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ATTAINING SUSTAINABLE FISHING IN NUI THANH DISTRICT, QUANG NAM PROVINCE, VIETNAM

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ABSTRACT

Coastal fisheries play an essential role in the economic development of Nui Thanh district. Various reports state that the fisheries currently suffer from overfishing and overcapacity but have no quantitative research or numeric data to support that claim. Primary and secondary data are used to analyse the status and trends in the number of fishermen, fishing effort, landings, CPUE and examine current management policies. Bio-economic models are also used to estimate several fisheries management reference points. The fishing capacity and landings have increased while CPUE has decreased. The maximum sustainable yield (MSY) is estimated to be at about 26,500 tons which is reached when the fleet has a total capacity of 80,500 HP (f_{MSY}). Furthermore, maximum economic yield (MEY) estimated to be 25,500 tons which is reached when the fleet's capacity is around 64,300 HP. That would yield a profit of appropriate 864.5 billion VND (39.3 million USD). Finally, the Nui Thanh's coastal marine biomass stock is estimated at maximum level of about 126,500 tons. Fishing capacity controls should be implemented to reduce excessive fishing effort. ITQ and TURF management policies are feasible methods to move the coastal fisheries of Nui Thanh district towards a sustainable path.

Key words: *bio-economic models, sustainable fishing, coastal area, Nui Thanh district, Vietnam*

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ABBREVIATIONS

MSY	Maximum Sustainable Yield
f_{MSY}	Fishing effort level at MSY
MEY	Maximum Economic Yield
f_{MEY}	Fishing effort level at MEY
FMS	Fisheries Management Systems
MCS	Monitoring, Control and Surveillance
FJS	Fisheries Judicial System
TURFs	Territorial Use Rights
IQs	Individual Quotas
ITQs	Individual Transferable Quota scheme
CPUE	Catch Per Unit of Effort
FAO	Food Agriculture Organization
CPE	Common Property Equilibrium
VND	Vietnam Dong currency
USD	United States Dollar
ADN	Agriculture Department of Nui Thanh

1. INTRODUCTION

Fisheries in Quang Nam province are among the top ten most important fisheries in Viet Nam as is evidenced by 4,157 fishing vessels (>171,358 horse powers). The province has a coastline of 125 km with an exclusive economic zone of more than 40,000 km^2. It has abundant marine resources and high species diversity (Luong *et al*. 2014).

Marine capture fisheries in Vietnam are not readily classified into small-scale or industrial. Hull length, engine power, distance from shore, depth when fishing and gear deployed all play some role in defining of type of fishing. However, Vietnam's marine fisheries are generally considered to be small-scale as they focus on near shore waters. As a consequence, the pressure on near shore fisheries resources has been increasing and the overfishing is seen to be a problem (Pomeroy *et al*. 2009).

Fisheries in the Nui Thanh district – which is located in the province of Quang Nam – are small-scale and play an important role on the coast. They are however in a bad shape. The vessels operating in coastal areas use variety of illegal fishing gears which undermines the future growth of the biomass: small mesh-sized fishing nets catch juvenile fish, which reduces quality of the harvest and reduces future spawning, fishing using electricity, explosives and poisons increases waste. Also, trawling with powerful engines near the shore and negatively affects the benthic ecosystem (Vu 2015, Hung 2009, Du 2015).

There are variety of government supports in fisheries. For example, crew insurance, fishing licence and registration fee was subsidised by the government. In period of 2011 – 2014, the local authority provided more than 100 billion VND (5 million USD) in support of offshore fishing activities, such as fuel price subsidy, crew insurance, investment grants, and training. Furthermore, the central government has granted billions for offshore fishing, leading to 2.5-fold increase in offshore fishing capacity between 2010 and 2015 (Huu 2015).

Like Vietnam fisheries in general, the fisheries of Nui Thanh are considered to overexploited (Luong *et al*. 2014, Agriculture Department of Nui Thanh 2014). These problems are recognized by various central and lower levels of government, such as the provincial and district levels (Agriculture Department of Nui Thanh 2014, Gioi 2014). There are too many fishing vessels operating, and no explicit regulations to reduce fishing effort.

Conflicts among fishermen on the fishing ground is increasing as a result of decreasing marine biomass and harvest. According to them the catch has decreased by about 30 – 40 percent over the last 5 years. This has reduced the benefits from fishing, and as a result, the quality of life of fishermen and their families has decreased (Luong *et al.* 2014).

Despite these problems, few have studied the fisheries management aspect of the Nui Thanh fisheries and no quantitative research has been conducted. The issues have been identified but are neither verified nor quantified by any data analysis. There are no estimates what total allowable catch or of reasonable fishing effort level or possible benefits of different policies. Local authorities do not have a sound base upon which to design and implement appropriate management policy, as available reports contain few proposals on how to improve policies, planning or management of this valuable resource.

The above problems will be addressed by analysing available data, supported by collection of new data, and feasible fisheries management policies proposed. To achieve that goal, the main impacts of fisheries on coastal communities and marine resources will be assessed. Maximum sustainable yield (MSY), fishing effort level at the MSY and potential benefits from the Nui

Thanh district's fisheries will be estimated and feasible solutions to achieve sustainable fisheries will be discussed.

The study will help local authorities to understand nature of the fisheries by giving them an improved overview of the fisheries as well policy suggestions which enables them to attain sustainable fisheries in given area. If successful this could serve as an example for fisheries in other areas, resulting in further economic benefits.

1.1 Goals and objectives

The main objective of this project is to analyse the fisheries Nui Thanh district, Quang Nam province, Viet Nam and to propose policies to attain sustainable and efficient fishing.
In the project, we will:

- Analyse the coastal fishing activities, including the status and trends in the number and size of fishing vessels, number of fishermen and catch over time.
- Outline the current fisheries management policies.
- Develop a bio-economic model which contains the following:
    - Estimates of maximum sustainable yield (MSY) and the fishing effort at MSY which are obtained by surplus production estimation (Schaefer model).
    - Estimates of costs, net benefits and maximum economic yield (MEY).
- Suggest the suitable recommendations for sustainable fishing.

2. LITERATURE REVIEW

Fisheries management is characterised by multiple objectives, some of which may be conflicting, such as conflict between jobs and catch, especially in small-scale fisheries where the overfishing and overcapacity are issues (Simon *et al.* 2002). Unfortunately, policy makers do neither set priorities taking into account trade-offs between the various objectives, nor set measurable targets for individual objectives. This makes it difficult to determine whether the objectives have been achieved. A tentative hierarchic tree of objectives can be developed based on the known structure of the fishery under analysis. A typical structure in the natural resource management consist of 4 main groups of objectives: biological, economic, social and political (Simon *et al.* 2002).

A property rights based fisheries management regime seems appropriate to address common problems that these fisheries are facing such as overfishing and low profits. Natural resources in general, and fisheries in particular are rarely subject to individual property rights. In fact, the common property is so pervasive in fisheries that even the richest fish stocks are decimated, and all the economic benefits of these resources wasted on excessive fishing fleets and effort (Arnason 2015). In order to alleviate the common property problems such as overfishing, overcapacity and unsustainable fisheries management is needed. Effective fisheries management systems consist of three essential components (Arnason 2015) such as: i) Rules of conduct – Fisheries management systems (FMS); ii) Implementation – Monitoring, control and surveillance (MCS); and iii) Enforcement – Fisheries judicial system (FJS).

These three activities form the fisheries management regime. This project focuses on the first component.

The fundamental aspects of fisheries consist of sets of inputs and outputs (Figure 1)

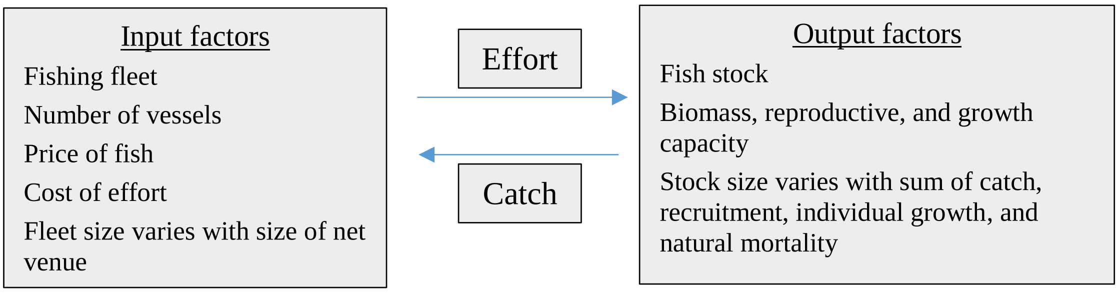

Figure 1: Input and output factors in fisheries. Source: (Anderson and Seijo 2010)

The fish stock, measured as biomass, is affected by several factors. An equilibrium stock size will be reached when increase in stock due to recruitment and individual growth are exactly offset by the decrease due to total mortality.

Effective management policies must take into account all the factors above (Figure 1). In particular, it must include capacity management programmes (Ward *et al*. 2004). Various such programs exist and they can be broadly subdivided into two categories: i) Intensive blocking programmes which includes limited entry programs, buyback programs, gear and vessel restrictions, aggregate quotas, non-transferable vessel catch limits, and individual effort quotas; and ii) Incentive adjusting programmes which consists of individual transferable quotas, taxes and royalties, group fishing rights (such as community development quotas, and other community-based management), and Territorial Uses Rights (TURFs) (Ward *et al.* 2004). Various approaches for reducing overcapacity have been adopted without success in the past in Vietnam (Pomeroy *et al*. 2009). For example, buy-back programs for small-scale fisheries have been conducted in several places in Vietnam. In one case, in the Tam Giang Lagoon in Thua Thien Hue Province, boats of "floating fishers", fishing families that live and work on their boats, operating in the lagoon were purchased by the government and the fishers were provided with land in the northern part of the lagoon for resettlement. In less than a year, the fishers had sold the land, re-purchased vessels and were back fishing. While the family was provided with land, they were not provided with any training in new livelihoods and returned to the sea. Given these realities, therefore, the only feasible solution may be one based on a coordinated and integrated approach involving mixed strategy of resources management (access control and property rights), resource restoration, economic and community development, and new governance arrangements (Pomeroy *et al.* 2009).

One of the most promising indirect economic fisheries management systems is fisheries property rights. There are various types of fisheries property rights such as TURFs, individual quota (IQ) and individual transferable quota scheme (ITQs) that have been introduced in many fisheries with good results such as in Iceland, Japan, New Zealand and Norway. According to Arnason (2015), the small-scale, artisanal fisheries, where quota restrictions are difficult to enforce on an individual fisher's basis, community fishing rights may constitute the best alternative. Specifically, organizing fishers into certain communities holding community ITQs and with some TURFs may be a practical as well as an efficient way to go (Arnason 2009, 2015).

In a study on rents drain in the Lake Victoria Nile Perch fishery, Arnason (2009) argues that all bio-economic fisheries models must include three aspects. Those aspects are i) biomass growth function, noted $G(x)$; ii) the harvesting function, noted $Y(f,x)$; and the cost function, noted $C(f)$. In addition, he shows how estimates of essential fishery parameters such as biomass, harvest, effort, profits and rents can be obtained using the logistic and Fox model. In a similar bio-economic analysis on the Jamaican industrial spiny lobster *(Panulirus argus)* fishery, Morris (2010) developed static and dynamic models for estimating bio-economic equilibrium model in that fishery. The analysis here follows similar routes.

3. METHODOLOGY

A mix of descriptive statistical analysis and subjective assessment methods will be used. For that purpose, primary and secondary data will be analysed and informal interviews conducted.

3.1 The place of study

The project studies the fisheries in Nui Thanh district, Quang Nam province, Vietnam. The study area is defined as the line from point 7' to point 8' regulated in Decree no.33/ND-CP that was approved by the Prime Minister in 2010, the study area is showed in Figure 2.

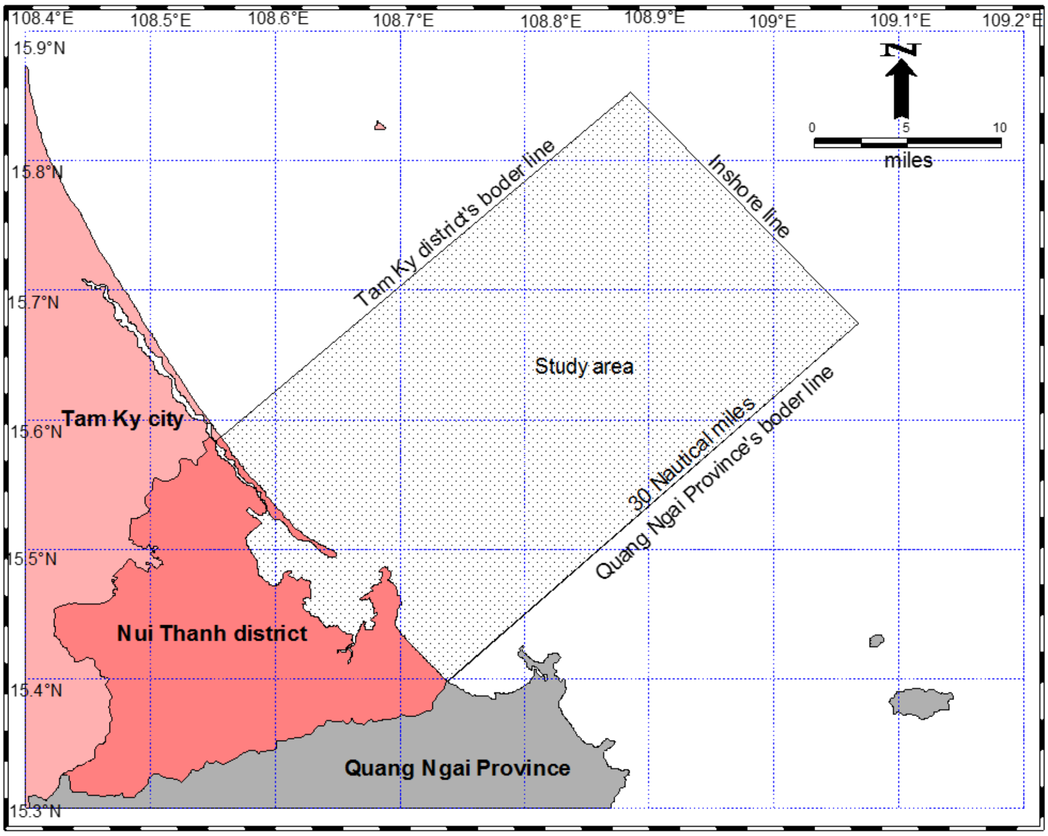

Figure 2: The study area as defined by the government (Source: Author's own graph based on the government regulation)

3.2 Data collection

The data collection consisted of two methods as follows:

3.2.1 Secondary data

Published papers and government reports in Nui Thanh district's fisheries were used to infer the status of the fisheries including socioeconomic information and management policies. Background information of modelling is based on papers, books and conference reports. This material together with analysis of data were used to infer feasible solutions in terms of fisheries management planning and policies.

3.2.2 Primary data

The primary data was used to assess the status and dynamics of the fishing efforts. The data consists of number of fishers and landings between 2003 and 2013 were taken from Agriculture Department of Nui Thanh district. From that other variables, such as catch per unit of effort (CPUE) and marine resources, can be inferred. We will also use subjective assessments and quality indicators to support the analysis.

In addition, a survey was carried out for this study. The data consists of fishing trip cost, fishing distance from shore, a yearly cost of fishing, catch of a fishing trip, price of main fish species, proportion of main fish species and the total revenue each year[1]. There were 80 captains and owners that selected randomly to collect sample data. They were chosen through stratification by classification in order to represent the population.

Informal data were also collected directly from authorities and specialists by various means of communication such as e-mail and telephone.

3.3 Modelling

There is various type of models, some are static, others are dynamic; and some are stochastic while others are non-stochastic. The bio-economic models include stock growth, harvesting, cost and net benefit functions. Therefore, both the biological and economic aspects are taken into account (Anderson and Seijo 2010).

The fisheries model used in this project is based primarily on a basic surplus production model that was published as a FAO Fisheries Technical Paper (Seijo *et al.*, 1998). This simple model was introduced by Gordon (1953). However, it is referred to as the “Schaefer model” (Anderson 1981, Anderson and Seijo 2010). The main reasons for selecting this model is because little data is required and the available data on Nui Thanh district’s fisheries is poor. The basic model is as follows:

- The model gives us estimates of MSY and f_{MSY} which are necessary parameters to establish the relationship between the biomass and biomass growth.
- The Schaefer logistic growth model uses the parameters to model the relationship between the biomass and the biomass growth. Net growth can be obtained by subtracting the harvest from the natural growth rate.

3.3.1 Surplus production model in fisheries

The surplus production model is used to estimate maximum sustainable yield and fishing effort at level of MSY. The following input data is required:

- f_i is fishing effort in year i, where i= 1,2,3…, n
- Y_i is yield in year i, where i= 1,2,3…., n
- $\frac{Y}{f}$ is yield (catch in weight) per unit of fishing effort in year t.

According to Schaefer (1954) and Sparre and Venema (1998), $\frac{Y}{f}$ is a function of the effort, f, in the linear model, as follows:

[1] The questionnaire can be found in Appendix 1.

$$\frac{Y}{f} = \frac{Y_i}{f_i} = a + b \cdot f \quad (\text{if } f_i \leq -\frac{a}{b}) \qquad (1)$$

where the intercept "a" is the $\frac{Y}{f}$ value obtained just after the first boat fishes on a virgin stock. The intercept then must be positive. The slope "b" must be negative if the biomass decreases for increasing effort f. Therefore, $-\frac{a}{b}$ is positive and $\frac{Y}{f}$ is zero for f = $-\frac{a}{b}$ (Sparre and Venema, 1998)

The surplus production model will be used to estimate MSY and f_{MSY} for fisheries in Nui Thanh district, Quang Nam province where the model will use CPUE and fishing effort over-time. In the project, we will use equation (1) to determine MSY, f_{MSY}. The Schaefer model, is a parabola, which has its maximum value of Y_i, the MSY level, at an effort level:

$$f_{MSY} = \frac{-a}{2 \cdot b} \text{ and the corresponding yield } Y_{MSY} = \frac{-a^2}{4 \cdot b}$$

3.3.2 The Schaefer logistic growth model

The Schaefer growth model shows the relationship between the grow rate and biomass over time. A simple function accounts for important elements of population stock dynamics of real-world fish stocks. The model assumes that recruitment, individual growth, and natural mortality can be represented simultaneously by a logistic growth equation (Anderson and Seijo 2010). This model allows the instantaneous growth in stock biomass, X_t, to be represented with a differential equation:

$$\frac{dx}{dt} = G(x_t) = r \cdot x_t \cdot (1 - \frac{x_t}{K}) \qquad (2)$$

The equation can be written as follows:

$$G(x) = \alpha \cdot x - \beta \cdot x^2 \qquad (3)$$

Where: G(x) is biomass growth; α=r is intrinsic growth rate; $\beta = \frac{r}{K}$, β is the mortality rate which is negative; K is carrying capacity of the environment, the largest size that the stock can reach given food supplies, habitat, etc.

The maximum growth rate can be found by taking the first derivative of equation (3), setting it equal to zero, and solving for X.

That results in $x_{MSY} = \frac{\alpha}{2\beta}$ where maximum growth rate at $G(x) = \frac{\alpha^2}{4\beta}$

Regarding to function (2), $x_{MSY} = \frac{K}{2}$ where maximum growth rate at $G(x) = \frac{r \cdot K}{4}$

3.3.3 Schafer logistic growth with harvest

When the fish stock is affected by certain fishing effort, the net biomass growth can be represented as follows:

$$\dot{x} = G(x) - y \qquad (4)$$

In discrete time, the net biomass growth can be revised as follows:

$$x_{t+1} = x_t + G(x_t) - y_t \qquad (5)$$

where: x_{t+1} is stock size of next year; y_t is harvest this year (t); x_t is stock size this year (t)
In this case, the stock size will reach an equilibrium where $G(x_t) = y_t$ (Anderson and Seijo 2010)

3.3.4 Schaefer harvest function

According to Anderson and Seijo (2010), the harvest function concerns the relationship between fishing effort and stock size and can be described as follows:

$$y = Y(f, x) = q \cdot f \cdot x \qquad (6)$$

where

- y is harvest;
- q is the catchability coefficient,
- f is fishing effort, and
- x is stock size.

In order to get an equilibrium yield, growth must equal short-term harvest.

$$\alpha \cdot x - \beta \cdot x^2 = q \cdot f \cdot x$$

or equivalently

$$r \cdot x \cdot \left(1 - \frac{x}{K}\right) = q \cdot f \cdot x$$

$$x = K \cdot \left(1 - \frac{q \cdot f}{r}\right) \qquad (7)$$

By substituting x in the equation (6) into above equation (7), we get the long term catch equation.

$$y = q \cdot K \cdot f - \frac{q^2 \cdot K}{r} \cdot f^2 \qquad (8)$$

This implies that, in the short term the stock size will only depend on fishing effort, although harvest is a function of effort and stock size for the long term. While the sustainable yield becomes only a function of fishing effort as well.

Equation (8) takes a form of a parabola with dependent variable, y, and independent variable, f. Dividing the equation to fishing effort, f, we have

$$\frac{y}{f} = CPUE = q \cdot K - \frac{q^2 \cdot K}{r} \cdot f \qquad (9)$$

The primary unknown parameters of the sustainable fisheries model are x, K, r and q that will be estimated by CPUE, DCPUE and effort. The estimation procedure will be described in appendix 9.

3.3.5 Cost function

The cost function in bio-economic models follows that of Anderson and Seijo (2010) that we use 2nd degree polynomial instead of logarithmic form:

$$C(f) = fk + b \cdot f + c \cdot f^2 \quad (10)$$

Where C(f) is the total cost; b, c are parameters; f is fishing effort; fk is fixed cost. The latter two terms combined are variable cost. This functional form was chosen as to get the best fit for the survey data. The estimation procedure will be described in chapter 4.2.2.

3.3.6 Net benefit (profits)

Net benefit function is the total revenue less the total cost (Anderson and Seijo, 2010).

$$\pi = p \cdot Y(f, x) - C(f) \qquad (11)$$

$$\pi = p \cdot y - C(y, x) \qquad (12)$$

The effort levels at Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY) will estimated as following:

a) A virgin biomass can be defined by solving equation (12) for x
   $X_0 = \frac{r}{K}$ (13)
b) The fishing effort level at Maximum Sustainable Yield (MSY) will estimated as equation 14 below

$$f_{MSY} = \frac{r}{2q} \qquad (14)$$

$$Y_{MSY} = \frac{r \cdot K}{4} \qquad (15)$$

3.4 Assumptions

Majority of fishing vessels have a small engine and fish close to shore (Decree no.33/ND-CP). In order to assess the fishing activities in the Nui Thanh district, the following assumptions are made:

Assumption 1: the number of fishing vessels in Nui Thanh’s water are the number of vessels just come from Nui Thanh (Flaaten 2011). Vessels from other districts that might fish in the area *(such as Tam Ky city and Quang Ngai province)* would be equal to and balanced by vessels of Nui Thanh district fishing outside the area. Engine power of vessel will be used as a measure for fishing effort.

Assumption 2: The survey data is assumed to represent the population, in particular the harvest is assumed proportional to the population in general, and costs and revenues are assumed to be similar as in the population. Also, fish price is quite stable in the year and not strongly affected by the harvest. The improvements in fishing technology and efficiency are not taken into account in the project analysis. Also, the catchability parameter, q, is stable and constant over time within the study area.

Assumption 3: the relative size of each main species remains constant in the study area.

4 RESULTS

4.1 Fisheries overview

4.1.1 Location

Nui Thanh, Quang Nam is a coastal district which located in central Vietnam (Figure 3).

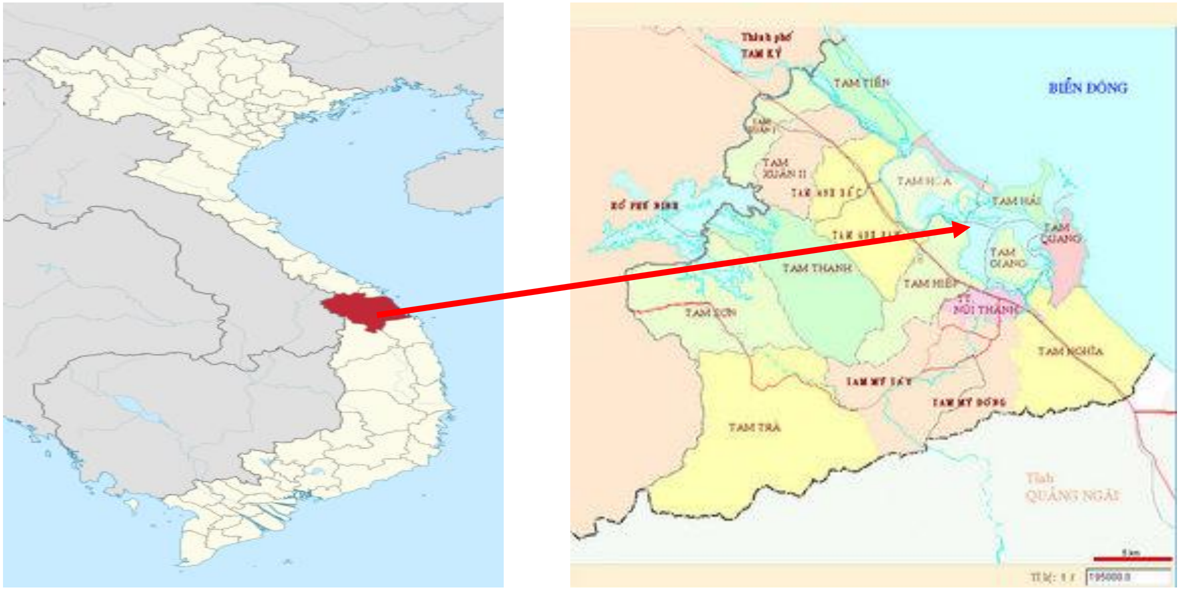

Figure 3: The location of Nui Thanh district, Quang Nam province, Vietnam

The Nui Thanh district has a population of 140,000, most of whom belong to either Kinh or Cor ethnic group. About 52 percent of the population (73,000 people) belongs to the working-age population, among whom 58.2 percent work in agriculture (including fisheries), 23.5 percent in industry and construction, and 18.3 percent in commercial services (Luong *et al*. 2014, Huu 2015) (Figure 4).

The Nui Thanh district's per capita income is 26 million VND per year (1,180 USD) on average. In 2014, the district contributes 59 percent to the total economy of Quang Nam province. Fisheries contribute about 18 percent to the economic in 2014 (Huu 2015).

Fisheries (including aquaculture) account for more than 77 percent of agricultural production (which consists of fisheries, agriculture and forestry). The year is divided into two fishing seasons, depending greatly on weather conditions of sea area. The main fishing season is called "South season" and runs normally from February to September (from February to August in lunar year). The low-season is called "North season" runs from the rest of months (Agriculture Department of Nui Thanh 2014).

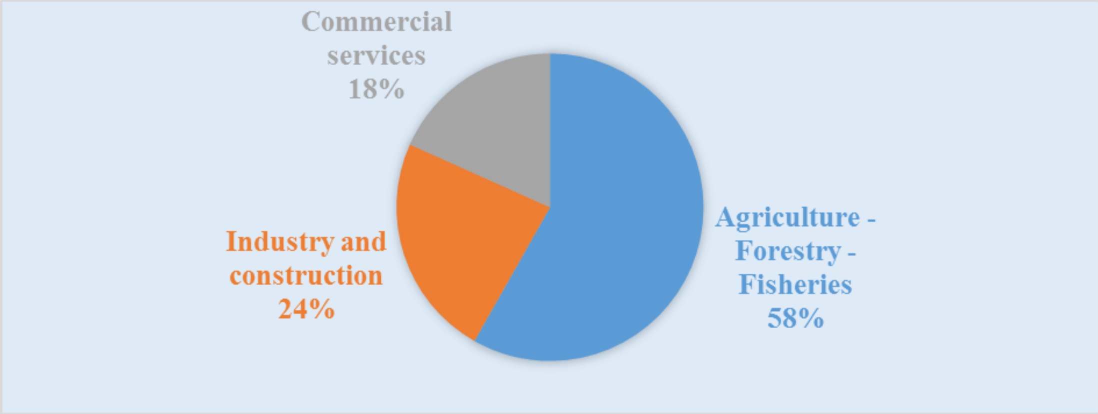

Figure 4: The labour groups in Nui Thanh district in 2014

4.1.2 The Nui Thanh sea area

The seafloor of continental shelf waters in Nui Thanh district are generally steep and can reach up to 50 meters depth within a few nautical miles. Nearshore seabed topography is rich of coral reefs mound and seaweeds, which is a home and spawning area of various marine species. That is especially true at depth between 4 and 6 meters where the coral reefs are dense and rich of biological resources (Hieu 2006).

4.1.3 Labour in fisheries

The overall trend in the amount of labour in fisheries was relatively stable over the last decade with around 17,500 employees (Figure 5). Interestingly, there was gradually decrease in farming sector while increase regularly in fishing sector. A government fuel subsidy is the main reason for the increase in 2006 - 2007. The slow increase since 2010 may be in part because of government reforms which encourages and supports fishing activities, such as fuel price subsidy, support for building and upgrading fishing vessel, subsidised insurances etc. Due to the recent in subsidies, it is predicted that the number of crew will increase quickly when the bigger and more powerful vessels are building in coming years. The total subsidies amounted to 100 billion VND (50 million USD from 2011 to 2014). A more detailed account of labour of fisheries can be found in Appendix 2.

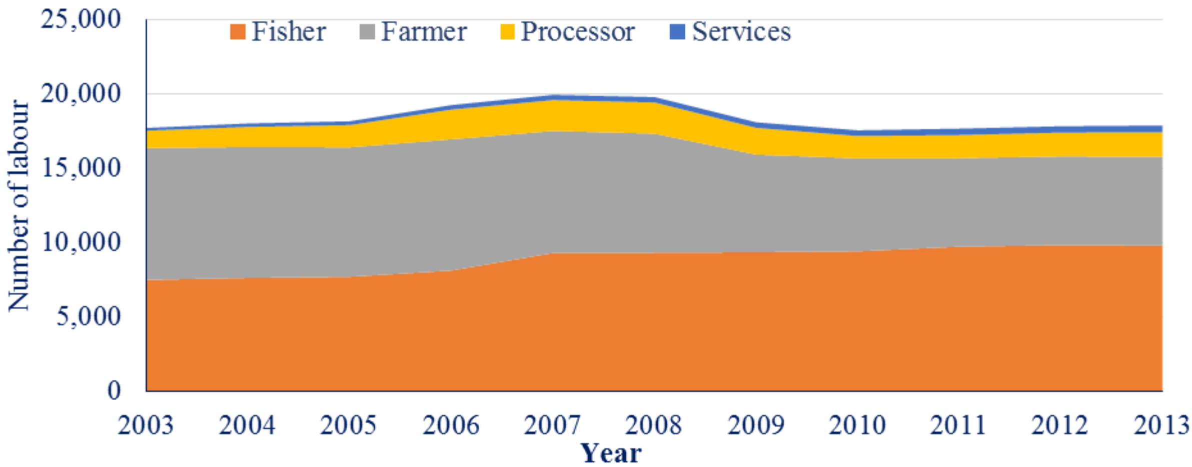

Figure 5: The trend of fishery labour in Nui Thanh district from 2003 to 2013 (based on data from ADN)

The education level of fishermen in Nui Thanh district is fairly low (Figure 6). A large proportion (nearly 60%) have only finished primary education level, while just over a third has finished a junior high level. Almost 6% of all fisherman are illiterate. The figure shows that the fishermen have encountered difficulties in applying advanced technologies for off-shore fishing (Phuong, 2014).

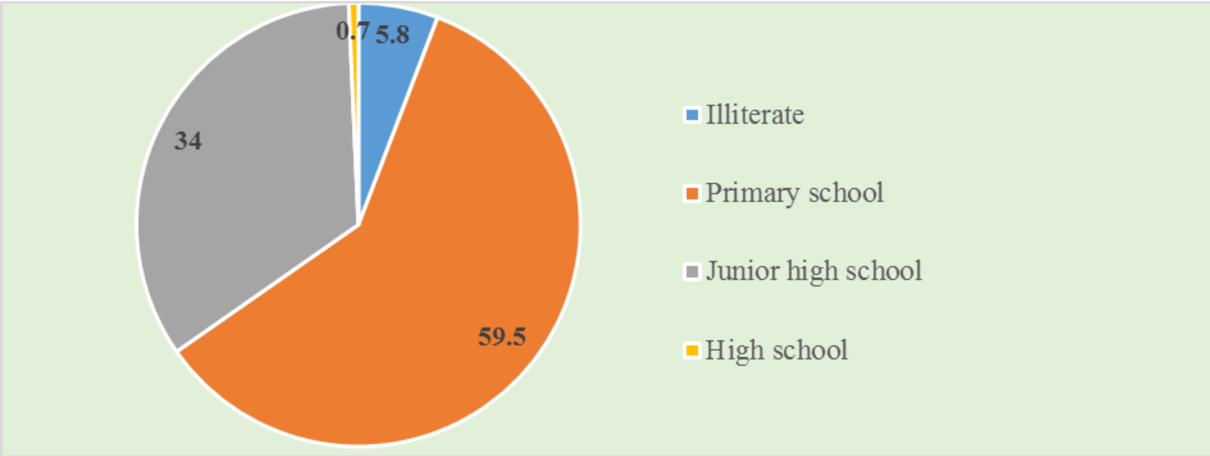

Figure 6: The percentage of fishermen's education level in Nui Thanh modified from Phuong (2014)

4.1.4 Fishing effort

Fishing effort is a multidimensional indicator of fishing activities that include many aspects of the capacity of vessels, fishing gear and crew. Effective effort is therefore extremely difficult to accurately quantify, and no comprehensive global or Vietnamese statistics are available (DANIDA 2010). Here we follow the example of fishery management authorities, at both local and central level, and use engine power as an approximation for effort. This measure has been used to analysis productivity in fishing activities regardless of fishing gears, and allows for a direct comparison with other reports in the country.

The number of motorised fishing vessels has increased sharply from 975 in 2003 to 1,527 in 2013. Now they account for 58.6 percent of total fishing vessels in Quang Nam province. Most vessels (86%) are small, less than 90 horse power (HP). Small vessels mainly fish the near shore area. There are 6 fisheries in Nui Thanh district including trawl, purse seine, gill-net, lift net, longline, diving.

The trend of fishing effort in terms of the number of vessels and the horse power have increased over the period from 2003 – 2013 (Figure 7) (see further details in Appendix 3). Number of fishing vessels increased sharply from 1,127 vessels in 2006 to about 1,500 vessels in 2007. The sharp increase could be a result of increased fuel price subsidy in a response to increased fuel price (Agriculture Department of Nui Thanh 2014). As an unintended consequence, decommissioned vessels where brought back in use.

The total engine power of all vessels was about 27,600 horse power in 2003. It had doubled by 2010, before doubling again by 2013 (Figure 7). A faster increase rate in engine power than in vessels indicates that fishermen have tended to build bigger and more powerful vessels, especially over the last 5 years. It could be that the costal marine resources are being depleted and that is driving the fishers to operate further from the shore, which in turn requires larger and more powerful vessels (Luong *et al.* 2014, Phuong 2014).

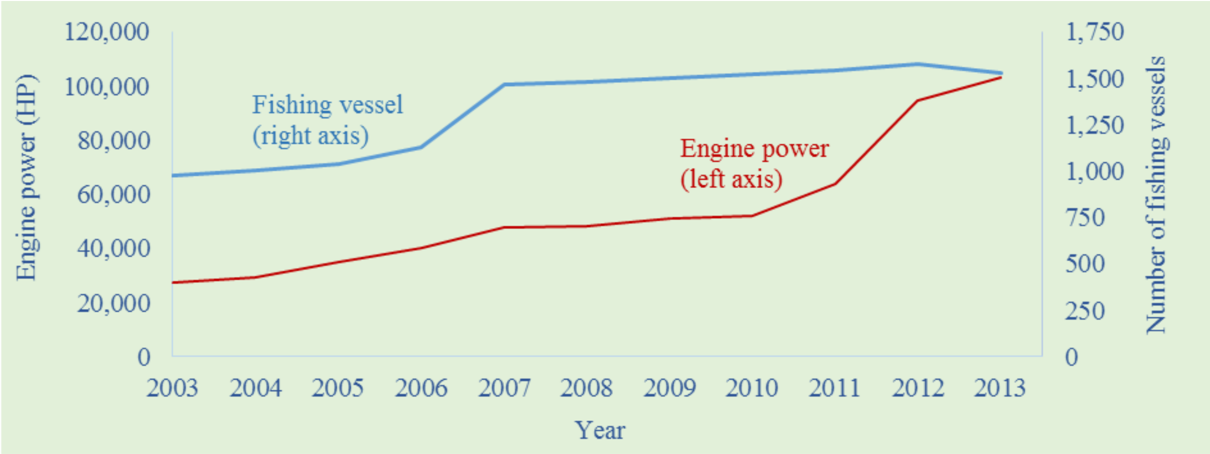

Figure 7: Number of vessel and engine power in 2003 – 2013 (Based on data from ADN)

The average engine power of each vessel increased from 28 HP/vessel in 2003 to 34 HP/vessel in 2010 and then rose more sharply to approximately 68 HP/vessel in 2013 – a total increase of 2.4 times in comparison to that in 2003 (Figure 8). This increase is attributable partly to more and more supporting policies to Nui Thanh district's fisheries sector, both by the central and the local government. The fishermen have been given incentives to build new big vessels or to upgrade to more powerful vessels.

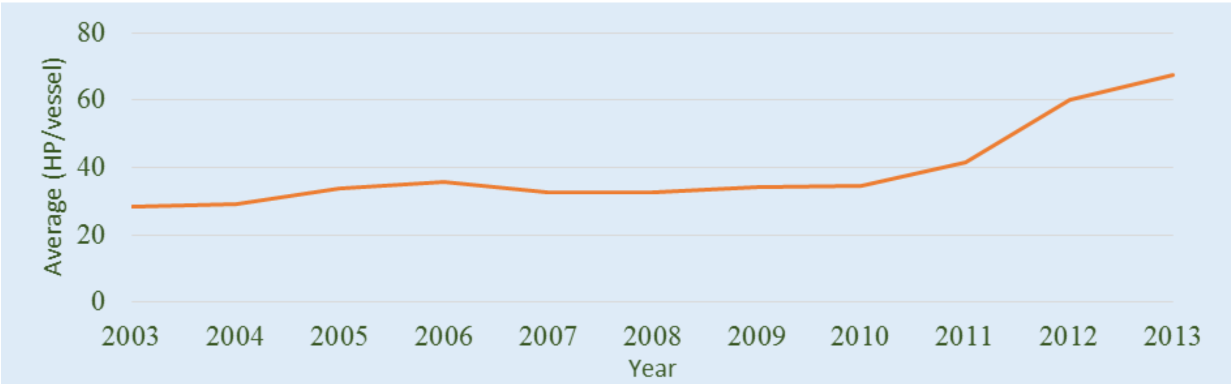

Figure 8: Changing in average engine power from 2003 to 2013 (Based on data from ADN)

The Figure 9 below shows how fishing vessels in different gear categorised by group of engine power in Nui Thanh district in 2013. The number of boats in each group varies significantly across the fishing gears. The number of gill-net vessel was above 600 units (accounted for 39.4 percent) which mostly consists of vessels with engine less than 20HP. The number of other gears have varied a range of around 150 to 200 vessels. The diving vessels had small engine power in general, or under 20HP (see further details in Appendix 3), while the trawl and purse seine vessels had proportionately more vessels with engines between 20-90HP, with around 100 vessels each, compared with the others. Generally, the fishing vessels that operate near shore are mainly small ones with engine less than 20HP.

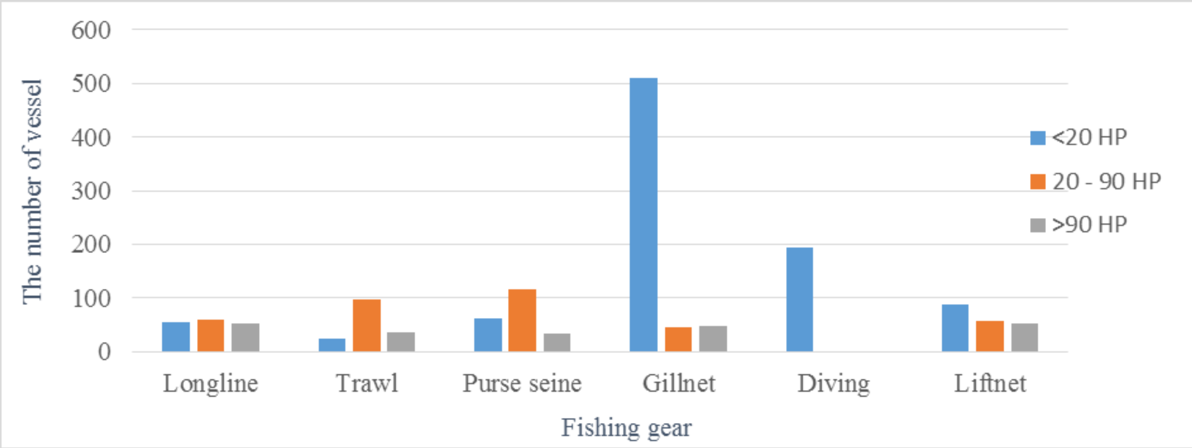

Figure 9: The vessels classified by fishing gear and engine power based on data from ADN

Fishing range of various fishing gears are illustrated as Figure 10. The operation area of fishing gears mainly concentrates in a range between 5 and 40, but this study is limited to fisheries within 30 nautical miles. Trawling and diving are the most concentrated in a narrow range that is within 5 - 10 nautical miles from the shoreline; while purse sein, longline and gillnet operate in a wider range (over 20 nautical miles). The broken line is out of study area. Diving is close to shore. As a consequence, Diving is carried out quite close to shore in sensitive coral habitats and have been found to affect these negatively (Phuong 2014).

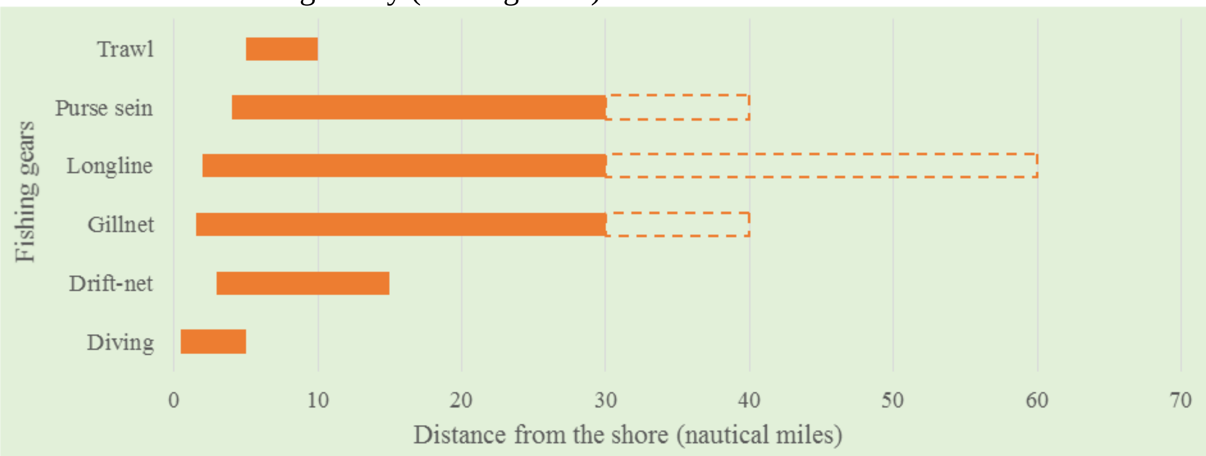

Figure 10: Operation areas of fishing gears based on survey data

The more powerful fishing vessels are, the further from the shore they tend to operate. Fishing vessels with engine between 20 and 90HP, generally, operate within 5 to 30 nautical miles from the shoreline (Figure 11).

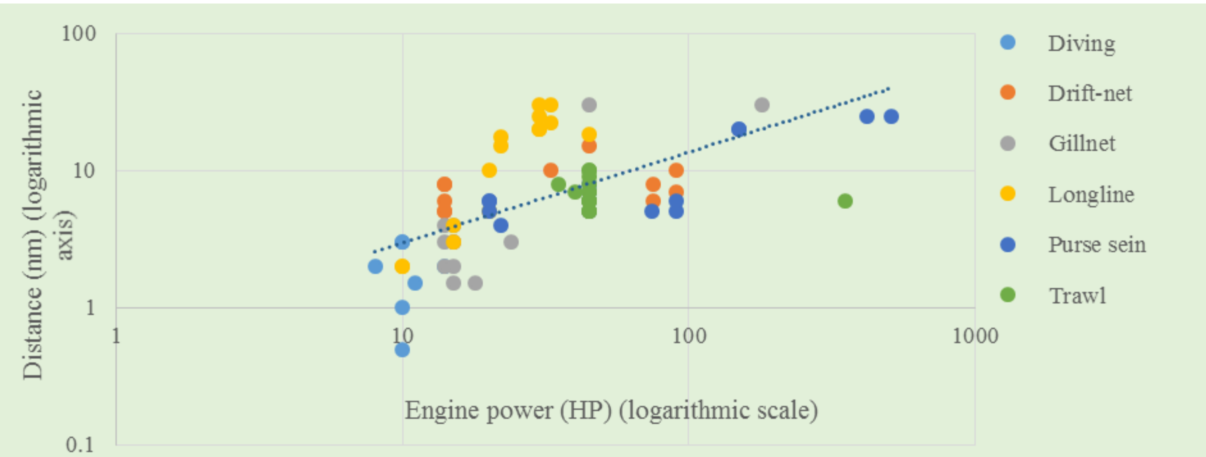

Figure 11: Relationship between engine power and fishing distance (based on survey data)

The cost per unit of effort differs greatly between different types of vessels (Figure 12). The trawls seem to have the highest cost, possibly due to high fuel cost, while the cost for each unit of effort is lower for diving vessels that are more labour intense have higher cost per unit of effort. This may reflect the shortcomings of effort as a measurement for effort.

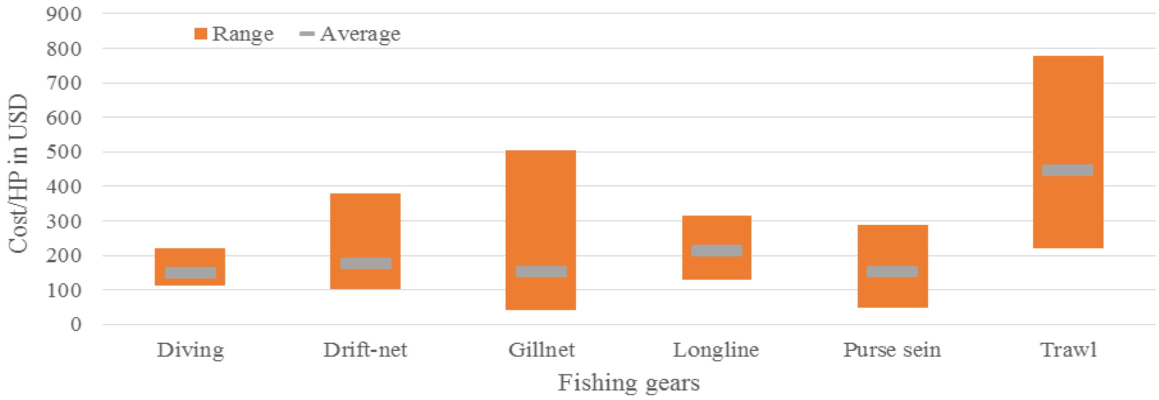

Figure 12: Relationship cost per unit of effort (HP)

4.1.5 Harvest

While the harvest increased gradually from 2003 to 2013, the catch per unit of fishing effort (CPUE) declined (Figure 13)[2]. The landings were around 17,000 tons in 2003 and rose about 7.5% annually to over 34,000 tons in 2013. Catch per unit of fishing effort significantly decreased from 0.62 tons/HP in 2003 to 0.34 tons/HP in 2013.

This trend is similar to the CPUE trend seen in the overall fisheries at national level which is considered to be overexploited (Phuong and Phu 2013). That may indicate that the marine resources of Nui Thanh are also overexploited. It is therefore necessary to address the fisheries management to this area (see Appendix 3).

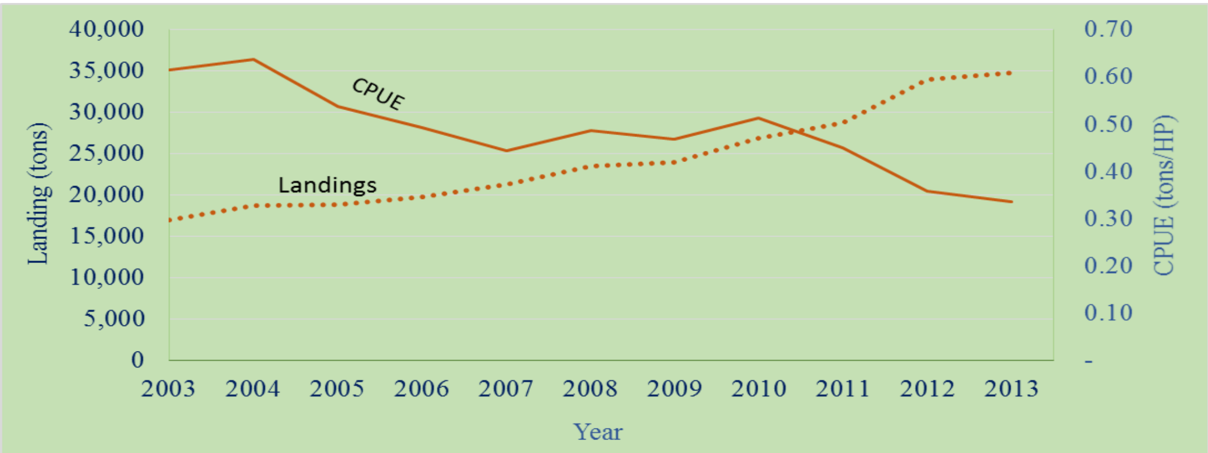

Figure 13: Catch per unit of effort (CPUE) and landings between 2003 – 2013 (based on data provided by ADN)

[2] CPUE is calculated that landings are divided by fishing effort over time

4.1.6 *Productivity*

CPUE by species in coastal fisheries within 30 nautical miles

Catch per unit of effort (CPUE) has in most instances decreased during the last 5 years, with the exception the Pony-fish)[3] (See further details in Appendix 4). CPUE is highest for squid at 12.22 tons/HP, followed by Anchovy and Lizarfish at 6.70 tons/HP and 3.38 tons/HP, respectively (Figure 14). The fish species with over 3.0 tons/HP are mainly pelagic species which spawn and grow in coastal areas.

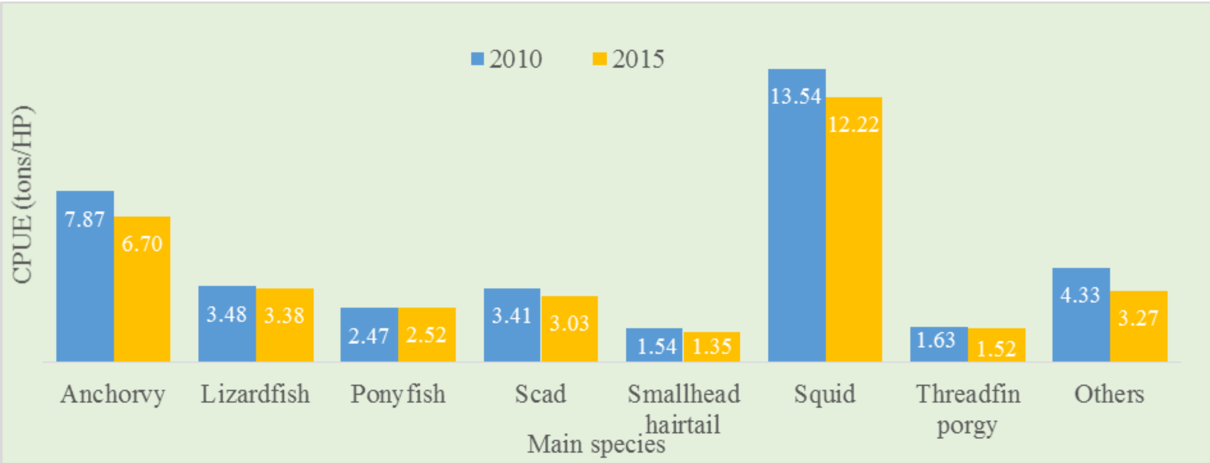

Figure 14: Changes in CPUE by species for 5 years (based on survey data)

CPUE by fishing gear

Analysis of surveyed data shows that the CPUE varied considerably with gears but decreased for all gear types from 2010 to 2015 (Figure 15). The Drift-net and Trawl fisheries had higher CPUE values than the others. This means that coastal marine resources have currently suffered difficulties to recover in that situation (see Appendix 5).

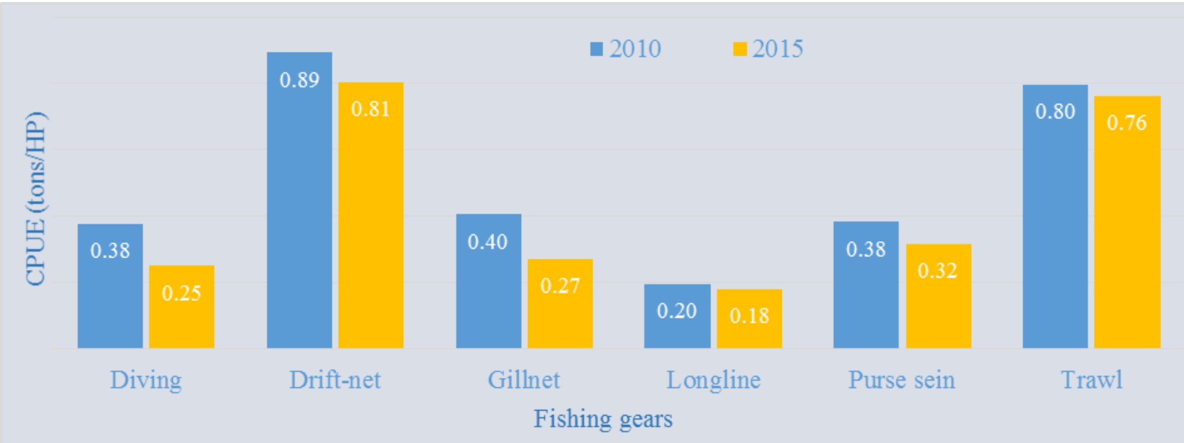

Figure 15: CPUE by fishing gear between 2010 and 2015 based on survey data

[3] Only species found within 30 nautical miles, classified as coastal resources, are included. Main species include Anchovy (*Stolephorus commersonnii)*, Lizard-fish (*Saurida elongata*), Pony-fish (*Photopectoralis bindus)*, Scad (*Decapterus maruadsi)*, Smallhead-hairtail (*Eupleurogrammus muticus)*, Squid, Threadfin-porgy (*Evynnis cardinalis*) (Fishbase, 2015)

CPUE by engine power

In general, the CPUE of each engine power group decreased slightly over the period (Figure 16). The CPUE of engine power with range of 20 and 90 HP are highest value that is followed by the CPUE of under 20 HP engine power class. Fishing vessels under 90 HP account for 86 percent of the total engine power. This suggests that most landings and fishing productivity come from near-shore resources.

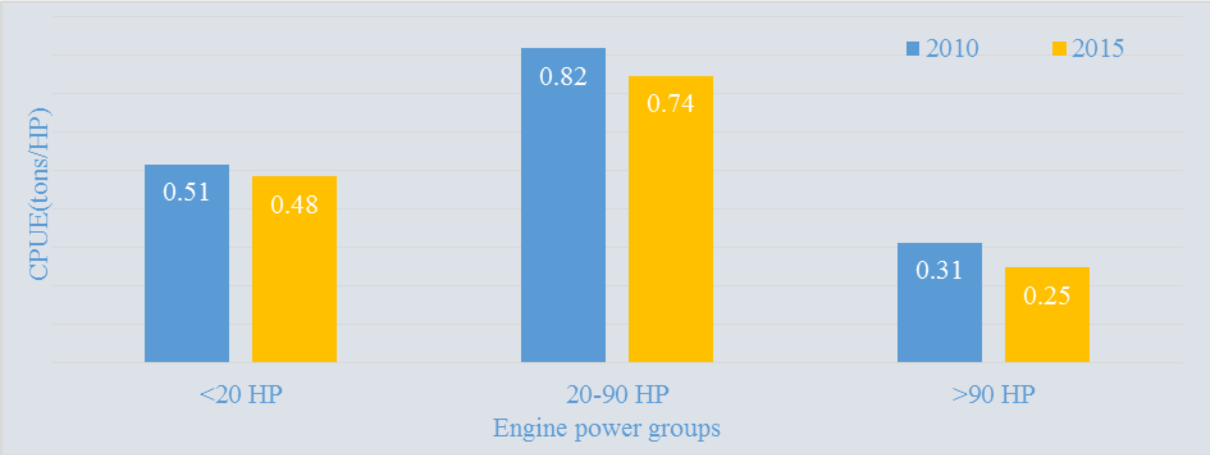

Figure 16: CPUE by the group of engine power in 2010 and 2015 (based on data provided by ADN)

Productivity, measured as CPUE, has declined for almost every species, fishing gear and vessel class which is a strong indication that there is overfishing and the capacity of the fleet in coastal area of the Nui Thanh district should be reduced.

4.1.7 Current fisheries management policies

The government has implemented a range of management policies in order to develop sustainable marine fisheries. There has been some success. But, the goals of the government have not been reached (Pomeroy *et al*. 2009). And, there are no estimates of appropriate reference parameters. A sound base upon which to design appropriate management policies is missing. Existing policies are also not properly implemented by authorities and fishermen.

Current management policies

The current fisheries law was approved by the president in 2003. This law provides a strong and comprehensive legal base for marine fisheries and aquaculture. Sustainable and responsible management through ecosystem based approaches and integrated management are advocated. These include protected species, fishing gear and closed seasons and areas.

In January 2006, the Prime Minister approved a new master plan for fisheries development to 2010 and orientations towards 2020 (Decision number 10/2006/QD-TTg). The plan calls for reducing fishing capacity to 50,000 vessels and the catch to 1.5 million tons by 2010. The purpose was to enhance living standards of fishing communities that depend on coastal resources, to contribute to poverty alleviation within those communities and to assure food security, enhance income and create new opportunities (Pomeroy *et al*. 2009). Despite the effort, the fishing capacity was at approximately 130.000 vessels and the catch was at about 2.2 million tons in 2010.

In March 2010, the Prime Minister issued a decree to manage behaviour of both people and organizations fishing in Vietnamese water (Decree number 33/2010/ND-CP). Boats with engines under 90 HP are required to operate in coastal area (near-shore). But, in fact, boats with large engine who often operate in near-shore.

Last but not least, in August 2014 the Prime Minister issued a decree on fisheries development policies (Decree no. 67/2014). Loan in 700 million USD were to be granted through 2016 for building and upgrading vessels for off-shore fishing. For building and repairing vessels of above 400 HP, fishermen can get loan for up to 95% of the value at a special interest rate of 7% of which 6% is a government subsidy. Nui Thanh district is one of the areas which has benefited the most from these policies. However, only 11 out of 38 (29%) powerful vessels had been able access to capital from a bank by the end of year 2015 (Khang 2015, Phin 2015).

<u>Local management policies</u>

In 2014, the local government issued comprehensive regulations regarding the management, protection and development of marine resources in Quang Nam province (Decision no. 28/2014/UBND). [4]

Regulation number 18 states that fishing vessels under 90HP are allowed to fish within the 30 nautical miles line. They are not to be allowed to fish beyond the inshore line nor outside provincial borders. The fishing vessels have to be marked with orange lines indicating which vessel belongs to what zone.

The regulation also bans fishing vessels and other activities in the inshore area of the Nui Thanh district such as fishing with light power over 5,000, electricity, explosives and poisons. Fishing activities should not destroy or impact coral reef and seaweed *(Sargassum)* negatively. The harvest season to seaweed is limitation from 15th May to 30th November each year and the harvesting must not harm the seaweed or other marine ecosystem resources. For example, sickles are only allowed for cutting the seaweed and shall leave at least length of 10 centimetres and least 25% of the seaweed areas must be left for the spawning and habitat of other marine species. Moreover, there are mesh size gear and minimum fish size regulation on fishing in some seasons is prohibited (Appendix 8).

1 Estimation of basic parameters for a bio-economic model

4.1.8 Estimation of biological parameters

In this study, the basic parameters are based on three main variables including the landings (tons), the fishing effort (HP) and CPUE (tons/HP) based on published official statistics from 2003 to 2013 (Table 1)

Regression analysis was used to estimate alpha, beta and q that are 0.839, 0.00000663 and 0.00000521, respectively.

[4] The regulation is comprised of 6 chapters and 32 articles. It is closely linked to the Fisheries Law, the Decree no. 33/2010/ND-CP and the Circular no.02 in which the last one issued to guide the conduct of fishing activities.

Table 1: Landings and fishing effort in Nui Thanh from 2003 to 2013 (ADN, 2014)

Year	*Landings (tons)*	*Fishing effort*		*Productivity*	
		Number of vessels	*Engine power (HP)*	*CPUE (tons/HP)*	*DCPUE (tons/HP)[5]*
2003	17,000	975	27,625	0.615	
2004	18,700	1,007	29,305	0.638	0.037
2005	18,850	1,035	35,000	0.539	0.156
2006	19,840	1,127	40,327	0.492	0.087
2007	21,300	1,467	47,950	0.444	0.097
2008	23,479	1,480	48,200	0.487	0.097
2009	24,000	1,498	51,300	0.468	0.040
2010	26,840	1,519	52,250	0.514	0.098
2011	28,780	1,544	64,000	0.450	0.125
2012	34,000	1,578	94,859	0.358	0.203
2013	34,750	1,527	103,151	0.337	0.060

4.1.9 Estimated cost function

The construction of the cost – function is based on the idea that the least efficient vessels would drop out if the effort would be constrained. If only one ship would be allowed to fish, that would be the vessel with the least cost per horsepower. If two ships were allowed, the second most efficient vessel would be added. By adding the costs and the fishing effort of the vessels this way, one-by-one, we construct the relationship between the total effort and total cost, which forms the basis for the cost function. Thus, we ordered the observations in the survey data, from the most efficient to the least efficient vessel, and found the accumulated cost and accumulated effort for each one that is added. This is represented in Figure 17, as well as the result from a regression, based on a second-degree polynomial relationship; it presents the relationship between cost and engine power, the fishing effort increase, the more expensive it will be to catch the fish.

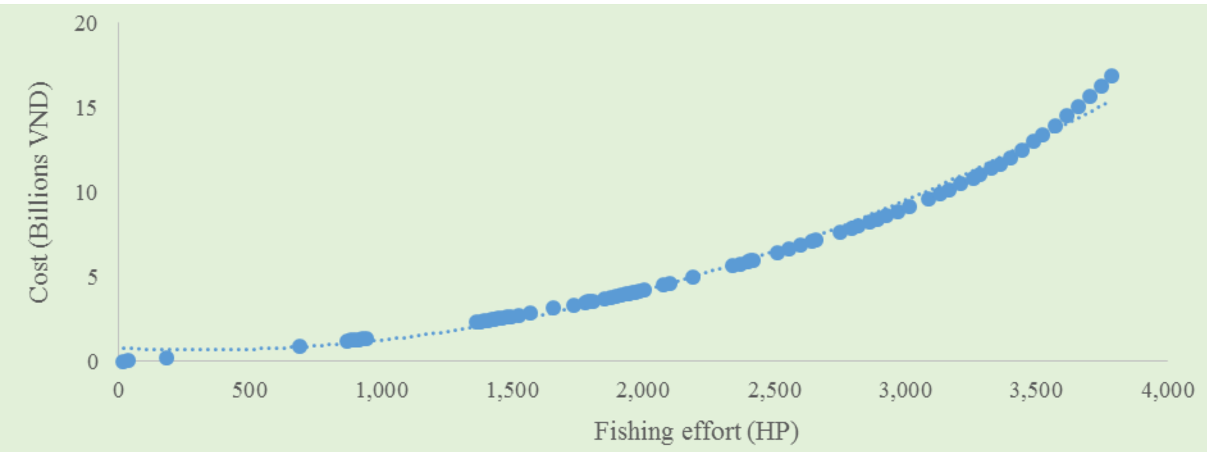

Figure 17: Relationship between cost and fishing effort based on survey data

As the survey data only represents around 5.3% of the total fisheries, we scaled both the cost and the effort up to 100%. For example, the Gillnet is underrepresented in the survey data while the Trawl was overrepresented. However, as Figure 18 shows, not every type of fishing vessel had

[5] $DCPUE = \frac{CPUE_{t+1}}{CPUE_t} - 1$

the same relative representation. Therefore, we used a different scale, depending on the type of vessel.

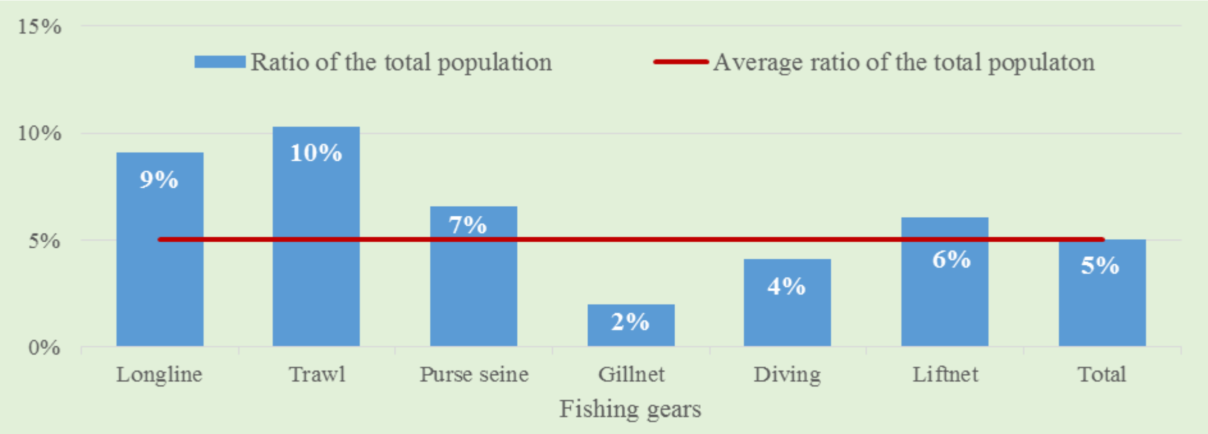

Figure 18: Average ratio of the total fisheries

A fishing cost function, therefore, is estimated for the Nui Thanh fisheries (Figure 19) when the cost function is fitted to scale of the population. Coefficient of determination (R^2=0.99) implies that the fitted regression model is very close to the relationship between fishing cost and effort in the fisheries. The cost function is estimated as below equation:

$$C(f) = 44.79 \cdot f^2 - 748{,}511.94 \cdot f + 21{,}704{,}453{,}796.69$$

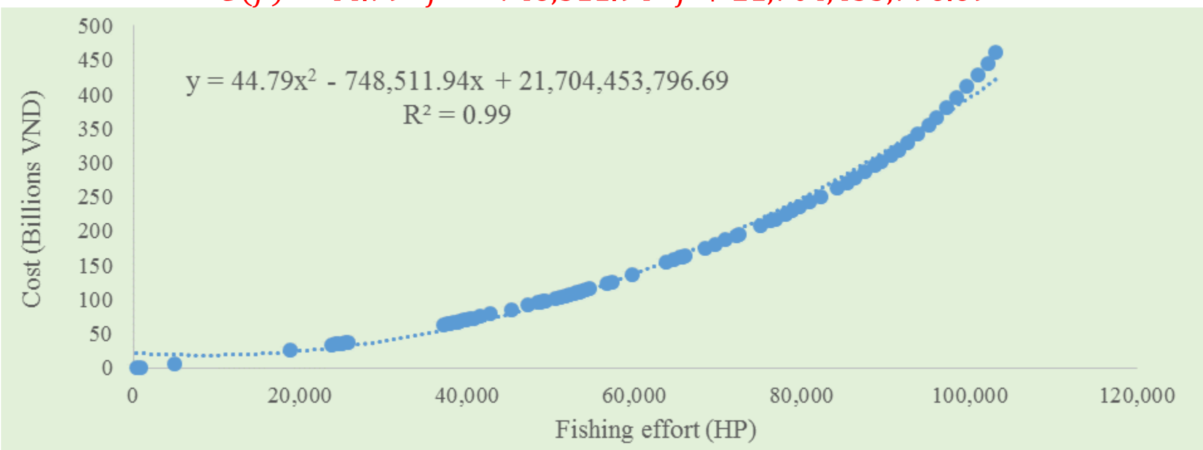

Figure 19: Relationship between cost and fishing effort in the fisheries

4.1.10 Estimated stock biomass and maximum profits

CPUE and fishing effort was used for fitting regression analysis in order to estimate some necessary biological parameters. The results are presented in Table 2 below (further details can be found in Appendix 6).

Table 2: A summary of the main results about estimation of reference points in the fisheries

No.	Variable	Unit	CPE	MSY	MEY
1.	Biomass	Tons	26,094	63,273	76,008
2.	Effort	HP	127,811	80,506	64,302
3.	Harvest	Tons	18,380	26,545	25,470
4.	Cost	USD	32,123,678	12,326,491	7,780,554
5.	Revenue	USD	32,123,678	49,064,099	47,076,327
6.	Profit	USD	0	36,737,608	39,295,773
7.	Virgin biomass: 126,546				
8.	*Exchange rate: 1UDS = ~22,000 VND in 2015*				

According to the sustainable fisheries model, the maximum stock biomass, the level would eventually be reached if there was no harvest, is at about 126,500 tons and the stock at maximum sustainable yield (MSY) is estimated to around 63,000 tons in Nui Thanh district (Table 2).

The MSY slightly above of 26,500 tons indicating that the catch in 2013 significantly exceeds the MSY i.e. the current harvest exceeds maximum sustainable levels. The MSY should be obtained at the level when the combined engine power of all fishing vessels is around 80,500 HP. Thus, by definition, the coastal marine resource in study area are over-exploited. These results are further strengthened by the CPUE analysis results in Chapter 4 (4.1.6) where CPUE was dissected by main species, fishing gear groups, engine power classes and distances of fishing operation.

From the survey data, the harvesting cost that consists of variable and fixed costs was estimated under three groups of engine boat categories (see more details in Appendix 7).

The maximum economic yield (MEY) was estimated at about 25,500 tons which corresponds to level of fishing effort at 64,300 HP (Table 2). The MEY is lower than MSY. The biomass at MEY, which is the level the biomass would eventually reach when the harvest corresponds with the MEY, therefore, was estimated much higher than the level reached at the MSY, at around 76,000 tons.

By maximizing profits in the Nui Thanh district coastal sustainable fisheries, they could generate up to 39.3 million USD compared with current estimated profit of 24.6 million USD (in 2013).
The graph illustrates that the relationship between the biomass and harvest in the fisheries (Figure 20). When the fishing effort increases from zero towards f_{MSY}, the catch increases proportionately and reaches the MSY (26,500 tons) while the biomass decreases. When fishing effort goes beyond the f_{MSY} the catch will decrease (see Appendix 7). The effort level in 2013 exceed effort at MSY by excess about 22,600HP.

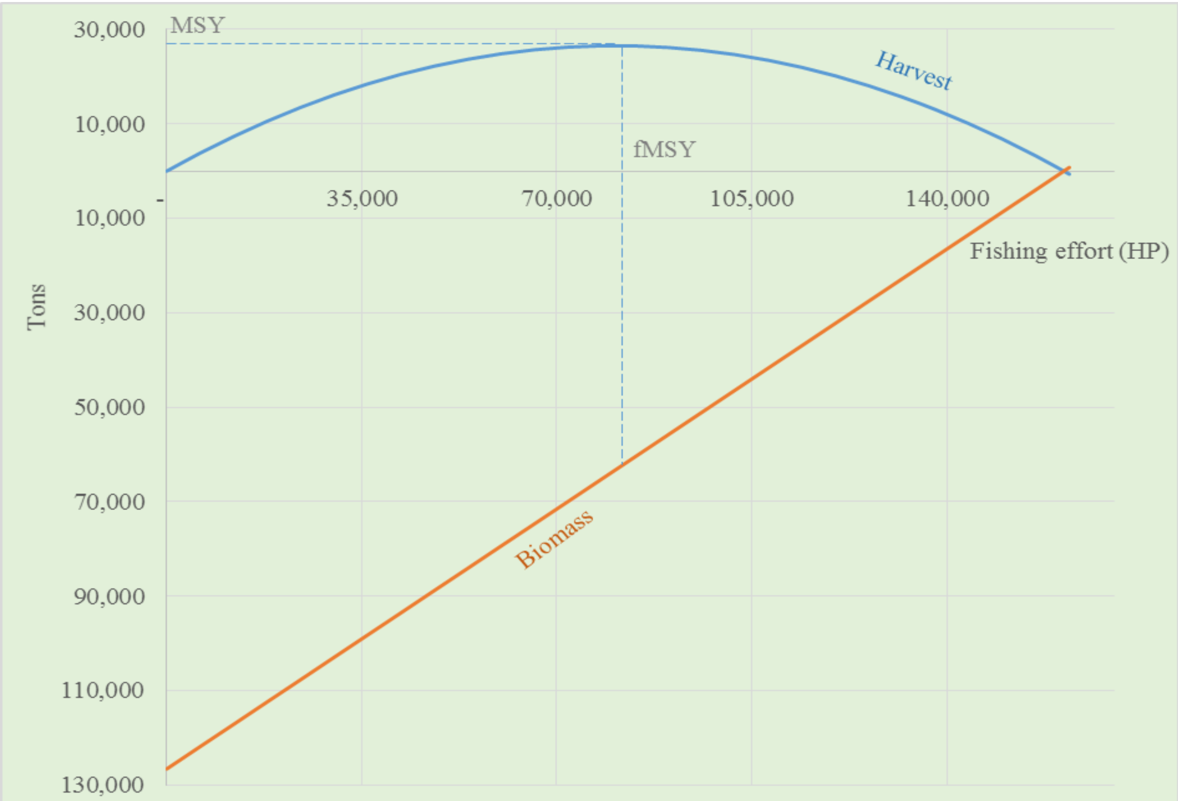

Figure 20: The chart shows relationship between harvest and biomass

According to the bio-economic model the Nui Thanh district's coastal fisheries would reach at maximum profit, fishing effort was reduced to around 64,300 HP (Figure 21). Effort in excess of 64,300 HP would lead to reduce profit. Revenues are maximized at f_{MSY}, if when fishing effort about 80,500 HP. Beyond this point, equilibrium revenues as well as the biomass level will be reduced. Finally, the model predict that continue to rise in effort may lead to a collapse of the fisheries.

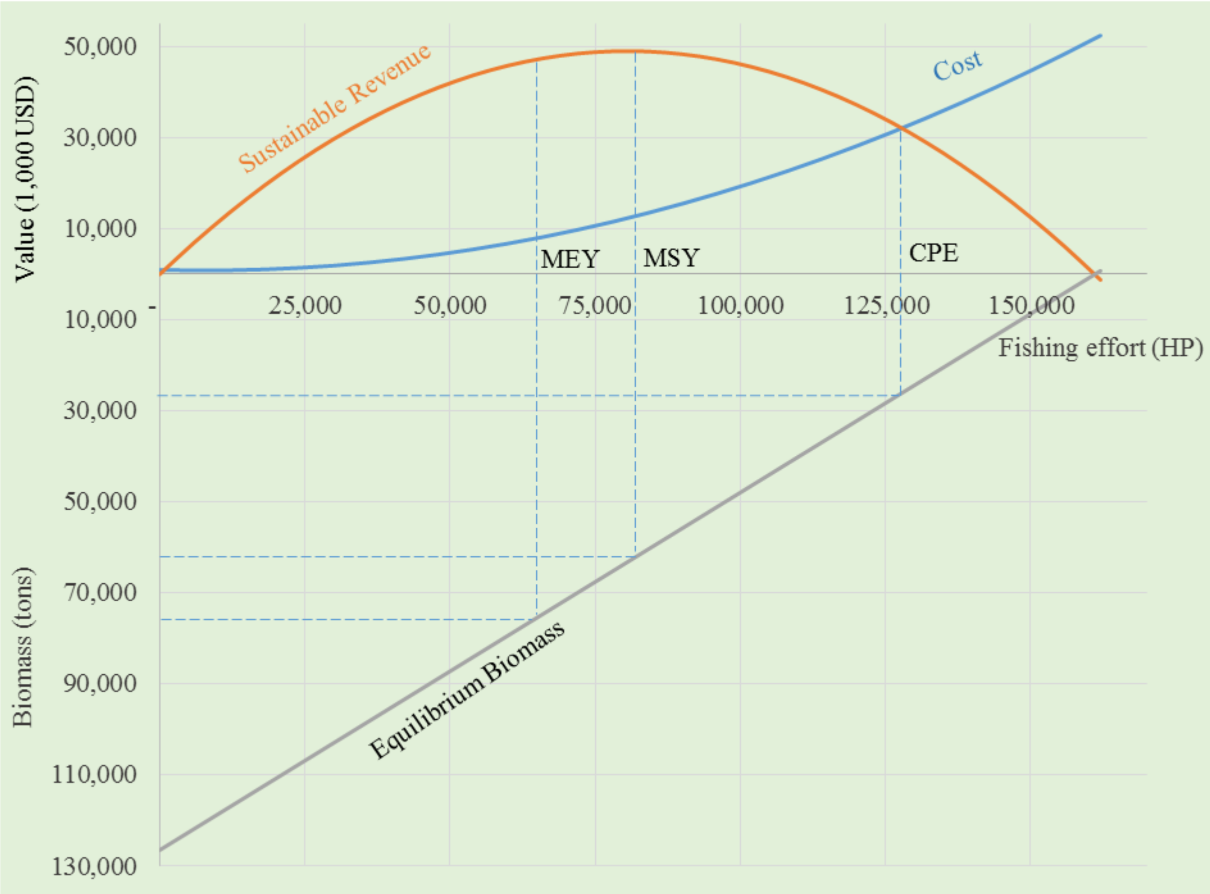

Figure 21: The model of relationship between effort, biomass, profits the Nui Thanh fisheries showing MSY, MEY, CPE

It should be noted that under the common property equilibrium (CPE) of the fisheries, an equilibrium at fishing effort will be found at about 127,800 HP. At this level of fishing effort, fishing costs equal revenues and there are no profits in the fisheries. Compared to the net-benefits obtainable by the optimal fishery (MEY), the common property situation is highly wasteful. Not only does it generate no net economic benefits, it also implies a much smaller biomass level. In the fact, it can easily be verified from inspection of Figure 21, the common property fishery may easily imply the exhaustion of the biomass altogether.

If nothing is done, fisheries will likely move towards this equilibrium, and when subsidies are taken into account, they may even go beyond that.

Specially, if the current increase of fishing effort continues, the Nui Thanh's coastal fisheries will almost surely collapse in near future. Therefore, the fisheries have to be controlled and brought back to a reasonable level.

4.1.11 Estimation of main species catch

Based on survey data, the proportion of each main species was calculated and applied to the whole coastal harvest. The MSY for each species is estimated (Table 3). Scad species is highest catch at 5,309 tons followed by Threadfin porgy and Anchorvy at 3,451 tons and 2,655 tons, respectively.

Table 3: The proportion of main species within MSY

No.	Main species	Proportion of total catch (%)	Estimated MSY (tons)
1.	Scad (*Decapterus maruadsi)*	20	5,309
2.	Threadfin porgy (*Evynnis cardinalis*)	13	3,451
3.	Anchorvy (*Stolephorus commersonnii)*	10	2,655
4.	Smallhead hairtail (*Eupleurogrammus muticus)*	9	2,389
5.	Squid	6	1,593
6.	Lizardfish (*Saurida elongata*)	5	1,327
7.	Ponyfish (*Photopectoralis bindus)*	4	1,062
8.	Others	34	8,760
	Total *Maximum sustainable catch (MSY)*	**100%**	**26,545**

2 Solution

Based on the results of the study, several feasible suggestions are proposed:

4.1.12 Solution of capacity management policies

Two options for fishing capacity control policies in Nui Thanh's fisheries are considered:

***First option**: move the fisheries towards maximum sustainable yield*

This is an immediate solution to eliminate the overfishing situation of Nui Thanh district's coastal marine resources. Fishing effort needs to be reduced to 80,506 HP in order to reach the maximum sustainable yield at 26,545 tons. The main focus could eliminate small fishing vessel (<20HP) that are both inefficient and have negative effect on the ecosystem. This alone will reduce effort by around 22,600 HP and no new licence should be issued. In this case, government action will be required that is on the basis of agreement and support fishermen have suitable alternatives.

***Second option:** the fisheries towards maximum economic yield (max profits)*

This should be a long-term strategy. The local government should aim towards maximizing profits in the fisheries. This means that the fishing effort level need to be reduced at 64,300 HP in order to reach the maximum economic yield at 25,500 tons and maximum benefits for the local fishery communities at 39.3 million USD. In this case, the capacity needs to be reduced by about 38,800 HP from the effort level in 2013. An integrated and general solution from local and central government levels needs to be formulated to solve this problem. As a strategic policy tool, buybacks can help re-structure relations among participants in the fisheries, creating positive incentives that reinforce conservation and management objective (Squires *et al.* 2006). Creating alternatives and training may also play an important role. Limited access then is a critical precondition in reducing capacity, specially, limiting free entry into the fisheries by new vessels. It should be noted that buyback programs and other incentive - blocking programs seemed very limited in actual practice, fishers can circumvent these restrictions by one way or others, if it is worth doing so (Holland *et al.* 1999, FAO 2008). In the short term, fishing effort may be reduced in a fishery. However, as long as (regulated) open access fishery incentives remain, improvements in stock abundance will attract additional effort into the fishery. Therefore, only if buybacks are used in conjunction with the implementation of rights – based management systems that adjust economic incentives will individual fishers to more likely to conserve their resource stocks including the fish stock. For example, the incorporated a buyback program with the introduction of an ITQ program could be work very well (FAO 2008).

The second option is optimal in the sense that it maximizes the joint profits and should therefore be considered as a long-term goal.

It should be noted that these recommendations are based on current cost function. It could very well happen that fisheries management policies that improve incentives could result in a lower cost function. If that happens, a government intervention will be needed in order to move the harvest toward MSY level.

4.1.13 Possible changes to government subsidies

A variety of subsidies including crew insurance, no tax on natural resources and fuel price that have played a significant part in the increase of fishing capacity and economic losses in fisheries. It is advisable to reduce or eliminate some of the subsidies. This way, the most inefficient vessels may be eliminated.

4.1.14 Policy permanence

In addition to restricting access, the new policies should also provide permanence so that those that have fishing permits, whether it's in a form of a quota or some other form, are confident that they will keep their permit for a long term they would have the incentives to invest in gear and better handling facilities, more efficient vessels and other development. If they don't have this security they will not make large investments because they might lose everything as soon as they lose their permits. With the ability to plan into the future, they will probably be able to get loans, and no have need for any subsidies.

4.1.15 Solution of sustainable management policies

The improvement of fishers' education plays a key role in terms of enhancing community's awareness of the importance to manage coastal marine resources going towards the sustainable fisheries in the long-term. When fishermen aware they may learn fishing technology to off-shore fisheries. It leads to reduce pressure of coastal fishing activities supply the recovery of coastal marine resource.

The government at the central as well as at the local level should put more emphasis on reducing coastal fisheries. It is impossible to reduce excessive fishing effort without support from the communities. One of important solutions is to recognize that solutions should target not just the individual fisher but the whole household and its broader economic livelihood strategy. No single solution can be successful. It is necessary to implement a coordinated and integrated approach involving a mixed strategy of coastal resource management such as access control and property rights, resource restoration, economic and community development, and new governance arrangements in order to move towards sustainable fisheries.

Territorial Use Rights in Fishing (TURFs) in association with Individual Transferable Quotas (ITQs) is another way to control fishing effort by causing fishers within a specific community to behave as if property rights for a fishing ground exist. When the fishers access to or use the coastal area is restricted to a small group within communities. This community can therefore determine how to harvest fish from the fishing ground and to whom the fish is allocated.

5 CONCLUSION AND DISCUSSION

5.1 Summary

Attaining sustainable fishing in the Nui Thanh fisheries is of crucial importance. By analysing primary and surveyed data the study has found that while the harvest increased gradually from 2003 to 2013, the catch per unit of fishing effort (CPUE) declined, and this was true when CPUE was analysed separately for different fishing gears, size classes of vessels and by different species. Stock size, maximum economic yield, maximum sustainable yield and their corresponding level of fishing effort, and maximum profits were estimated and suitable solutions for sustainable fishing were proposed. These results indicate that landings and effort level in 2013 are greatly exceed these MSY level, Nui Thanh fisheries have been overexploited and economic efficiency could be improved. Several fisheries management policies and regulations have been implemented with a goal of sustainable fisheries development. They have, however all failed. A feasible solution may be based on a coordinated and integrated approach involving mixed strategy of resources management such as governmental buyback programs, access control and property rights, resource restoration, economic and community development, and new governance arrangements.

Territorial use rights in fishing (TURFs) and Individual transferable quotas (ITQs) have been employed in several fisheries around the world with seemingly very good results. In fact, the Nui Thanh fisheries could also be managed on the basis of communal or group, even as one large TURF for the whole area. Indeed, relying on the area as defined by the government, TURFs could be easily realised if local communities are empowered through community based management. Under these approaches, resource ownership remains with the self-management scheme that give fishers a financial incentive to reduce capital investment and labour used in exploiting the fish stock in order to increase individual profitability.

It should be noted that fishing vessels with engine above 90 HP are not allowed to fish in coastal area, but they should be controlled and patrolled more frequently from fisheries authorities. The CPUE for those vessels may be low because the marine resource cannot be exploited more efficiently by larger vessels, due to the density of biomass. Another reason could be that an effort is not approximated as a linear function of the engine size, in which case the effort for the more powerful vessels would be overestimated, and CPUE underestimated.

5.2 Limitations

The present findings must be interpreted in the context of a number of potential limitations and also based on some mentioned assumptions. The management reference points such as MSY, f_{MSY}, stock size, MEY, f_{MEY} and maximum benefits should be used with some caution. However, the findings are consistent with results from other at the national level.

The sustainable revenue is a result from the simple sustainable fisheries model is based on aggregate data from 2003 - 2013 while the cost function is estimated using the cost for different vessels the year 2015. The cost functions for individual vessels might differ from that of the cost function for the fisheries in whole. They therefore might not be entirely compatible. Furthermore, there is some autocorrelation and heteroscedasticity in the model which is not accounted for. Due to few data points, it is not possible to amend this with our current set of data.

In addition, the models do not include salaries, which are a certain proportion of the profit. However, this will not affect the value of MSY, MEY or the CPE, as the profit after the salaries would be proportional to the profit in the models.

In this study, engine power of vessel (HP) is used as a measure for fishing efforts may not reflect all combined characteristic of fishing gears as well as proportional to fishing mortality. In practice, however, the government believe that HP unit can be used as a suitable measure because it is shown to be linearly related to the catch rate. All vessels should be required to keep a logbook to register the time spent fishing and send to the government as a database for making proper management policies.

5.3 Importance and the wider context

Nui Thanh district's coastal fisheries play an important role in developing local economic as livelihood for thousands of people. The fishermen are 17,500 but the whole community, with a population of 140,000, is highly dependent on fisheries in one way or the other. As discussed in chapter 4 (4.1.3), the number of fishers are approximately 10,000. With an average family size of 5 people, this affects above a third of the population. This is without taking into account all dependent jobs related economic activity. The community is therefore highly dependent on the fisheries as a livelihood. Thus, it matters a great deal how the fisheries are managed and controlled.

By maximizing profits in the Nui Thanh district coastal sustainable fisheries, they could reach up to 39.3 million USD compared with a current level of about 24.6 million USD (estimated). This would raise GDP per capita, and therefore the living standards of the average person, by about 38.7%.[6] It is necessary to move the fisheries of Nui Thanh towards maximum economic yield by reducing fishing capacity. It is also important to prioritize toward off-shore fishing activities rather than near-shore fishing.

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[6] The living standards of the average person is calculated as below:

$$x = \frac{\pi_{MEY} - \pi_{Current}}{GDP\ per\ capita \cdot Polulation} \cdot 100\%$$

Where: π_{MEY} is profit at MEY; $\pi_{current}$ is profit at the level in 2013; GDP per capita is 1,180 USD per year; Population is current number of persons in Nui Thanh district (140,000 persons in 2014).

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APPENDICES

Appendix 1: Questionnaire form for a survey in Nui Thanh fisheries in December 2015

QUESTIONNAIRE FORM – PHIẾU KHẢO SÁT

Please make you answer as accurate as possible. If you don't know the right answer, please give us your best guess. We promise you a full confidentiality. The data will only be used for research purposes.

<table>
<tr><td>1</td><td>Fishing gear
(Nghề khai thác chính)</td><td colspan="3">No. of Crew
(Số thuyền viên)</td><td colspan="2">Engine power (HP)
(Công suất máy)</td></tr>
<tr><td>2</td><td>How far do you fish from shore on average?
(Khai thác cách bờ bao nhiêu hải lý)</td><td colspan="5">How many days is each fishing trip on average?
(Số ngày/chuyến biển)</td></tr>
<tr><td>3</td><td>Landing per day? (kg)
Sản lượng của 4 chuyến biển gần nhất</td><td><u>Today</u></td><td><u>Yesterday</u></td><td colspan="2"><u>Day before yesterday</u></td><td><u>Average</u></td></tr>
<tr><td>4</td><td>Average landing per year? (tấn)
Sản lượng trung bìnhcủa 3 - 4 năm gần nhất</td><td><u>This year</u></td><td><u>Last year</u></td><td colspan="2"><u>Five years ago</u></td><td></td></tr>
<tr><td>5</td><td>Composition of main species
Tỷ lệ thành phần loài khai thác chủ yếu</td><td colspan="3">Fish species
(Loài cá)</td><td colspan="2">Percentage (%)
(Tỷ lệ phần trăm)</td></tr>
<tr><td></td><td>Species 1 (Loài 1)</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td></td><td>Species 2 (Loài 2)</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td></td><td>Species 3 (Loài 3)</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td></td><td>Others (Loài khác)</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>6</td><td colspan="6">Fishing cost (Chi phí hoạt động khai thác):</td></tr>
<tr><td>7</td><td>Cost of a fishing trip
(Chi phí 1 chuyến biển)</td><td colspan="2">Unit
(ĐVT)</td><td colspan="2">Price (VNĐ)
(Giá thành VNĐ)</td><td>Cost
(Thành tiền)</td></tr>
<tr><td></td><td>Fuel (Nhiên liệu: Dầu, nhớt)</td><td colspan="2">(Liter)</td><td colspan="2"></td><td></td></tr>
<tr><td></td><td>Ice (Đá)</td><td colspan="2">(Stick)</td><td colspan="2"></td><td></td></tr>
<tr><td></td><td>Food (Thực phẩm)</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td>Labour cost (Thù lao thuyền viên)</td><td colspan="2">(no. of persons)</td><td colspan="2"></td><td></td></tr>
<tr><td></td><td>Other cost per trip (chi phí khác)</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td>Total cost per trip (Tổng chi phí chuyến biển)</td><td colspan="5"></td></tr>
<tr><td>8</td><td>Fixed cost (chi phí cố định)</td><td colspan="5">VND (Triệu đồng)</td></tr>
<tr><td></td><td>Repair and Maintenance per year
(Duy tu, sửa chữa hàng năm)</td><td colspan="5"></td></tr>
<tr><td></td><td>Labour insurance per year
(Bảo hiểm thuyền viên)</td><td colspan="5"></td></tr>
<tr><td></td><td>Vessel insurance per year
(Bảo hiểm thân tàu)</td><td colspan="5"></td></tr>
<tr><td></td><td>Other fixed costs (chi phí khác)</td><td colspan="5"></td></tr>
<tr><td></td><td>Total fixed costs (Tổng chi phí)</td><td colspan="5"></td></tr>
<tr><td>9</td><td>Revenue of a fishing trip
(Doanh thu 1 chuyến biển)</td><td colspan="2">Harvest (kg)
(Sản lượng kg)</td><td colspan="2">Price per kg
(Giá thành VNĐ)</td><td>Revenue
(Thành tiền)</td></tr>
<tr><td></td><td>Species 1 (Loài 1)</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td>Species 2 (Loài 2)</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td>Species 3 (Loài 3)</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td>Others (Loài khác)</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td>Total revenue of a fishing trip
(tổng doanh thu chuyến biển)</td><td colspan="5"></td></tr>
<tr><td>10</td><td>Total annual revenue (million VND)
(Doanh thu 1 năm – triệu đồng)</td><td colspan="4"></td><td></td></tr>
<tr><td>11</td><td>Total annual cost (million VND)
(Tổng chi phí một năm – triệu đồng)</td><td colspan="4"></td><td></td></tr>
<tr><td>12</td><td>Debt – related to fisheries (Vốn vay ngân hàng)</td><td colspan="4"></td><td></td></tr>
</table>

Thank you for your participation! Chân thành cám ơn./.
Name of Collector/ Cán bộ điều tra

Appendix 2: The trend in number of fishermen in Nui Thanh district's fisheries

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Fishery labour	17,703	18,009	18,150	19,240	19,931	19,780	18,080	17,545	17,654	17,820	17,864
Fisher	7,490	7,624	7,700	8,120	9,300	9,320	9,350	9,410	9,722	9,830	9,804
Farmer	8,860	8,800	8,700	8,820	8,200	8,000	6,560	6,250	5,950	5,960	5,960
Processor	1,170	1,350	1,500	2,000	2,081	2,100	1,800	1,500	1,554	1,600	1,650
Services	183	235	250	300	350	360	370	385	428	430	450

Appendix 3: The landings, fishing efforts in Nui Thanh over time

Year	Landings (tons)	Fishing vessels (unit)	Engine power (HP)	CPUE (tons/HP)	CPUE (tons/vessel)
2003	17,000	975	27,625	0.62	17.44
2004	18,700	1,007	29,305	0.64	18.57
2005	18,850	1,035	35,000	0.54	18.21
2006	19,840	1,127	40,327	0.49	17.60
2007	21,300	1,467	47,950	0.44	14.52
2008	23,479	1,480	48,200	0.49	15.86
2009	24,000	1,498	51,300	0.47	16.02
2010	26,840	1,519	52,250	0.51	17.67
2011	28,780	1,544	64,000	0.45	18.64
2012	34,000	1,578	94,859	0.36	21.55
2013	34,750	1,527	103,151	0.34	22.76

The classification of fishing vessel by engine classes and fishing gear in 2013

No.	Engine power classes (HP)	The number of vessel classified by fishing gear in 2013						Total
		Longline	Trawl	Purse seine	Gillnet	Diving	Lift-net	
1	<20	54	23	62	509	195	88	931
2	20 - 90	59	97	116	45	0	57	374
3	>90	52	35	34	48	0	53	222
Total		165	155	212	602	195	198	1527

Appendix 4: CPUE by main species in different fishing distances

No.	<15 nautical miles	2010	2015	Estimate
1.	Anchorvy	2.32	2.26	Decreasing CPUE
2.	Coral fishes	0.84	0.48	Decreasing CPUE
3.	Crab	0.84	0.71	Decreasing CPUE
4.	Crimson jobfish	0.57	0.46	Decreasing CPUE
5.	Escolar			n
6.	Flyingfish	0.25	0.21	Decreasing CPUE
7.	Lizardfish	3.48	3.38	Decreasing CPUE
8.	Ponyfish	2.47	2.52	Increasing CPUE
9.	Scad	1.87	1.78	Decreasing CPUE
10.	Smallhead hairtail	1.23	1.04	Decreasing CPUE
11.	Squid	8.95	8.20	Decreasing CPUE
12.	Threadfin porgy	1.63	1.52	Decreasing CPUE
13.	Tuna			n
	Average	2.22	2.05	Decreasing CPUE

No.	15-30 nautical miles	2010	2015	Estimate
1.	Anchorvy	5.56	4.44	Decreasing CPUE
2.	Coral fishes			n
3.	Crab			n
4.	Crimson jobfish			n
5.	Escolar	0.84	0.62	Decreasing CPUE
6.	Flyingfish			n
7.	Lizardfish			n
8.	Ponyfish			n
9.	Scad	1.54	1.24	Decreasing CPUE
10.	Smallhead hairtail	0.31	0.31	Decreasing CPUE
11.	Squid	4.59	4.01	Decreasing CPUE
12.	Threadfin porgy			n
13.	Tuna	0.98	0.79	Decreasing CPUE
	Average	2.30	1.90	Decreasing CPUE

No.	<30 nautical miles	2010	2015	Estimation
1.	Anchorvy	7.87	6.70	Decreasing CPUE
2.	Lizardfish	3.48	3.38	Decreasing CPUE
3.	Ponyfish	2.47	2.52	*Increasing CPUE*
4.	Scad	3.41	3.03	Decreasing CPUE
5.	Smallhead hairtail	1.54	1.35	Decreasing CPUE
6.	Squid	13.54	12.22	Decreasing CPUE
7.	Threadfin porgy	1.63	1.52	Decreasing CPUE
8.	Others	4.33	3.27	Decreasing CPUE
	Average	4.78	4.25	Decreasing CPUE

NO.	>30 nautical miles	2010	2015	Estimate
1.	Anchorvy			
2.	Coral fishes			
3.	Crab			
4.	Crimson jobfish	0.33	0.22	Decreasing CPUE
5.	Escolar	2.42	1.41	Decreasing CPUE
6.	Flyingfish			
7.	Lizardfish			
8.	Ponyfish			
9.	Scad			
10.	Smallhead hairtail	0.08	0.05	Decreasing CPUE
11.	Squid	0.17	0.1	Decreasing CPUE
12.	Threadfin porgy			
13.	Tuna	1.21	0.71	Decreasing CPUE
	Average	0.84	0.50	Decreasing CPUE

Appendix 5: CPUE by fishing gear

No.	Fishing gears	Landings (tons) during 2010 to 2015		
		2010	2015	Total engine (HP)
1.	Diving	44.5	29.6	118.0
2.	Drift-net	440.0	397.0	493.0
3.	Gillnet	234.4	156.6	579.0
4.	Longline	106.3	98.0	545.0
5.	Purse sein	725.0	599.0	1,899.0
6.	Trawl	804.0	771.0	1,010.0
	Total (tons)	2,354	2,051	4,644

No.	Fishing gears	CPUE by fishing gear (tons/HP)		
		2010	2015	Estimation
1.	Diving	0.37712	0.250847	Decreasing CPUE
2.	Drift-net	0.89249	0.805274	Decreasing CPUE
3.	Gillnet	0.40484	0.270466	Decreasing CPUE
4.	Longline	0.19505	0.179817	Decreasing CPUE
5.	Purse sein	0.38178	0.315429	Decreasing CPUE
6.	Trawl	0.79604	0.763366	Decreasing CPUE
	Grand Total	0.50693	0.441688	Decreasing CPUE

Engine power groups	CPUE by engine power groups (tons/HP)		
	2010	2015	Estimation
< 20HP	0.514634	0.484146	Decreasing CPUE
20-90 HP	0.816939	0.744949	Decreasing CPUE
> 90 HP	0.313556	0.248216	Decreasing CPUE

Appendix 6: Results of Regression analysis to estimate biological parameters

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.483710618
R Square	0.233975962
Adjusted R Square	0.015111951
Standard Error	0.101840397
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.022175175	0.011087587	1.069047217	0.393412717
Residual	7	0.072600266	0.010371467		
Total	9	0.094775441			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.839064951	0.612120723	1.370750767	0.21278555	-0.60837056	2.286500457
Engine power	-0.00000521	3.72142E-06	-1.40032103	0.204148968	-1.4011E-05	3.58858E-06
CPUE (tons/HP)	-1.272363982	0.8864064	-1.43541832	0.194304241	-3.36838205	0.823654088

RESIDUAL OUTPUT

Observation	*Predicted DCPUE*	*Residuals*	*Standard Residuals*
1	-0.087887	0.124826	1.38982
2	-0.125565	-0.03043	-0.33884
3	-0.028586	-0.05793	-0.64496
4	0.0029382	-0.10003	-1.1137
5	0.0239882	0.072595	0.808274
6	-0.031903	-0.00768	-0.08547
7	-0.023527	0.121527	1.353085
8	-0.086813	-0.03777	-0.42054
9	-0.066617	-0.13633	-1.51785
10	-0.111312	0.051211	0.570184

PROBABILITY OUTPUT

Percentile	*DCPUE*
5	-0.20294
15	-0.156
25	-0.12458
35	-0.09709
45	-0.08651
55	-0.0601
65	-0.03958
75	0.036939
85	0.096583
95	0.098

Estimate for alpha = 0.839064951; beta = 0.00000663; q = 0.00000521

Appendix 7: Simple sustainable fisheries models

Biological parameters		Economic parameters	
Parameters	*Values*	*Parameters*	*Values*
alpha	0.839064951	price	1,848 USD/ton
beta	0.00000663	b	-748,511.94
q	0.00000521	c	47.79
X_{max}	126,546 tons	fk	21,704,453,796.69
X_{MSY}	63,273 tons	$C(f)=(fk+b.f+c.f^2)/22{,}000$	
Step_effort	6,000		
MSY	26,545 tons		
K	126,546 tons		

Calculation results from model fitting

Effort	Biomass	Harvest	Revenue	Cost	Profit	Biomass
-	126,546	-	-	986,566	-986,566	-126546
6,000	121,830	3,809	7,040,822	860,628	6,180,193	-121830
12,000	117,114	7,324	13,536,590	891,094	12,645,496	-117114
18,000	112,399	10,543	19,487,306	1,077,964	18,409,343	-112399
24,000	107,683	13,468	24,892,969	1,421,237	23,471,732	-107683
30,000	102,968	16,097	29,753,579	1,920,913	27,832,666	-102968
36,000	98,252	18,432	34,069,136	2,576,994	31,492,142	-98251.9
42,000	93,536	20,472	37,839,640	3,389,478	34,450,162	-93536.3
48,000	88,821	22,217	41,065,091	4,358,365	36,706,726	-88820.7
54,000	84,105	23,668	43,745,490	5,483,657	38,261,833	-84105
60,000	79,389	24,823	45,880,835	6,765,352	39,115,483	-79389.4
66,000	74,674	25,683	47,471,128	8,203,450	39,267,677	-74673.8
72,000	69,958	26,249	48,516,367	9,797,952	38,718,415	-69958.1
78,000	65,243	26,519	49,016,554	11,548,858	37,467,696	-65242.5
84,000	60,527	26,495	48,971,688	13,456,168	35,515,520	-60526.9
90,000	55,811	26,176	48,381,768	15,519,881	32,861,888	-55811.2
96,000	51,096	25,562	47,246,796	17,739,998	29,506,799	-51095.6
102,000	46,380	24,653	45,566,771	20,116,518	25,450,253	-46380
108,000	41,664	23,449	43,341,693	22,649,442	20,692,251	-41664.3
114,000	36,949	21,950	40,571,562	25,338,770	15,232,793	-36948.7

120,000	32,233	20,157	37,256,379	28,184,501	9,071,878	-32233.1
126,000	27,517	18,068	33,396,142	31,186,636	2,209,506	-27517.5
132,000	22,802	15,685	28,990,852	34,345,174	-5,354,322	-22801.8
138,000	18,086	13,007	24,040,510	37,660,117	-13,619,607	-18086.2
144,000	13,371	10,033	18,545,114	41,131,462	-22,586,348	-13370.6
150,000	8,655	6,765	12,504,666	44,759,212	-32,254,546	-8654.92
156,000	3,939	3,202	5,919,165	48,543,365	-42,624,200	-3939.29
162,000	-776	-655	-1,211,389	52,483,922	-53,695,311	776.3387

Appendix 8: The regulation of fishing gear and fish size

No.	Fishing gear	Minimum mesh size (mm)	Main marine species	Minimum fishable fish size (mm)
1	Sardine gillnet	28	Sardine (Sardinella jussieu)	80
2	Mackerel gillnet	90		
3	Shrimp	44	Shrimp (Penaeus indicus)	120
4	Purse sein, lift-net	18	Flying fish (Cypselurus spp)	120
5	Anchovy purse seine	10	Anchovy (Anchovy spp.)	50
6	Fish Trawl		Smallhead hairtail (Trichiurus lepturus)	300
	- Under 90HP	28	Squid	100-150
	- 90 – 150HP	34		
	- Above 150	40		
7	Shrimp trawl			
	- Under 45CV	20		
	- From 45CV	30		

Appendix 9: Statistical estimation of the biological parameters

We solved equation 4 and 5 in the main text, assuming discrete time, as follows:

$$x(t+1) - x(t) = \alpha \cdot x(t) - \beta \cdot x(t)^2 - q \cdot e(t) \cdot x(t)$$

Dividing x(t) in two sides of equation above, we have

$$\frac{x(t+1)}{x(t)} - 1 = \alpha - \beta \cdot x(t) - q \cdot e(t) \qquad (18)$$

It can be seen that $y(t) = q \cdot e(t) \cdot x(t)$ ➔ $\frac{y(t)}{e(t)} = q \cdot x(t)$ or $x(t) = \frac{y(t)}{e(t) \cdot q}$

From that, substituting to equation (18), we have the equation as below

$$\frac{\frac{y(t+1)}{e(t+1)} \cdot q}{\frac{y(t)}{e(t)} \cdot q} - 1 = \alpha - \beta \cdot \frac{y(t)}{e(t) \cdot q} - q \cdot e(t)$$

$$\frac{\mathrm{CPUE(t+1)}}{\mathrm{CPUE(t)}} - 1 = \alpha - \frac{\beta}{\mathrm{q}} \cdot \mathrm{CPUE(t)} - \mathrm{q} \cdot \mathrm{e(t)} \qquad (19)$$

We reduce and shortly make equation as linear function as below

$$Y = A + B \cdot CPUE(t) + C \cdot e(t) \qquad (20)$$

Where, $Y = \frac{CPUE(t+1)}{CPUE(t)} - 1$; $A = \alpha$; $B = -\frac{\beta}{q}$; $C = -q$

Assuming long term equilibrium imposes requirements on the model which allows us to determine net benefit. Solver function was used to estimate maximum profit corresponding to fishing effort.

Appendix 10: Summary of survey data

Survey data	Average	Min	Max
Fishing gear			
Number of crews	4.6375	1	17
Engine power (hp)	58.05	8	508
Distance from shore (nautical miles)	10.26875	0.5	60
Days/ trip	2.8125	1	24
Landing/ trip (kg) today	563	10	17,000
Landing/ trip (kg) yesterday	595	10	19,000
Landing/ trip (kg) day before yesterday	599	10	18,500
Landing/ trip (kg) fourth	368	8	4,500
Average fishing trip	531	10	13,629
Cpue fishing trip (kg/hp)	7	1	32
Landing per year (ton) 2015	26	2	150
Landing per year (ton) 2014	27	2	170
Landing per year (ton) 2013	24	2	100
Landing per year (ton) five year ago	29	1	170
Fuel unit (liters)	254	2	5,000
Fuel price (VND)	2,449,800	0	100,600,000
Ice unit (sticks)	25	0	800
Ice price (VND)	17,454	16,000	20,000
Food (VND)	944,375	50,000	20,000,000
Owner's share (%)	50	40	50
Crew's share (%)	50	50	60
Others cost per trip (VND)	374,250	10,000	3,000,000
Total cost per trip (VND)	5,127,698	97,000	100,600,000
Repair & maintenance per year (VND)	13,331,250	500,000	60,000,000
Other (VDN)			
Total (VND)	13,446,750	500,000	60,000,000
Revenue species 1	#DIV/0!	0	0
Revenue catch 1	414	1	13,000
Revenue price 1 (VND)	51,225	9,000	200,000
Revenue species 2	#DIV/0!	0	0
Revenue catch 2	85	2	2,000
Revenue price 2 (VND)	56,041	10,000	200,000
Revenue species 3	#DIV/0!	0	0
Revenue catch 3	150	4	#NAME?
Revenue price 3 (VND)	41,684	7,000	#NAME?
Revenue total (VND)	16,924,338	330,000	297,000,000
Annual revenue (VND)	41,684	7,000	100,000
Annual cost (VND)	223,037,500	14,000,000	950,000,000