FISHERIES BENEFITS FROM PROTECTING CORALS

The case of the Nha Trang Bay Marine Protected Area and Trao Reef Marine Reserve

By

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Abstract

The value of a coral reef is one of the ways to indicate the success of a Marine Protected Area (MPA) and protected resources. Khanh Hoa has two MPAs with the abundance coral reefs with status quite good and a developing fisheries industry. This paper will examine the link between fishery and coral reef using two models, essential fish habitat (EFH) model and facultative habitat (FH) model. The final goal is to estimate contribution of coral reef in a production function of fishery in Khanh Hoa. The empirical results indicate that the EFH model is better suited in this case than the FH model, so the value of coral reefs is estimated by using the EFH model. With 1 hectare (ha) coral reef, it can be produce for the fishery in harvest about 680 tones, with revenue of 885.001 USD. And benefit from protecting coral reefs after established MPA in Khanh Hoa region is achieved when the implementation of the MPAs has saved 73 ha of coral coverage, with to 243,315 tones of harvest over the period 2002-2008 and amounts benefit of nearly 275 million USD. However, the open access condition in which currently practice in Khanh Hoa is causing damage the coral reefs, and effect negative to the harvest when still increase the effort, thus management should used the policies to reduce the pressure on the coral reef and fishery sector.

Key words: coral reefs, fishery, MPA, EFH model and FH model.

- Note: Exchange rate on 10th, April 2010 is 1 US Dollar = 19.000 Vietnamese Dong using for whole thesis.
  US Dollar is USD and Vietnamese Dong is VND.

1. Chapter 1: Introduction

Coral reefs are one of the most important habitats of marine environments that are known. They are very productive, constitute high biodiversity marine ecosystem and are important habitat for many species, including some of commercial value (Foley *et al*. 2009). Corals are extremely ancient animals that evolved into modern reef-building forms over the last 25 million years. Coral reefs are unique and complex systems, however coral reefs are easily broken (http://coris.noaa.gov/about/what_are dated 24/12/2009).

Estimating the value of coral reefs is an important task and is needed to develop proper management for fisheries and wildlife conservation. The coral reefs are one of the important habitats in MPA such as the biological, fishery and others to indicate the successful of MPA (Amstrong, 2010). Coral reef can protect the shoreline from waves and storms; it is the places as for recreation, sources of food, pharmaceuticals, livelihoods and revenues for the fishery. However, there are types of values of coral reefs that we do not know such as how the affection of coral reef in reducing the global warming. (http://www.aaas.org/international/africa/coralreefs/ch1.shtml, dated 02/05/2010).

Coral reefs provide a necessary function; however they are currently under threat (Nguyen, 2009). There are many factors which are leading to the destruction of coral reefs. Human activities such as recreational and tourism industry, over fishing, coastal development and destructive fishing methods including blast fishing, poison fishing, and trawlers fishing are all activities which contribute significantly to the destruction of coral reefs. Environment factors such as global warming (Nguyen, 2009) and natural events such as hurricanes, earthquake, predator outbreaks and periods of high temperature (Nguyen, 2009) are also factors that may threat the health and existence of coral reefs.. Socio-economically we have relied heavily on exploitation of natural resource such as coral reefs. We need sustainable development, and the development of bioeconomic theory which can help form sound policies and management is a step on the way.

In the Phu Quoc Marine Protected Area (MPA) in Kien Giang province, Vietnam, there is a signboard in a visible area where people can learn more about the important role of coral reefs: “We need water like fish need coral reefs”. Coral reefs are like the forest of the ocean, when the coral reefs are destroyed, the fish which live in a symbiotic relationship with the reef are no longer able to survive. Thus, if the coral reefs are reduced, it will have a negative effect on the fish stock. This reduction of fish stock will have a domino effect through the fishing industry as the value of the fishery will be reduced, which will lead to lower revenue from the harvest of some commercial species (Armstrong,2009). In addition to the lost value for the fishing industry, the world's oceans are a huge source of still-undiscovered plant and animal species which may contain compounds that could provide potent disease treatments (see http://ehp.niehs.nih.gov/members/2004/112-8/focus.html, date 23/02/2010). Finally, there are many other functions that coral reefs may serve that we do not yet know about and if we destroy this resource, the value may be higher than we now at the present.

MPA is one of the tools used to of manage and protect habitats (coral reefs, mangroves, sea grass etc,). A Marine Protected Area was define by International Union for the Conservation of Nature and Natural Resources (now the World Conservation Union) (IUCN) in 1999 as "*Any area of intertidal or subtidal terrain, together with its overlying waters and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part of all of the enclosed environment*". MPAs can be used for many purposes. Some main goals of MPAs are conservation, benefiting fisheries and helping other sectors such as tourism, recreation. (Armstrong, 2010).

Under open access resources can be heavily exploited in the long run, and there can be economic losses associated with the destruction of natural habitats supporting fisheries (Barbier and Strand 1998, Barbier 2002). The term biological over–fishing normally refers to the case when a fish stock is lower than that corresponding to maximum sustainable yield, while economic over-fishing is when stocks are below the levels that would generate maximum economic yield. Under open access effort is attracted to the fishery until profit equals zero, and participants do not care about the habitat resources such as coral reef are reduced or destroyed. This thinking means that fisherman do not care about the habitat, leading to further habitat destruction (Armstrong, 2009). The resources are going to be over fishing and the economic value will be lower than it was before, the natural habitat will also be smaller of attribution value (Barbier, 2002).

There are few models that connect habitat size and fish populations (Armstrong and Petersen, 2008). The habitat effects upon commercially interesting species could be included in bioeconomic models via the carrying capacity or the growth of the fish stock in question (Armstrong and Petersen, 2008, Amstrong 2007). Models linking habitat and fishery can be used to estimate the biological and economic value of certain habitats such as sea-grass, corals and mangrove to fisheries. This models we can estimate the benefit from protecting coral reefs when implementation MPA with assumption no MPA was established.

Habitats can be divided into two sub-categories: i) Essential habitat, a type of habitat that is necessary for the survival of the stock; without habitat the fish stock will go extinct. The habitat concentrates the fish and positively affects the growth of the fish stock (Armstrong, 2009). ii) Facultative habitat, a type of habitat that will enhance the growth of the stock, but if this type of habitat disappears, it will not cause the stock go extinct. The coral reefs are used by fish species as nurseries or to protect juveniles and concentrates the fish which decreases the cost of harvesting (Armstrong, 2009). Modeling of essential fish habitat has been done in Barbier and Strand 1997 and 2002 and Foley et. al 2009. The idea of facultative habitats has been developed by Foley *et al.* 2009.

In my thesis I estimate one part of the value of coral reefs; its value to the fisheries. Both the EFH and the FH models are used in an attempt to link coral reefs with fisheries in the Khan Hoa province that to know the significance of role in coral reefs in enhancing and necessary with fish stock in Nha Trang bay MPA, Trao Reef Marine Reserve and fishery economic in Khanh Hoa province. This paper is one of the first attempts to analyze the value of coral reefs to commercial fisheries. Both the EFH and FH models will be used together with data from the period from 1995 to 2008 to estimate the value of protecting coral reefs in Khanh Hoa region. And calculate the benefit when we establish MPA from protecting coral reef in Khanh Hoa by estimate the models from 1995 to 2001 before established MPA to find coefficients of harvest function. Hence, we can estimate the harvest and benefit is lost by no established MPA with calculate how coral coverage will be lost from 2002-2008.

The following text is organized as follows: Chapter 2 provides background information about the Khanh Hoa region, the fishing fleet there, the Nha Trang MPA and the Trao

Reef Marine Reserve. Chapter 3 outlines the basic bioeconomic theory forming the fundament for the modeling of the habitat-fish stock interactions, as well as the model used for estimating the value of coral reefs to fisheries. In chapter 4 the data used are described, while results, discussion and conclusion are given in chapter 5.

2. Chapter 2: Background

2.1. Khanh Hoa Marine Resources

The Khanh Hoa province consists of 5.197 km^2 including about 385 km of seashore, canals, lagoons, bays, many islands and a large sea area. This region is the place that is not only a favorable condition for building a deep water port but is also the ideal place for breeding and growing of many aquatic species. A large proportion of the people living in the Khanh Hoa province are dependent on fishing for food and income, hence marine capture fisheries have been recognized as an important economic sector. The percentage of Gross Domestic Product (GDP) of Khanh Hoa province is generated by agriculture is about 16.33% (see http://vi.wikipedia.org/wiki/Kh%C3%A1nh_H%C3%B2a dated 19/02/2010). The fisheries sector's contribution to GDP of the entire economy in 1990 was less than 3%. In 2000 the rate was 4% and this rate continues to be maintained (http://www.khafa.org.vn/?file=privateres/htm/xnk/tt_vt.htm.aspx, dated 02/05/2010). The total population of Khanh Hoa is about 1.156.903 people, of which about 31,500 (about 2.7%) people are working directly and indirectly in fishery in Khanh Hoa (Khanh Hoa Department of Fisheries, 2009). The average income for someone working in fishery is greater than 500 US Dollar (USD) per person per year, which is higher than average income in the province which was about 309 USD per person in 2004 (Ola Flaaten, 2010), indicating that one might expect increasing pressure on fish stocks and their habitats.

In Khanh Hoa, marine resources are abundant and include a high number of species such as crustaceans, mollusks, and seaweed. The whole marine stock in Khanh Hoa Province is estimated around 92.000 – 110.000 tones (exclusive of contributions from Spratly Islands where resources are rich and bountiful, but claims of ownership are currently under dispute), occupying approximate one tenth of the national volume. More than 600 fish species have been discovered and 50 of which have considerable economic value (Tram Anh, 2008).

The main activity of fishery in Khanh Hoa is the small scale (most of them has engine power lower than 90 HP (90%), the engine power in here are the measurement of horse power for vessels and are used in fishing technology to harvest), with multi species and diversified gear types. Table 1 shows the number of boats in the region for certain HP/gear combinations.

Table 1: Characteristics of Khanh Hoa fisheries in 2007

Catogories	**Total number of vessels**		**Type of gear**									
			Trawler		**Pure seinse**		**Drift net**		**Line**		**Others**	
	vessels	%	vessels	%	vessels	%	vessels	%	vessels	%	vessels	%
Ne < 90 Hp	5,725	90.39	661	10.44	746	11.78	562	8.87	342	5.40	3,414	53.90
Ne 90 -<150Hp	512	8.08	88	1.39	6	0.09	86	1.36	70	1.11	61	0.96
Ne 150 - <400Hp	94	1.48	13	0.21	4	0.06	31	0.49	43	0.68	4	0.06
Ne >=400 Hp	3	0.05		0.00		0.00		0.00	3	0.05		0.00
Total	**6,334**	**100.00**	**762**	**12.03**	**756**	**11.94**	**679**	**10.72**	**458**	**7.23**	**3,479**	**54.93**

(Source: Khanh Hoa Department of Fisheries)

Khanh Hoa provine has two areas where coral reefs are protected, Hon Mun in Nha Trang Bay and Trao reef in Van Ninh.

2.2. Coral reefs resources

2.2.1. Nha Trang Bay MPA (Hon Mun MPA)

Nha Trang Bay is the capital city of Khanh Hoa and Nha Trang MPA is about 13,000 hectares and comprises many important habitats including coral reefs, sea-grass and mangrove areas. Nha Trang Bay houses the highest coral reef diversity of any surveyed location in Vietnam (http://www.nhatrangbaympa.vnn.vn/intro/01nhatrangbay_en.htm dated 15/12/2009).

Nha Trang Bay MPA with a great deal of essential ecosystem components such as coral reefs, sea-grass and mangrove was established in 2001. Nha Trang Bay MPA was the first project on marine protection in Vietnam, and the intention was “to improve livelihoods of local island communities and together with stakeholders to protect and manage marine biodiversity effectively as a model of marine protected areas management based on communities in Vietnam” (KimLan 2009).

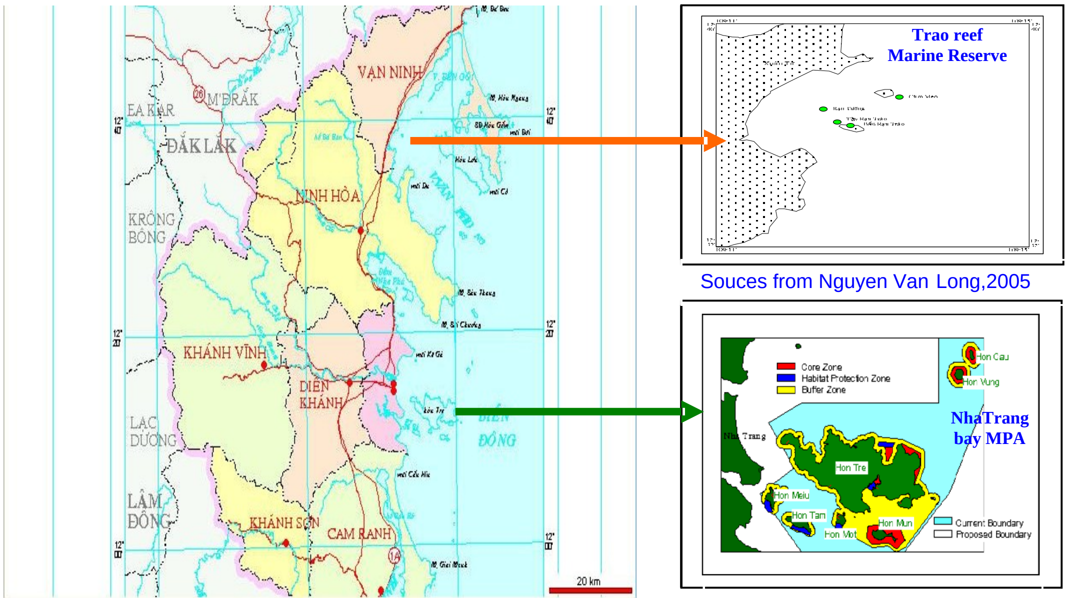
The Nha Trang Bay MPA includes a group of nine islands such as Hon Tre, Hon Mieu, Hon Tam, Hon Mot, Hon Mun, Hon Cau, Hon Vung, Hon Rom, Hon Noc and surrounding waters and located to the south of Nha Trang city, Khanh Hoa Province, on the south-central coast of Vietnam. Its total area is approximate 160km^2 of which 38 km^2 are land and 122 km^2 are waters surrounding those islands (Nam *et al*., 2005, Kim Lan 2009).

Nha Trang Bay is considered to have the highest biodiversity in comparison to other costal areas in Vietnam (Tuan et al.,2002, Kim Lan,2009). There are some 350 species of reef-building scleractinian corals (64 genera, 15 families, including distribution range extensions for some 40 species and 1 genus into Vietnam). In addition 220 species of demersal fishes (102 genera, 38 families), 106 species of molluscs, 18 species of echinoderms and 62 species of algae and sea-grass were recorded (Tuan *et al.*,2002)

2.2.2. Trao Reef Marine Reserve

Trao Reef Marine Reserve is at the coast of Van Phong Bay, Van Ninh, Khanh Hoa province. It was established in 2001 by the community in Van Hung and is one of the first examples of a Locally-Managed Marine Reserve in Vietnam with the support of the Centre for Marinelife Conservation and Community Development (MCD). Trao Reef is a small area of about 2km^2 near Xuan Tu village, and includes 25ha of coral reefs, seagrass. Trao Reef has hard coral reefs (cover about 60%) and soft coral (cover about 10%) distributed over 13 large and small reefs, this area still contains many kind of high value marine species such as abalone, sea horse, sea cucumber and sea anemone. The purpose of Trao Reef Marine Reserve is to ‘protect the reef from overfishing and destructive fishing practices, and to allow the reef to rehabilitate’ (Bronwyn J. Cumbo, 2009, P.2).

Figure 1 shows a map of the Khanh Hoa region and the location of the Nha Trang MPA and the Trao Reef Marine Reserve.



Souces from Nguyen Van Long,2005

Source from Kim Lan,2009.

Figure 1: Map of Khanh Hoa that included Trao Reef and Nha Trang Bay. (Source: http://est.congdulich.com/index.php?mod=bando&go=content&lg=vn&state=511 dated 18/03/2010)

3. Chapter 3: Theory and Models approach

3.1. Theory

3.1.1. Stocks

A group of fish of the same species that live in a defined geographical area and has the ability to reproduce itself is called a stock or a population. For marine stocks, it is difficult to know exactly the boundaries of the sock, as there can be some migrational exchange between different stocks of the same species. A stock has different characteristics that can be genetic, or due to environments, or mixture of both. (Flaaten,2009). A stock is a subpopulation of a species of fish. Total stock size is calculated in numbers or by weight of individuals which can (or potentially can) reproduce. (http://www.nefsc.noaa.gov/techniques/tech_terms.html, dated 23/04/2010).

Population or stock size is determined by intrinsic parameters (growth, recruitment, mortality and fishing mortality), so the fish stock change will be equal to

Stock change = Recruitment + Individual growth - Natural mortality – Harvest (Flaaten, 2009). In order to be able to make bioeconomic models, stock change needs to be formulated mathematically. The next section describes a basic mathematical bioeconomic model.

3.1.2. Growth of fish stocks

The following symbols will be used, where *t* indicates point in time

$X(t) =$ Stock level (weight of the stock)

$X(t) = \frac{dX(t)}{dt} =$ Change in stock per unit of time.

$F(X) =$ Natural growth function

For the natural growth function $\frac{dX}{dt} = F(X)$ the following characteristics are valid

$$(1.1)\ F'(X) = \frac{dF(X)}{dX} \gtreqless 0 \text{ for } X \lesseqgtr X_{MSY}$$

The figure 2 shows the possible shapes of the growth curve describe by function (1.1).

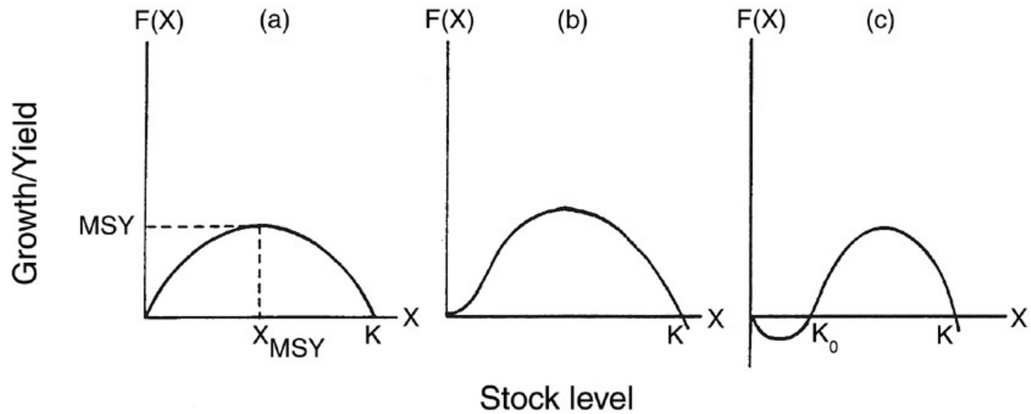


Figure 2: Growth curves with (a) compensation, (b) depensation, and (c) critical depensation. (Flaaten,2009, p.8)

The logistic growth function represented in Figure 2(a) represents a compensated growth function (growth rate always declining).

The natural growth of fish stocks can be harvested. Initially, there is no growth, then over some range of stock (up to X_{MSY}), stock growth increases. X_{MSY} is the stock level with maximum natural growth and maximum harvest is achieved, most referred to as maximum sustainable yield (MSY). After X_{MSY}, the growth of the stock is decreases.

The connection between fish stock growth and stock is supported by the ecosystem. When a stock is low, the ecosystem will support increased growth, when the stock grow, as the stock grows there will be increasing competition for more resources and the growth of the stock will be slow. When growth equals 0, this is at the maximum stock *K* (*K* is called carrying capacity of the environment and is a biological equilibrium) and occurs when stock size is zero.

Figure 2(b) represents a depensated growth function, where the growth rate firstly increases and then decreases.

Figure 2(c) is a critically depensated growth function where X_0 gives the minimum viable of stock level. If stock falls below this level, growth becomes negative and stock becomes irreversibly headed towards 0. This may be caused by management which allow too much to be harvested which leads to irrevocable stock extinction.

3.1.3. Effort and production

When a firm or a fisher catches fish, land it round, gutters or processed of the fish using inputs such as fuel, bait, gear and labour are harvesting. To produce an output the only the variable which change with each firm is these inputs. A firm or a fisher can vary the amount of inputs, but the fish stock is one kind of direct contribution from natural resource that the fishermen can not control. So for a given amount of ordinary inputs the firm's output varies with the stock level and availability of the fish. (Flaaten,2009)

The total fishing gear in use for a specified period of time is called fishing effort. When two or more kinds of gear are used, they must be adjusted to a standard. (http://www.nefsc.noaa.gov/techniques/tech_terms.html). Fishing effort is well understood conceptually but difficult to measure. Measuring the fishing effort correctly is essential for successful management. There are very heterogeneous with respect to their effect on the resource stock, and fishing power is considered to measure the potential ability of a vessel to catch fish, with this potential being defined in terms of average vessel characteristics such as size of vessel and engine power (Taylor and Prochasca, 1985). This is used to find a correct function for the effort response of each type of characteristic area which is called standardized effort and it is use by the management in order to achieve their specific goals.

Determining the fishing effort looking as factors such as hours of trawling, capacity, number of vessels is produced by optimal of inputs and is expressed in the production function.

(1.2) $E = \psi(v_1, v_2, ..., v_n)$

E is effort and v_i is factor i. This is could look like a regular production function of the firm from the theory. But, the effort E is not a final product to be sold, it play an intermediate role of an input in the production of harvest. (Flaaten,2009).

The function of effort and stock can be expressed in the harvest function and is also called "catch – the product of fish harvesting firms (production function). (Flaaten,2009)

(1.3) $H = f(E, X)$

H expresses the harvest (measured in tones, metric tones, kilograms,) of the stock.
E is the amount of fishing effort allocated to the stock.
X is stock of fishing (measures in tones, metric tones, kilograms).

The figure 3 gives the examples of two stock levels (H is high and L is low) and shows the impacted on catch in the short run at time *t*. To increase the catch it is not always necessary to increase effort (Flaaten,2009).

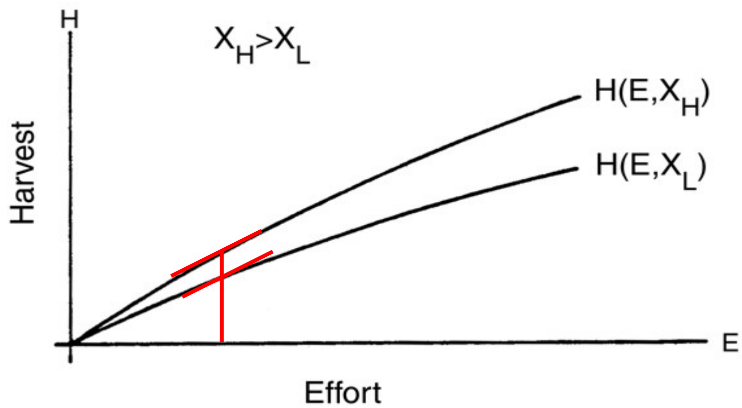


Figure 3: .Short-run variations in harvest as a function of effort. (Flaaten,2009)

The effort *E(t)* and stock *X(t)* interact. The slope of the harvest functions above is the marginal product of effort *E*. When stock $X_H > X_L$, then the marginal product is higher at a given level of effort *E*. (Steven C. Hackett).

3.1.4. Yield and stock effects of fishing

We assume $X=K$ represents an "unexploited' fishery. If the harvest H everywhere is higher than the growth rate $F(X)$, X will fall to zero. When $H_{MSY} > F(X)$ it will causes X to decline. This process will continue until $X = X_{MSY}$, at which point $H = F(X)$ and no further reduction in stock occurs. On the other hand, if the fishery had been over-harvested in the past and the stock is at $X<X_{MSY}$, then $H_{MSY}>F(X)$, which causes X to decline. This process continues until $X= 0$, the stock will be extinct.

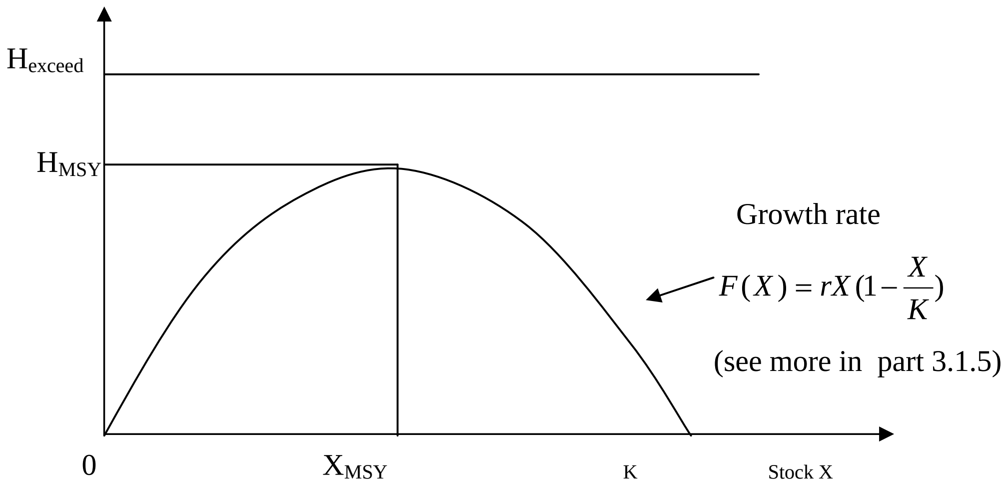


Figure 4: Harvest and growth rate mechanisms (Steven C. Hackett).

Fish stock levels are affected by total harvest and growth of stock. The growth equation expresses the change in stock.

(1.4) $\dot{X} = F(X) - H$

From this equation follows (1.4) $X \gtrless 0$ if $H \lessgtr (X)$

The growth of the stock harvest must be lower than the natural growth. Biological equilibrium is by definition achieved when $\dot{X} = 0$.

(1.5) $f(E, X) = F(X)$

This equilibrium harvest is often called sustainable yield since it can be sustained by the stock for a given level of effort.

To simplify the analysis we now assume that the short run harvest function is linear in effort and stock level:

(1.6) $H = qEX$

This harvest function is called the Schafer function as it was discovered in 1957. This function is highly restrictive. To simplify analysis, we need to assume that both stock X and effort E is homogeneous to follow the conditions of this function. q is a constant that expresses the effectiveness of the effort at a given in the stock level. When the effort is measured in, for example, days at sea, q gives the rate between catch per day at sea $\frac{H}{E}$, and stock level X. So that, q is directly related to the scaling of E. (Flaaten, 2009)

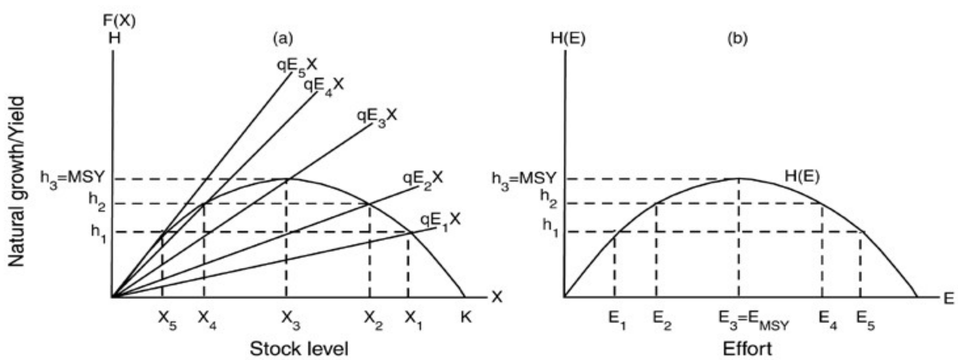


Figure 5: The sustainable yield curve shows harvest as a function of effort and is derived from the natural growth curve and the harvest curve. (Source: Flaaten, 2009)

From figure 5, the yield functions, not every point is sustainable (growth = catch). Only one point for each Yield function is sustainable. In the figure there are five harvest functions, thus yielding five equilibriums points. We assume there are many harvest functions in figure 5; this will give many points that connect to become equilibrium growth function.

The short run harvests for five different effort levels are the straight lines can be shown in panel (a) of figure 5. For the smallest effort E_1 the harvest curve crosses the growth curve with high stock X_1 and relatively small catch H_1 to over a sufficiently long time. The higher effort level E_2 gives a lower stock X_2 but higher sustainable catch H_2. However in higher effort like E_4 with stock X_4 lower than X_2, the sustainable catch H_4 still equal H_2. In Figure 4 the highest possible harvest is reached for effort level E_3 and this harvest is called the maximum sustainable yield (MSY).

In figure 5, the natural growth $F(X)$ stock level curve in panel (a) has been converted into the sustainable harvest $H(E)$- effort curve in panel (b) that also call the sustainable yield curve and it is the long run harvest potential to fishing effort. This is the same form as the growth curve of Schaefer short run harvest function $H = f(E, X)$ and linear in both effort and stock. The difference between is the short run harvest function in panel (a) described as straight lines that are used for any combination of effort E and stock X at any time, but sustainable yield curve $H(E)$ that is the conditional on equilibrium harvest. (Flaaten,2009)

3.1.5. The Gordon-Schaefer model

"The Gordon–Schaefer model is a bioeconomic comparative static fishery model based on logistic biological growth, constant harvest price, constant unit cost of effort, and harvest linear in stock biomass and fishing effort."
(http://demonstrations.wolfram.com/TheGordonSchaeferModel/, date 24/04/2010).

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In the 2nd part (effort and production) a bell shaped graph is used to show for natural growth as a function of stock size. The logistic growth function is a mathematical equation of biomass growth of an animal stock. (Flaaten, 2009).

Stock change per unit of time is show by the equation:

(1.7) $$\frac{dX}{dt} = F(X) - H$$

This function is named by economist H. Scott Gordon and biologist M. B. Schaefer in 1954 and is based on the logistic type natural growth equation. (Flaaten, 2009).

(1.8) $F(X) = rX(1 - \frac{X}{K})$

P. F. Verhulst, 1938, was the first person that designed and discussed the equation (1.8), then R.Pearl,1925 re-discovered.

(1.9) $H = qEX$

In Schaefer (1957) catch and effort data were used to estimate fish stock changes. In the equilibrium for this model that harvesting means $\frac{dX}{dt} \equiv 0$ and catch means $H \equiv F(X)$ in equation (1.7) and from (1.9) follows $X = \frac{H}{qE}$. Substituting this expression for X in (1.8) gives

(1.10) $H = \frac{rH}{qE}(1 - \frac{H}{qEK})$

Rearranging equation (1.10) somewhat gives

(1.11) $H = H(E) = qKE(1 - \frac{qE}{r})$ when $H \equiv F(X)$ (Flaaten, 2009)

The two equations (1.11) and (1.8) are quadratic functions, the equilibrium harvest function (1.11) is quadratic in the product qE, while natural growth function (1.8) is quadratic in X. The product qE has to be less than r to have a positive harvest in (1.11). If qE is equal or higher than r the stock becomes extinct and makes equilibrium harvest as zero. (Flaaten, 2009).

- The open access fishery:

Assume there are no property rights in the fishery so anyone can catch as much fish as much as he or she wants, this is usually called "open access".

The analysis of effort and stock levels in the equilibrium of open access conditions are affected by changes in parameter values. With a competitive market, p is the price of fish landing at quay, which may dependent on quality and/or quantity of fish that is landed, but is treated as a constant in this model. In open access, equilibrium can only occur when marginal cost of effort (*MC(E)*) is equal to average revenue of effort (*AR(E)*) (no incentive to enter or exit). If the cost function is linear in effort, this also implies that profit is zero. Here total cost $TC = cE$, and total revenue $TR = pH$ so that profit equal zero when *TC*=*TR.*

Economic efficiency occurs when the quantity of effort is selected where *MR* = *MC*. Yet under open access, the equilibrium level of effort is occurs where *MC* > *MR*. So open-access equilibrium always features an inefficiently with large amount of effort in the fishery.

Bioeconomic efficiency is in the effort levels where stocks are greater than or equal to MSY. Open access can be bioeconomically inefficient when low marginal effort costs *c* result in high levels of effort that can make stocks below MSY.

So the open access can occur when efforts to manage fisheries by the government, private or common property have failed. Each vessel gives a reduction in the stock, thereby causing an externality to others, thus generating harvest costs that are higher for all vessels.

Price p of fish is assumed constant. p is multiplied by quantity in equation (1.11), we have the total revenue

(1.12) $TR(E) = pH = pqKE(1 - \frac{qE}{r})$

The total revenue $TR(E)$ curve and the harvest $H(E)$ curve in the figure 4, panel (a) is for $p > 1$, so that the harvest curve is above total revenue (Flaaten,2009).

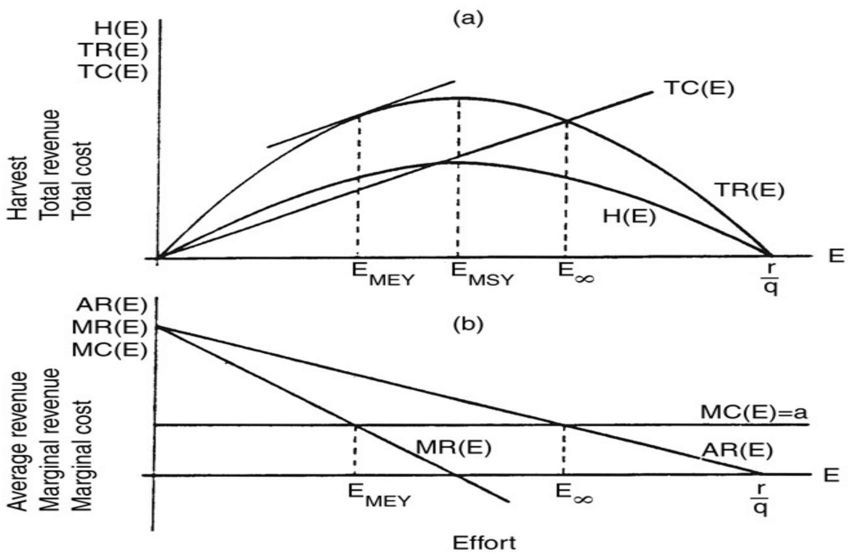


Figure 6: The sustainable harvest and revenue curves, as well as total cost, are shown in Panel (a), and the marginal and average revenue and cost curves of the Gordon - Schaefer model are shown in Panel (b) (Flaaten, 2009.)

Assuming a constant of unit cost of effort c, total harvest costs increase with effort, so total cost equals

(1.13) $TC(E) = cE$ -> (1.13') $AC(E) = c$

This equation (1.13) is the straight line like in figure 6, panel a. Panel b shown that $MC(E) = AC(E) = c$ in the open access condition. From equation (1.12) to find average and marginal revenue of effort equals

(1.14) $AR(E) = \frac{TR(E)}{E} = pqK(1 - \frac{qE}{r})$ (Flaaten, 2009)

In figure 6, panel b shows the average revenue $AR(E)$ curve is a straight downward sloping line. When E is close to zero the $AR(E)$ is close to its maximum, and the equilibrium stock level will be close to its carrying capacity K. Average revenue $AR(E)$

move to zero when the effort E close to $\frac{q}{r}$. The stock will be extinct when the effort kept at $E > \frac{q}{r}$ for a long time. (Flaaten, 2009)

In the open access equilibrium, total revenue is equal total cost in equilibrium with no fishermen entering or existing to the fishery. Combine equation (1.12) with (1.13) to find open access effort level for Gordon-Schafer model

$$(1.15) \quad E_{\infty} = \frac{r}{q}(1 - \frac{c}{pqK})$$

From this equation, open access equilibrium of fishing effort depends on both biological and economic parameters. With a given ratio of intrinsic growth rate r, increased fish price p and carrying capacity K, and effort cost decrease.

So that substituting E_{∞} from equation (1.15) for E in equation (1.11) to find equilibrium harvest in open access condition (Flaaten, 2009)

The unit cost of harvesting and the resource rent per unit harvest are used of equation (1.9) and (1.13) become:

$$(1.16) \quad c(X) = \frac{TC(E)}{H} = \frac{cE}{qEX} = \frac{c}{qX}$$

This shows that the unit cost $c(X)$ of harvest decreases with an increase in stock size X. So that, increasing stock size X will have a cost-saving effect of the fishery. The price of fish, p, remains constant, the resource rent per unit harvest is

$$(1.17) \quad b(X) = p - \frac{c}{qX}$$

The stock level X_∞ can be found follows the equation (1.17) in the open-access equilibrium $b(X) = 0$, we have

(1.18) $X_\infty = \dfrac{c}{pq}$ (Flaaten,2009)

Function of economic and harvest technical parameters give the model of the open access equilibrium stock level. The functions (1.15) and (1.18) are given the stock and effort in the equilibrium under open access. (Flaaten, 2009).

The theory above is the basic background for fisheries economics and management. This theory can be extended in a number of ways in order to do both theoretical and empirical research deemed necessary for the economy and society. In the part 3.2 I will use a part of the literature which has extended the basic theory to include interactions between the fish stock and its habitat. Two models, the essential fishery habitat model and facultative habitat model are described. Both models will be used to estimate the linkage between coral reefs and fisheries and are based on the theory decribed in part 3.1.

3.2. Models approach

The models used in the analysis of fisheries benefits from coral reefs follow Barbier and Strand (1998) and Foley *et al.* (2009). Barbier and Strand (1998) value the mangroves with indirect value with fishery linkages, and Foley *et al.* (2009) is valuing the indirect value of cold water coral linkages with redfish under open access conditions. Both studies suggest that they are important of habitats (mangroves and cold water coral, respectively) and suggest they are an essential input to the fisheries.

In the following two different models of interactions between habitats and fish stocks will be presented. The first is the Essential Fish Habitat (EFH) model presented by Barbier and Strand (1998), in which the habitat is considered essential to the stock. The second model suggests that the habitat is preferred or facultative, in which case the presence of the habitat enhances the stock but is not essential to the survival of the species. Both models are based on the Gordon Schaefer model which is a single species biomass model, where effort is the control variable, and fish stock is the state variable (Foley *et al*. 2009),

Variables in the models:

- $L(t)$: Area of coral reefs cover at time *t*.
- $E(t)$: Effort of trawler fishing at time *t*.
- $F(X_t, L_t)$: Biological growth at time *t* was modified with allow for the influence of coral reefs.
- $h(X_t, E_t)$: Net of harvesting at time *t*.

In a model of essential habitat, Barbier and Strand (1998) alter the standard open access bioeconomic model to allow for the influence of habitat on a commercial fish stock. Following Barbier Strand (1998) that choose discrete time model of the open access fishery, define X_t as the biomass of stock at time *t*, changes in growth can be express as:

(2.1) $X_{t+1} - X_t = F(X_{t,} L_t) - h(X_t, L_t)$; $F_X > 0; F_L > 0; F(X,0) = 0$

Barbier and Strand (1998) modify the logistic growth function to iclude the effect of mangrove forest on the growth of a shrimp stock. Here, the logistic growth function is adjusted to allow for the influence of the coral reefs as habitat for fish stocks, for purposes such as nursery and breeding ground. The size of the coral reef is denoted by L and growth is defined by:

(2.2) $F(X_t, L_t) = rX_t[K(L_t) - X_t]$

In the equation (2.1) there are several forms to express the growth and harvest functions. Barbier and Strand (1998) follow the easily of analytical models and assume a simple version of the Schaefer Gordon model (2.2). Thus they also assume a basic Schaefer production process for harvesting h_t

(2.3) $h_t = qX_tE_t$

Where q_t is the 'catchability' coefficient. Substituting Equation (2.2) and equation (2.3) to equation (2.1), resulting in the equation (2.4)

(2.4) $X_{t+1} - X_t = [r(K(L) - X_t) - qE_t]X_t$

Where r as the intrinsic growth of fish each period, K is the environmental carrying capacity of the system and coral reefs area, L has a positive impact on carrying capacity.

Following standard analysis, we assume the fishing effort next period will adjust in reaction to the real profits in the current time. Letting p represent constant fish prices per unit harvested of fish, c the real unit cost of effort and $\phi > 0$ the adjustment coefficient, then the fishing effort equation is

(2.5) $E_{t+1} - E_t = \phi[ph(X_t, E_t) - cE_t]$ (Barbier and Strand (1998))

3.2.1. In open access equilibrium

In equilibrium, both the stock and the level of fishing effort are assumed to be constant over time such as $X_{t+1} = X_t = X$ and $E_{t+1} = E_t = E$. In addition, we assume initially that the coral reef area is at equilibrium, i.e. $L_{t+1} = L_t = L$. Equations (2.4) and (2.5) can therefore be solved for steady state levels of fish stock X and effort E

(2.6) $X_\infty = \dfrac{c}{pq}$, for $E_{t+1} = E_t = E$

(2.7) $E_\infty = \dfrac{r[K(L) - X]}{q}$, for $X_{t+1} = X_t = X$ (Barbier and Strand (1998))

We rearrange function (2.7) and substitute function (2.6) into function (2.7), we can have the effort level in the open access

(2.7') $E_\infty = \dfrac{r}{q}[1 - \dfrac{X}{K(L)}] = \dfrac{r}{q}[1 - \dfrac{c}{pqK(L)}]$

Compared with the Gordon Schafer in the function (1.15) of effort and (1.18) of stock at the open access equilibrium, the stock in function (2.6) and (1.18) are the same and depend on unit cost of effort c , unit price of fish p and catch-ability coefficient q. The effort in function (1.15) and (2.7') are the same exception the K in (2.7') depend on coral reef cover L.

3.2.2. Estimation of Coral reefs Fishery Linkages

a. Essential Fish Habitat (EFH) model

A ratio connecting between coral reef area and carrying capacity is assumed. Let $K(L) = \alpha L, \alpha > 0$. Substituting the harvest function into the effort function (equation number) with $K(L) = \alpha L$, we have the function of harvest with a linkage between the fish stock and the coral reefs, and the linkage is constructed in a way that demonstrate coral reefs are essential for the existence of the stock. We also call the Essential Fish habitat model. (Foley *et al.* 2009)

(2.8) $$h_t = qE_t K(L_t) - \frac{q^2}{r} E_t^2 = q\alpha E_t L_t - \frac{q^2}{r} E_t^2$$

b. Facultative Habitat (FH) Model:

Now we consider the coral reefs and fish with the facultative linkage. In this case the coral reefs may enhance the stock of the species, and may contribute to wide variation in recruitment, but are not necessary for the survival of the species. (Foley et.al,2009)

The growth function now becomes;

(2.9) $$F(X_t, L_t) = rX_t(K + \beta L_t)(1 - \frac{X_t}{K + \beta L_t})$$

Where β is a coefficient that shows what degree K and r is affected by L. Assuming the effect of coral reefs on the growth of the fish stock is positive, $\beta \geq 0$. When $L \geq 0$ the species is assumed to find alternative coral reefs and continues to grow. To substitute it into the steady state level of effort E and the harvest function for the facultative habitat model is (Foley *et.al*,2009)

(2.10) $$h_t = qKE_t + qE_t \beta L_t - \frac{q^2}{r} E_t^2$$

3.2.3. The Comparative Static Effects of a Change in Coral reefs cover

From Equation (2.4) and (2.7), the comparative static effect of a change in the coral reefs area on the equilibrium level of fishing effort, for examples point A, E^A is fishing effort in the equilibrium at A:

(2.11) $r[\alpha dL - dX^A] - qdE^A = 0$

The effect of a marginal increase in the coral reef size on effort, measured in equilibrium A, is then

Or (2.11') $\frac{dE^A}{dL} = \frac{\alpha r}{q} > 0$

Hence, the loss of the coral reefs area will result in a lower of equilibrium fishing effort. From equation (2.11) and (2.6), the loss of harvest is express in equation (2.12);

(2.12) $dh = qXdE = \alpha rXdL = \frac{\alpha rc}{pq} dL > 0$

So, the change in gross revenue of the fishery is;

(2.13) $pdh = \frac{\alpha rc}{q} dL > 0$

A reduction of coral reefs area will result in a decline in both fishery harvest and the gross revenue. The impacts of this loss are based on the biological and economic parameters of model (α, r and q) combined with prices and costs for the fishery (p and c), the effects of the comparative static value of coral reefs can be estimated by the revenue generated by the fishery. (Barbier and Strand,1998)

4. Chapter 4: Data

4.1. Secondary data

4.1.1 Data of catch and effort

The secondary data about harvest (total catch); effort (engine power by horse power Hp) in Khanh Hoa from 1995 to 2008 is from the Khanh Hoa Department Fisheries. Figure 7 shows the development in effort and harvest over this period.

There are some data about the cover of coral reefs in the report of Hon Mun MPA and Local Marine Life Conservation and Community Development (LMCD). However, these data come from two independent surveys and have a limited number of observations between 1995 and 2008. To run the two models, it was necessary to make an assumption about how coral reefs changed before and after the establishment of the MPA in Nha Trang and Trao Reef Marine Reserve. It was therefore assumed in Trao Reef Marine Reserve coral reefs cover was reduced by 1 ha per year prior to the establishment of the MPA, but after the MPA established coral reefs cover increased by 0.5 ha per year. For Nha Trang MPA it was assumed that before the was MPA established in Hon Mun, the coral reefs cover was reduced 5 ha per year, and after it increased by 3 ha per year.

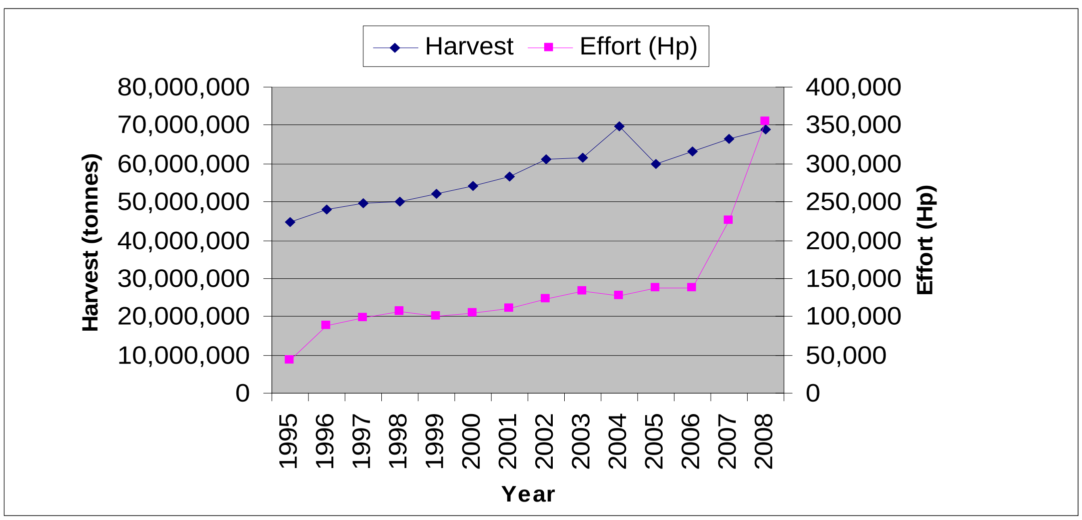


Figure 7: Development in harvest and effort in the period 1995-2008 of Khanh Hoa.

Figure 7 shows that harvest and the effort increased from 1995 to 2005. Until 2006-2008, the effort was increasing rapidly, while the harvest increasing only slightly. In 2005, the government started subsidizing the fuel for the fisherman, which may be a reason for the increase in engine power seen in the following period.

4.1.2. Data of coral reefs

In Nha Trang Bay MPA, the coral reef cover shows improvement after the establishment of the Hon Mun MPA (Nha Trang Bay MPA), because of bans on destructives fishing practice and poison fishing in the core zone and buffer zone (Tuan Vo, 2005). Table 2 shows the status for the coral reef for 2002 and 2005.

Table 2: Approximated the cover of coral reef in Nha Trang Bay

Coral reef type	**Approx.Area (ha),% of tow**	
	2002	**2005**
Coral reef / community - good condition (live cover > 11 % and > dead cover)	73 ha, 24%	78 ha, 28%
Coral reef / community - degraded (live cover ≤ dead cover)	101 ha, 33%	109 ha, 39%

Source: Marine and coastal habitats of Nha Trang Bay Marine Protected Area, Khanh Hoa, Vietnam, Reassessment 2002-2005 (Tuan Vo, 2005,P.20)

- <u>Notes:</u> Coral reef / community - good condition (live cover > 11 % and > dead cover) means the that a coral reef in good condition has 11% greater area of live coral reef then dead coral and that the area of live coral is greater than the area of coral reef dead. Similarly with coral reef /community-degraded (live cover ≤ dead cover) means that the coral reef has a lower percentage of live cover than death cover.

From table 2, we can see that from 2002 to 2005 (4 years), the coral reefs increase about 14 ha, so each year after establish MPA, the coral reefs increase about 3 ha per year.

According to the previous assumption, in Trao Reef before the MPA was established the coral reef cover was reduced by 1 ha per year and after it increased by 1 ha per year. In

2001 the total covers increase 1 ha per year. When we look at the table showing the coral growth in the reserve during this period (table 3), the coral growth in Trao Reef is unstable, it looks like a small increase in coral cover during this period.

Table 3: The percentage of coral reefs cover in Trao Reef

Year	Trao Reef North (%)		Trao Reef West (%)		Cum Meo (%)		Tuong Reef (%)	
	HC	SC	HC	SC	HC	SC	HC	SC
2001	43	11					5	15
2003	40	12					6	13
2004	39	14	29	5	10	3	15	5
2005	19	23	31	4	13	4	7	31
2009	37	19	47	7	22	2	8	28

(Reef Check Assessment Report, 2009**,** Bronwyn J. Cumbo,2009 in Trao reef.)

- Note: HC is hard coral reef and SC is soft coral reef.

The area of Trao Reef consists of about 40 ha of protected buffer zone and about 27 ha of coral reef which is the core zone in 2004 (International Marinelife Alliance (IMA) and Van Ninh district committee report, 2004). I assumed that the coral reefs cover in Ran Trao in 1995 was about 30 ha, from 1995 to 2001 the cover was reduced by 1 ha per year. After established Marine Protected in Trao Reef in 2001, the coral reef was cover has increased 1 ha every two year.

4.2. Primary data

4.2.1. Data of catch and effort

The Khanh Hoa fishery is multi species fishery. We normally use the term multispecies for fisheries were it is possible to target one species at the time, Since data on catch by species and gear is not available, this analysis will use data from the catch of all species. Furthermore, there is no data on days at sea; hence real effort is impossible to calculate. Instead, two measures of potential effort are used as proxies; total number of vessels and total fleet engine power (measured in horse power (Hp)).

Some primary data was collected to examine the appropriate measure for effort. During this survey some information about cost and price of fish were also gathered in order to investigate the effect of coral reefs on the fishery in Khanh Hoa.

I collected 150 samples, divided on each categories for each type of gear in three main fishery areas of Khanh Hoa which are Nha Trang Bay (90 samples), Cam Ranh (30 samples) and Van Ninh (30 samples).

Table 4: Number of vessels in types of gear in 2007 of Khanh Hoa

Catogories	Total	samples		Type of gear					
				Trawler	samples		Pure seinse	samples	
	vessels		%	vessels		%	vessels		%
Ne < 90Hp	5,725	95	1.66	661	15	2.27	746	20	2.68
Ne 90 -<150Hp	512	34	6.64	88	5	5.68	6	2	33.33
Ne 150 - <400Hp	94	19	20.21	13	5	38.46	4	2	50.00
Ne >=400Hp	3	2	66.67						
Total	**6,334**	**150**	**2.37**	**762**	**25**	**3.28**	**756**	**24**	**3.17**

Catogories	Type of gear								
	Drift net	samples		Line	samples		Others	samples	
	vessels		%	vessels		%	vessels		%
Ne < 90Hp	562	10	1.78	342	10	2.92	3,414	40	1.17
Ne 90 -<150Hp	86	10	11.63	70	10	14.29	61	7	11.48
Ne 150 - <400Hp	31	5	16.13	43	5	11.63	4	2	50.00
Ne >=400Hp				3	2	66.67			
Total	**679**	**25**	**3.68**	**458**	**27**	**5.90**	**3,479**	**49**	**1.41**

(Source: Fishery Department of Khanh Hoa)

The variation in CPUE by engine power (kg/Hp/day) in my samples is larger than the variation in CPUE based on number of vessels (kg/vessel/day). For example, in 2009, the maximum CPUE (kg/Hp/day) of total types of gear is 7.33 kg/Hp/day, and the minimum is 0.63 kg/Hp/day, so the maximum is about 12 times higher than the lowest measure.

However the maximum CPUE (kg/vessel/day) is 1175 kg/vessel/day, and the minimum is 8.5 kg/vessel/days, implying that the maximum is more than 138 times higher than about the lower measure. Thus I decided to run the models with engine power (Hp) as an indicator of effort.

This data I used only to compare the CPUE by engine power (Hp) and CPUE by number of vessels to choose the best approximation on effort in secondary data to apply in the models.

4.2.2. Data of price and cost

Since I use total harvest of all species to run the model, I use weighed average prices. This is necessary because of each kind of fish is sold at a difference price. Season and quality also affect the price of fish. The data price of my thesis is not exactly for all kinds of fish, it is only significant as an average price to estimate to average revenue of coral reefs.

First, I collected data of different kinds of fish from middle man who buy fish directly from the fishermen. The fishermen also have the notebook in which they record the price of fish during this period, but sometime it does not correspond to the price quoted by the middleman. The fishermen that I spoke to, do not known exactly the price of fish during this period, but on occasions I got them to check the information from middle man regarding the price at the time the fish was purchased. I got data from the Khanh Hoa Fishery Department about the percentage of fish, shrimp and squid in weight during this period. Then I divide fish to 6 main species (belt fish, yellow fin tuna, skipjack tuna, scad fish, mackerel and anchovy fish), using the assumption that individuals of the same category have the same weight. There are other commercial fish, but there volume is small and I have placed them into another category for the purpose of this analysis. The shrimp and squid are divided in to 3 kinds, and it is assumed that they are harvested in equal amounts. Shrimps include coral shrimp, baby shrimp and tiger shrimp and squids include broad squid, cleaned squid and cuttlefish squid. The average price is calculated by using the percentage in weight of each species, and then an average price is calculated for the whole harvest. Because of some species are only present in a low quality and cannot assign specific statistics to them so I include them in another category.

To find the unit cost of effort, *c*, I used the condition for the open access equilibrium, total revenue equal total cost, $pH = cE$, implying $c = \frac{pH}{E}$.

Table 5: The average price and cost of fish in Khanh Hoa

Year	Effort Total engine power (Hp)	Harvest (kg)	Price (VND/kg)	Cost (VND/Hp)
1995	43,668	44,520,000	15,618	15,922,963
1996	87,692	47,800,000	16,437	8,959,369
1997	98,033	49,500,000	16,329	8,244,827
1998	105,844	50,000,000	19,084	9,014,933
1999	100,028	52,000,000	21,116	10,977,117
2000	105,028	54,087,000	22,105	11,383,604
2001	111,578	56,645,000	24,517	12,446,429
2002	123,900	60,972,000	25,632	12,613,780
2003	132,602	61,735,000	26,124	12,162,334
2004	127,260	69,702,000	26,485	14,506,300
2005	137,000	59,702,000	31,138	13,569,484
2006	137,778	63,118,000	32,869	15,057,621
2007	224,775	66,610,000	33,688	9,983,063
2008	354,121	68,800,000	34,956	6,791,294
mean	**134,951**	**57,513,643**	**24,721**	**11,545,223**

As can be seen in the table 5, the price shows that increased during this period. The figure used to calculate in the result part at mean of effort is 134,951 Hp can be harvest about 57,513 tones. With average cost of effort is 11,545,223 VND per year (about 608 USD) and unit average price of fish is 24,721 VND (about 1.3 USD)

5. Chapter 5: Results and discussions

5.1. Result:

5.1.1. Parameter estimates and test statistics coefficient of two models

The results from the estimations of equations (2.8) and (2.10) are listed in table 6:

Table 6: Parameter estimates and test statistics: results of statistic analysis, parameter estimates and t-statistics

Dependent Variable: harvest (kg)
(mean: 57.513.643 kg)

Model A: Essential Habitat	
Coral reef (L)(ha) * Effort (E)	3.192*
Effort squared (E^2)	- 0.002*
Adj R^2	0.980
Dubin Watson(2,14)	1.584
F(2,12)	350.849
Model B : Facultative Habitat	
Effort (E)	676.390**
Coral reef (L) * Effort (E)	- 0.162**
Effort squared (E^2)	- 0.001*
Adj R^2	0.983
Dubin Waston(3,14)	1.566
F(3,12)	266.364

* Significant at $\alpha \geq 0.05$; ** significant at $\alpha \geq 0.1$

For the EFH model, all coefficient estimates are significant at the 5% level. So in the remaining analysis of the economic impacts of reductions in coral reef coverage, I use the results from the EFH model

The sign of the variables are as expected in the EFH model, a result which corresponds with the findings of Barried Stand (1997) and Foley *et al*. (2009). The coefficient on EL is positive and equals 3.192 and the coefficient on E^2 is negative and equals -0.002. This means that when Effort (Hp) x coral reef cover (ha) increases (decreases) 1 unit, the harvest will be increase (decrease) by 3.192kg. Contrary to the impact of EL on harvest, effort squared (E^2) has a effect negative on harvest, i.e. when the E^2 increase (decrease) by 1 unit, the harvest decrease (increase) by 0.002 units.

Parameter estimates for the facultative habitat are mostly significant at the 1% level, with the exception of our estimates for E^2 which is significant at the 5% level. The sign of the coefficient on *EL* in the FH model is negative. The reason for the unexpected finding may be that the data that I use is highly aggregated. Some species might be independent of the coral reef and may be dependent on the other kind of habitat such as mangroves or sea grass. If there is no destruction of these habitats or if it occurs at a slower rate then the destruction of corals, there might be an increase in the harvest of these species of fish that outweighs the loss of harvest of coral-dependent species. This theory is supported by the findings from when I run the regression of 2.9 using all kinds of habitat in Nha Trang Bay and Trao Reef as *L*. In this case the habitat/fisheries interaction term gets the expected sign (see results in table 7).

Table 7: Parameter estimates and test statistics for the facultative model with include all habitats: results of statistic analysis, parameter estimates and t-statistics

Dependent Variable: harvest (kg)
(mean: 57.513.643 kg)

Effort (E)	0.161**
Coral reef (L) * Effort (E)	0.001**
Effort squared (E^2)	- 0.001144*
Adj R^2	0.983
Dubin Waston(3,14)	1.696
F(3,12)	294.187

*Significant at $\alpha \geq 0.05$; ** significant at $\alpha \geq 0.1$

From the histogram of SPSS program (Figure 8), the error terms are independently normally distributed with mean nearly zero, standard deviation is approximately equal about 0.9 and variance σ^2, and when we looked at the graph of histogram of SPSS, both of models show a normal distribution. The figures are used are time series data, so that we need to test autocorrelation by using the Durbin Watson test.

The Durbin-Watson test statistic tests the null hypothesis that the residuals from an ordinary least-squares regression are not autocorrelated against the alternative that the residuals follow an AR1 process. The Durbin-Watson statistic ranges in value from 0 to 4. A value near 2 indicates non-autocorrelation; a value toward 0 indicates positive autocorrelation; a value toward 4 indicates negative autocorrelation. The rules for when we must reject the hypothesis of no autocorrelation are summarized in table 8.

Table 8: The practice to using test autocorrelated in Durbin –Watson

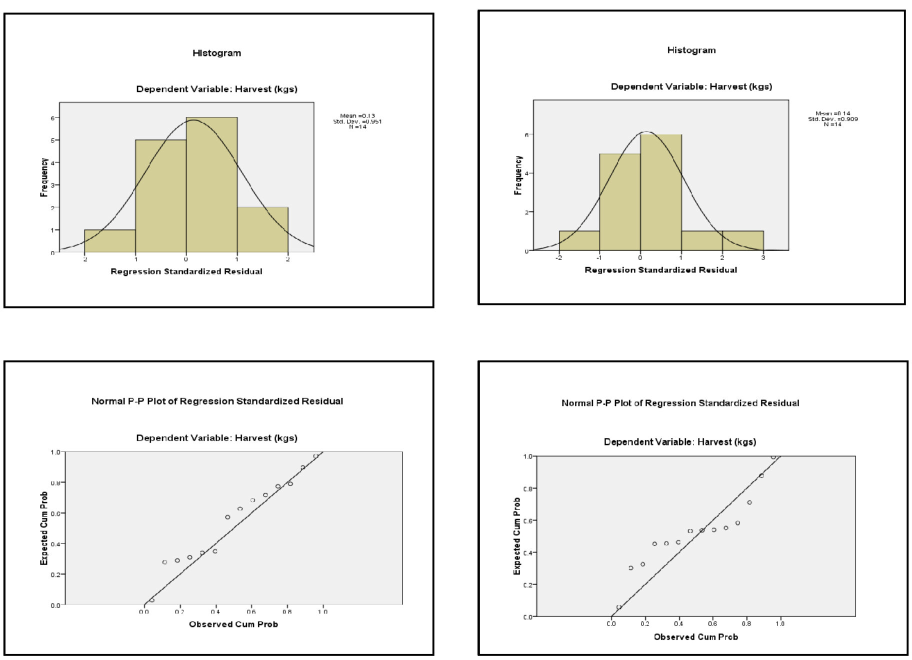
Hypothesis H_0	**Decided**	**If**
Non positively autocorrelated	Reject H_0	$0 < d < d_L$
Non positively autocorrelated	Inconclusive	$d_L \le d \le d_U$
Non negatively autocorrelated	Reject H_0	$4 - d_L < d < 4$
Non negatively autocorrelated	Inconclusive	$4 - d_U \le d \le 4 - d_L$
Non positively and/or negatively autocorrelated	Do not reject H_0	$d_U \le d \le 4 - d_U$

Source: Econometrics textbooks - Faculty of statistics - Ministry of Economy Math - University of Economics Ho Chi Minh City, 2004

From Durbin-Watson tables, when the regression does not contain an intercept term, refer to Farebrother, denoted d_M (Table A.3), instead of Savin and White, lower bound d_L (Table A.1). Durbin-Watson Statistic: 1 Per Cent Significance Points of d_M and d_U.

Using the table d_M and d_U in statistics d (Durbin-Watson Significance Tables), in two case of model the value of DW are tested hypothesis H_0 is non positively and/or negatively autocorrelated. The result give d of DW(2,14)=1.566 is the range (0.552,1.254) by using the Durbin-Watson Significance Tables for EFH model that $d_U = 1.254 \leq 1.566 \leq 4 - d_U = 4 - 1.254 = 2.746$ and similarly for facultative model d of DW (3,14)=1.696 is the range (0.448,1.490) that $d_U = 1.490 \leq 1.696 \leq 4 - d_U = 4 - 1.490 = 2.510$. We can not reject H_0, and both models have not autocorrelated.

The overall P value (prob>F) is significant for all ranges rejecting the hypothesis that all explanatory variables are simultaneously equal to zero. The F-statistic is significant: to reject the hypothesis that all coefficients are equal zero, each of them is have the significant in the model.



EFH model Facultative model

Figure 8: The empirical histograms and standardized residual of EFH and FH models,

5.1.2. Comparative Static for an Essential Habitat

Due to the unexpected signs of the coefficient on $L*E$ in the FH model, the comparative static will only be done for the EFH model. From the table 7, I calculate the marginal productivity, output elasticity estimates, elasticity and harvest and revenue loss results are equal from equation (2.8) with coefficients of $q\alpha = 3.192$ and $-\frac{q^2}{r} = -0.002$ at mean of E, h and L.

The marginal productivity of coral reefs thus calculated equals

$$(4.1)\quad MP_L = \frac{\partial h}{\partial L} = q\alpha E$$

From the result of table 7 and equation (4.1), we can calculate the marginal productivity of coral reef MP_L = 430,762 kg, which means for one ha of coral reefs area will change more than 430 tones at an average level of effort.

The output elasticity of coral reefs at mean effort is calculated by the equation

$$(4.2)\quad \in_{h,L} = \frac{\partial h}{\partial L}\frac{L}{h} = MP_L \frac{L}{h}$$

Output elasticity equals 1.589 by using mean *L* and *h* values. It describes the coral reefs area is increasing returns to scale, so that coral has a more than proportionate impact on the output of fish in Khanh Hoa.

The marginal productivity of fishing effort will be:

$$(4.3)\quad MP_E = \frac{\partial h}{\partial E} = q\alpha L - 2\frac{q^2}{r}E$$

The marginal productivity of fishing effort is negative in 2007 and 2008. This means that increased fishing effort in 2007 and 2008 had a significant negative impact on fishing production. At mean of effort and coral reefs cover, the marginal productivity equal more than 137 kg, when effort is increased by one unit of effort, the harvest changes by about 137 kg.

The output elasticity of effort equals

$$(4.4)\quad \in_{h,E} = \frac{\partial h}{\partial E}\frac{E}{h} = MP_E \frac{E}{h} = 0.322$$

implying decreasing return to scale at mean of effort and harvest. This equation indicates that for each of effort engine power horse power (Hp) increases, the output (harvest) will be increase by a less than proportionate amount.

From 1995 to 2008, effort increased with more than 7 times (700%), however the harvest only increased by about a half (54%). The output elasticity with regards to effort in the open access management leads to the negative effect on fish production.

Table 9: Marginal Products, Output Elasticity and Comparative Statics

MP_L	430,761.996
$E_{h,L}$	1.589
MP_E	137.358
$E_{h,E}$	0.322
Marginal change in equilibrium harvest (∂h)(kg)	680,188.469
Marginal change in equilibrium revenues ($p\partial h$) (VND)	16,815,030,839.975
% marginal change in annual revenues and harvest	1.183

Note: The marginal productivities, MP_L, MP_E and output elasticity $E_{h,L}$, $E_{h,E}$ estimates are evaluated at the mean coral reef cover $L = 212$ ha and effort level $E = 134{,}951$ HP.

The assumption in the open access condition is that total revenues equal total costs. From the result of regression the change of harvest at means point when 1 ha of coral reef change will be equal the function (2.12). c is the unit of cost and p is the price of fish at mean. Marginal change in equilibrium harvest is about 680,188 kg, this means that changing in 1 ha of coral reefs, the harvest will be change about 680 tones with revenue changes about 16.8 billion Vietnamese Dong (about 885.001 USD, exchange rate on 10th, April 2010 is 1 US Dollar = 19.000 VND).

5.1.3. Benefit from protecting corals when established MPA

Find the difference between coral coverage in the case of no MPA and the case with a MPA for all years, given an assumption regarding the coral coverage change. Before 2001, when Nha Trang MPA and Trao Reef was established, coral coverage declined by 6 ha per year, after the implementation it increased with 3.5 ha per year.

In 1995 the coral coverage in Khanh Hoa region is 230 ha, with an annual reduction by 6 ha until 2001, the coral coverage was 194 ha. If the MPAs had not been implemented, and the coral coverage had continued to decline at the same rate, the coral coverage would have been 152 ha. With the MPAs the coral coverage was 225 ha in 2008, implying that the implementation of the MPAs have saved 73 ha of corals. What is the benefit to fisheries from this rescued coral coverage?

In order to answer this question I run regression of equation 2.8 to estimate the parameter values for the years prior to the MPAs were established (1995-2001) for the EFH model.

Table 10: Parameter estimates and test statistics for EFH model using data from the period before establishment of MPAs

Dependent Variable: harvest (kg)	50,650,286.714
Coral reef (L) (ha) * Effort (E)	3.839*
Effort squared (E^2)	- 0.003**
Adj R^2	0.983
Durbin Watson (2,7)	1.207
F(2,5)	143.955

* Significant at $\alpha \geq 0.05$; ** significant at $\alpha \geq 0.1$

From the table 10, it shows that the coefficients of equation before established MPA are $q\alpha = 3.839$ and $\frac{q^2}{r} = -0.003$ at mean of E, h and L. This means that when Effort (Hp) x coral reef cover (ha) increases (decreases) 1 unit, the harvest will be increase (decrease) by 3.839 kg and when the E^2 increase (decrease) by 1 unit, the harvest decrease (increase) by 0.003 units.

Using the coefficients in table 10, the estimated coral coverage in the period 2002-2008 in the case of no MPAs and mean effort of the period 1995-2001 in equation 2.8, we can get an estimate of what the annual catch would have been in the period 2002-2008 if the MPAs had not been established. These figures are listed in table 11

Table 11: The development in coral coverage and estimated harvest in the case of no MPA over the period using average effort for the period 1995-2001.

Year	Coral coverage	Effort	Harvest (kg)
2002	188	93,124	41,194,333
2003	182	93,124	39,049,314
2004	176	93,124	36,904,296
2005	170	93,124	34,759,278
2006	164	93,124	32,614,260
2007	158	93,124	30,469,242
2008	152	93,124	28,324,223
Sum			243,314,946

Hence, the implementation of the MPAs has saved 73 ha of coral coverage, corresponding to 243, 315 tones of harvest over the period 2002-2008. Using average prices and cost for the period, this amounts to 5,224,409,006,720 VND (274,968,895 USD).

5.2. Discussions

- The applied models and theory to run regression

In the theory, the model of Schafer is usually used to the data of singles species with standardized effort and the fish homogenously distributed in the sea. In this model, we need to use aggregate stock of different species, with assumption that the sea near Nha Trang is representative of the sea around the rest of Vietnam. This assumption is important because the fishermen go to fishing wherever they can catch more fish, and sometimes they may go to other areas of the country to catch fish. In addition, the fishermen from other areas such as Binh Dinh, Ninh Thuan, Da Nang come to Khanh Hoa to fish. Hence, for the interpretation of the results it is important that the data of harvest and effort to run the model for the Khanh Hoa province is fairly representative for surrounding areas. If that is the case, the effects coral reefs have on the fishery of Khanh Hoa with respect to the harvest and effort will be similar in other provinces. However, the fishermen in Khanh Hoa usually catch in the fishing ground in Khanh Hoa, they prefer to catch in this because they know the area well and know it is a place where there is a plentiful supply of fish. When they cannot catch enough fish in Khanh Hoa, they will go to other fishing grounds, but only for a short time.

- Data

The data used to run the regression is highly aggregate over species and. The characteristics of the different types of gears and stocks are quite heterogeneous. Gear will vary with characteristics such as net, capacity to harvest, cost and stocks characteristics will vary with respect to price, the characteristics of biology and fishing ground of different fish. Because I did not have data for single species harvest with one kind of gear in harvest and effort this aggregation was necessary. When I use data high aggregated that I can not know exactly which species depend on coral reef and which species depend on others habitat. So when I run the regression of FH model, it make wrong sign of the coefficient Effort (Hp)x coral reef (ha). And I run again this model with the total area of all habitats such as mangrove, coral reef and seagrass instead of coral reefs, it make right sign of this coefficient. For choose which kind of effort better than to run regression. I go survey which different kind of gears and vessels that find a good standardized effort for run model. I had two choices to use in determining effort, one is number of vessels and the other is engine power (Hp) of vessels. After the survey, I decided to use engine power (Hp) to represent effort when running the model and capacity run by regression have more significant than number of vessels.

The got data about from middle man and fishermen in order to determine the price of fish at landing, then I use average weight method to calculate to average price of all species species. This price is only for references and estimating the changes in revenues which occur as a result of changes in coral reef cover.

In the models we use to assume that we are in equilibrium, the data of harvest, effort and coral coverage are stabilized in the equilibrium. However, according to the data that we have, as harvest, effort and coral coverage used to run regression to estimate the result is changing in this period. So it adds to some uncertainty to the figures that are estimated from models and it is not know exactly how it will affects to the results.

- Open access and MPA

From the result, we can see that the benefit from protecting coral reefs during time established the MPAs. However, in the open access condition, the fishermen can be increase the effort from this benefit. The marginal productivity of fishing effort is negative in 2007 and 2008, so that will negative impact in the harvest and revenue in fishery sector in the next period. This is will high pressure in the protecting coral reef and habitat in the MPA. The management should be parallel with the established the MPA to achieve the goals of MPA and enhance benefit to the fishery.

5.3. Conclusions

In recent years, there have been many studies of the role of coral reefs as habitats for fish, especially for the commercial fish. These studies have indicated that coral reefs will contribute to supporting the developing fishery about the harvest and revenues. In my thesis use the production function to evaluate the role of coral reefs as places for reproduction, habitat, and shelter of fish.

The first model is the EFH model which considers the coral reef as essential habitat of fish; if there is no coral reef, the fish cannot survive. When we run the regression using this model, this is significant about the figure and coefficient. The second model is a facultative model says coral reefs play an important role in improving the number of fish, but even without the reef the fish will still survive. However, when using this model, the coefficients get the "wrong" sign according to theory when the result of this coefficient is significantly different from zero. So we will used the EFH model to estimates the value of coral reef, and describe the result. From my result part, increasing coral reef coverage by 1 ha, will result in an increase in the harvest by about 680 tones, with a corresponding increase in revenue of about 16.8 billions VND (about 885.001 USD).

The benefit from protecting coral reefs from 2002 to 2008 in EFH model, the establishment of the MPAs has protected 73 ha of coral coverage, corresponding to 243, 315 tones of harvest and benefit is amount 274,968,895 USD.

The impact of marine protected areas is that there will be an increase in the quality and quantity of coral reefs cover. This increase will increase the areas capacity to produce fish as well as increase revenue for the fisheries sector. Marine conservation should be used as a tool to support government policies in the management and fisheries development in the future, and hopefully it will be effective with certain features such as multi-gear and multi-species present in Vietnam. With open access to today's fishing in general, and Khanh Hoa in Vietnam in particular, fishing and some forms of nature affect coral reefs, such as high job has little to no impact the decline of coral reefs, which are inadvertently destroying the revenue yields which the fisheries sector in the future will come from coral reefs. The evaluation and rational use of resources, in particular coral reefs, and marine ecosystems in general will help to increase revenues for fisheries and conservation of coral as well as marine ecosystems, to preserve the value of the reefs and fisheries and contribute to value in the future.

Open access conditions in the fishery develop socio- economic nowadays has relied heavily on exploitation of marine resource. It makes using marine resource wasteful that economic run inefficiency and destructive has taken a significant toll on the habitat like coral reefs, mangroves. The management should be assistant for the economic and biology. Each of regions has different characteristics. The management should be flexible and get in close contact with the local people to receive sympathizing. For the sustainable development economic and ecosystems, it is essential that maintenance the marine resource which includes the habitats is integrated into future fishery economic sector development planning.

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Appendix

Questionnaire

I. GENERAL INFORMATION:

1. Full name: Gender:
2. Address: Phone number:
3. Age:
4. Main occupation Additional occupation:
5. Education level:
6. Experience in fishery:
7. How many people in your family working in fishery?

II. FISHING ACTIVITIES

Year	Equipment	Capacity(HP)	Harvest	Cost	Income
1995					
2000					
2005					
2009					

Thank you very much for your participation!

Questionnaire about price of fish

Unit	Species	1995	1996	1997	…	2008
1	Belt fish					
2	Yellow fin tuna					
3	Skipjack tuna					
4	Scad fish					
5	Mackerel					
6	Anchovy fish					
7	Coral shrimp					
8	Baby shrimp					
9	Tiger shrimp					
10	Broad squid					
11	Cleaned squided					
12	Cuttlefish squid					
13	Others					
14	Others					
15	Others					
16	Others					
17	Others					