Is green growth possible in Vietnam? The case of marine capture fisheries

Thanh Viet Nguyen,[a] Manh Hung Nguyen[b], Quang Le Van[c]

a. University of Economics and Business, Vietnam National University and Hanoi University of Natural Resources and Environment
b. Toulouse School of Economics, INRA, University of Toulouse Capitole
c. IREEDS and Rouen University

Abstract

The objective of this study is to assess sustainable development and the potential for green growth of the marine capture fisheries in Vietnam. We use "standard" bio-economic models with additional terms to correct some of ecosystem externalities and to define reference points for the fisheries. The results show that Vietnam's marine capture fisheries are unsustainable and the fishing effort needs to be reduced about 0.35 and 0.39 of present effort in order to achieve the maximum sustainable yield (MSY) and maximum economic yield (MEY), respectively. If ecosystem externalities are taken into account, the situation is even worse. The potential for green growth in the fisheries is estimated to be about 7.3 billion USD, higher than the export value for fisheries and aquaculture products in Vietnam in 2016. Green growth policies for the fisheries include public subsidies to environmentally friendly industries, reducing the "trash" fish catch and more efficient regulations more effectively enforced.

Key words: Marine capture fisheries, green growth, sustainable development, Vietnam.

1. Introduction

The fisheries sector represents an important source of economic growth, employment, nutrition, and foreign exchange in Vietnam (McCoy, Thurlow et al. 2010). Over five percent of export earnings stem from fisheries aquaculture products, which is worth US$ 7.05 billion in 2016 (Anon 2016). There are approximately 130 commercially valuable species in Vietnam's sea waters with a total official fisheries catch of 3.07 million MT in 2016 (Anon 2016). There are five main fishing areas in Vietnam: the Gulf of Tonkin, shared with China; the Central area of Vietnam; the South-eastern area of Vietnam; the South-western area of Vietnam (part of the Gulf of Thailand), shared with Cambodia and Thailand; and the Central South China Sea. Vietnam's marine fisheries are concentrated on coastal waters, which has resulted in heavy pressure on near-shore fisheries resources (Pomeroy, Thi Nguyen et al. 2009). Near-shore fisheries are considered to be over-exploited by fishers and the government and the proportion of low value/"trash" fish in the total catch of these fisheries continues to rise (Edwards, Tuan et al. 2004, Pomeroy, Thi Nguyen et al. 2009). The composition of low value/"trash" fish in the total catch varies depending on the type of gear used to fish and the fishing grounds, but most are from trawling (Edwards, Tuan et al. 2004). In 2004, the catch composition (%) of "trash" fish in landings by pair trawl in the the Gulf of Tonkin was about 70% and 42% in the Southeast area (Son, Thi et al. 2005). Long (2001) estimated that the real catches in the Gulf of Tonkin had exceeded maximum sustainable yield (MSY) since 1994 (Long 2001). Thanh (2011) also showed that the shrimp trawl fisheries in the Gulf of Tonkin were fully exploited both in terms of maximizing yield and maximizing profits. As the result, the fishing effort in that area should be reduced by roughly 12-44% to achieve the MSY and 46-61% to reach the maximum economic yield (MEY). Agencies such as the provincial Departments of Capture Fisheries and Resource Protection (SubDecafirep) have lacked the budgetary resources to provide the required management, monitoring, surveillance or regulation enforcement in both Vietnam's inshore and offshore waters (Zweig, Thong et al. 2005). In addition, fishing licenses are normally imposed and granted on the basis of submitting a number of supporting documents such as vessel inspection, registration papers and a small license fee (proportional to engine size). In this case, the registration for a license is not an obstacle for joining the sector; therefore, marine capture fisheries in Vietnam are, in fact, an open access resource (Thanh 2011). With the increasing population pressure and the development of more effective (and/or destructive) fishing gears, inshore resources have been increasingly overexploited. One possible solution to these issues sustainability in the Vietnamese marine fisheries is the adoption of green growth principles. Green growth is defined as fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies (OECD 2011). Green growth could be seen as part of sustainable development in the sense that only a subset of the capital stocks relevant to meeting the needs of future generations is explicitly considered (Schmalensee 2012). Green growth is also described as growth that is efficient in its use of natural resources, clean (as it minimizes pollution and environmental impacts) and resilient (as it accounts for natural hazards) (WB 2012). Sumaila (2011) has defined green growth in fisheries as moving from the current situation where fishing is unsustainable to one where fishing is equal to or less than the growth of wild stocks. However, green growth in fisheries could be understood in much broader terms than just reducing the growth of overfishing. Green growth in fisheries may include reducing recruit overfishing and correcting all ecosystem externalities which can affect fisheries productivity (Ryan, Holland et al. 2014). These externalities may include habitat degradation by using destructive fishing gears, crowding fishing, bycatch of forage species or juveniles of the target species. Green growth in fisheries can be achieved by developing environmental friendly fishing industries and using an ecosystem approach to correct environmental market failures (Nielsen, Ravensbeck et al. 2014).

Traditional bio-economic models do not generally take into account ecosystem externalities (Pascoe, Hutton et al. 2018); therefore, using standard reference points derived from these models to assess sustainable development of fisheries is questionable (Larkin 1977, Downing and Plante 1993). Larkin (1977) pointed out that the maximum sustained yield (MSY) was not sufficient for assessing sustainable exploitation of fisheries resources. He also suggested that a more sophisticated concept urgently needs to be developed. Downing and Plante (1993) noted that sustainable fish yields should be lower for larger fish species, at high latitudes, and higher for higher temperatures or under more eutrophic conditions. They recommended that sustainable yields are about 10% of biological production (Downing and Plante 1993). Labrosse *et al* (2000) also estimated that the MSY of demersal reefal and lagoonal finfish in the Northern Province of New Caledonia was about 10 % of the total stocks assessed in the Northern Province.

Hilborn et al (1995) noted that temporal changes in environmental conditions may affect sustainable yields. He suggested that successful management of fisheries will rest on better institutional arrangements for creating incentives for fishermen and controlling fishing activities. Hilborn (2007) provided an additional emphasis on protection of non-target species, and on protection of ecosystems beside the traditional maximum sustainable yield in order to have successful fisheries. Pauly et al (2002) recommended tools for sustainable fisheries including zoning the oceans, reducing subsidies and fishing capacity. Stobutzki et al (2001) raised issues of fishery bycatch and impacts of trawling on bycatch species. Adrianto et al (2005) proposed a framework for analyzing fishery sustainability indicators by involving the fishery stakeholders in the Yoron Island, Japan. Pascoe and Hillary (2016) showed that management of fisheries in Australia targeting maximum economic yield (MEY) while New Zealand targets maximum sustainable yield. Pascoe et al (2015) proposed a framework to estimate target reference points for multispecies and mixed fisheries. Pascoe et al (2018) developed a generic multispecies bioeconomic model to include changes in consumer surplus as well as the inclusion of non-market values associated with bycatch.

The objective of this study is to assess sustainable development and potential green growth for the marine capture fisheries in Vietnam. We use "standard" bio-economic models with additional terms to correct some of ecosystem externalities and to define reference points for the fisheries. Aggregate catch and effort data from 1976 to 2016 and other economic data for the fisheries were collected from the Vietnam Ministry of Agriculture and Rural

Development (MARD). The reference points of the fisheries are analyzed to assess sustainable development and the potential for green growth of the marine capture fisheries in Vietnam.

The paper will be constructed as follows: the next section presents the data and the models used. The following sections describe the empirical results from the models and green growth policies for marine capture fisheries in Vietnam. The last section summarizes the main conclusions.

2. Methods and data

2.1. Methods

In this section, we use "standard" bio-economic models with additional terms to correct some of ecosystem externalities to define reference points for a fishery with respect to sustainable development and the potential for green growth.

A general growth model for an exploited stock by a fishery with fishing effort *(E)* and stock biomass *(X)* can be expressed as follows (Clark 1990):

$$\frac{dX}{dt} = F(X) - H(E,X) \qquad (1)$$

Where: *F (X)* is the biological growth of the stock; *H (E, X)* is the production function or harvest function of the fishery, which depends on fishing effort *(E)* and stock biomass *(X)*.

The biological growth of the stock F(X) was first proposed as a population model by P.F. Verhulst in 1838 (Verhulst 1838, Clark 1990):

$$F(X) = rX(1 - \frac{X}{K}) \qquad (2)$$

Where: *K* is the environmental carrying capacity; *r* is in this case is called the intrinsic growth rate.

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

$$H(E,X) = qEX \qquad (3)$$

Where:

- *E* fishing effort
- *X* stock biomass
- *q* gear and stock specific constant, referred to as the catchability coefficient.

At the steady state conditions (equilibrium), $\frac{dX}{dt} = 0$, the sustainable yield can be derived from the following equation (Clark 1990):

$$F(X) \equiv H(E, X) \quad (4)$$

We assume that fishing effort *(E)* is measured by aggregated horse power and the biomass variable X consists of a number of different harvested species (to be measured in tons). From (2), (3) and (4), we will have:

$$qEX = rX\left(1 - \frac{X}{K}\right) \leftrightarrow qE = r - \frac{rX}{K} \leftrightarrow X = K - \frac{KqE}{r} \quad (5)$$

The "standard" sustainable yield for a given level of effort:

$$H_s(E) = qKE - \frac{q^2K}{r}E^2 = \gamma_0 E + \gamma_1 E^2 \quad (6)$$

where $\gamma_0 = qK;\ \gamma_1 = -\frac{q^2K}{r}$

Pascoe *et al* (2018) and Armstrong *et al* (2017) have both included the externalities, as cost in the profit and objective function, however, they do not change the catch and growth function. Pascoe *et al* (2018) includes non-market value (as a cost) for iconic species bycatch, which by definition has nothing to do with the growth function for the target species. Armstrong *et al* (2017) includes both use and non-use values of habitat (in their case study they use cold-water coral habitats) in the profit function of the fishery. The use-value is the present value of cold-water corals, while the non-use-values are the cultural value of cold-water corals. In this paper, we have included the externalities differently compare to Pascoe *et al* (2018) and Armstrong *et al* (2017) since we include bycatch (trash fish) and habitat damage by changing the sustainable yield. It is assume that bycatch (trah fish) and habitat damage are caused by non-selective gears (e.g. trawls) and they are depend on fishing effort (E). We introduce additional terms to account for the bycatch $L = \alpha E$ and habitat damage $B = \beta E$ associated with fishing activities, where E is fishing effort and α, β are parameters. The sustainable yield that account for ecosystem externalities for a given level of effort:

$$H_{se}(E) = qKE - \frac{q^2K}{r}E^2 = \delta E + \gamma_1 E^2 \quad (6')$$

where $\delta = \gamma_0 - \alpha - \beta;$

The sustainable catch per unit of effort (CPUE) for a given level of effort :

Without externalities

$$CPUE_s(E) = \frac{H_s(E)}{E} = \gamma_0 + \gamma_1 E \qquad (7)$$

With externalities

$$CPUE_{se}(E) = \frac{H_{se}(E)}{E} = \delta + \gamma_1 E \qquad (7')$$

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

$$TR = pH_s(E);\ TC(t) = cE \qquad (8)$$

Where

p constant price per unit of harvested biomass

c constant cost per unit of effort

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

Without externalities

$$\pi_s(t) = pH_s(E) - cE = (p\gamma_0 - c)E + p\gamma_1 E^2 \qquad (9)$$

With externalities

$$\pi_{se}(t) = pH_{se}(E) - cE = (p\delta - c)E + p\gamma_1 E^2 \qquad (9')$$

The equilibrium level of the fishing effort that produces the maximum sustainable yield (MSY), is determined by differentiating $H_s(E)$ and $H_{se}(E)$ from equation (6) and (6') with respect to E. The results are shown in Table 1. Equation (9) implies that accounting for ecosystem externalities such as habitat damage and bycatch would decrease the sustainable economic rent from π_s to π_{se}.

Table1. MSY and E_{MSY} for the Verhulst-Schaefer models

	Effort at MSY(E_{MSY})	MSY
Standard	$E_{MSY} = -\frac{\gamma_0}{2\gamma_1} = \frac{r}{2q}$	$MSY = -\frac{{\gamma_0}^2}{4\gamma_1} = \frac{rK}{4}$
Ecosystem externalities	$E_{MSY} = -\frac{\delta}{2\gamma_1} = \frac{r(qK - \alpha - \beta)}{2q^2K}$	$MSY = -\frac{\delta^2}{4\gamma_1} = \frac{r(qK - \alpha - \beta)^2}{4q^2K}$

Maximum economic yield (MEY), usually less than MSY, is the degree of exploitation that provides maximum economic benefit or profit to society. If a fishery is an open access resource (the resource rent equals zero), the resource rent at MEY is the potential for green growth (Nielsen, Ravensbeck et al. 2014). The equilibrium level of fishing effort that produces the maximum economic rent is found by differentiating $\pi_s(E)$ and $\pi_{se}(E$ from equation (9) and (9') with respect to E. The results are presented in Table 2.

Table.2. MEY and E_{MEY} for the Verhulst-Schaefer models

	Effort at MEY(E_{MEY})	MEY
Standard	$E_{MEY} = \frac{c - p\gamma_0}{2p\gamma_1} = \frac{r(pqK - c)}{2pq^2K}$	$MEY = \frac{c^2 - p^2{\gamma_0}^2}{4p^2\gamma_1} = \frac{r(p^2q^2K^2 - c^2)}{4pq^2K}$
Ecosystem externalities	$E_{MEY} = \frac{c - p\gamma_0}{2p\gamma_1} = \frac{r(pqK - p\alpha - p\beta - c)}{2pq^2K}$	$MEY = \frac{c^2 - p^2{\gamma_0}^2}{4p^2\gamma_1} = \frac{r[p^2(qK - \alpha - \beta)^2 - c^2]}{4pq^2K}$

Table 1, 2 show that standard reference points (MSY, E_{MSY}, MEY and E_{MEY}) are not only depend on traditional factors such as intrinsic growth rate (r), technology (q) and carrying capacity (K) but also factors that account for ecosystem externalities such as habitat damage (α) and bycatch (β). Downing and Plante (1993) and Labrosse *et al* (2000) suggested that sustainable yields (correcting for ecosystem externalities) are about 10% of biological production or about 20% of the traditional MSY (about 50% of biological production). It implies that by taking into account ecosystem externalities, the estimated coefficient γ_0 would reduce by 80%. According to MARD (2012), gillnet, longline and trawl are the main fishing gears in Vietnam. Among these fishing gears, trawl is the least selective fishing gear and the most harmful fishing gear for habitats. Trawlers (single and pair) account for about 18% of the total fishing vessels in Vietnam (MARD 2012). We assume that α and β, accounting for a part of ecosystem externalities, reduce 18% the estimated coefficient γ_0 (δ =0.82 γ_0).

Green growth policies for fisheries require a focus on three aspects (Hallegatte, Heal et al. 2012): (i) optimize the effective quantity of production inputs E and X in equation (3); in this case, production factors are complements therefore protecting the environment is necessary to maintain economic production; (ii) produce productivity gains by correcting environmental market failures and enhancing efficiency of resource use (e.g. at steady state conditions); (iii) shift the production frontier by correcting all ecosystem externalities which can affect the productivity in fisheries (e.g. reducing bycatch, improving habitats and increasing K).

2.2. Data

Marine capture fisheries in Vietnam play an important role both in term of production and employment. The marine capture production in Vietnam accounted for about 46% of the total fisheries and aquaculture production in 2016 (Anon 2016). Gillnet, longline, trawl (single and pair) and purse seine are traditional fishing gears in Vietnam. There were about 42 thousand gillneters, 21 thousand longliners, 20 thousand trawlers and 4.5 thousand purse seiners, accounted for about 37%, 19%, 18% and 4% of total fishing boats respectively in 2012 (figure 1).

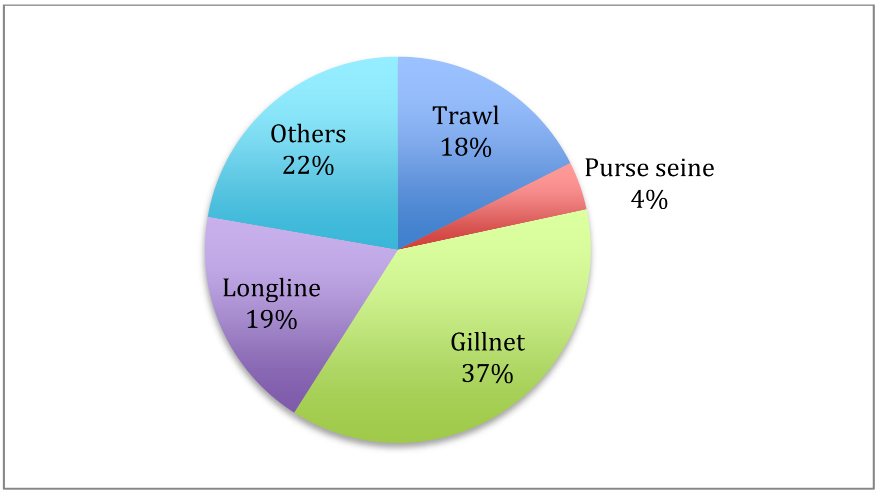

Figure 1. Fishing gears in Vietnam in 2012
Source of data: MARD

Most of fishing boats are small scale with engine lower than 50 HP (73%) and exploit coastal areas. There were about 19% of fishing boats to be considered as offshore fishing boats with engine higher than 90 HP where only 4% of total fishing boats with engine higher than 400 HP in 2012 (figure 2).

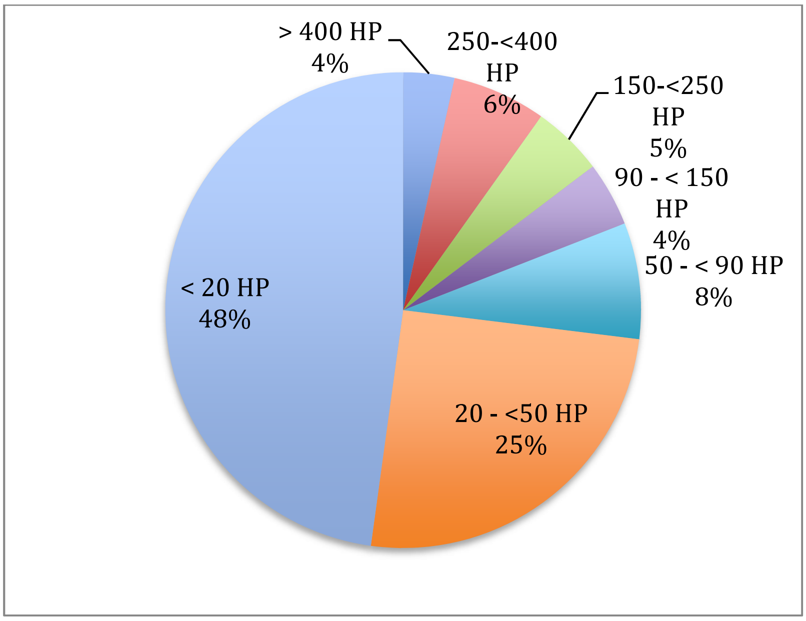

Figure 2. Capacity of fishing fleet in Vietnam in 2012
Source of data: MARD

Time series data of annual catch and fishing effort collected from Ministry of Agricultural and Rural Development (MARD) for the period from 1976 to 2016 were used in this study. We selected data on aggregate horse power to represent fishing effort (denoted capacity). The catch, effort and CPUE data for the entire Vietnamese marine fisheries are described in table 3.

Table 3. Summary statistics of catch, effort and CPUE data (1976-2016)

Variable	Number of Observations	Mean	Standard deviation	Min value	Max value
Catch (tons)	41	1,307,975	821,044	377,192	3,076,000
Effort (HP)	41	2,082,611	1,883,244	453,871	6,123,000
CPUE	41	0.67	0.33	0.25	1.22

Data from the Vietnam House Living Standards Survey (VHLSS) (2014) were used to estimate p (price per unit of catch) and c_h (cost per unit of catch) (Table 4).

Table 4. Summary statistics of price and cost data (VHLSS 2014)

Variable	Number of Observations	Mean	Standard deviation	Min value	Max value
P (million VND)	670	59.20	71.23	1	1036
c_h *(million VND)*	670	12.69	34.45	0.08	782

3. Empirical results

The results show that fishing effort since 2012 (about 8.53 million HP) has exceeded the E_{MSY} (figure 3a and 3b), thus the exploitation of Vietnam's seafood is demonstrably unsustainable. Based on the relationship between catch per unit effort (CPUE) and fishing effort (Equation 6), we can derive the following model (C is constant):

Table 5: Estimated coefficients for the Verhulst-Schaefer model

Variables	Estimates (standard deviation)
C	0.93 * (0.15)
$Capacity_t$	-5.95E-08 * (1.88E-08)
R^2	0.41
F statistic	26.68
DW statistic	1.68
Rho	0.88

*The dependent variable is CPUEt, * p <0.05, the number of observations is 41, using the autocorrelation model Prais-Winsten AR (1).*

Thus, the estimated coefficients are: $\gamma_0 = 0.93$, $\gamma_1 = -5.95E\text{-}8$. The MSY and fishing effort at MSY are calculated as follows:

$$MSY = \frac{{\gamma_0}^2}{4\gamma_1} = 3.63\ (million\ tons);\ MSY_E = 2.44\ (million\ tons)$$

Fishing effort at MSY

$$E_{MSY} = \frac{\gamma_0}{2\gamma_1} = 7.82\ (million\ HP);\ E_{MSYe} = 6.41\ (million\ HP)$$

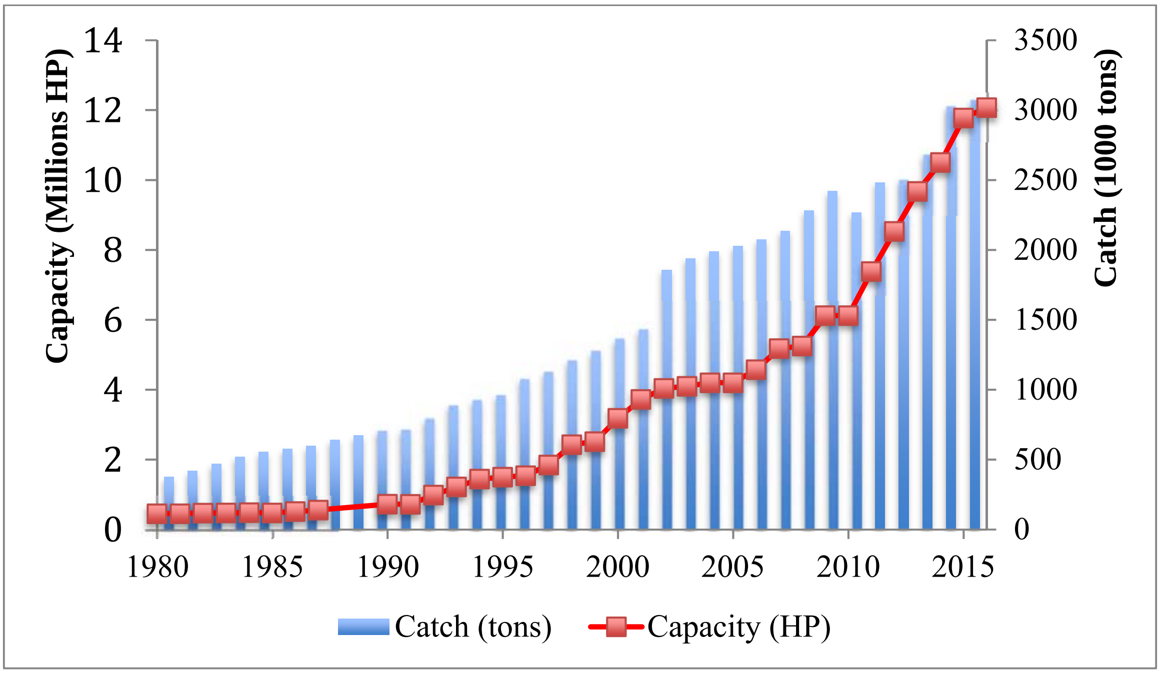

Figure 3a. Catch and capacity for Vietnam marine marine capture fisheries
Source of data: MARD

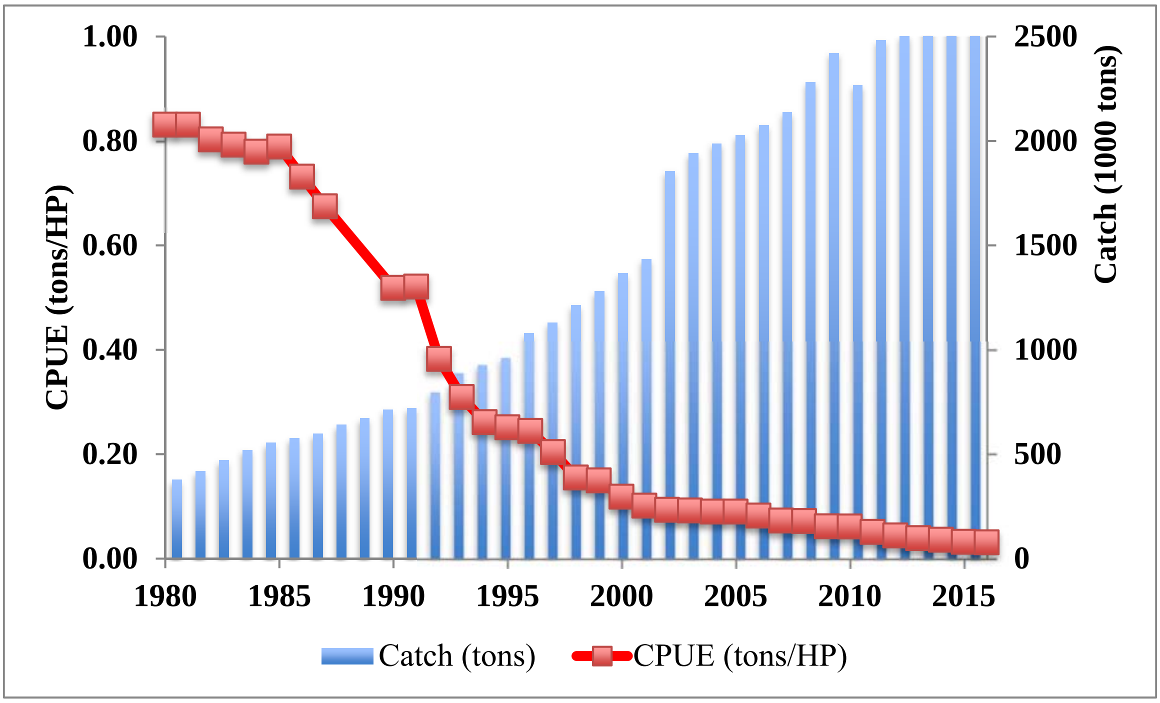

Figure 3b. Catch and CPUE for Vietnam marine marine capture fisheries
Source of data: MARD

Figure 3a shows that the optimal effort has been exceeded but catch continues to increase. One of explainations is that the catch increases but the effeciency (CPUE) of the fisheries is declining (figure 3b). Since CPUE is one index of stock then maybe the catch inceased by running down the stock.

The mean value of price and cost per unit of catch according to the VHLSS[1] 2014 data (table 4) are:

p = 59.20 (1000 VND/kg) = 59.20 million VND/ton

c_h = 12.69 (1000 VND/kg) = 12.69 million VND/ton

We decided to use 59.20 million VND/ton as the price estimate for the model. With statistical data from GSO of marine catch (about 3 million tons) and the total capacity (12 million HP) in 2016 , the average cost per unit effort is caculated as follows:

$$c = \frac{TC}{E} = \frac{Hc_h}{E} = 3.23\ million\ VND/HP$$

The reference points are: MEY = 3.62 million (tons); E_{MEY} = 7.36 million (HP); MEYe = 2.44 million (tons); E_{MEYe} = 6.41 million (HP); and the results can be summarized in table 6. The results show that the potential gains of correcting some of ecosystem externalities (bycatch and habitat destruction) is about 2.4 billion USD.

Table 6. MSY, MEY, E_{MSY} and E_{MEY} for the marine capture fisheries in Vietnam

	MSY (millon tons)	**E_{MSY}** (million HP)	**MEY** (million tons)	**E_{MEY}** (million HP)
Standard	3.63	7.82	3.62	7.36
Ecosystem externalities	2.44	6.41	2.44	6.41

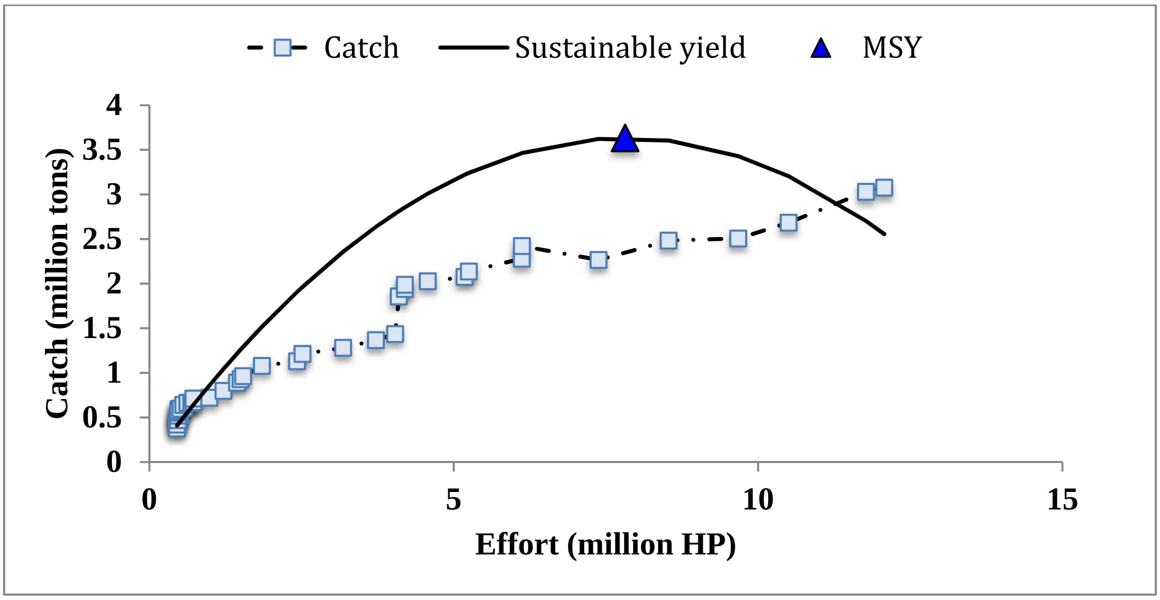

Figure 4. Catch and modeled sustainable yield

In figure 4, the sustainable yield and MSY are derived from the Verhulst-Schaefer models. The catch data in the light blue diamonds is annual catch statistics. There seem to be three trend lines in the annual catch statistics. First was almost vertical – a doubling in catch with almost no increase in fishing effort, it was coressponding to the period from 1970s to the end of 1980s under the planned economy (figure 3). For the second period, there was a steady increase in catch with increasing effort up to about 4 millon HP, it was corresponding to the period from early 1990s to early 2000s under open door policy from the goverment. For the third period, there was a jump to a new trend line from 2000s but then a steady increase again since the late 2000s. This was the period when the goverment had provided subsidies to the offshore fishing program (from 1997 to 2003) and Vietnam joined WTO in 2007. The fishing effort has significantly increased due to market driven incentives. The E_{MSY} (about 7.82 million HP) has reached since 2012. The fishing effort in 2016 (about 12 million HP, figure 3) was more than 1.5 times the fishing effort corresponding to the MSY (E_{MSY}).

Figure 5 shows TR, TC and MEY derived from the Verhulst-Schaefer models. The fishing effort in 2016 (about 12 million HP, figure 3) was more than 1.6 times the fishing effort corresponding to the MEY (E_{MEY} is about 7.36 million HP, figure 5).

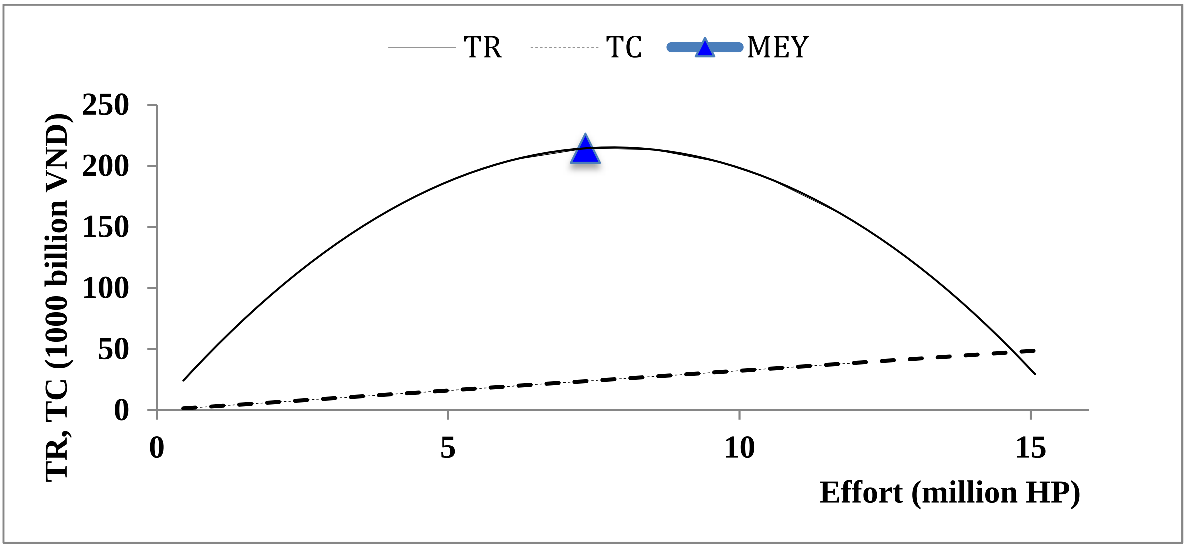

Figure 5. Total cost (TC) and total revenue (TR) in relation to fishing effort for the fisheries

In conclusion, the results from the Verhulst-Schaefer models show that the fishing effort in 2016 was more than 1.5 times the fishing effort corresponding to the MSY and 1.6 times higher than the corresponding MEY. If ecosystem externalities are partly taken into account, the fishing effort will be more than 1.88 times the fishing effort corresponding to the MSY and MEY. These results are consistent with previous studies and the statistical trend of catch per unit of effort (CPUE), which is declined from 1.2 to 0.4 ton/HP/year between 1985 and 2010 (Tuan 2012, GSO 2014). The potential for green growth of the fisheries or the resource rent at MEY is estimated at about 168,000 billion VND (7.3 billion USD)[2]. The potential for green growth of the fisheries is higher than the export value for fisheries products in Vietnam in 2016 (about 7.05 billion USD).

4. Discussion

Green growth is defined as fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. It is hard to achieve the green growth in a society with (presumably) continued growth in population and affluence, leading to more demand for fish. The marine capture fisheries in Vietnam is not an exception. The results show that the green growth path appears to not be occurring in the Vietnamese marine capture fisheries. Policies are needed to move the fisheries from the current situation where fishing is unsustainable to one where fishing effort corresponds to the reference points (E_{MSY} and E_{MEY}) (Figure 4, 5). In addition, all ecosystem externalities such as habitat degradation by using destructive fishing gears, crowding fishing, bycatch of forage species or juveniles of the target species need to be corrected in order to increase the productivity of the fisheries (e.g reducing trawlers). Nielsen et al. (2014) have defined the potential policies to achieve the green growth in fisheries, including public subsidies to environmental friendly industries, raising prices and economic optimal regulation of market failures. OECD has also proposed different policies to achieve the green growth in fisheries (OECD 2015). These policies include improving governance and energy efficiency in the capture fisheries sector, reducing waste in the capture fisheries sector and changing in the value of fish. These potential policies for the marine capture fisheries in Vietnam will be discussed as follows.

4.1. Public subsidies to environmental friendly industries

Gillnet, longline and trawl are the main fishing gears in Vietnam. Among these fishing gears, trawl is the least selective fishing gear and the most harmful fishing gear for habitats. In 2012, there were about 20, 000 trawlers (single and pair), accounting for about 18% of the total fishing vessels in Vietnam. Most of the trawlers are small scale and exploit coastal areas. Zweig *et al.* (2005) estimated that "trash" (i.e. non marketable) fish landings of trawlers were between 50 and 70 percent and were mainly used for direct feeding to fish or livestock or for conversion into fish sauce. "Trash" fish landings are likely to increase in the future, unless trawl net designs are modified to reduce catches of small fish (Zweig, Thong et al. 2005). "Trash" fish could also be reduced over time by regulation with phase out of old small mesh nets and replacement by large mesh nets with little cost to the fishers. The number of small fishing boats which are less selective, illegal and inefficient must decrease in coastal areas. Fishermen could switch to other sustainable livelihoods such as organic aquaculture, responsible tourism and organic farming and some other appropriate trades to compensate for reduced income and seafood protein availability due to reduced inshore fisheries production.

If the number of trawlers and the fishing pressure in coastal areas were significantly reduced and trawl nets were modified to be more selective, habitats would be less degraded and the carrying capacity (K) of the fisheries would be increased as demonstrated by application of the Verhulst-Schaefer model to the Vietnamese marine fisheries. The bycatch of the fisheries would also be decreased so that the sustainable economic rent in equation (9) will increase. K increase by 20% in response to these technology improvements (Figure 6).

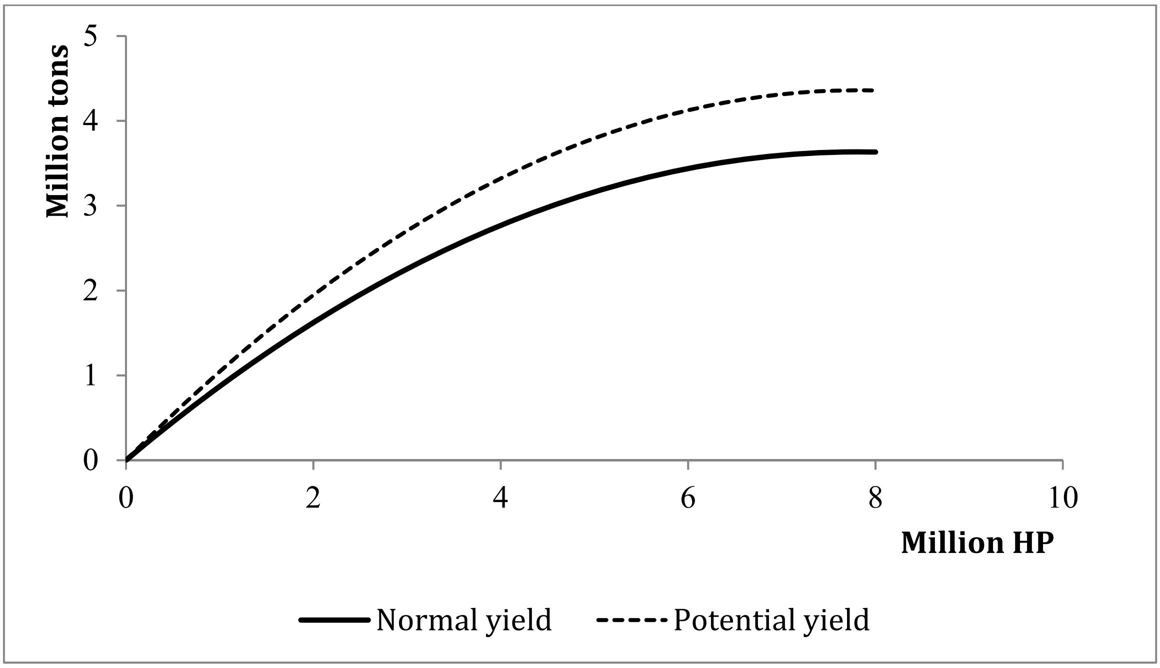

Figure 6. Present and potential yield of the Vietnam marine fisheries with technology improvement

4.2. Raising the price of landed fish

Edwards *et al* (2004) estimated "trash" fish landings at 33 percent of total marine fish landings in Vietnam. The fisheries in the South-Western area of Vietnam had the highest proportion of "trash" fish (averaging around 60% of the catch), compared to just 5% in central, and 14% in northern regions (Edwards, Tuan et al. 2004). "Trash" fish quality is poor[3] so reducing "trash" fish catches is a potential mechanism to increase prices of landed fish. In addition, current government policy is to ease the pressure on coastal resources by further developing the industry through better utilization of deep-sea resources[4]. The government has embarked on a program to shift the focus from inshore to offshore fishing by increasing incentives, such as loans and grants, to enable fishermen to shift their production away from inshore fishing. Oceanic tuna species are offshore target species which fishers have been encouraged to exploit due to their high export values. Figure 7 shows potential TR for the Verhulst-Schaefer model when the price of landing fish rises (20%).

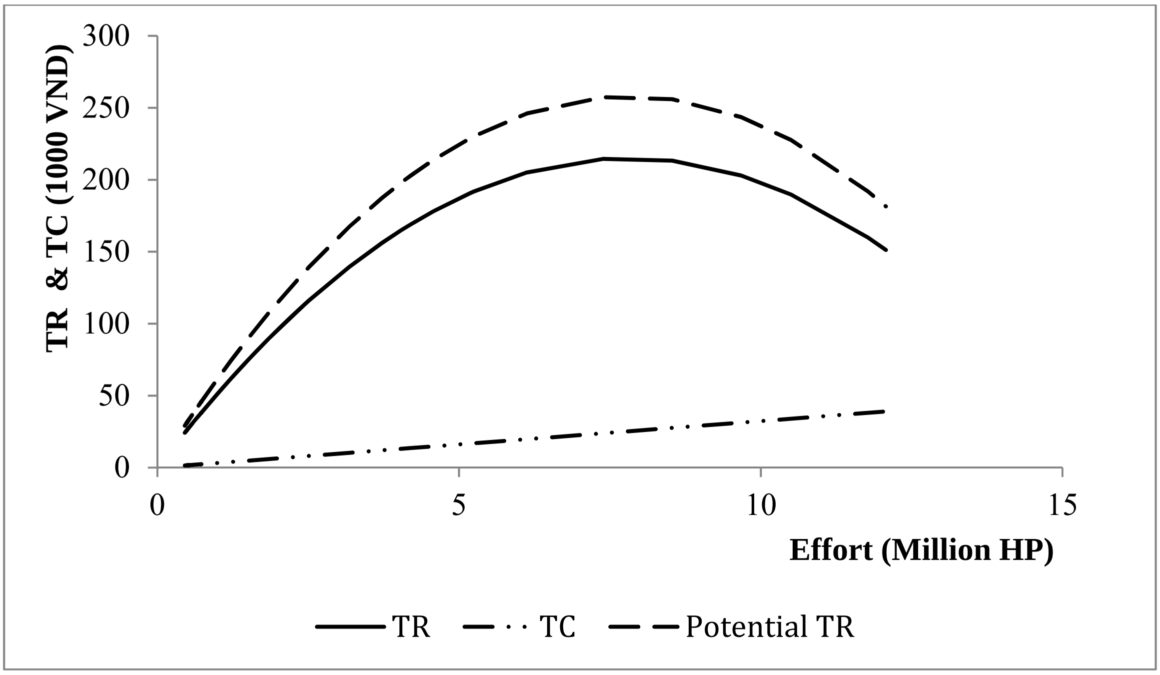

Figure 7. Present total revenue (TR), total cost (TC) and potential total revenue for the fisheries in response to a fish price increase of 20%

4.3. Optimal regulations.

Vietnamese marine fisheries are regulated according to the size of the boat engine and the location of fishing activity (Decree 33/2010/ND-CP, Article 5). Boat operators are required to obtain a marine fishing license depending on their operation zones, the size of the boat engine, and the gear type employed, as well as various other conditions. The fee levied is proportional to the engine size of the boat. Boats under 0.5 Gross Register Tonnage (GRT) are exempt from any license payment. The procedure for license applications is widely considered to be relatively straightforward, and a license application generally leads to a license being granted. In this case, Vietnamese marine capture fisheries can be viewed to be in an 'open access' or unregulated situation (McCoy, Thurlow et al. 2010). The government has been attempting to reduce the fishing effort in coastal areas. However, the results were not satisfied due to poor coordination and lack of clear demarcations between authorities, a poorly developed scientific basis for management, and scarcity of investment funds. The governance system now purely reflects the diversity, complexity, and dynamic of the fisheries. For example, top down management is dominant in the fisheries. In coastal provinces, local fisheries administration authorities are Provincial Agriculture and Rural Development Departments, they are units of the Provincial People's Committees and under the professional management of the Ministry of Agriculture and Rural Development (MARD). There is only one official organization of fishermen, Vietnam Fisheries Society (VINAFIS), which is a government-sponsored organization (It was established follow Decision No. 33/2000/ QĐ- BTCCBCP, Date 5/5/2000, of Minister of Civil Affairs). At present there are also no specific regulations for bycatch and discard reduction of trawl fisheries in Vietnam. In addition, agencies such as the provincial Departments of Capture Fisheries and Resource Protection (SubDecafireps) lack staff and budget resources to provide the required management, monitoring, surveillance and regulation enforcement in both Vietnam’s inshore and offshore waters. With increasing population pressure and the development of more effective (and/or destructive) fishing gears, inshore resources have been increasingly over-exploited. In this situation, a policy of population stabilization and co-management, the sharing of responsibility for resources management between local communities and government agencies, may be a better option for improved resource management (Zweig, Thong et al. 2005). At local level, there is a need to organize for collective, representative participation in governance. This necessitates the building of capacity and competencies. Multiple categories of fishers’ organizations should be established according to need such as geographically-based categories[5]. Almost two decades ago Ruddle (1998) argued, "*Given the problems of managing the diverse and often remote fishing communities along the very long end ecologically varied coastline of Vietnam, it would now seem opportune to make selective use of the marine ecological knowledge and management system of local fishers, by involving them in the design, implementation, monitoring, and enforcement of local rules and regulation aimed at national and provincial fisheries policy*". While beyond the direct scope of this analysis, it must also be recognized that numerous foreign fishing boats continue to fish illegally in Vietnam’s marine waters, with an annual catch estimated at about 100,000 tons (FAO 2005), despite bilateral agreements between Vietnam and neighboring countries (e.g. China, Thailand). While only 2.2% of the Vietnamese catch, this illegal fisheries impacts heavily on specific fisheries (e.g longline fisheries) and is increasing rapidly. Thus, sustainability of Vietnam’s marine fisheries also requires the support and cooperation of neighbouring countries.

5. Conclusion

In this paper, we have assessed sustainable development and the potential for green growth in the marine capture fisheries in Vietnam. Standard bio-economic models with additional terms to correct some of ecosystem externalities are applied to Vietnam's marine capture fisheries, which are both small scale and multi-species. Aggregate catch and effort data from 1976 to 2016 and other economic data of the fisheries were collected to estimate the potential green growth for the fisheries. The results show that fishing effort since 2012 has exceeded the fishing effort at MSY. Current fishing effort is more than 1.5 times greater than the fishing effort corresponding to the MSY and more than 1.6 times greater than the fishing effort corresponding to the MEY. If ecosystem externalities are taken into account, the situation is even worse. Thus, fishing in Vietnam is unsustainable; the potential for green growth of the fisheries is estimated at about 7.3 billion USD, higher than the export value for fisheries products in Vietnam in 2016. Green growth policies for the fisheries include public subsidies to environmentally friendly industries, raising the prices of landed fish and more efficient and effectively enforced regulations.

The results were derived from the simple, rather old and theoretical models and lack of data observations which may not fully grasp the dynamics of a complicated system. Better methods of measuring effort and controlling other factors should also be investigated in order to have more precise estimates of the model parameters*. How to reduce effort and cost/benefit of reducing effort to achieve the reference points should also be studied further in order to improve proposal regulations.

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References

Adrianto, L., et al. (2005). "Assessing local sustainability of fisheries system: a multi-criteria participatory approach with the case of Yoron Island, Kagoshima prefecture, Japan." Marine Policy **29**: 9–23.

Anon (2016). Report on implementation of the annual plan in 2016 and orientations for the annual plan in 2017, Directorate of Fisheries**:** 34p.

Armstrong, C. W., et al. (2017). "Use and Non-Use Values in an Applied Bioeconomic Model of Fisheries and Habitat Connections." Marine Resource Economics **32**(4): 351-369.

Clark, C. W. (1990). Mathematical bioeconomics: the optimal management of renewable resources, Wiley-Interscience Publication.

Clark, C. W. and G. R. Munro (1975). "The economic of fishing and modern capital theory: a simplified approach." Environmental economics and management **2**: 92-106.

Downing, J. A. and C. Plante (1993). "Production of Fish Populations in Lakes." Can. J. Fish. Aquat Sci **50**: 110-120.

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Edwards, P., et al. (2004). A survey of marine trash fish and fish meal as aquaculture feed ingredients in Vietnam. ACIAR Working Paper, Australian Centre for International Agricultural Research: 56.

Eide, A., et al. (2003). "Harvest functions: The Norwegian bottom trawl cod fisheries." Marine Resource Economics **18**.

FAO (2005). "Vietnam fisheries." Country profile. Retrieved 8 November, 2005.

GSO (2014). Statistical Yearbook, General Statistics Office of Vietnam.

Hallegatte, S., et al. (2012). "From Growth to Green Growth - a Framework." NBER Working Paper No. 17841.

Hilborn, R. (2007). "Moving to Sustainability by Learning from Successful Fisheries." AMBIO: A Journal of the Human Environment **36**(4): 296-303.

Hilborn, R., et al. (1995). "Sustainable exploitation of renewable resources." Annu. Rev. Ecol. Syst. **26**: 45-67.

Labrosse, P., et al. (2000). "Fish stock assessment of the northern New Caledonian lagoons: 3 – Fishing pressure, potential yields and impact on management options." Aquat. Living Resour. **13**(2): 91−98.

Larkin, P. A. (1977). "An Epitaph for the Concept of Maximum Sustained Yield." Transactions of the American Fisheries Society **106**(1): 1-11.

Long, N. (2001). Status of offshore fishing technology in Vietnam. Marine Fisheries Research, Vietnam, Agriculture Publishing House.

MARD (2012). Report on fishing gears and fisheries resources in Vietnam. Hanoi, MARD.

McCoy, S., et al. (2010). The Fisheries Sector in Vietnam: A Strategic Economic Analysis. Hanoi, Fisheries Sector Programme Support (FSPS) II: 138.

Nielsen, M., et al. (2014). "Green growth in fisheries." Marine Policy **46**: 43-52.

OECD (2011). Towards Green Growth: A Summary for Policy Makers. Paris, OECD.

OECD (2015). Green Growth in Fisheries and Aquaculture. Paris, OECD Publishing: 114p.

Pascoe, S. and R. Hillary (2016). Bioeconomic target reference points for the Commonwealth Small Pelagics fishery. Report to the Australian Fisheries Management Authority (AFMA). Hobart, CSIRO: 21.

Pascoe, S., et al. (2018). "Offsetting Externalities in Estimating MEY in Multispecies Fisheries." Ecological Economics **146**: 304-314.

Pascoe, S., et al. (2015). Setting economic target reference points for multiple species in mixed fisheries. Brisbane, CSIRO: 102p.

Pauly, D., et al. (2002). "Towards sustainability in world fisheries." Nature **418**: 689-695.

Pomeroy, R., et al. (2009). "Small-scale marine fisheries policy in Vietnam." Marine Policy **33**(2): 419-428.

Ryan, R. W., et al. (2014). "Ecosystem Externalities in Fisheries." Marine Resource Economics **29**(1): 39-53.

Schaefer, M. B. (1954). "Some considerations of population dynamics and economics in relation to the management of the commersial marine fisheries." Bull. IATTC **1**: 26-56.

Schmalensee, R. (2012). "From “Green Growth” to sound policies: An overview." Energy Economics **34, Supplement 1**(0): S2-S6.

Son, D. M., et al. (2005). Some information on low value and trash fish in Vietnam. Regional workshop on low value and “trash fish” in the Asia - Pacific region, Hanoi, The Asia-Pacific Fishery Commission (APFIC).

STOBUTZKI, I., et al. (2001). "Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch." Environmental Conservation **28**(2): 167–181.

Sumaila, R. (2011). Fisheries: Investing in natural capital. Towards a green economy, United Nations Environment Programme.

Thanh, N. V. (2011). "Sustainable management of the shrimp trawl fishery in Tonkin Gulf, Vietnam." Applied Economics Journal **18**(2): 65-81.

Tuan, N. A. (2012). Vietnam fisheries and aquaculture over 50 years development (in Vietnamese), Directorate of Fisheries.

Verhulst, P. F. (1838). "Notice sur la loi que la population poursuit dans son accroissement." Correspondance mathématique et physique **10**: 113–121.

WB (2012). Inclusive green growth: the pathway to sustainable development. Washington, The World Bank**:** 171p.

Zweig, R., et al. (2005). Vietnam fisheries and aquaculture study. Hanoi, The World Bank.

[1] VHLSS is the acronym of Vietnam Household Living Standard Survey

[2] About 7.3 billion USD at 31st December 2016 exchange rate

[3] However, “trash” fish could starve or malnourish poor people who can only afford poor quality fish.

[4] Decision No. 375/QD-TTg 01/3/2013 and Decree No. 67/2014 / ND-CP of the Prime Minister on fisheries development policy.

[5] Due to the diversity, complexity and dynamic of the fisheries.