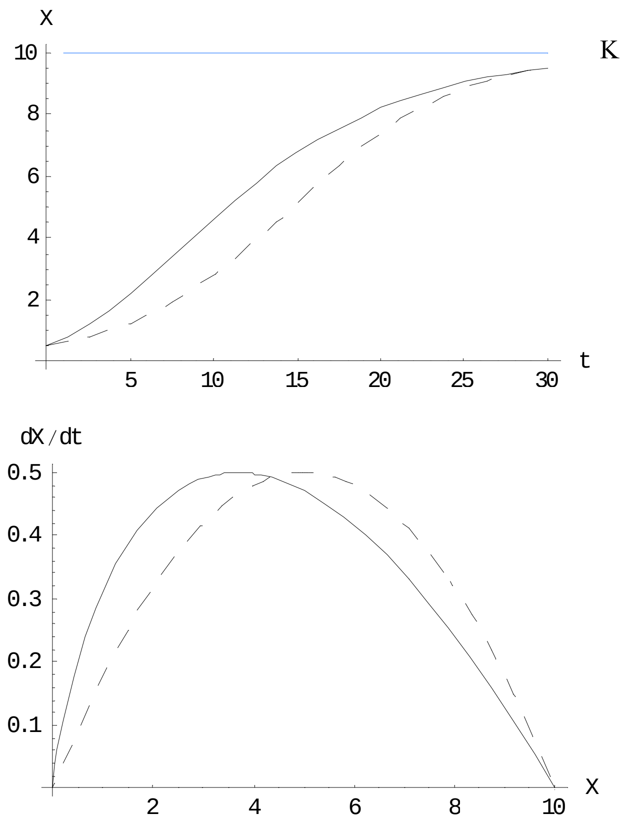

Figure 10 The Logistic (broken line) and Gompertz models

The Logistic model predicts that the maximum growth rate would be obtained at 50% of the maximum population level. In contrast, the Gompertz model predicts the maximum growth rate would be obtained from a population level at about 37% of maximum. The Gompertz growth model predicts the stock may be more compensative than the Logistic model with all the other factors remaining constant.

2. The harvest function

2.1. General models

A general growth model for an exploited stock can be expressed (Clark, 1990)

$$\frac{dX}{dt} = F(X) - H(E, X) \qquad (5)$$

Where

F (X)	the biological growth of the stock
H (E, X)	the harvest function, which depend on fishing effort (E) and stock biomass (X).

In equilibrium $\frac{dX}{dt} = 0$, the stock remains at a constant level. In other words, the natural growth $F(X)$ also equals the *sustainable yield* that can be harvested while maintaining a fixed stock level X (Clark, 1990:9). Hence, at the steady state conditions (equilibrium), the sustainable yield can be derived from the function:

$$F(X) \equiv H(E, X) \qquad (6)$$

The harvest function of a fishery is often assumed to be expressed by a Cobb-Douglas function (Clark, 1990; Clark & Munro, 1975; Eide et al., 2003):

$$H = H(E, X) = qE^{\alpha} X^{\beta} \qquad (7)$$

Where

E	fishing effort
X	stock biomass
q	gear and stock specific constant, referred to as the catchability coefficient.
α, β	positive constants

In case α = β = 1, the harvest function simplifies to:

$$H(E, X) = qEX \tag{8}$$

Fishing effort (E) here is in this study aggregated from a number of different harvesting activities and measured by towing hours. Similarly the biomass variable X consists of number of harvested shrimp species (to be measured in kg).

2.2. Verhulst-Schaefer model

This model assume that the biological growth follows the Logistic growth function

$$qEX = rX(1 - \frac{X}{K}) \Leftrightarrow X = K - \frac{KqE}{r} \tag{9}$$

The sustainable yield for a given level of effort:

$$H_1(E) = qKE - \frac{q^2K}{r}E^2 \tag{10}$$

2.3. Gompertz-Fox model

This model assume that the biological growth follows the Gompertz growth function

$$qEX = rX \log_e\left(\frac{K}{X}\right) \Leftrightarrow X = \frac{K}{e^{\frac{qE}{r}}} \tag{11}$$

The sustainable yield for a given level of effort:

$$H_2(E) = \frac{qKE}{e^{\frac{qE}{r}}} = qKEe^{-\frac{qE}{r}} \tag{12}$$

3. Economics

Total sustainable revenue (TR) and total cost (TC) of the fishery are defined (Clark, 1990; Schaefer, 1954):

$$TR(t) = p * H(E(t), X(t)) \tag{13}$$

$$TC(t) = c * E(t) \tag{14}$$

Where

p	constant price per unit of harvested biomass
c	constant cost per unit of effort

The difference between total sustainable revenue TR and total cost TC is called *the sustainable economic rent* provided by the fishery resource at each given level of effort E:

$$\prod(t) = TR(t) - TC(t) = p * H(E(t), X(t)) - c * E(t) \qquad (15)$$

The equation that maximize the present value (PV) of the fishery can be expressed

$$\max PV = \max \int_{t=0}^{\infty} e^{-\delta t} \prod(t) dt \qquad (16)$$

Subject to the constraint $\frac{dX}{dt} = F(X) - H(E, X)$

The equation to solve for optimal biomass under discounting is (Clark, 1985; Clark, 1990; Clark & Munro, 1975):

$$F'(X) - \frac{a'(X)F(X)}{p - a(X)} = \delta \qquad (17)$$

Where:

δ	Discounted rate
$F(X)$	Growth rate of the stock
$a(X)$	Cost per unit of harvest

4. Estimating the parameters

4.1. Verhulst-Schaefer model

The model uses the Logistic growth function, the relationship between CPUE and effort is linear as derived from the sustainable yield equation (10):

$$CPUE_1 = \frac{H_1(E)}{E} = qK - \frac{q^2K}{r}E \Leftrightarrow CPUE_1 = \gamma + \gamma_1 E$$
$$where: \gamma = qK; \gamma_1 = -\frac{q^2K}{r} \quad (18)$$
$$\Rightarrow H_1 = \gamma E + \gamma_1 E^2$$
$$\Pi_1 = pH_1 - cE = (p\gamma - c)E + p\gamma_1 E^2$$

4.2. Gompertz-Fox model

The model uses the Gompertz growth function, the relationship between Log (CPUE) and effort is linear as derived from the sustainable yield equation (12):

$$CPUE_2 = \frac{H_2(E)}{E} = qKe^{-\frac{qE}{r}} \Leftrightarrow Ln(CPUE_2) = Ln(qK) - \frac{q}{r}E = \gamma + \gamma_1 E$$
$$where: \gamma = Ln(qK); \gamma_1 = -\frac{q}{r} \quad (19)$$
$$\Rightarrow H_2 = Ee^{\gamma + \gamma_1 E}$$
$$\Pi_2 = pH_2 - cE = E(pe^{\gamma + \gamma_1 E} - c)$$

5. Reference points

5.1. Open access yield (Y_{OA})

In the open access situation, fishers will join in the fishery until marginal cost (MC) is equal average revenue (AR). In this case, the open access stock biomass (X_{OA}) is defined by cost per unit effort, price and the catchability coefficient:

$$MC = AR \Leftrightarrow c = \frac{p * H}{E} = pqX_{OA} \Rightarrow X_{OA} = \frac{c}{pq} \quad (20)$$

The yield and effort in the open access situation are shown in table 4

Table 4 Yield and effort in open access

Models	E_{OA}	Y_{OA}
Verhulst-Schaefer	$E_{OA1} = \frac{c - p\gamma}{p\gamma_1} = \frac{r}{q}\left(1 - \frac{c}{pqK}\right)$	$Y_{OA1} = \frac{c^2 - pc\gamma}{p^2\gamma_1} = \frac{rc}{pq}\left(1 - \frac{c}{pqK}\right)$
Gompertz-Fox	$E_{OA2} = \frac{\ln c - \ln p - \gamma}{\gamma_1} = \frac{r}{q}\ln\frac{pqK}{c}$	$Y_{OA2} = \frac{c(\ln c - \ln p - \gamma)}{p\gamma_1} = \frac{cr}{pq}\ln\frac{pqK}{c}$

5.2. Maximum Sustainable yield (MSY)

The equilibrium level of the fishing effort that produces the maximum sustainable yield, found by differentiating equations H_1, H_2 from (18) and (19) with respect to E. The results are showed in table 5.

Table 5 MSY and E_{MSY} for Gompertz-Fox and Verhulst-Schaefer models

Models	***Effort at MSY(E_{MSY})***	***MSY***
Verhulst-Schaefer	$E_{MSY1} = -\frac{\gamma}{2\gamma_1} = \frac{r}{2q}$	$MSY_1 = -\frac{\gamma^2}{4\gamma_1} = \frac{rK}{4}$
Gompertz-Fox	$E_{MSY2} = -\frac{1}{\gamma_1} = \frac{r}{q}$	$MSY_2 = -\frac{1}{\gamma_1}e^{\gamma-1} = \frac{rK}{e}$

5.3. Maximum Economic Yield (MEY)

The equilibrium level of fishing effort that produces the maximum economic rent, found by differentiating equations Π_1 Π_2 from (18), (19) with respect to E. The results are presented in table 6.

Table 6 MEY and E_{MEY} for Gompertz-Fox and Verhulst-Schaefer models

Models	***Effort at MEY(E_{MEY})***	***MEY***
Verhulst-Schaefer	$E_{MEY1} = \frac{c - p\gamma}{2p\gamma_1} = \frac{r(pqK - c)}{2pq^2K}$	$MEY_1 = \frac{c^2 - p^2\gamma^2}{4p^2\gamma_1} = \frac{r(p^2q^2K^2 - c^2)}{4p^2q^2K}$
Gompertz-Fox	$E_{MEY2} = \frac{-1 + w}{\gamma_1}$ ♣	$E_{MEY2} = \frac{-e^{-1+\gamma+w} + \frac{c}{p}}{\gamma_1}$

♣ $we^w = \frac{ce^{1-\gamma}}{p} = \frac{ce^{1-\ln qK}}{p}$

5.4. Optimal biomass, yield and effort

Optimal biomass can be determined in the Logistic model from equation (18)_(Clark, 1990; Clark & Munro, 1975):

$$X_1^* = \frac{K}{4}\left(\left(\frac{c}{pqK}+1-\frac{\delta}{r}\right)+\sqrt{\left(\frac{c}{pqK}+1-\frac{\delta}{r}\right)^2+\frac{8c\delta}{pqKr}}\right) \qquad (21)$$

Optimal biomass for the Gompertz model can be determined (Clarke, Yoshimoto & Pooley, 1992):

$$\ln\left(\frac{K}{X_2^*}\right)-\left(1+\frac{\delta}{r}\right)\left(1-\frac{c}{pqX_2^*}\right)=0 \qquad (22)$$

Optimal yield ($F[X_{1,2}^*]$) and optimal effort ($E_{1,2}^*$) can be determined by following equation:

$$E_{1,2}^* = \frac{F\left[X_{1,2}^*\right]}{qX_{1,2}^*} \qquad (23)$$

Data

1. Standardization

In order to apply the bioeconomic models on the shrimp trawl fishery, catch and effort of different shrimp trawler groups need to be standardized. Standardized catch and effort are computed based on the data derived from the ALRMV project (see appendix 5). The data includes monthly indicators for difference shrimp trawler groups, average CPUE to be measured in kg/towing hour; average effort to be measured in towing hours/boat; average percentage of shrimp in catch; average price of shrimp to be measured in 10^3 VND; average variable cost per towing hour to be measured in 10^3 VND. The questionnaire and equations to estimate these indicators are shown in appendix 3 and 4.

1.1. CPUE (for shrimps)

Standardized CPUE of different trawler groups is calculated based on average CPUE and average percentage of shrimp in catch[2]

$$CPUE_F = MeanCPUE * ps_F$$

Where:

$CPUE_F$	standardized CPUE of fleet F in a month, to be measured in kg shrimp/towing hour
$MeanCPUE$	average CPUE of fleet F in that month, to be measured in kg (mixed fish)/towing hour;
ps_F	average percentage of shrimp in the catch of fleet F in that month;

1.2. Fishing effort

Efforts of the different trawler groups are standardized based on their *relative fishing powers*. Which is defined, and can be measured as the ratio of the CPUE of the group to

[2] These indicators are derived from appendix 5

that of another group taken as a standard and fishing on the same density of fish on the same type of ground (Beverton & Holt, 1993). In this way each group can be allotted a *power factor* which is used to compute its standardized effort. The standardized effort of the fishery is estimated by following steps:

1.2.1. Effort per month of fleet F is estimated

$$E_F^{month} = e_F * n_F * pf_F$$

Where:

E_F^{month} total effort per month of fleet F, to be measured in towing hours

e_F average effort per month of one boat in fleet F, to be measured in towing hours;

n_F number of boats in fleet F for the period of study;

$pf_F = \frac{CPUE_F}{CPUE_S}$ power factor of fleet F to the standard fleet (S) in that month;

1.2.2. Effort per a half year of fleet F is estimated

$$E_F^{Halfyear} = \frac{\sum_{i=1}^{m} E_{iF}^{month}}{m} * 6$$

(m ≤ 6) where m- number of months that fleet F were observed in that half year

1.2.3. Total effort per a half year of the fishery is estimated

$$E = \sum_{F=1}^{k} E_F^{HalfYear}$$

Where k- number of fleet (or boat groups)

1.3. Catch

Catch are then standardized based on some steps. First, the landing shrimp of each group is estimated by multiplying the CPUE with average effort of one boat and the number of boats in the group. Afterward, total landing shrimp of the fishery is computed by summing the landing shrimp of different shrimp trawler groups. The standardized process of the catch is described by following equations:

1.3.1. Catch per month of fleet F is estimated

$$H_F^{month} = CPUE_F * e_F * n_F$$

Where:

H_F^{month} landing shrimp (catch) per month of fleet F, to be measured in kg

1.3.2. Catch per a half year of fleet F is estimated

$$H_F^{Halfyear} = \frac{\sum_i^m H_{iF}^{month}}{m} * 6$$

(m ≤ 6) where m- number of months that fleet F were observed in that half year

1.3.3. Total catch per a half year of the fishery is estimated

$$H = \sum_{F=1}^{k} H_F^{HalfYear}$$

Where k- number of fleet

1.4. Price of shrimp

The fixed price is calculated as the weighted average price (of catch) for the period of study (2000-2004)

$$p = \frac{\sum_{F=1}^{k} \sum_{j=2000}^{2004} \sum_{i=1}^{m} p_{Fji} H_{Fji}^{Month}}{\sum_{F=1}^{k} \sum_{j=2000}^{2004} \sum_{i=1}^{m} H_{Fji}^{Month}}$$

Where:

p_{Fji} average price of 1 kg shrimp in month i of year j that fleet F caught, to be measured in 10^3 VND

H_{Fji}^{Month} catch in month i, year j of fleet F

1.5. Cost per unit of effort

Cost per unit of effort per month of one boat in one group (c_F) is computed by summing of average variable cost (c_{vc}) and average fixed cost (c_{fc}) per month of the boat:

$$c_F = c_{vc} + c_{fc}$$

Cost per unit of standardized effort of the fishery is computed as the weighted average cost (of effort) for the period of study (2000-2004) by the following equation:

$$c = \frac{\sum_{F=1}^{k} \sum_{j=2000}^{2004} \sum_{i=1}^{m} c_{Fji} E_{Fji}^{Month}}{\sum_{F=1}^{k} \sum_{j=2000}^{2004} \sum_{i=1}^{m} E_{Fji}^{Month}}$$

Where:

c_{Fji} cost per unit of effort in month i, year j of fleet F, to be measured in 10^3 VND

E_{Fji}^{Month} effort in month i, year j of fleet F

2. Data tables

2.1. Sources and criteria of data

Demand data for the models are derived from the ALRMV project phase II. The project was supported by DANIDA and carried out in Vietnam from 2000 to 2004. The fleet was divided into groups based on the fishing gears and the horse power of the main engines. Data from interviews, which were monthly conducted at local harbors, were used to estimate indicators of the fleet including CPUE; the price, and percentage of shrimps in catch; average effort, and average variable cost per boat per month. Other relevant data such as the number boats were collected from both the ALRMV project and departments of the Ministry of Fishery (MOFI).

In this study, shrimp trawlers (with engine lower than 45 HP) are divided into three groups. Otter trawlers with the engine from 20-45 HP, the biggest group, are chosen as the standard group (group 1) for aggregating effort of the fishery. Otter trawlers and beam trawlers with the engine lower than 20 HP are assumed homogeneous and will be consider as one group (group 2). The third group is the beam trawlers with the engine from 20-45 HP (group 3). In the ALRMV project, total collected samples for the three groups (2000-2004) were 8285, in which group 1 was collected 5177 samples, group 2 was collected 1562 samples and group 3 was collected 1546 samples.

2.2. Data tables

Table 7 Standardized catch, effort, CPUE of the fishery by half years

Year	Half year	Catch (kg)	Effort (h)	CPUE (kg/h)
2000	1	7,522,878	4,158,473	1.81
2001	2	7,906,749	4,686,582	1.69
	3	7,476,235	3,581,219	2.09
2002	4	5,887,093	3,619,525	1.63
	5	7,218,815	4,226,861	1.71
2003	6	5,699,222	4,124,319	1.38
	7	3,877,434	5,627,033	0.69
2004	8	5,494,582	3,544,291	1.55
	9	4,065,578	4,708,158	0.86

Table 8 Average fixed costs for different trawler groups in 2001

Fixed cost (10^6 VND/boat)	Beam & otter trawlers <20HP		Beam trawlers 20-45 HP		Otter trawlers 20-45 HP	
	Year	Month	Year	Month	Year	Month
Boat repairs	5.70000	0.4750	4.378943	0.3649	9.7048390	0.8087
Interest	0.96270	0.0802	8.236421	0.6864	1.9862900	0.1655
Tax	-	-	1.196842	0.0997	0.1487097	0.0124
Depreciation	4.72099	0.3934	16.247650	1.3540	10.7215600	0.8935
Total	**11.38370**	**0.9486**	**30.059900**	**2.5050**	**22.5614000**	**1.8801**

Source: *Data from the ALRMV project and IFEP, 2005*

Table 9 Standardized cost and price of shrimps in the shrimp trawl fishery

Average price (10^3 VND/kg)	Cost per unit of effort (10^3 VND/towing hour)
23.755	34.057

Table 10 The shrimp stock biomass in 2003

Southwest monsoon season **(10^3 kg)-4/2003**	***Northeast monsoon season*** **(10^3 kg)-9/2003**
4165	6687

Source:(Thi et al., 2004)

3. Relevant data

3.1. Trend of CPUE

Trend of CPUE of three trawler groups and their standard deviations are showed in figure 11, 12, and 13. The main reason for the variation of CPUE may be uncertainty of fishing activities in practice. For beam trawlers 20-45, the CPUE seems to be increasing since late 2002. However, the standard deviations were high, indicating that the trend is not clear. For other trawler groups, the trend of CPUE also is not clear. It needs statistical tests to have reasonable conclusions.

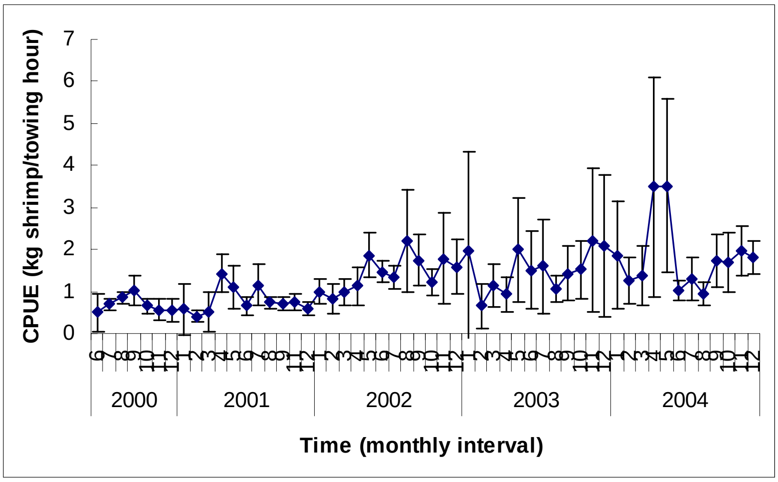

Figure 11 CPUE of beam trawlers 20-45
(*Data from the database of the ALRMV project, 2005)*

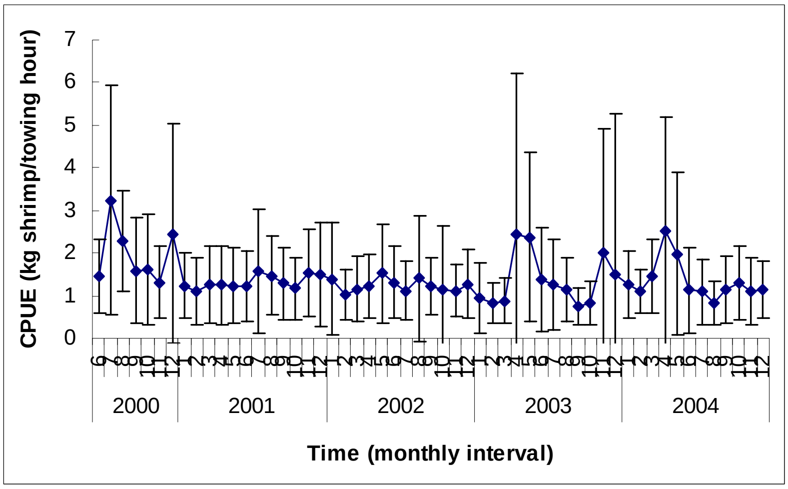

Figure 12 CPUE of otter trawlers 20-45
(*Data from the database of the ALRMV project, 2005)*

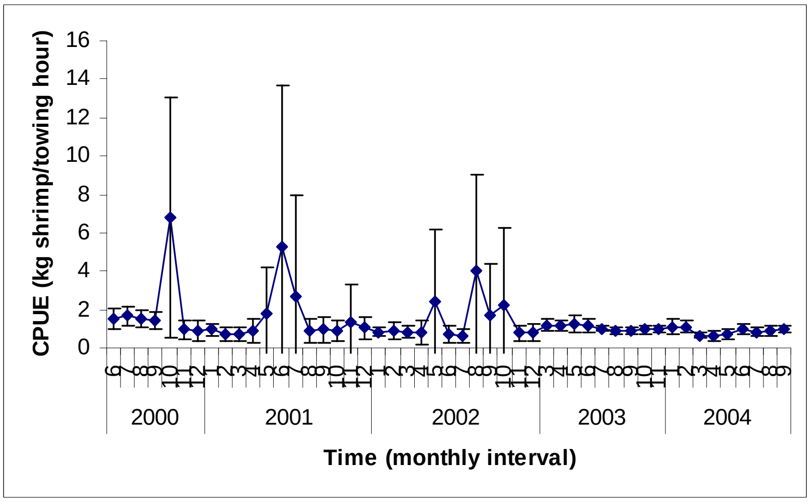

Figure 13 CPUE of OT<20 (2000-2002) and BT<20 (2003-2004)
(*Data from the database of the ALRMV project, 2005)*

3.2. Average mesh size

Figures 14, 15, 16, and 17 show the average mesh size (cod end mesh size) of different shrimp trawler groups in comparison with the minimum legal mesh size (Circular No 01/2000/TT-BTS date 28/4/2000). It is clear to see that most of shrimp trawler groups have violated the minimum mesh size relegation in the Tonkin Gulf. Otter trawlers 20-45 HP and beam trawlers 20-45 HP seriously violated the regulation since the mesh size of these groups were not only used lower than the minimum legal mesh size but also tended to be reduced overtime.

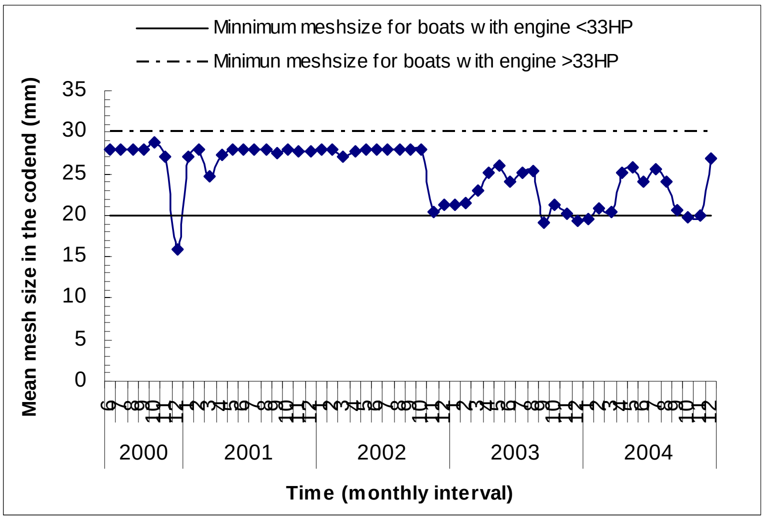

Figure 14 Mesh size in the codend of beam trawlers 20-45
(Data from the database of the ALRMV project, 2005)

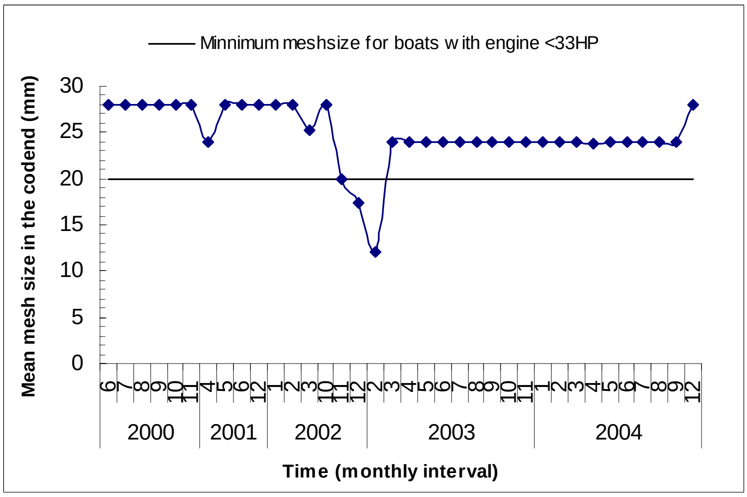

Figure 15 Mesh size in the codend of beam trawlers <20HP
(Data from the database of the ALRMV project, 2005)

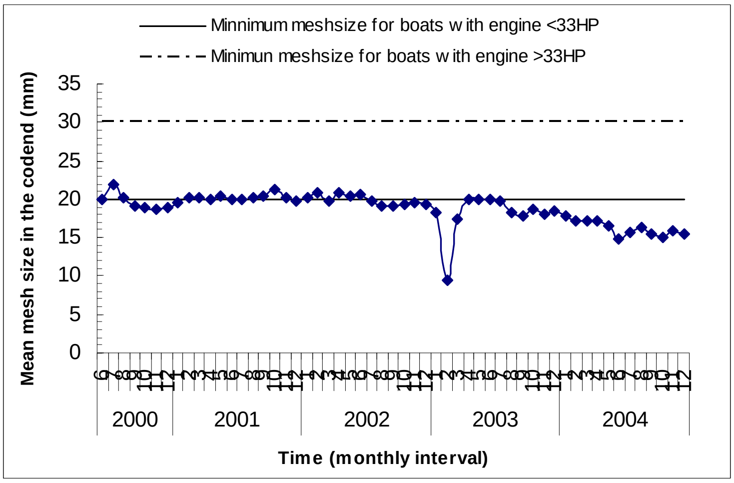

Figure 16 Mesh size in the codend of otter trawlers 20-45 HP
(Data from the database of the ALRMV project, 2005)

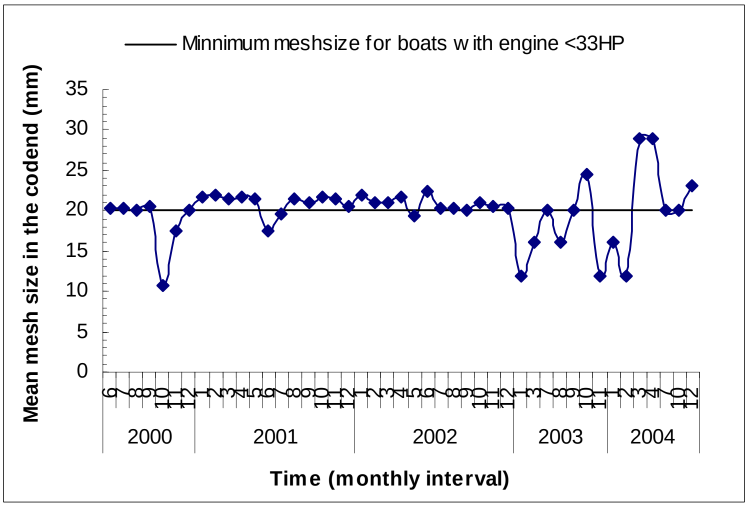

Figure 17 Mesh size in the codend of otter trawlers <20 HP
(Data from the database of the ALRMV project, 2005)

Results

1. Parameters

The results of estimating coefficientsγ, γ_1 from equations (18) and (19) are shown in Table11. For both Verhulst-Schaefer and Gompertz-Fox models, the results indicated an expected negative relationship between CPUE and effort, slope coefficient equal -5.056*10^{-7} and -4.302*10^{-7} for Verhulst-Schaefer and Gompertz-Fox models respectively. The P-values indicating that the slope coefficients are different from zero with a significance level of 95%. The R^2 values 0.581 and 0.635 indicate that about 60% percent of CPUE variations are explained by Verhulst-Schaefer and Gompertz-Fox models respectively, by the explanatory variable effort. The observed R^2 values shows that the two models give reasonable fit to the data, the Gompertz-Fox model was slightly better than the Verhulst-Schaefer model.

Table 11 Estimated coefficients using OLS method

	Verhulst-Schaefer model		**Gompertz-Fox model**	
	Estimated coefficient	t-value	Estimated coefficient	t-value
γ	3.640	5.212*	2.176	4.106*
γ_1	-5.056x10^{-7}	-3.114*	-4.302x10^{-7}	-3.491*
	df	8	df	8
	R^2	0.581	R^2	0.635
	F	9.696	F	12.187

***** Significant at the 5% level

Table 12, 13 shows predicted catchability (*q*), intrinsic growth rate (*r)* and the carrying capacity (*K*) from the models for the fishery. The catchability was computed from the estimated biomass, which were derived from independent surveys in 2003. Afterward, intrinsic growth rate and the carrying capacity were calculated based on estimated coefficients, which were derived from the two models (table 11). Verhulst-Schaefer model predicted intrinsic growth rate almost three times that of the Gompertz-Fox model. In case of the carrying capacity, it was vice versa for the two models.

Table 12 The catchability (q) in 2003

Southwest monsoon season **(10^{-7} hour^{-1})**	***Northeast monsoon season*** **(10^{-7} hour^{-1})**	***The average catchability*** **(10^{-7} hour^{-1})**
3.31779	1.03047	2.17413

Table 13 Estimated r, K parameters

Parameters	**Models**	
	Verhulst-Schaefer	**Gompertz-Fox**
r	1.564950	0.505324
K	16.740900	40.528400

r = intrinsic growth in a half year^{-1}

K = carrying capacity in 10^6 kg

2. Results from models

The graph of the equilibrium yields derived from the two models against effort are shown in figure 18. The two models showed considerable differences in predicted reference points (table 14). The Gompertz-Fox model (short broken line) showed that the MSY of the shrimp fishery was 15% higher than that of the Verhulst-Schaefer model (long broken line). If this comparison is extended to the effort level at MSY, it is shown that the Gompertz-Fox model was 35 % lower than the one of the Verhulst-Schaefer model. While estimated profits at MSY ($p*MSY-c*E_{MSY}$) showed the Gompertz-Fox model with a higher profit of 200% because of differences in predicted effort. The Gompertz-Fox model predicted the stock was heavily exploited, while the Verhulst-Schaefer model predicted the stock was fully exploited.

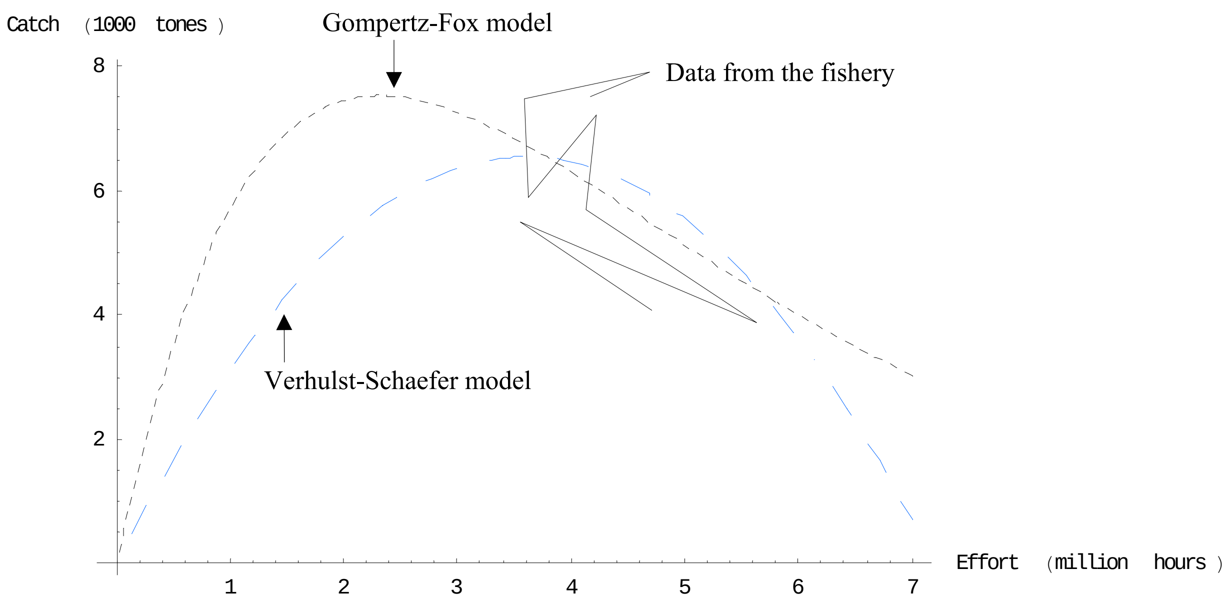

Figure 18 Catch versus effort

Figure 19 shows TC and TR derived from the two models against effort. The two models showed the MEY varies by 27% while corresponding effort varies by 28% (table 13, 14). Profit at MEY varies by 100% for the two models. The Verhulst-Schaefer model (broken line) showed the break even point was closer the MSY than that of Gompertz-Fox model (solid line).

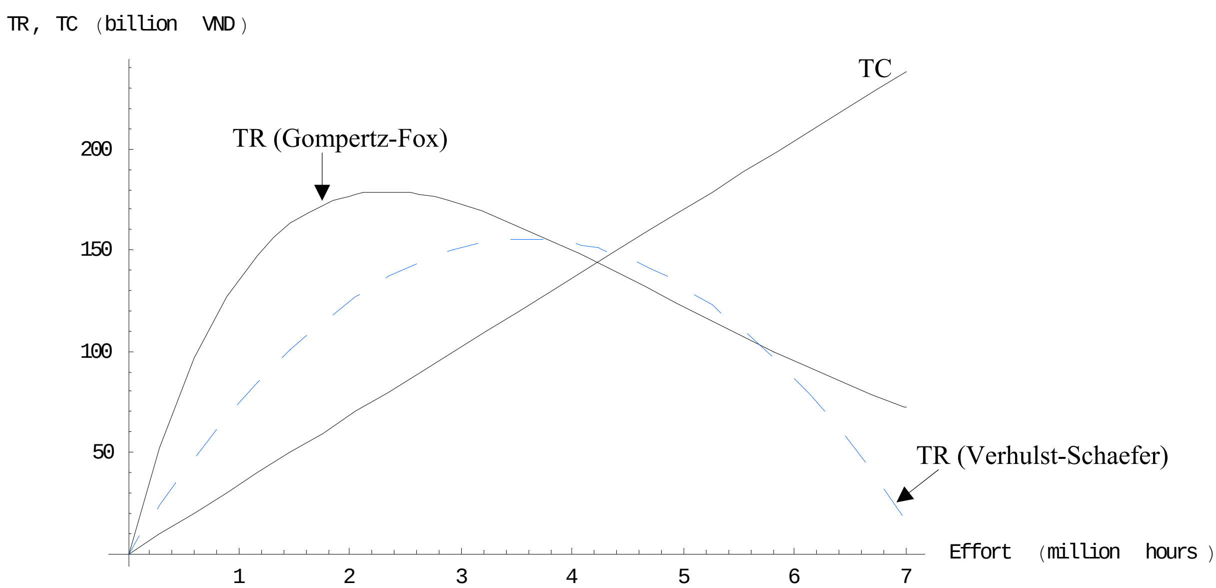

Figure 19 TR, TC versus effort

Table 14 Catch Reference Points

Models	*OA (10^6 kg)*	*MSY (10^6 kg)*	*MEY (10^6 kg)*
Verhulst-Schaefer	6.25477	6.54969	5.53345
Gompertz-Fox	6.05070	7.53417	7.05241

Table 15 Effort Reference Points

Models	*E_{OA} (10^6 hours)*	*E_{MSY} (10^6 hour)*	*E_{MEY} (10^6 hours)*
Verhulst-Schaefer	4.36275	3.59904	2.18137
Gompertz-Fox	4.22040	2.32426	1.57845

Assume that the fishery was in the open access situation, table 12 and 13 show the amount of landing tax, effort tax and entry tax that need to be imposed to achieve MSY and MEY. Graphs and equations for tax policies are shown in the appendix 1.

Table 16 Tax policies to achieve MSY

Models	*Landing tax (10^3VND/kg)*	*Effort tax (10^3VND/hour)*	*Entry tax (10^3VND/boat/month)*
Verhulst-Schaefer	5.04073	9.17333	1385.68
Gompertz-Fox	13.24850	42.94550	4189.40

Table 17 Tax policies to achieve MEY

Models	*Landing tax (10^3VND/kg)*	*Effort tax (10^3VND/hour)*	*Entry tax (10^3VND/boat/month)*
Verhulst-Schaefer	10.3292	26.2018	2398.89
Gompertz-Fox	16.1325	72.0788	4775.15

3. The results under discounting

Table 18 Optimal reference points

Models	*δ (%)*	*Y^* (10^6kg)*	*E^* (10^6hour)*	*X^* (10^6kg)*	*π^* (10^9VND)*	*$CPUE^*$ (kg/hour)*
Verhulst-Schaefer	0	5.53345	2.18137	11.66760	57.156187	2.536686
	5	5.60297	2.23073	11.55280	57.126581	2.511720
	10	5.66832	2.27880	11.44100	57.041850	2.487414
	20	5.78732	2.37115	11.22620	56.723531	2.440723
	∞	6.25477	4.36275	6.59427	0	1.433676
Gompertz-Fox	0	7.05241	1.57845	20.55050	113.772728	4.467934
	5	7.20065	1.69317	19.56080	113.387150	4.252763
	10	7.31203	1.80103	18.67380	112.359594	4.059916
	20	7.45235	1.99751	17.16010	109.001376	3.730820
	∞	6.05070	4.22040	6.59427	0	1.433679

Discounted optimal values for Y^*, E^*, X^*, $CPUE^*$ and estimated resource rent are shown in table 18. The discount rates are representative of biological considerations (5%), social accounting (10%), and private interest rates compounded by risk (20%)_(Clark, 1990; Clarke et al., 1992). Models results at 0% (no discounting rate) and ∞ confirm values estimated for static MEY and OA (table 13, 14). The two models showed the same trends optimal reference points over the range of the discount rate (δ between 0% and 20%) although absolute value values vary. On a percentage basis, estimated optimal effort values vary the most over alternative discounted rates within a model (6.37-10.91%), while estimated resource rents vary the least (0.05-0.56%). Optimal yield vary at the same low level for the two models (1.17-2.10%). Optimal biomass and CPUE vary by 0.98-1.88 % and 4.82-8.11% for the Verhulst-Schaefer and the Gompertz-Fox model respectively.

Table 19 Tax policies to achieve optimal reference points

Models	*δ (%)*	*Landing tax (10^3VND/kg)*	*Effort tax (10^3VND/hour)*	*Entry tax (10^3VND/boat/month)*
Verhulst-Schaefer	0	10.32920	26.2018	2398.89
	5	10.19580	25.6089	2397.66
	10	10.06330	25.0315	2394.10
	20	9.80135	23.9224	2380.74
	∞	0	0	0
Gompertz-Fox	0	16.13250	72.0788	4775.15
	5	15.74680	66.9674	4758.97
	10	15.36640	62.3863	4715.84
	20	14.62640	54.5686	4574.89
	∞	0	0	0

On a percentage basis, estimated effort tax values vary the most over alternative discounted rates within a model (7.09-12.53 %), while estimated entry tax vary the least (0.05-0.56%). Estimated tax on landing varies by 1.29-2.60 % for the Verhulst-Schaefer model and by 2.39-4.82 % for the Gompertz-Fox model.

4. Relevant results

4.1 The trend of CPUE for different trawler groups

The regression results (table 20) indicated a negative relationship between CPUE and time for BT&OT 20 and OT 20-45 groups and the positive relationship for BT 20-45, slope coefficients equal -4.391, -3.253, and 13.569 for BT&OT, OT20-45 and BT20-45 correspondingly. P-values are indicating that the slope coefficients are different from zero with a significance level of 95%. Those mean that CPUE of BT20-45 is expected to be increased over time and *vice versa* for OT&BT 20 and OT 20-45. However, the observed R^2 values are low (0.355, 0.120, and 0.172); indicating that the models we have chosen do not fit well to the data.

Table 20 Test for the trend of CPUE of shrimps in the fishery

	BT 20-45		BT&OT<20		OT 20-45	
	Estimated coefficient	t-value	Estimated coefficient	t-value	Estimated coefficient	t-value
Intercept	8.767	2.356*	30.555	9.371*	45.284	7.611*
Slope	13.569	5.197*	-4.391	-2.472*	-11.880	-3.253*
	df	50	df	46	df	52
	R^2	0.355	R^2	0.120	R^2	0.172
	F	27.009*	F	6.112*	F	10.579*

***** Significant at the 5% level

4.2 The trend of mesh size in cod end of different trawler groups

The regression results in table 21 indicated a negative relationship between mesh size and time (mesh size is expected to be reduced against time) for all trawler groups except OT<20. For OT<20, however, the P-value of 0.855 is quite high, indicating that the slope coefficient is not statistically significantly different from zero. In addition, the R^2 value of 0.0007 means that only ≈ 0.07 percent of variation in mesh size of OT<20 is explained by the model (mesh size increase over time), by the explanatory variable time. The observed R^2 is quite low; indicating the model which was chosen gives poor fit to the data.

Table 21 Test for the trend of mesh size in the fishery

	BT <20		**BT 20-45**		**OT <20**		**OT 20-45**	
	Estimated coefficient	t-value	Estimated coefficient	t-value	Estimated coefficient	t-value	Estimated coefficient	t-value
Intercept	46.548	3.665*	95.006	7.080*	20.957	1.852*	119.394	8.029*
Slope	-1.129	-2.228*	-2.675	-5.039*	0.102	0.183**	-4.880	-6.184*
	df	35	df	54	df	44	df	54
	R^2	0.127	R^2	0.324	R^2	0.0007	R^2	0.419
	F	4.963*	F	25.389*	F	0.034**	F	38.250*

***** Significant at the 5% level
****** P value equal 0.855

Discussion

1. Models

The two models, Verhulst-Schaefer and Gompertz-Fox, appeared to estimate valid biological parameters and reasonable economic results for the shrimp trawl fishery in the Tonkin Gulf. The two models also had statistically significant coefficients, which might make their results to be acceptable. Theoretically, the Gompertz-Fox model may predict a growth compensation as the stock is reduced than the corresponding compensation described by the Verhulst-Schaefer model. Both models could be considered as special cases of the Pella and Tomlinson model (when $m \rightarrow 1$ and $m = 2$). Furthermore, data ranges of catch and effort were small (see figure 18) which may give poor background for choosing a priority model.

In this study, the relevant results indicated that the fishery was in a situation of overexploitation. Mesh size in the cod end of almost all trawler groups were significantly decreased (except the OT<20 group), indicating a compensation of reduced landing of shrimps overtime. The CPUE of OT 20-45, OT&BT<20 trawler groups had also decreased, even though the CPUE of the BT 20-45 trawler group was increased. The landing shrimp price and the mesh size in cod end of this trawler group had been reduced, implying that less valuable species and juvenile shrimp had been caught. Long (2001; 2003) argues that shrimp trawler fleet are shortened both in size and number due to overfishing problems. Chinh (2005) shows that the density of penaeid stocks have been reduced by a half over the last thirty years (1975-2002).

The fish stock being overexploited means that the shrimp biomass was below the biomass level of MSY. The Verhulst-Schaefer model proposed the current multi species shrimp biomass to be closer to the MSY level than the Gompertz-Fox model did. The Verhulst-Schaefer model also predicted the intrinsic growth rate of the shrimp stock (per a half year) three times higher than the Gompertz-Fox model predicted. In addition, the regression results (table 11) showed slightly better fit for the Gompertz-Fox model than the Verhulst-Schaefer model. However, the data which used for the two models was the short time series data. It implies that the results may not globally describe the development of the fishery. The reference points derived from the models may be just local reference points. In this study, a range of reference points, which derived from the two models are chosen in order to take consideration of uncertainty in practice.

2. Reference points

The results from the two models showed the open access yield of the fishery was around 6,000 tones for a half year (12,000 tones per year). This yield is in accordance with the official catch statistic, which was around 11,445 tones in 2003 (Chinh, 2005). The open access yield figure may also be appropriate to the figure of the shrimp biomass, which was estimated about 4,165 tones in the southwest monsoon season and approximately 6,687 tones in the northeast monsoon season (Thi et al., 2004). Since the penaeid shrimps, which are short life span species, have high turn-over growth rate annually. It is quite common for the shrimp population to have an annual growth which in biomass terms exceeds the population size at some points during the year. Fox (1970) argues that commercial exploitation of marine fish population is usually directed towards mature individuals and, if spawning occurs during the year, survival of the population may be ensured – even at 100% annual fishing mortality. Other arguments could be derived from multispecies considerations. The species composition probably has changed over time, typically towards less valuable species. This could change the MSY value dynamically over time. The possibility depletion of one species may be reduced by the increase of other species (Guland & Rothschild, 1984).

The two models showed that the fishery was at least fully exploited both in terms of maximizing yield and maximizing resource rent. The E_{MSY} and E_{MEY} of the fishery from the Verhulst-Schaefer model were about 3.6 and 2.2 millions towing hours respectively. The E_{MSY} and E_{MEY} of the fishery from the Gompertz-Fox model were around 2.3 and 1.6 millions towing hours correspondingly (table15). The effort of the fishery in 2004 (average effort for a half year) was estimated around 4.1 millions towing hours (table 7), indicating that the harvest of the shrimp stock was not sustainable regarding to the referent points. The effort of the fishery should be strongly reduced to achieve optimal reference points. The current effort of the fishery (2004) should be reduced roughly 12 % (Verhulst-

Schaefer model) to 44 % (Gompert-Fox model) to archive the MSY and about 46 % to 61% to reach the MEY.

The data (figure 14-17) showed that for the otter trawler groups, the mesh size seem to violate the minimum mesh size regulation more than what was the case in the beam trawler groups. It means otter trawlers probably harvested smaller shrimps than beam trawlers did. Furthermore, iron tickler chains of otter trawlers which were used to round up the shrimp in the sand, may destroy critical habitats in coastal areas. For those reasons, it seems like effort of otter trawlers, the dominant group in the shrimp trawl fishery, should first be reduced in order to reach the reference points (MSY or MEY). The OT 20-45 was the biggest group and the one violating the minimum mesh size regulation the most. The CPUE and mesh size of the OT 20-45 also had been reduced over time, implying that the effort of this group should strictly be controlled.

3. Management

3.1 The present regulations

Many regulations have been applied in the shrimp trawl fishery but the compliance of these regulations is questionable. This aspect will be discussed through analyzing the efficiency of some major regulations which have been applied for the shrimp trawl fishery both in practical and theoretical aspects.

3.1.1 The minimum legal length regulation

The data showed that, the minimum legal length regulation seems to be violated in the shrimp trawl fishery. Landing shrimps were quite small compared with the minimum legal shrimp size. The difficulties in monitoring are substantial since the fishery is multi species which may be managed appropriately by input regulations.

Minimum size regulation opens for discarding captured undersized individuals. Some fisheries where catch is not harmed by catching method may exist, such as mollusks gathered by hand or crustaceans caught by traps. In other fisheries, e.g. trawling, the probabilities of fish surviving after discarding, are very small (King, 1995). The idea is to change gears or fishing areas in such cases. Those imply that the minimum legal length regulation has little application to the shrimp trawl fishery both in terms of theoretical and practical aspects. Alternative regulations such as marine protected areas or closed seasons may be applied appropriately for the shrimp fishery.

3.1.2 The minimum mesh size regulation

Minimum mesh size is applied to allow small individuals to escape and grow to a more valuable market size (to prevent growth overfishing). A further aim may be to allow individuals to reach size at which they can reproduce at least once before capture. In respect of trawl nets, the selection in shrimp species with long lateral appendages occurs over a wide size range of individuals. This suggests that minimum mesh size regulations applied to trawl used on species such as shrimps are less efficient in conserving small individuals than those applied to trawls used on other species (spindle-shaped fish)_(King, 1995). Garcia (1988) also argues that the mesh size selection is not very efficient since it covers a large part of the life span of shrimps and the filtration effect can be altered easily by the fishers.

In the Tonkin Gulf, the data showed that shrimp trawlers had been heavily violating the minimum mesh size relegation. Almost all trawler groups used smaller mesh size than the legal minimum (figure14, 15, 16 and 17). In addition, average mesh size in the cod end of most shrimp trawler groups had been significantly reduced over time (table 15). Those imply that the minimum mesh size at present seems to be an inefficient regulation in the shrimp trawl fishery.

3.1.3 Tax regulation

According to Degree No 68/1998/ND-CP data 03/09/1998 of the Government (regulating and guiding the implementation of the natural resources tax ordinance), a tax on landing was imposed. The taxation was 2% the catch value and it was collected based on the landing of trawlers. However, the landing or output control had not been applied for the shrimp trawl fishery. In practice, an entry tax was collected around 0.66 % the fixed cost for the OT 20-45 and about 3.98 % of the fixed cost for the BT 20-45 annually (table 8). The data did not show tax value for the BT&OT< 20.

Even though tax regulation is an indirect management mean, it seems to be more efficient than direct management means such as the minimum size and mesh size regulations.

3.2 Alternative regulations

Fisheries regulations are imposed on the fishery to support a strategy designed to achieve predefined objectives. It is unlikely that any single management measure will produce the desired results, and a combination of several regulations may be needed (King, 1995). There are two types of regulations, one is used to control fishing effort (input regulations), and another used to control catch (output regulations). Input and output regulations are further divided into direct and indirect controls (table22).

Table 22 Types of fisheries regulations

	Input	**Output**
Indirect controls	Effort, entry tax	Landing tax
Direct controls	License, minimum mesh size, closing seasons	Quota, TAC, minimum legal length

For the shrimp trawl fishery, the entry tax was still applied effectively in the fishery. However, the tax value should be increased a lot in order to accomplish the reference points of the fishery. The entry tax should be imposed between 1.4 millions and 4.2 millions VND/boat/month to achieve the MSY. Under social discounted rate ($\delta = 10\%$), the entry tax should be imposed around 2.4 millions to 4.7 millions VND/month/boats to attain the MEY (table 23). The current tax was around 0.1 millions VND/boat/month (table 8). It is required to increase the current tax 14 to 47 times to achieve selected reference points. This tax figure seems to be too high for the poor fishing communities. It may only be complied by the most efficiency boats. The government should directly invest the tax to the poor fishing communities and fishers who can not join in the fishery due to the strict tax policy.

Table 23 Proposal entry tax/boat/month (10^3VND)

Reference point	**Verhulst-Schaefer model**	**Gompertz-Fox model**
MSY	1385.680	4189.400
MEY (at 10% discounted rate)	2394.100	4715.840

For the direct controls, it is shown that the license and minimum mesh size regulations were inefficient for managing the shrimp trawl fishery. Closed season regulation may be a solution. Table 24 shows percentage of the present fishing season should be reduced to achieve selected reference points for a half year. In order to achieve the MSY or MEY, the current fishing season should be reduced 12% to 44% or 45% to 56% for a half year respectively. Accurate times for closing fishing seasons depend on shrimp spawning seasons, specific areas and fishing communities.

Table 24 The proposal closed season for a half year to achieve selected reference points

Reference point	Verhulst-Schaefer model	Gompertz-Fox model
MSY	12 %	44 %
MEY(at 10% discounted rate)	45 %	56 %

In summary, entry tax and closed season regulation may be appropriate management means for the shrimp trawl fishery. These regulations should be applied for the fishery until the yield reaches the MSY or MEY by using the effort equally E_{MSY} or E_{MEY}. Theoretically, it is difficult to impose tax regulations in the situation of the open access fishery since fishers have not any supernormal profits; they obtain only a normal profit. In this situation, it requires strong controls such as the closed seasons.

4 Future works

The results were derived from the simple models which may not fully grasp the dynamics of a complicated system. Ecological interactions of shrimps and other species should be paid attention. Better methods of measuring effort should also be investigated in order to have more precise estimates of the model parameters. How to reduce effort and cost/benefit of reducing effort to achieve the reference points should also be studied further in order to improve proposal regulations.

Conclusions

In this study two surplus production models (Verhulst-Schaefer and Gompertz-Fox) have been presented and parameterized when applying catch and effort data from a Vietnamese shrimp fishery. The data is aggregated in time periods of half year in accordance with the biological year of the shrimp stock in the Tonkin Gulf. Results derived from the models are reasonable compared with the independent surveys and official statistics. The models should be applied in a flexible way regarding the biological characteristics of the stock. On the other hand, for the fast growing species with a high turn-over rate (short life span) in tropical areas such as for these shrimps, using data from the enumerator program could be an alternative method and may reduce the problems of inefficient statistic data.

The two models, Verhulst-Schaefer and Gompertz-Fox, appeared to estimate valid biological parameters and reasonable economic results for the shrimp trawl fishery in the Tonkin Gulf. The two models also have statistically significant coefficients, which may make their results be acceptable. In addition, data ranges of catch and effort were small which may give poor background for choosing a priority model. Besides, the data which was used for the models is the short time series data. It implies that the results may not globally describe the development of the fishery. The reference points derived from the models may be just local reference points. A range of reference points, which derived from the two models, are chosen in order to take consideration of uncertainty in practice.

The two models showed that the fishery was at least fully exploited both in terms of maximizing yield and maximizing resource rent. The harvest of the shrimp stock was not sustainable regarding to the referent points. The current effort of the fishery (2004) should be reduced roughly 12 % to 44 % to archive the MSY and about 46 % to 61% to reach the static MEY (at 0% discounted rate).

Minimum mesh size, legal length regulations may not appropriate for the shrimp trawl fishery both from a theoretical and a practical point of view. Entry tax and closed season may be preferable management means for the shrimp trawl fishery. The entry tax should be imposed between 1.4 millions and 4.2 millions VND/month/boat to achieve the MSY.

Under social discounted rate (δ = 10%), the entry tax should be imposed around 2.4 millions to 4.7 millions VND/month/boats to attain the MEY. The closed season regulation should be imposed based on shrimp spawning seasons, specific areas and fishing communities. The present fishing season should be reduced 12% to 44% (for a half year) to achieve MSY and 45% to 56% (for a half year) to attain MEY under social discounted rate (δ = 10%). Both entry tax and the closed season regulation should be applied for the fishery until the yield reaches the MSY or MEY by using the effort equally E_{MSY} or E_{MEY}. Theoretically, it is difficult to impose tax regulations in the situation of the open access fishery since fishers have not any supernormal profits; they obtain only a normal profit. In this situation, it requires strong controls such as the closed seasons.

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Appendix 1: **Tax policies to achieve reference points**

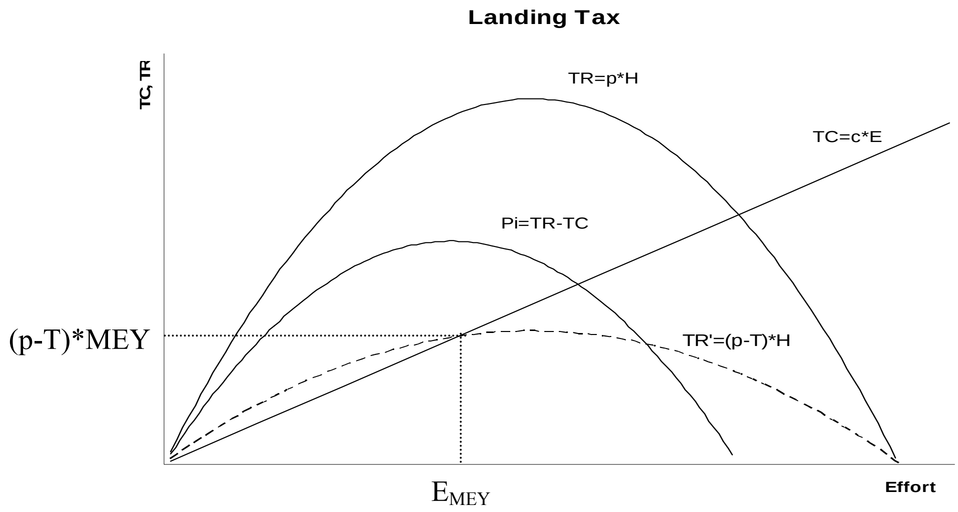
1. *Landing tax:*

Assume that the fishery is in the open access situation. T is the landing tax that needs to be created in order to achieve MEY (or MSY); T is defined by an equation:

$$(p - T)*MEY = c*E_{MEY}$$

Hence:

$$T = p - c*E_{MEY}/MEY$$



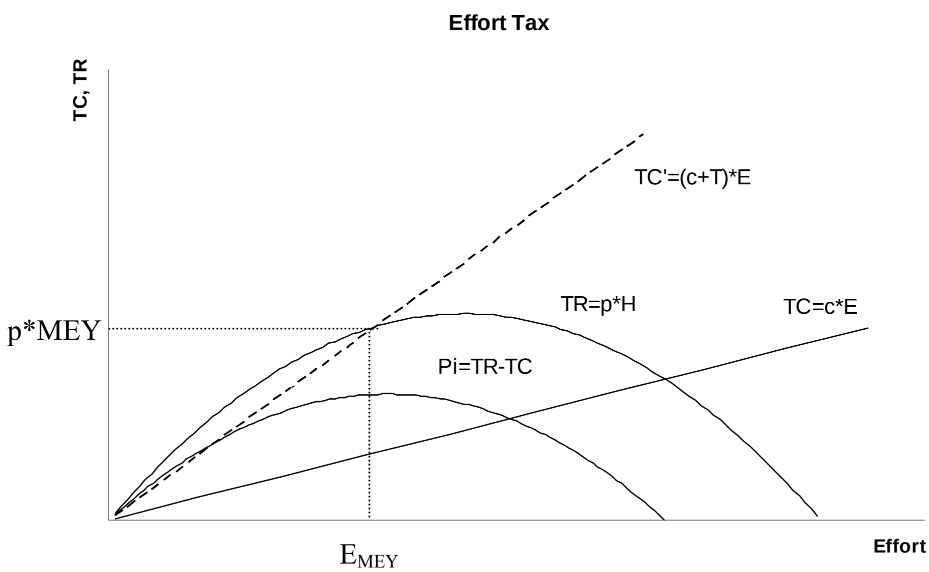
2. *Effort tax:*

Assume that the fishery is in the open access situation. T is the effort tax that needs to be created in order to achieve MEY (or MSY); T is defined by an equation:

$$p*MEY = (c + T)*E_{MEY}$$

Hence:

$$T = [(p*MEY)/E_{MEY}] - c$$

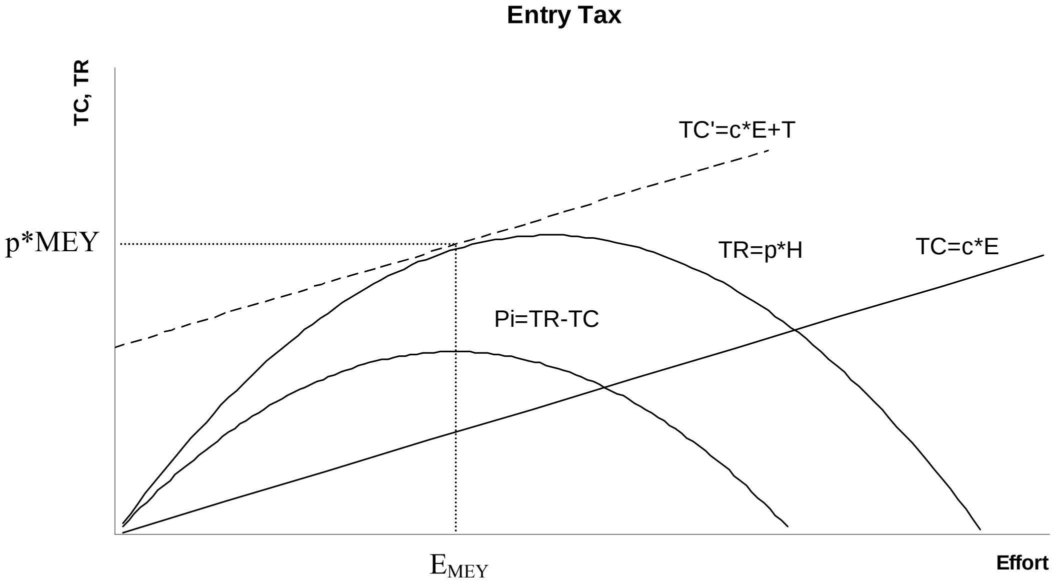


3. Entry tax:

Assume that the fishery is in the open access situation. T is the entry tax (for the whole fishery) that needs to be created in order to achieve MEY (or MSY); T is defined by an equation:

$$p*MEY = c*E_{MEY} + T$$

Hence: $$T = p*MEY - c*E_{MEY}$$



Appendix 2: Regression results

1. Relation between CPUE (Log CPUE) and Effort:

1.1 Schaefer model:

ParameterTable →

	Estimate	SE	TStat	PValue
1	3.63968	0.698334	5.21195	0.00123667,
eff	-5.05646×10^{-7}	1.62383×10^{-7}	-3.11391	0.0169879

RSquared → 0.580749, AdjustedRSquared → 0.520856,
EstimatedVariance → 0.0966172, ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	0.936843	0.936843	9.69644	0.0169879
Error	7	0.67632	0.0966172		
Total	8	1.61316			

1.2 Fox model:

ParameterTable →

	Estimate	SE	TStat	PValue
1	2.17604	0.530008	4.10568	0.00454049,
eff	-4.30244×10^{-7}	1.23242×10^{-7}	-3.49104	0.0101145

RSquared → 0.635176, AdjustedRSquared → 0.583059,
EstimatedVariance → 0.0556537, ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	0.678271	0.678271	12.1874	0.0101145
Error	7	0.389576	0.0556537		
Total	8	1.06785			

2. Test the trend of CPUE against time:

Beam trawlers 20-45HP

ParameterTable →

	Estimate	SE	TStat	PValue
1	8.7673	3.72098	2.35618	0.0225081 ,
cpue	13.569	2.61094	5.197	3.92318×10^{-6}

RSquared → 0.355337, AdjustedRSquared → 0.342181,
EstimatedVariance → 145.378, ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	3926.48	3926.48	27.0088	3.92318×10^{-6}
Error	49	7123.52	145.378		
Total	50	11050.			

Beam and otter trawlers <20HP

ParameterTable →

	Estimate	SE	TStat	PValue
1	30.5552	3.26052	9.37128	3.81872×10^{-12},
cpue	-4.39139	1.77633	-2.47217	0.0172764

RSquared → 0.119574, AdjustedRSquared → 0.100009,
EstimatedVariance → 169.198, ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	1034.07	1034.07	6.11161	0.0172764
Error	45	7613.93	169.198		
Total	46	8648.			

Otter trawlers 20-45HP

ParameterTable →

	Estimate	SE	TStat	PValue
1	45.2839	5.94983	7.61095	5.92013×10^{-10},
cpue	-11.8797	3.65244	-3.25253	0.00203144

RSquared → 0.171795, AdjustedRSquared → 0.155556,
EstimatedVariance → 201.4, ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	2130.6	2130.6	10.5789	0.00203144
Error	51	10271.4	201.4		
Total	52	12402.			

3. Test for trend of mesh size against time:

Beam trawlers 20-45HP

ParameterTable →

	Estimate	SE	TStat	PValue
1	95.0062	13.4185	7.08021	3.35026×10^{-9},
ms	-2.67545	0.530977	-5.03873	5.79349×10^{-6}

RSquared → 0.323883, AdjustedRSquared → 0.311126,
EstimatedVariance → 176.811, ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	4489.02	4489.02	25.3888	5.79349×10^{-6}
Error	53	9370.98	176.811		
Total	54	13860.			

Beam trawlers <20HP

ParameterTable →

	Estimate	SE	TStat	PValue
1	46.5476	12.6996	3.66527	0.000835446,
ms	-1.12878	0.506692	-2.22775	0.0326203

RSquared → 0.127374, AdjustedRSquared → 0.101709,

EstimatedVariance → 99.7103, ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	494.848	494.848	4.96286	0.0326203
Error	34	3390.15	99.7103		
Total	35	3885.			

Otter trawlers 20-45HP

ParameterTable →

	Estimate	SE	TStat	PValue
1	119.394	14.8708	8.02876	1.00672×10^{-10},
ms	-4.87971	0.789008	-6.18461	9.19224×10^{-8}

RSquared → 0.419174, AdjustedRSquared → 0.408215,

EstimatedVariance → 151.891, ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	5809.76	5809.76	38.2494	9.19224×10^{-8}
Error	53	8050.24	151.891		
Total	54	13860.			

Otter trawlers <20HP

		Estimate	SE	TStat	PValue
ParameterTable →	1	20.9574	11.3135	1.85242	0.0708378,
	ms	0.10209	0.556732	0.183374	0.855366

RSquared → 0.000781392, AdjustedRSquared → -0.0224563,

EstimatedVariance → 176.374, ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	5.93076	5.93076	0.0336261	0.855366
Error	43	7584.07	176.374		
Total	44	7590.			

Appendix 3: The questionnaire which was used in the ALRMV project

Questionnaire **Page 1**

General information	Vessel information
Sampling Province :	Skipper name :
Enumerator :	
Sampling data :	Vessel registration code :
Sample No :	Horse power (HP) :
Landing data :	Length of vessel (m) :
Landing place :	Fishing days in the last month :

Trip information	Cost of trip (1000 VND)
Number of crew :	Fuel :
Fishing ground : ☐ Not know☐ Out of	Bait :
Fishing depth (m) :	Storage cost :
Target sepcies :	Others (Fees, Small repair cost, Food for crew (specify)) :
Length of trip (days) :	....
Non-active days during this trip :	....
Number of haul :	....
Duration of the haul (hour) :	....
Fishing time : (day/night/day & night)	....

Gear

Name of gear		Technical parameters				
		Total length (m)	Mesh size (2a) (mm)	Number of gear	No. of hooks/line	Height of gear (m)
Gill net	Drift net					
	Stationary net					
	Trammel net					
Trawl	Pair trawl	$L_{\text{Load rope}}$	in cod end :			
	Otter trawl	$L_{\text{Load rope}}$	in cod end :			
	Beam trawl	$L_{\text{Load rope}}$	in cod end :			
Purse seine	Purse seine		in cod end :			
	Anchovies p.s.		in cod end :			
	A.D./use light		in cod end :			
Lines	Long line					$L_{\text{Hanging line}}$
	Fish hand line			Number of lines :		
	Squid hand line			Number of lines :		
Stick held falling net		Circut of the opening :				
Lift net		Area (m^2)				
Portable Lift net		The wing spread :				
Dredging for clam		Length of steel frame:				Height of steel frame:
Stownet		Length of steel frame:	in cod end :	Number of net:		

Questionnaire **Page 2**

Catch infomation			
Commercial groups	**Weight (Kg)**	**Price per Kg (1000 VND)**	**Value in total (1000 VND)**

Appendix 4: Estimating indicators in the ALRMV project (Thuy, 2005)

1. Mean CPUE (kg/hour)

CPUE of trip t:

$$\text{CPUE}_t = \frac{C_t(kg)}{E_t(hour)}$$

where CPUE_t: CPUE of trip *t*

C_t: Catch of Trip t

E_t: Fishing effort of trip t

Mean CPUE of fleet F in month *i* of year *j*:

$$\text{Mean CPUE}_{ij} = \frac{\sum_{t=1}^{n} CPUE_t}{n} \qquad (n \geq 5)$$

Where

n number of observations (total number of trips interviewed of fleet F in month *i* of year *j*)

2. Active days per month

This indicator describers the mean active days per month of fleet, by measuring the total number of days away from harbor for fishing purpose in a month. Mean active day per month of fleet F in month *i* of year *j*:

$$\text{ActiveDay}_{ij} = \frac{\sum_{t=1}^{n} AD_t}{n} \qquad (n \geq 5)$$

Where

AD_t Active days of the last month derived from interview of trip t

n number of observations (total number of interviews with Active days of the last month information of fleet F in month *i* of year *j*)

3. Effort per month (hours)

$$StE_{month} = \frac{MeanActivedaypermonth}{MeanTripduration(day)} * StE_{trip}$$

Where:

$$StE_{trip}(h) = Number\ haul * HaulDuration$$

4. Cost per hour (variable cost):

Cost per hour of trip t:

$$\text{CostperHour}_t = \frac{Cost_{Tript}}{StE_t(h)}$$

Where cost trip t:

$\text{Cost}_t = \text{Cost}_{Ice} + \text{Cost}_{Fuel} + \text{Cost}_{Food} + \text{Cost}_{Salary} + ...$

Cost per hour from fleet F in month *i* of year *j*:

$$\text{MeanCostPerHour}_{ij} = \frac{\sum_{t=1}^{n} CostperHour_t}{n} \qquad (n \geq 5)$$

Where

n number of observations (total number of trips interviewed with cost information of fleet in month *i* of year *j*)

5. Catch composition

This indicator describer the catch composition by percentages of fish groups in the monthly catches of fleets

Percentage of group A in the catches of fleet F in month *i* of year *j*:

$$\text{PercentageOf GroupA}_{ij} = \frac{\sum_{t=1}^{m} C_{At}}{\sum_{t=1}^{n} C_t}$$

Where

C_{At} Catch of fish group A in trip *t*

C_t Catch of trip *t*

m total number of trips interviewed of fleet F in month *i* of year *j*, which have group A in their catches

n total number of trips interviewed of fleet F in month *i* of year *j*

Appendix 5: Data table from the ALRMV project

Otter trawl (2000-2002) and Beam trawl (2003-2004) <20HP

Year	Month	Mean CPUE (kg/h)	Mean Effort (h)	Average percentage of shrimp in Catch (%)	price of shrimp (1000 VND/kg)	Cost Per Trip (1000VND)	Trip duration (h)	Cost Per Hour (1000VND)	Number of samples
2000	6	4.12	198.52	37.29	17.52	139.95	8.70	16.09	20
	7	5.53	163.56	30.23	18.73	158.17	9.22	17.16	23
	8	4.34	178.52	34.87	17.06	155.85	8.77	17.77	13
	9	8.37	114.57	20.47	18.54	191.40	8.07	23.71	14
	10	8.43	127.60	74.71	9.50	157.66	7.24	21.77	35
	11	7.93	109.56	14.23	15.80	190.98	7.90	24.19	43
	12	11.15	157.56	9.91	11.79	152.95	7.47	20.47	19
2001	1	6.76	167.94	21.13	19.62	139.36	8.49	16.41	50
	2	5.01	169.54	19.40	17.70	128.56	8.39	15.32	46
	3	4.74	172.38	19.36	16.65	133.82	8.78	15.25	49
	4	5.51	178.88	18.56	17.10	147.00	8.74	16.81	45
	5	5.91	179.61	31.52	14.84	143.28	8.83	16.22	48
	6	6.28	178.99	78.64	15.43	136.13	8.91	15.28	43
	7	6.16	165.39	44.15	18.02	143.68	8.32	17.27	42
	8	6.30	167.86	17.95	18.84	138.88	8.33	16.67	42
	9	6.93	168.94	17.28	19.60	163.73	8.71	18.80	45
	10	6.81	178.60	16.95	17.25	163.77	8.73	18.77	44
	11	7.53	170.89	20.62	18.87	156.33	8.88	17.60	50
	12	6.23	179.02	19.86	18.11	153.07	8.41	18.19	41
2002	1	2.20	197.92	38.88	18.14	132.69	9.95	13.33	41
	2	6.49	154.17	17.59	21.18	144.26	8.46	17.06	47
	3	5.62	172.67	18.68	23.48	143.65	8.59	16.72	48
	4	6.58	165.19	16.11	26.04	148.16	8.73	16.98	44
	5	9.82	164.29	25.98	21.01	182.86	8.32	21.97	28
	6	9.04	162.24	11.11	25.06	174.57	8.81	19.80	35
	7	8.91	162.32	10.48	24.00	156.38	8.94	17.50	32
	8	9.43	168.76	43.07	17.71	156.03	9.18	17.00	31
	9	8.80	179.49	22.53	22.13	184.64	9.53	19.38	36
	10	8.56	161.93	28.45	23.37	158.06	8.58	18.42	31
	11	9.38	168.36	12.90	23.61	155.06	9.44	16.43	31
	12	10.65	158.58	11.68	24.73	162.78	9.33	17.45	32
2003	3	2.32	213.93	51.48	27.85	164.45	10.75	15.30	20
	4	2.21	210.94	51.79	26.70	141.00	10.60	13.30	20
	5	2.40	204.91	51.67	27.86	144.25	10.70	13.48	20
	6	2.24	216.44	53.97	26.29	149.25	10.90	13.69	20
	7	1.90	234.25	53.28	29.25	146.67	12.00	12.22	21
	8	1.88	234.60	48.70	25.56	138.05	12.00	11.50	20
	9	1.75	237.00	51.37	27.71	137.00	12.00	11.42	20
	10	1.88	230.86	50.39	27.38	138.00	12.00	11.50	20
2004	1	2.30	224.73	47.38	32.07	135.75	11.35	11.96	20
	2	2.10	215.46	53.10	33.93	133.65	11.4	11.72	20
	3	1.93	264.6	33.93	26.09	159.50	12.6	12.66	20
	4	1.57	281.75	41.00	27.86	168.75	14.375	11.74	20
	5	1.91	243.6	38.46	25.57	161.50	12.6	12.82	20
	6	2.09	222.14	48.12	24.55	151.00	11.6	13.02	15
	7	2.02	215.76	40.71	25.04	149.15	11.6	12.86	20
	8	2.09	227.7	42.74	26.90	146.68	11.5	12.75	24

Beam trawl 20-45 HP

Year	Month	Mean CPUE (kg/h)	Mean Effort (h)	Average percentage of shrimp in Catch	price of shrimp (1000 VND/kg)	Cost Per Trip (1000VND)	Trip duration (h)	Cost Per Hour (1000VND)	Number of samples
	6	1.17	209.97	41.52	82.21	164.93	8.86	18.62	14
	7	1.20	188.60	58.63	70.45	192.00	8.29	23.15	17
	8	1.63	198.86	52.28	62.51	177.00	8.00	22.13	15
2000	9	1.89	204.90	54.35	50.95	245.71	8.33	29.49	12
	10	5.00	202.63	9.85	64.36	319.30	9.45	33.77	11
	11	1.31	191.26	42.57	67.36	187.79	8.32	22.58	19
	12	0.97	249.84	58.46	49.50	175.90	10.91	16.12	29
2001	1	1.17	179.34	49.71	78.12	207.32	9.47	21.88	19
	2	0.97	196.84	41.23	84.66	185.85	8.60	21.61	20
	3	1.38	209.56	35.97	63.05	197.33	9.11	21.66	9
	4	2.82	200.39	50.68	32.05	210.24	8.24	25.53	17
	5	1.95	200.00	55.89	41.03	218.00	8.00	27.25	14
	6	1.42	223.35	47.24	64.88	225.82	9.29	24.30	17
	7	1.80	232.47	62.28	49.30	212.89	9.53	22.34	17
	8	1.66	223.57	43.88	65.98	199.15	8.92	22.32	13
	11	1.42	194.35	52.93	48.37	235.05	9.89	23.76	19
	12	1.20	180.19	50.00	51.92	220.94	9.05	24.41	19
	1	2.60	189.89	38.49	28.87	199.47	8.63	23.11	19
	2	1.82	150.98	46.05	32.14	203.72	8.67	23.51	18
	3	3.57	193.22	30.78	36.15	203.37	8.68	23.42	19
	4	2.23	190.99	50.69	40.32	210.50	8.25	25.52	20
	5	3.93	191.79	47.35	26.37	208.80	8.20	25.46	20
	6	3.33	168.77	44.02	22.00	202.61	8.22	24.64	18
	7	3.87	199.89	34.58	19.08	205.00	8.58	23.90	19
2002	8	4.47	185.45	49.06	23.99	189.00	8.53	22.17	19
	9	4.29	196.44	40.93	29.43	219.40	8.60	25.51	20
	10	2.99	140.72	40.87	24.76	237.58	8.16	29.12	19
	11	4.28	204.00	42.30	27.47	227.31	10.67	21.31	36
	12	4.05	201.49	39.40	19.38	226.78	10.22	22.19	32
	1	3.53	152.81	55.76	22.65	235.67	9.49	24.84	39
	2	2.10	155.79	30.84	40.33	237.04	9.41	25.20	27
	3	2.79	185.21	41.12	27.43	225.20	9.98	22.57	46
	4	2.02	205.14	47.02	27.07	234.66	10.41	22.53	41
	5	3.04	177.24	64.09	18.84	242.64	9.56	25.39	36
	6	4.05	196.28	20.31	26.11	662.03	13.70	48.33	38
2003	7	3.28	182.89	48.97	26.40	281.48	9.94	28.32	33
	8	2.31	164.82	46.37	29.73	221.03	9.85	22.43	41
	9	3.71	214.30	39.27	23.01	223.57	11.23	19.91	44
	10	3.36	197.38	44.83	24.71	243.40	10.74	22.67	57
	11	5.23	209.72	41.78	21.37	248.98	10.67	23.34	51
	1	4.46	168.11	40.66	28.57	228.20	10.06	22.68	49
	2	2.94	189.46	41.22	30.43	220.40	10.47	21.05	55
	3	3.49	195.87	38.84	25.77	235.40	10.42	22.60	55
	4	7.54	184.71	45.16	18.46	239.00	10.10	23.66	35
	5	6.20	177.50	55.31	13.92	229.17	9.37	24.47	30
	6	2.30	202.20	44.66	23.24	200.00	11.10	18.02	20
2004	7	2.40	184.58	52.78	22.00	234.46	9.41	24.93	37
	8	2.00	216.62	47.04	24.83	201.25	11.50	17.50	8
	9	4.56	174.60	36.38	23.32	308.35	10.01	30.81	55
	10	4.71	162.61	34.52	20.47	280.98	9.51	29.55	54
	11	4.96	179.30	37.62	22.61	376.90	9.90	38.07	40

Otter trawl 20-45 HP

Year	Month	Mean CPUE (kg/h)	Mean Effort (h)	Average percentage of shrimp in Catch	price of shrimp (1000 VND/kg)	Cost Per Trip (1000VND)	Trip duration (h)	Cost Per Hour (1000VND)	Number of samples
	6	5.99	317.01	12.24	31.52	1567.64	52.51	29.86	75
	7	11.22	129.93	17.15	22.32	791.17	19.92	39.72	50
	8	7.23	186.44	19.77	31.98	739.60	25.07	29.50	58
2000	9	7.27	166.19	24.34	25.86	332.65	16.58	20.06	101
	10	8.63	181.85	17.98	25.71	824.70	20.48	40.27	92
	11	11.48	205.88	13.39	26.82	787.85	20.91	37.68	119
	12	15.29	194.66	22.27	21.54	779.57	22.09	35.29	68
	1	6.96	174.16	21.34	36.58	584.92	17.65	33.14	115
	2	6.99	186.31	21.55	27.26	592.49	17.98	32.95	119
	3	7.60	188.65	26.45	25.55	587.65	15.74	37.34	119
	4	7.30	288.13	26.26	22.91	624.46	29.32	21.30	109
	5	7.28	200.12	26.21	22.32	525.75	17.79	29.56	115
	6	8.07	191.02	18.76	20.63	563.50	15.57	36.20	114
	7	7.41	174.14	28.79	22.27	635.03	15.97	39.77	118
2001	8	7.06	178.91	32.65	22.91	598.03	17.06	35.06	126
	9	7.73	195.03	26.26	21.31	667.50	18.41	36.25	117
	10	7.05	192.61	23.69	25.71	614.16	17.88	34.36	133
	11	7.93	176.11	26.97	21.14	562.90	17.94	31.37	125
	12	9.30	168.98	19.14	22.66	364.32	11.18	32.60	82
2002	1	4.59	181.62	28.70	24.46	794.88	20.52	38.73	94
	2	7.06	168.68	20.90	28.12	720.55	17.75	40.59	111
	3	6.39	184.50	22.24	25.65	681.10	17.60	38.69	111
	4	7.83	181.22	19.01	24.52	632.28	16.90	37.41	121
	5	8.36	176.50	24.46	22.02	639.02	18.65	34.27	116
	6	7.80	169.54	25.04	22.81	636.83	18.83	33.83	112
	7	8.64	168.07	18.28	22.16	664.00	17.51	37.92	114
	8	8.97	161.71	20.33	22.09	736.79	18.26	40.36	113
	9	8.60	170.36	16.65	21.72	676.72	18.06	37.46	109
	10	9.16	162.68	18.59	25.12	714.61	18.13	39.41	114
	11	8.14	159.36	22.44	27.24	676.90	17.46	38.78	114
	12	9.67	129.99	20.22	26.74	709.33	18.19	38.99	116
	1	13.84	120.64	7.65	36.38	391.90	9.90	39.59	60
	2	3.06	141.97	27.44	27.13	337.61	11.93	28.29	45
	3	8.99	127.55	12.24	26.35	336.90	9.97	33.81	86
	4	5.99	154.70	39.52	15.77	344.61	11.36	30.34	56
	5	5.65	157.05	26.99	16.09	523.98	14.66	35.75	58
	6	4.70	164.45	20.16	24.97	533.07	16.78	31.78	67
2003	7	5.79	160.31	12.65	28.39	621.94	16.87	36.87	68
	8	9.67	122.52	8.37	63.62	543.57	11.28	48.21	87
	9	12.44	107.99	5.77	79.23	507.48	9.00	56.39	65
	10	10.19	101.41	5.29	34.347	569.67	9.56	59.58	82
	11	13.55	123.12	9.64	35.75	560.13	11.91	47.03	72
	1	6.50	101.6544	24.41	35.97	386.74	10.76316	35.93	76
	2	5.77	144.1209	14.97	37.03	723.79	17.24138	41.98	87
	3	6.97	156.7335	21.45	29.95	531.24	15.40909	34.48	88
	4	10.54	158.7229	22.13	26.82	592.82	16.48889	35.95	90
	5	10.95	171.2464	18.67	25.03	568.02	14.84659	38.26	88
	6	11.37	135.2549	12.80	28.87	509.89	12	42.49	62
2004	7	8.89	160.8557	10.51	27.89	603.42	14.14535	42.66	86
	8	10.66	169.7121	7.54	32.16	551.79	14.02206	39.35	68
	9	9.53	156.6554	9.49	31.84	517.13	12.33133	41.94	83
	10	10.86	183.0211	12.20	27.99	664.36	15.0137	44.25	73
	11	9.60	166.5328	11.57	33.21	630.70	17.08791	36.91	91