Assessment of Tonkin Gulf Fishery - Vietnam based on the bio-economic models

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Abstract

During 1986-2006, fisheries in Tonkin Gulf had made rapid development. Total engine power increased 11.6 times while total catch only increased 2.9 times. Big increase in number of fishing boats has resulted to the overexploitation in near shore waters since 1995 and this situation has been spread out all over the Gulf now.

This paper give detail description of the current status of fisheries in Tonkin Gulf, dynamic trend in number of boats, catches, resources; and discuss relating issues such as capital, economic efficiency of key fisheries in Tonkin Gulf like trawl, purse seine, line fishery and others. In addition to that, fishery management issues toward sustainable development are also analyzed in deep.

Analysis, evaluations on marine capture fisheries in Tonkin Gulf have been done with bio-economy model have been made. The study figures out the fact of over-fishing on the resources and the excess of fishing capacity in Tonkin Gulf.

1. Review of the Tonkin Fisheries:

Tonkin Gulf is approximately 150,000 km^2 large, located in the North of Vietnam. The area is bordered on China and Vietnam along the sea coast in the West, North and East; contiguous to the sea in the South and bordered by latitude $17^0$30 N.

In the recent years, with the rapid development of the fisheries all over the country, fisheries in Tonkin Gulf have made a strong growth. During 1986-2006, the total fishing boats, horsepower, and catches in the Tonkin Gulf was increasing continuously. Total horsepower increased from 73,137 HP (in 1986) to 850,736 HP (in 2006)-growing 11.6 times as high, while total catch increased from 82,838 tones to 242,293 tones – growing only 2.9 times as high . This also means that catch per 1 HP went down continuously from 1.13 T/HP/year (in 1986) to 0.28 T/HP/year (in 2006).

Big increase in number of fishing boats has resulted to the overexploitation in near shore waters since 1995 and now this situation has been spread out all over the Gulf.

The over-fishing has caused many consequences to the fisheries in the Tonkin Gulf:

- Marine resources have been declined severely, especially in near shore waters.

- The decline of the resources and increasing number of fishing boats has led to the decreasing income of fishermen. This makes the fisheries competitions become harder and harder, and the resources get more and more declined.

- The excess of fishing capacity and the overexploitation in fact has been growing. It is necessary to restructure the fishing fleets as soon as possible, also mean to limit number of fishing boats to a level that fishing effort keeps corresponding to the catch ability of the resources to obtain sustainable fisheries in the Tonkin Gulf.

2. Fleet structure and fishing area.

- . *Fleet structure and fishing area in 1986-2006*

During 1986-2006, fishing fleets in Tonkin Gulf has grown up quickly both in number and scale. The number of boats increased from 6,094 in 1986 to 26,751 in 2006. Big growth in size of boat was recorded with average engine power per boat increasing from 12HP/boat in 1986 to 31.8 HP/boat in 2006.

- *Number of boats in Tonkin Gulf by horsepower group.*

Considering the number of boats in Tonkin gulf by Horse Power group is shown that number of boats less than 49 HP constitutes 81.8% of the total powered boats in the Gulf. This figures that most of fishing boats in Tonkin Gulf is small engine boats and main fishing areas are near shore waters.

- *Number of fishing boats by gear type*

Based on statistic data, the number of boat less than 90 HP constituted 97% of the total fishing boats. Concerning on the gear type, the most dominant group was line followed by gill net, trawl and lift net. Concerning on the horse power group larger than 90, the most dominant group was trawl (taking 37% of the group total) followed by purse seine (29.6%), others were not remarkable.

3. Catches by gear type

Tonkin Gulf has an abundant pelagic fish resource, giving good condition for the development of the lift-net-using-light fishery. In addition, the lift net fishery is very suitable for small size boats which are plenty here. This explains why catch produced by lift net has contributed 43.7% to the total catch.

With pretty even sea bed and average depth of 38.5 m, Tonkin Gulf is very favor trawl fishery. Catch by trawl fishery has contributed 28.3% to the total catch in the Tonkin Gulf. The catch by other fisheries has contributed as follow: Purse seine fishery – 8.09% of total catch in the gulf ; Gill net fishery- 8.07% ; Line fishery-7.59%....

4. The development of the main fisheries in Tonkin Gulf

- *Trawl fisheries :* In 2005, number of trawlers was taking 21.17% of the total trawlers overall country. However, trawlers <90 HP were most popular with taking 93.1% of the total trawlers in Tonkin Gulf. These small ones were mainly shrimp trawlers.

- *Purse seine fishery:* Purse seine fishery in Tonkin Gulf develops not as strongly as it does in Center and South East &West regions. Most of them are using light and luring devices for fishing. There are 703 in Number of purse seiners was taking 11.0% of the total pure seine boats all over the country, of which the boats are <90 HP taking 54.9%.

- *Line fishery :* In Tonkin Gulf, line fishing boats is small scale, number of boats <90 HP was taking 95.4% of the total number of line fishing boats in Tonkin Gulf.

- *Gill net fishery:* Gill net fishery in Tonkin Gulf is also small scale. Most of fishing boats are less than 90 CV, taking 97.2% of the total gill net fishing boats in Tonkin Gulf and main fishing area is near shore waters. Shrimp trammel net used to be very popular in Tonkin Gulf.

6. Fisheries management in Tonkin Gulf

6.1. Existings of Fisheires in Tonkin Gulf: Existings of fisheries in Tonkin Gulf as follow:

+ Overexploitation in traditional nearshore areas:

Traditional areas (less than 50 m deep) have an importance to the fisheries in Vietnam. These are active areas of small fishing boats, whose the quantity consists of 84% of the total powered boats, and thousands of non-engine fishing boats, providing livelihoods for poor fishermen, whose quantity consists of 88% of the total fishery labours. However, overfishing has happened in these areas, causing an unbalance between fishing capacity (number of fishing boats) and the potential of catch; illegal fishings happens very often; all give bad influences on the resource maintaning and recovering.

+ Competiontions between capture fisheries

The decline of resources, increasing number of boats, decreasing fishing efficiency is the causes of the harder competiontions on resources.

Currently, fishery competiontions have given bad influence on resources. This is main reason of illegal fishings (IUU fishing). Illegal fishing by foreign boats happens very often in EEZ of Vietnam.

+ The existing of harmful fishing gears and fishing technique

- Almost current fishing gears in fact violate the regulations on the mesh sizes. Using small mesh size gear results to high percentage of trash fish and small size fish in catches, that is 60-80% of the total catch by shrimp trawl, 40-80% by fish trawl, 90% by fixed net, 90% -93% by push net.
- Coral reefs, sea grasses have been degraded and damaged by improper activities.
- Harmful fishing gears are still active exterminating juvenile fish like stow net (at estuaries), push nets ...
- Harmful fishing techniques have not been deleted. Using explosive, chemical substances for fishing in many places stay uncontrolled.

+ The registration fishing boats stays unmanaged leading to uncontrolled number of fishing boats.

Number of fishing boats fishing in coastal waters is increasing and catches produced from those areas have exceeded far beyond the allowable limit. No proper management measures have been decided to control the increase of number of boats. The spontaneous recruitment to coastal fisheries of small boats with 724 boats/year makes the fishing effort on coastal areas heavier and heavier.

It is required proper management measures as soon as possible to reduce fishing pressure on coastal waters, meaning to reduce and limit number of fishing boats at a level that corresponds to the current carrying capacity of resources by applying “Fishing Permit” and “Boat Registration Certificate”

+ Low economic efficiency of fishing fleets.

As discussed above, uncontrolled increase of the number of coastal fishing boats results to the mismatch between fishing capacity and resources capacity in coastal area. That is why the coastal resources are declining and economic efficiency is going down. Additionally, fuel cost and other costs for fisheries are going up continuously, causing many difficulties to marine capture fisheries.

Poor post-harvest preserving techniques, lower quality of landings are also reasons affecting to the revenue of fishing trips.

To cover fishing costs, fishermen raise fishing effort and take all catches. The competition, thus, becomes harder and harder threatening the resources

+ Not available reliable statistics on number of fishing boats and annual catches.

7. Trend of resources and fisheries in Tonkin Gulf

-. Dynamic trend of resources :

Survey results which have been accumulated by RIMF in many years show that the marine resources and total allowable catch in Tonkin Gulf has been gradually decreased.

This decrease is resulted by the overfishing in near shore waters. According to the estimates based on survey on catch produced in coastal areas by fishery in Tonkin Gulf, total on catch produced in coastal areas takes 95,2% of the total catch in gill net fishery, 96% in trawl fishery; 79,4% in pure seine fishery and about 94,2% in others.

Total catch produced in near shore waters (<50 m deep) in 1994 was recorded 109,740 tones with 460 tons beyond the allowable limit of 109,280 tons stipulated for coastal waters . This was recorded 120,600 tons in 1997, including 12,600 tons produced by migrating boats of the Central provinces in Tonkin Gulf, with 11,320 tons beyond allowable limit. In conclusion, total catches in coastal areas have been exceeded the allowable limit of this area since 1994.

Every year, there are 800 big China fishing boats (with total power of 23,000 HP) that are allowed to fish in the common fishing area, together with 250 gill net boats and 500 purse seine

boats of the Southern provinces migrate to fish in this area, it is seen that the resources in Tonkin Gulf have been overexploited since 2004 when total catch reached 299,000 tons with 26,500 tons beyond the allowable limit .

- *Tendency in marine capture fisheries:*

During 1986-2006, the average catch per HP has been dropped continuously and down at 0.28 tons/hp/year in 2006.

Obviously, the increase of total engine power has resulted to a proportional increase of fishing costs, but slow increase in catches is still observed, saying in other words, the increase of catch is not proportional to the increase of engine power. That means the revenue per boat has been decreased and fishing effort has been raised to cover fishing coats, and consequently resources get more and more declined.

8. Analyse the capture fishery in the Tonkin Gulf based bio-economic models:

In the recent decades, the increasing fishing pressure in most fishing grounds have made some important fish stocks being over-fishing and depleted. The phenomenon of overcapacity in marine capture fishery has been also notably proclaimed. Nevertheless, the study on the bio-economic aspect has not been paid much attention. And, there are many challenges for evaluating Vietnam marine capture fishery including the multi-species and the availability of landing data, effort data and so forth. Additionally, the fisheries statistics system is really weak and not consistent. Therefore, it is impossible to isolate the fishing efforts and landed yields by fishing fleets, by commercial groups and fished species.

In this paper, the marine capture in the northern part of Vietnam, the Gulf of Tonkin, is evaluated based on the recorded data of the total annual fishing effort in terms of total engine capacity (CV) and landing data over 20 years, from 1986 to 2006. The Schaefer (1954) and Fox (1970) models were applied to estimate the trends in fishing cost, total revenue and changes in resource rent.

The total annual fishing effort was estimated by stratified method therefore the weighted factor was used for each fishing fleets. In detailed, fishing fleets were categorized into fishing gears and engine capacity. Then the effort was standardized and estimated for the whole industry.

$$Eff\,(CV) = \sum_{i=1}^{n} Fisheries \qquad (eq.1)$$

Where: Eff(CV) is the total effort of the fishery in terms of total engine capacity CV (Horse Power), Fisheries denoted the fishing fleets, fishing gears used, for examples, trawler fishery, gillnetter fishery, pure seiner fishery etc…

Each fishery, for instances, trawler fishery is comprised of many different fishing fleets which varied in engine capacity equipped, therefore, the total effort of one fishery is estimated as the following equation:

$$Eff_{Fishery} = \sum_{i=1}^{k} \overline{Eff_i} * f_i \qquad (eq.2)$$

Where: $Eff_{Fishery}$ is the total effort of a fishery calculated, k is the numbers of different fishing fleets grouped by engine capacity; and f_i is the weighted factor, is proportion of the number of fishing boats belonging to group k and the total number of fishing boats of the fishery.

Similarly, the fishing costs including variable cost, fixed cost were also basically calculated as equation 1 and 2. The year of 2005 was selected as the base one, the variable cost for one CV (horse power) of engine was estimated at US$205.7 per year, and the average fixed cost was also estimated about US$27.8 per CV per year. And the average price for one tone of the mixed fished product in 2005 was estimated at US$ 759.5 per metric tone.

In order to estimate the parameters of MSY, Effort $_{MSY}$, and resource rent for the marine capture fishery of the northern part of Vietnam, both models of Schaefer (1954) and Fox (1970) were applied in estimating of the Maximum Sustainable Yield (MSY) and the effort corresponding ($Eff_{MSY)}$. And, basically, MSY, Eff_{MSY} values calculated under these two models are presented as the following:

8.1. Schaefer (1954) model

The decline trend in the relative abundant index – CPUE (tones/CV/year) was obviously shown in the Gulf of Tonkin during 20 years, from 1986 to 2006. Accordingly, this trend was formulated as the following equation 1 (eq.3):

CPUE = -0.000001*effort + 0.958023 *(eq.3)*

Thus the long term equilibrium yield of the fishery here was followed the Schaefer (1954) model and described as:

Eq. Yield = -0.000001* effort^2 + 0.958023 * effort *(eq.4)*

The over-fishing state was obviously observed in the Figure 1a, it was reflected by the steeply slope of the declined trend in mean annual CPUE and the "predicted values" of the yearly yield based on logistic model. The MSY value was estimated at 229,452 metric tones and, responding to the total effort level at MSY was 479,012 CV per year. Therefore, comparing to the current fishing effort level of 850,736 CV in 2006, the fishing effort in this area needs to be removed almost an half in order to get the MSY value.

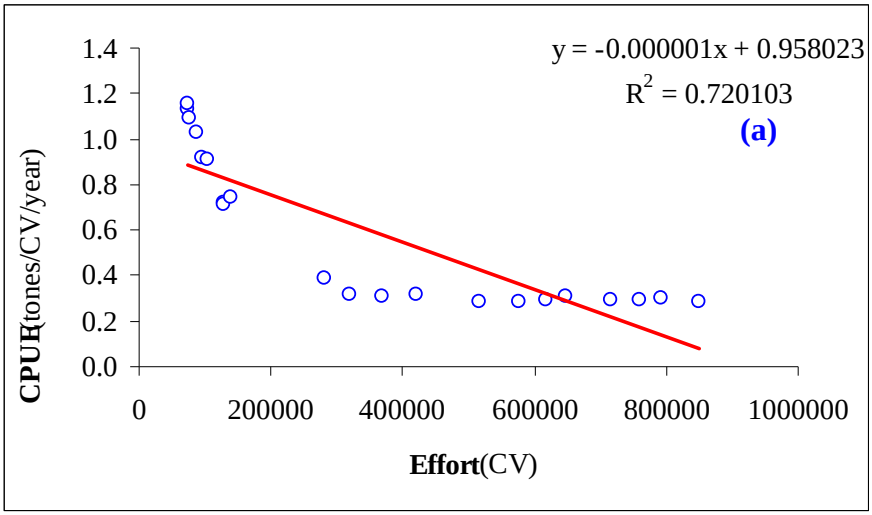


Figure 1a. Trend in the relative catch rate (CPUE(tones/CV/year)) corresponding to fishing effort of the marine capture fishery of the gulf of Tonkin based on Schaefer model during 1986 – 2006.

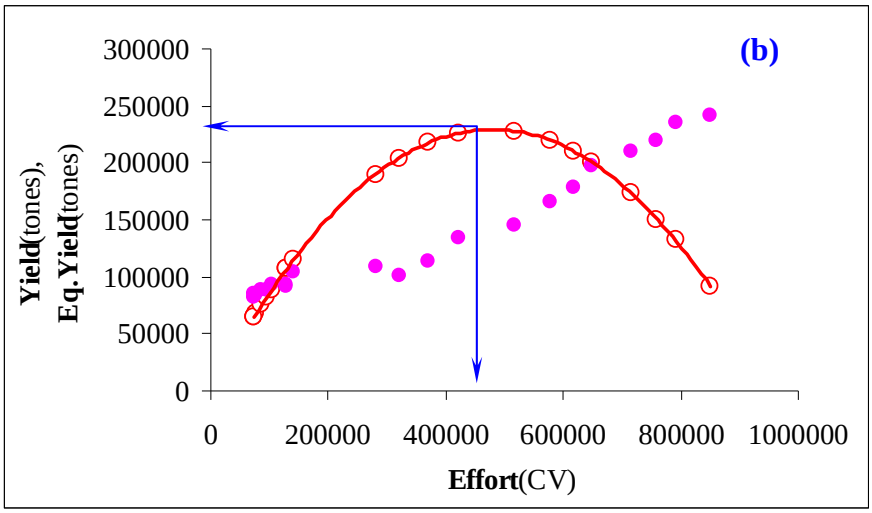


Figure 1b. Trend in the relative catch rate (CPUE(tones/CV/year)) corresponding to fishing effort of the marine capture fishery of the gulf of Tonkin based on Schaefer model during 1986 – 2006.

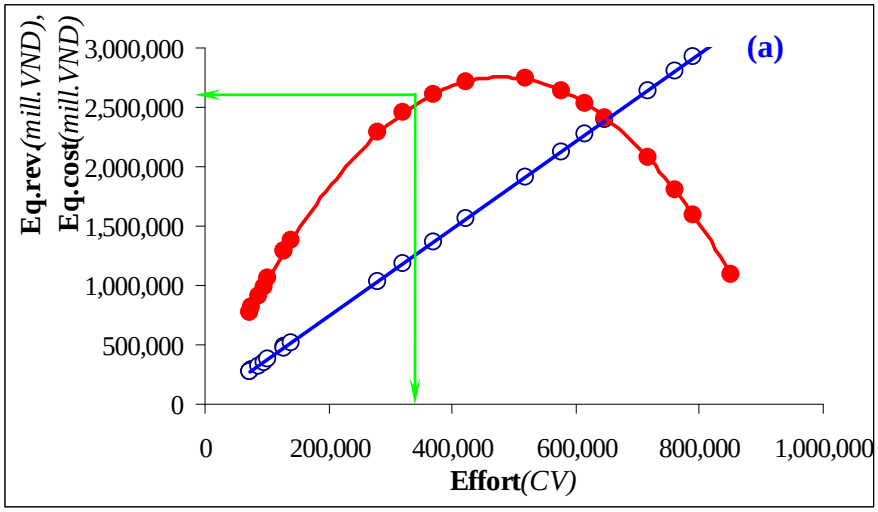
The total cost of the sector was comprised of the fixed cost and variable cost. Thus the equilibrium cost is comprised of the two components above and was also a linear ship function of the fishing effort and this was formulated as the following equation:

Eq. cost = effort*c + fk *(eq.5)*

The equilibrium revenue was estimated by integrated the short run harvest multiplied with average price. Therefore, the long term equilibrium revenue has also the same shape of the long run harvest. And, in this case study, the decreasing trend in revenue again the increasing fishing effort was clearly observed (Figure 2a). Similarly, the long term equilibrium profit, the differences between total revenues and total costs, had a trend followed by long run harvest function. Because, simply, the profit is determined as:

Eq. profit = Eq. total revenue – Eq. total cost *(eq.6)*

The similar trend in equilibrium profit and equilibrium resource rent was presented in Figure 2b. However, the difference in fixed cost makes the trend line of the equilibrium resource rent above the trend line of the equilibrium profit.



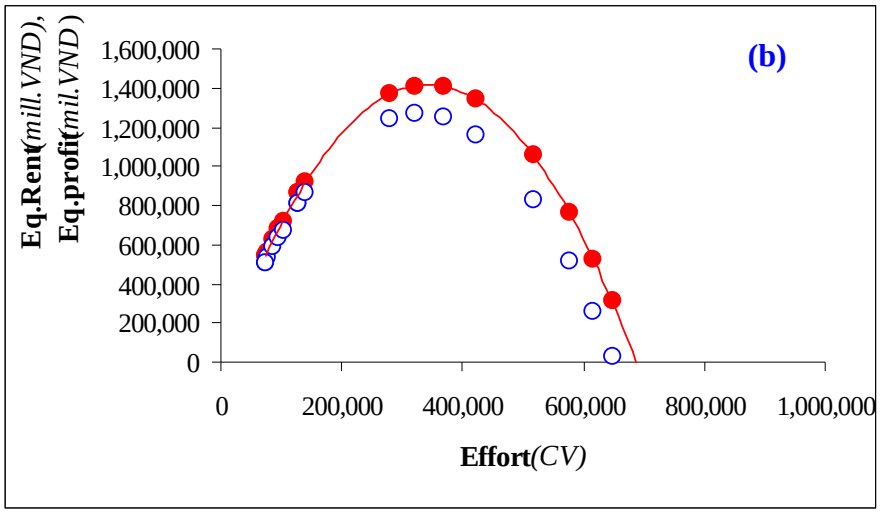


Figure 2. Trends in Equilibrium revenue, Equilibrium cost, Equilibrium rent and Equilibrium profit responding to the fishing effort levels based on Schaefer model for the marine capture fishery of the Gulf of Tonkin estimated during 1986 – 2006.

8.2. Fox (1970) model

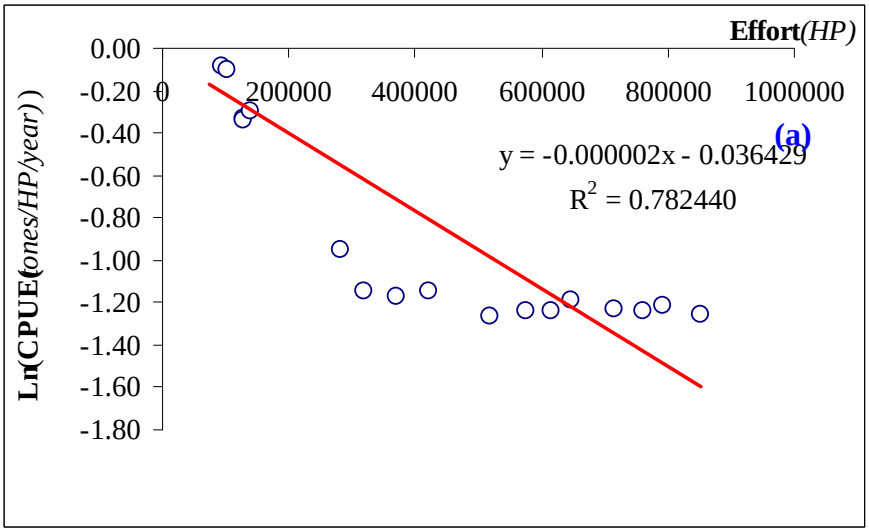
Similarly, in order to estimate the rents, costs and revenues as well as profits, Fox assumed the growth function of the fish stock following the equation as below:

$$G(x) = \alpha * x - \beta * x * Ln(x) \qquad (eq.7)$$

And, the catch rate (CPUE) is also a function of fishing effort (x) and the relationship is described as:

$$Ln(CPUE) = \alpha + \beta * x \qquad (eq.\ 8)$$

Based on the above assumption, the trends in mean catch rates in log scale and equilibrium yield, yield observed were graphically presented in Figure 3. Fox model showed more flat top curve of equilibrium yield compared to the Schaefer model (Figure 3b). However, this model also obviously illustrated the state of over-fishing occurred in the Gulf of Tonkin during 1986 – 2006.



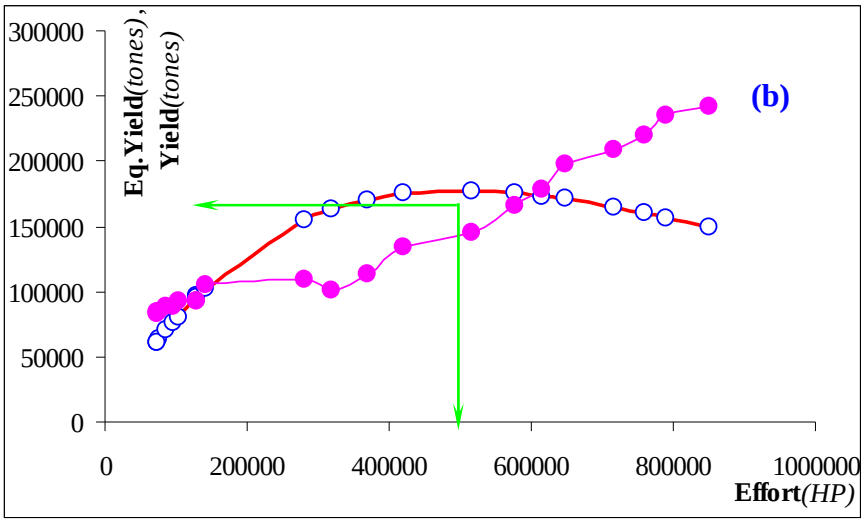
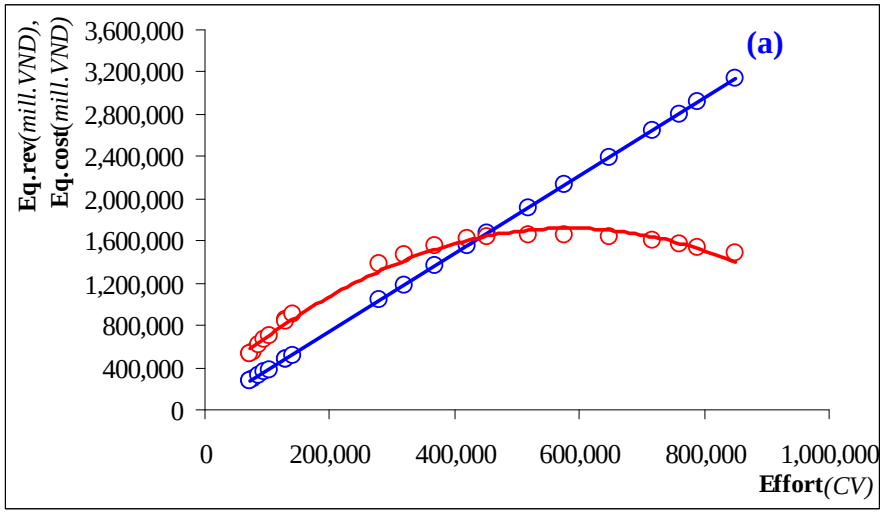


Figure 3. Trend in the relative catch rate (CPUE(tones/CV/year)) corresponding to fishing effort of the marine capture fishery of the gulf of Tonkin based on Fox(1970) model during 1986 – 2006.

The MSY and the responding fishing effort for the fishery of the Gulf of Tonkin were calculated based on the Fox model are about 193,450 mt and 546,700 CV, respectively. Therefore, the value of MSY estimated by Fox model is slightly less than its estimates by the previous model. However, compared to the statistic data of the present fishing effort of the Gulf, about 850,700 CV, the fishing effort at the current level needs to be decrease approximately 300,000 CV per year in order to maximize harvest yield and the total fishing yield must be subtracted about 50,000 mt per year.



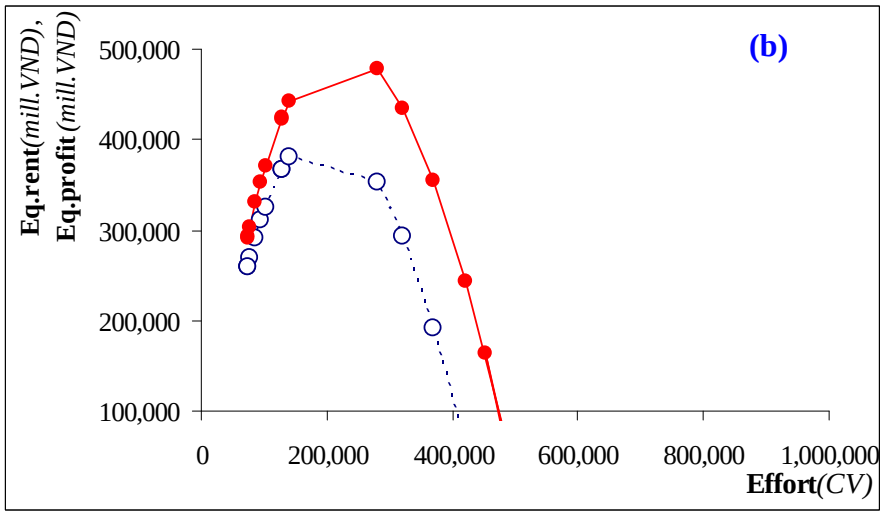


Figure 4. Trends in Equilibrium revenue, Equilibrium cost, Equilibrium rent and Equilibrium profit responding to the fishing effort levels based on Fox (1970) model for the marine capture fishery of the Gulf of Tonkin estimated during 1986 – 2006.

From calculation above, the main parameters are received as follow :

Table 13. Summary results estimated of some bio-economic parameters of the fishery in the Gulf of Tonkin during 1986 – 2006.

Parameters	***Models***	
	Logistic	*Fox*
Maximum sustainable yield, MSY (mt)	229,452	193,450
Fishing effort at MSY (CV)	479,012	546,700
Current fishing effort (CV) in 2006	850,736	850,736
Current landing yield (tones) in 2006	242,293	242,293

8.3. Estimating Fisheries Rents based on Suggestion of Ragnar Arnason (2006)

Input data: the year of 2005 was considered as the base year to estimate the rent loss for marine capture fishery of the Gulf of Tonkin. The input data are described as the following table, Table 14.

Table 14. The input data for estimating rent loss of the Tonkin Gulf fishery based on suggestion of Ragnar Arnason (2006).

Rank	***Parameters***	***Values***
1	Virgin stock biomass (metric tones - mt)	950,000
2	MSY (mt)	229,452
3	Landing in base year (mt)	234,813
4	Landing price in base year (US$/mt)	759
5	Net biomass growth in base year (mt)	-10,000
6	Profit in base year (ml.US$)	-6.39
7	Fixed cost ratio in base year	0.12
8	Schooling parameter	0.90
9	Fishing effort in base year (CV)	791,000

According to Logistic and Fox models, the current stock biomasses estimated were respectively 407,460 mt and 281,606 mt. And the optimal levels of the fish stock biomass estimated are 661,424 mt (Logistic) and 557.384 mt (Fox). Therefore, the optimal levels of the fish stocks of the gulf are obviously higher compared to the current levels estimated by both models. Simultaneously, the results showed a need to decrease harvesting yield as well as fishing effort to get the profit maximizing for the fishery of the Gulf of Tonkin. By decreasing the current fishing effort from 791,000 CV to about 422,808 CV (Logistic model) or 355,554 CV (Fox model), the profit can be increased approximately ml.US$ 44.8 (Logistic) or ml.US$ 59.4 (Fox). The detailed information of the profits, rents and fishing effort, fishing harvest and biomass estimated by Logistic as well as Fox model are presented in Table 15.

Table 15. Estimates of the Biomass (mt), Harvest (mt), Effort (CV), Profits (ml.US$) and Rents (ml.US$) of the marine capture fishery of the Gulf of Tonkin in the current and optimal regimes based on Fox and Logistic models.

Indices		*Current*		*Optimal*		*Difference*	
	Units	*Logistic*	*Fox*	*Logistic*	*Fox*	*Logistic*	*Fox*
Biomass	1000.mt	407.5	281.6	661.4	557.4	254.0	275.8
Harvest	1000.mt	234.8	234.8	194.1	195.1	-40.7	-39.7
Effort	HP	791,000	791,000	422,809	355,555	-368,191	-435,445
Profits	ml.US$	-6.4	-6.4	38.4	53.0	44.8	59.4
Rents	ml.US$	15.8	15.8	60.5	75.1	44.8	59.4

9. Discussion

The application of the bio-economic models, e. g Schaefer (1954), Fox (1970) is rather to the single species stocks than multiple species stocks. But, in the context of the general Vietnam fishery as well as the marine capture fishery of the Gulf of Tonkin, many difficulties are challenged for this approach, not only the numerous species but also the availability of landing and effort data. Therefore, all landing yield of hundreds fished species were pooled and treated as one fish stock. In addition, fishing efforts, fixed costs, variable costs were also standardized and assumed as “one fishery”. Thus biases of the estimates were inevitable.

Notably, the statistic system of Vietnam marine capture fishery is very weak and not consistent in terms of activity as well as methodology. Therefore, the BAC is not taken into account in this paper. Actually, not all fishing boats fish all time in the year. Therefore, fishing cost estimated in this paper perhaps higher than it was in practically.

However, this paper is also a good picture which presented the overall views of the fishery over 20 years, since 1986. The estimation of the current fish stock biomass was around 407,460 mt (Logistic model).

Unfortunately, the phenomenon of over-fishing has happened to the sector for years. And, bio-economic models proved the state of the fishery through the changes in reference points including MSYs, MEYs, and rent loss. Furthermore, the fisheries independent data also showed a significant decrease in the demersal fisheries resource of the gulf during the same period.

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