Estimating the Maximum Sustainable Yield for Coastal Fisheries: A Case Study in Nui Thanh District, Quang Nam Province, Viet Nam

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Many government reports recently indicate that the coastal fisheries of Viet Nam have experienced overfishing and overcapacity. Although few fishery management studies had been conducted to address the situation, no quantitative research had been carried out, possibly because of too much aggregation of data considering the different types of fishing operations that catch various species from different fishing grounds. Using the currently available data with some new data collected, an analysis was conducted to estimate the maximum sustainable yield (MSY) and the level of fishing effort in the coastal fisheries of Nui Thanh District in Quang Nam Province, Viet Nam. The ultimate goal is to determine the most appropriate economical fisheries management policy for the sustainability of coastal fisheries in Quang Nam Province in particular and the whole of Viet Nam in general.

Coastal fisheries in Nui Thanh District, Quang Nam Province of Viet Nam (**Fig. 1**) is considered small-scale but plays very important role in the economic development of the Province and livelihoods of fishers, being one of the ten most important fisheries in Viet Nam as is evidenced by the presence of 4,157 fishing vessels with total capacity of more than 171,358 horse power (**Fig. 2**). With a coastline of 125 km, Quang Nam Province embraces an exclusive economic zone of more than 40,000 km^2, which is abundant in marine fishery resources with high species diversity (Luong, 2014).

Marine capture fisheries in Viet Nam could not be readily classified into either small-scale or industrial, as there are many factors such as hull length, engine power, distance from shore, depth of fishing grounds exploited, and gear deployed, that should be considered in defining the types of fisheries. However, the country's marine fisheries could be generally considered small-scale due to the fact that these are operating in near-shore waters, and as a consequence, near-shore fishery resources are overfished (Pomeroy, 2009). Reports have indicated that in Nui Thanh District, the number of fishing vessels with motor engines increased sharply from 975 in 2003 to 1,527 in 2013, and now accounts for more than 58% of the total fishing vessels in Quang Nam Province. Most of the fishing vessels in Nui Thanh District (86%) are small with less than 90 horse power (HP) engine capacity each.

The main fisheries operating in Quang Nam Province include trawl (**Fig. 3**), purse seine, gillnet, driftnet, longline, and

Fig. 1. Map of Viet Nam showing Quang Nam Province

diving, using about 871 small fishing vessels in coastal areas within 15 nautical miles from the shore. Recent reports have indicated that the fishery resources in the waters of Nui Thanh District are already in severe state of exploitation. Vessels operating in the coastal areas use variety of illegal fishing gears undermining the future increases in biomass, *e.g.* using small mesh-sized fishing nets in catching juvenile fishes that affect not only the quality of catch but also future spawning, using electrical impulses and explosives that tend to increase fish wastage. Moreover, banned trawls with powerful engines still operate near the shore negatively impacting on the benthic ecosystem (Hung, 2009; Quoc, 2013; Du, 2015).

As a result, the fishery resources of Nui Thanh are currently being overexploited (Luong, 2014; Agriculture Department of Nui Thanh, 2014), considering that too many fishing vessels are operating with no explicit regulations and ways to reduce fishing effort. Furthermore, conflicts on the utilization of fishing grounds among fishers had been rising because of decreasing catch. Fishers believed that the current annual catch had decreased by about 30-40% compared with that of 5 years ago (Luong, 2014). Reduced catch has led to diminishing benefits from fishing activities and reduced quality of life of fishers and their families. The central and lower levels of the Government, such as the provincial and

Fig. 2. Small-scale fishing boats in Nui Thanh District, Quang Nam Province

Fig. 3. A trawl fishing vessel anchored at Tam Quang Port, Quang Nam Province

district levels (Agriculture Department of Nui Thanh, 2014; Gioi, 2014) had recognized the problems and attempted to carry out studies on fisheries management systems, but not on the maximum sustainable yield (MSY) as well as on the fishing effort level at such estimated MSYs. Although the issues might have been identified, these could not be supported by any analysis due to insufficient data, as there had been no estimates of the total allowable catch and no analysis of reasonable fishing effort level in different fishing grounds and species. Thus, local authorities do not have any sound basis for designing and implementing the appropriate management measures, even if previous reports contain few proposals for the conduct of quantitative research on the improvement of policies, planning or management of this valuable resource. The main problem is insufficient data for assessing the coastal marine resources and for estimating the fishing effort. In order to address the aforementioned problems, new survey data had been compiled with the intention of coming up with information on the number and kind of fishing vessels operating in regulated near-shore areas; the MSY for different fishing gear; level of fishing effort compatible with the MSYs; and options for policy-makers to consider in order to achieve sustainable fisheries.

Compilation of Necessary Data

In order to compile the necessary data, a study was carried out from 2012 to 2014 in Nui Thanh District of Quang Nam Province, Viet Nam, defined within the line from point 7' to point 8' regulated in Decree no.33/ND-CP (approved by the Prime Minister in 2010 regulating the fishing activities by individual or company in Viet Nam waters). The study included estimation of the fishing effort, catch and catch per unit effort (CPUE) of each fishing gear in 2011-2014. Using the Schaefer Surplus Production Model 1, the MSY was determined and the level of fishing effort corresponding to such MSYs was also estimated for each main fishery. Such information would be useful for the development of some feasible fisheries policies by local policy-makers. During the study, data were obtained from secondary as well as primary sources. The secondary sources included published papers and government reports on Nui Thanh fisheries, where relevant information were used to infer and define the status of fisheries, including socio-economic information and fishing vessels. Models were then developed based on the information from those papers, books and conference reports, and the catch, fishing effort, and CPUE among others, were estimated. For the primary data, surveys were conducted to collect sample data on 110 vessels, chosen through stratification by classification in order to represent the population. The data compiled was used to assess the status and dynamics of fishing efforts and catch from 2011 to 2014. In addition, relevant information was also obtained through interviews with authorities, fishers, and specialists conducted by e-mail and through telephone.

Identification of Coastal Fishing Vessels

Four steps were used to define the types of fishing vessels operating in specific areas (**Box 1**). As a result, the list of coastal fishing vessels operating in the study area from 2011 to 2014 had been established and appropriately classified.

Estimation of Catch Landing

Estimating the catch by gear categories makes use of the FAO Guidelines (FAO, 2002), and was carried out after the coastal fishing effort had been determined using the Schaefer Logistic Model.

Productivity (CPUE)

The average catch per unit of effort (CPUE) of each fishing gear group was estimated using formula (1):

$$\overline{CPUE} = \frac{1}{n}\sum_{i=1}^{n} CPUE_i \quad \text{(1)}$$

where: ($\overline{CPUE}$) is the average CPUE (kg/fishing day); CPUEi is catch per unit effort of fishing vessel i; n is the number of fishing gear groups in the study area (i = 1-6)

Catch of each fishing gear

The catch of each fishing gear was determined by using equation (2)

$$C_i = \overline{CPUE}_i \cdot A_i \cdot BAC_i \cdot F_i \quad \text{(2)}$$

Box 1. Steps in identifying coastal fishing vessels (Phuong, 2015)

Step 1: A list of all fishing vessels with engine power lower than 20 HP was drawn from Nui Thanh District Agriculture Department, and those above 20 HP from the Department of Fishing and Marine Resource Protection in Quang Nam Province. This resulted in the availability of the **Initial List of Vessels (I)**.

Step 2: Based on the above list (**I**), some vessels were excluded, *i.e.* fisheries service vessels, oceanic squid longline vessels, purse-seine with high engine power defined by the Research Institute for Marine Fisheries (RIMF, 2007); syndication of boats, production teams at sea, such as: Paracel Islands Union and Spratley Islands Union where vessels always fish offshore and operate on long cruises; and fishing vessels that are not operating at study area based on the information from local fisheries authorities such as the number of days per fishing trip, the number of crew per fishing vessel. The output was the **Preliminary List of Vessels (II)**.

Step 3: In order to verify the vessels in **II**, probability survey questionnaires were used to determine the fishing area of given fishing vessels. Vessels that operate beyond 15 nautical miles were removed, where only fishing vessels in **II** as coastal fishing vessels were kept, other vessels were excluded. Field surveys were conducted at sea where the information obtained included a random sample of registered number of vessels for each fishing trip. This information was used to check and confirm the list of coastal vessels. The output was the **Final List of Coastal Fishing Vessels**.

Step 4: In determining the dynamics of fishing vessels overtime (2011-2014), the detailed information on each fishing vessel in **II** was compiled, such as the year built, year upgraded and the year of operation with registration. In addition, a qualitative assessment from local fishery managers and leaders of local communities was also obtained. The output was the **List of Coastal Fishing Vessels** operating in the study area from 2011 to 2014.

where: C_i is the catch of fishing gear group i (metric tons); $\overline{CPUE}_i$ is average catch per unit of effort in fishing group i (kg/fishing day); A_i is active days survey factor of fishing gear group i indicating the total number of potentially operating days of fishing vessels; BAC_i is boat activity coefficient expressing the probability that any vessel will be active on any given day of group i; F_i is the number of fishing vessels within group i that are estimated to fish in near-shore areas. The Surplus Production Model was used to estimate the maximum sustainable catch (MSY) and the corresponding effort level (f_{MSY}). The following input data were 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 (1992), $\frac{Y}{f}$ is a function of the effort f, computed as follows:

$$\frac{Y}{f} = \frac{Y_i}{f_i} = a + b \cdot f \text{ (where } f_i \leq -\frac{a}{b}) \quad \text{.........(3)}$$

Where the intercept "a" is the $\frac{Y}{f}$ value obtained just after the first boat fishes the stock for the first time. The intercept then must be positive. The slope "b" must be negative if the catch per unit of fishing effort $\frac{Y}{f}$ decreases for increasing effort f. Therefore, $-\frac{a}{b}$ is positive and $\frac{Y}{f}$ is zero for $f = -\frac{a}{b}$ (Sparre,1998). Here, equation (3) is used 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:

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

Results

The fishing effort in the coastal areas of Nui Thanh District was determined based mainly on small vessels with engine capacity of less than 45 HP (**Fig. 4**). In 2014, gillnet was the main fishery with 343 boats (39%), while driftnet and purse seine were operated with the least number of fishing boats.

Active Days Survey Factor (A)

The study indicated that the Active Days Survey factor (**Table 1**) had about 15 days less in January and February because of the celebration of the Vietnamese Lunar New Year, and also in November and December due to bad weather.

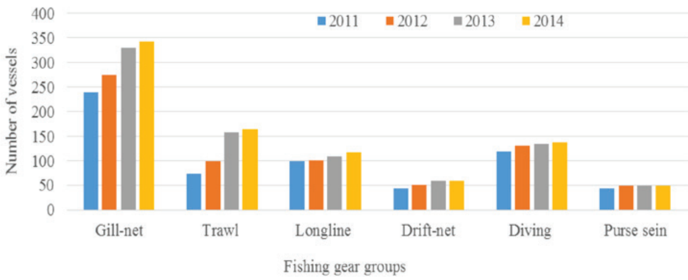

Fig. 4. Number of boats by fishing gear from 2011 to 2014

Table 1. The Active Days Survey of different fishing methods (days)

Fishing method	Months in a year (year 2014)												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Gillnet	17	17	26	25	26	25	26	25	21	21	20	23	**272**
Trawl	15	15	31	30	31	30	31	30	26	26	20	20	**305**
Longline	15	15	24	24	24	24	24	23	26	26	20	20	**265**
Driftnet	15	15	24	23	24	23	24	22	19	19	18	21	**247**
Diving	10	15	31	30	31	30	31	23	23	15	15	10	**264**
Purse seine	15	15	24	23	24	23	24	22	19	19	18	21	**247**

Table 2. Boat Activity Coefficient (BAC) by fishing gears

Fishing method	Months in a year (year 2014)												Average
	1	2	3	4	5	6	7	8	9	10	11	12	
Gillnet	0.60	0.50	0.60	0.67	0.80	0.80	0.70	0.93	0.70	0.60	0.60	0.67	**0.68**
Trawl	0.33	0.47	0.87	0.80	0.80	0.87	0.80	0.80	0.67	0.53	0.60	0.53	**0.67**
Longline	0.42	0.50	0.70	0.82	0.83	0.80	0.83	0.88	0.75	0.70	0.60	0.75	**0.71**
Driftnet	0.60	0.47	0.89	0.90	0.93	0.89	0.80	0.88	0.43	0.60	0.50	0.63	**0.71**
Diving	0.60	0.80	0.90	0.80	0.87	0.93	0.93	0.80	0.73	0.67	0.53	0.60	**0.76**
Purse seine	0.57	0.75	0.80	0.73	0.86	0.80	0.90	0.73	0.70	0.50	0.56	0.60	**0.71**

Table 3. Actual fishing days (days)

Fishing method	Months in a year (year 2014)												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Gillnet	10	9	16	17	21	20	18	23	15	13	12	15	**188**
Trawl	5	7	27	24	25	26	25	24	17	14	12	11	**216**
Longline	6	8	17	20	20	19	20	20	20	18	12	15	**194**
Driftnet	9	7	21	21	22	20	19	19	8	11	9	13	**181**
Diving	6	12	28	24	27	28	29	18	17	10	8	6	**213**
Purse seine	9	11	19	17	21	18	22	16	13	10	10	13	**178**

Boat Activity Coefficient

Results of the survey of Boat Activity Coefficient (BAC) of all fishing gear groups in the coastal areas of Nui Thanh are presented as **Table 2**. The general average BAC is about 0.71

Actual Fishing Days

Using A and BAC above, the actual fishing days are computed as AxBAC, the results of which are shown in **Table 3**.

Catch per Unit of Effort (CPUE)

The research results showed that the CPUE of each fishing gear are decreasing overtime as shown in **Table 4**.

As shown in **Table 4**, the productivity of each fishery is decreasing overtime. The productivity in 2014 had reduced at 44.00% compared with that of 2011. This shows that the coastal fishery resources of Nui Thanh are currently over-fished and the fisheries is experiencing over-capacity.

Table 4. Fishing productivity of each fishing gear overtime (kg/fishing day)

Fishing method	Year			
	2011	2012	2013	2014
Gillnet	48.10	44.04	37.20	31.03
Trawl	208.82	163.97	137.06	119.12
Longline	40.07	30.05	24.04	20.03
Drift-net	78.86	56.33	45.34	39.43
Diving	25.48	19.11	15.29	12.74
Purse seine	70.67	58.20	49.89	41.57
Average	**78.68**	**61.95**	**51.47**	**43.99**
Reduced rate compared with that of 2011 (%)		**21.00**	**35.00**	**44.00**

Estimation of Coastal Catch

Using the data in **Table 4**, the catch of each fishing gear in metric tons (MT) could be estimated, the results of which are shown in **Table 5**.

Table 5. Catch of all coastal fishery groups (in MT)

Fishing method	Year			
	2011	2012	2013	2014
Gillnet	2,140	2,242	2,273	1,970
Trawl	4,067	3,362	4,412	4,005
Longline	759	575	501	448
Driftnet	621	503	476	414
Diving	611	505	413	352
Purse seine	556	498	427	356
Total	**8,754**	**7,684**	**8,501**	**7,545**

Table 5 shows that the catch of trawl accounted for the highest proportion at 53% followed by gillnet at about 26% of the total catch.

Estimation of MSY and f_{MSY}

Based on the research results on catch and fishing effort in each fishery, the CPUE was estimated to be used as basis for modelling, in order to obtain the MSY and f_{MSY} of each fishery.

Gillnet and Trawl Fisheries

The maximum sustainable yield (MSY) and level of fishing effort of gillnet fishery at the MSY are 2,209 MT and 279 vessels, respectively. The corresponding values for trawl fishery are 4,217 MT and 146 vessels, respectively. The Schaefer models for each fishery are presented in **Fig. 5** and **Fig. 6**.

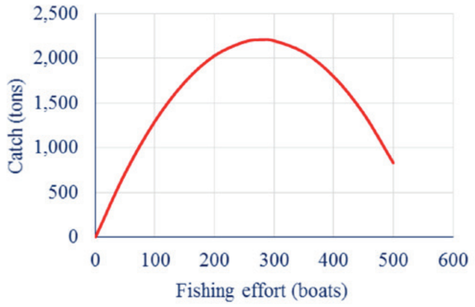

Fig. 5. Schaefer model for gillnet fishery

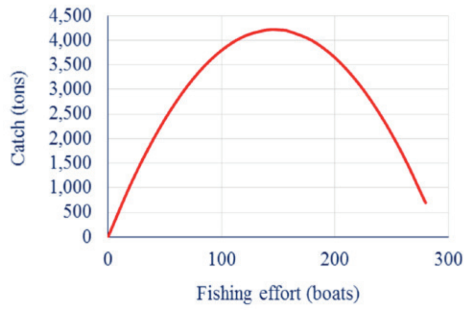

Fig. 6. Schaefer model for trawl fishery

Table 6. Estimation of MSY and f_{MSY} for coastal fisheries of Nui Thanh District

Fishery	Maximum sustainable level		Effort in 2014 (boats)	Reduced Effort (boats)
	Yield (metrictons)	Effort (boats)		
Gillnet	2,209	279	188	63
Trawl	4.217	140	216	11
Longline	831	69	194	49
Driftnet	609	39	181	21
Diving	853	78	213	59
Purse seine	780	29	178	20
Total	9,500	642	871	229

Longline and Driftnet Fisheries

The MSY and level of fishing effort of longline fishery at the MSY are 831 MT and 69 vessels, respectively. The corresponding values for driftnet fishery are 609 MT and 39 vessels, respectively. The Schaefer models for each fishery are presented in **Fig. 7** and **Fig. 8**.

Diving and Purse Seine Fisheries

For diving fishery, MSY was estimated at 853 MT and fishing level at MSY at 78 boats. In purse seine fisheries, the MSY and f_{MSY} values were 780 MT and 29 boats, respectively. The values of the Schaefer model for these fisheries are shown in **Fig. 9** and **Fig. 10**.

To summarize, the maximum sustainable yield and the fishing level at MSY (f_{MSY}) for the coastal fisheries of Nui Thanh District are presented in **Table 6**. The maximum sustainable levels in **Table 6** seem to suggest that fishing effort should be reduced and as such the suggested reduced effort are also shown in the table.

The results have indicated that the coastal fisheries of Nui Thanh are characterised by overfishing and overcapacity. Due to overcapacity, the catch and especially the CPUE had dropped by approximately 30-40% compared with those of five (5) years ago. It should also be noted that gillnet and trawl fisheries accounted for high catch and effort at about 67%.

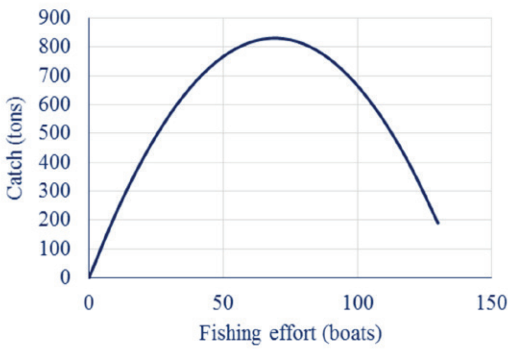

Fig. 7. Schaefer model for longline fishery

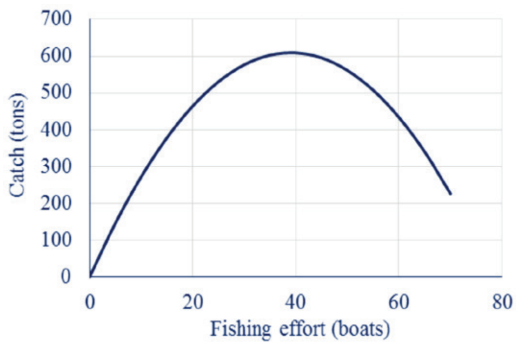

Fig. 8. Schaefer model for driftnet fishery

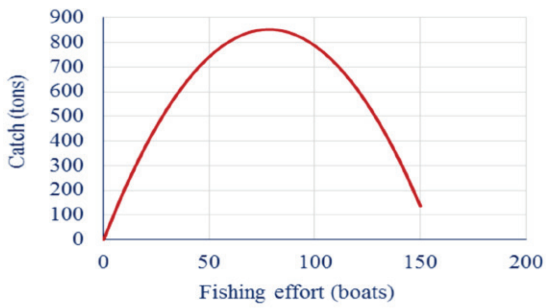

Fig. 9. Schaefer model for diving fishery

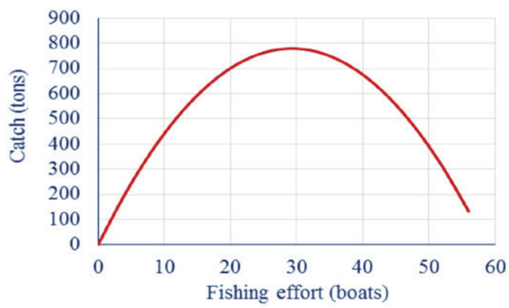

Fig. 10. Schaefer model for purse seine fishery

Conclusion and Recommendations

In order to reasonably utilize the marine coastal fishery resources in Nui Thanh District, it is necessary to reduce the current (2014) fleet by 229 fishing vessels. As indicated in **Table 6**, the MSY is estimated at 9,500 MT and effort level at MSY is expected at 642 boats. The results also show that the current stock resource is being overfished by around 26.0% due to overcapacity. Specifically, the current fishing effort exceeds the f_{MSY} by 35.7%. The above results could be used in improving the fisheries policy management regime in the District, and ultimately improving the living standards of its residents. Improvements in coastal fisheries of Nui Thanh District could also serve as useful example for fisheries authorities in other districts of the country.

Territorial User Rights in Fishing (TURFs) associated with Individual Quota (IQ) or Individual Transferable Quota scheme (ITQs) had been introduced in many fisheries with good results. According to Arnason (2015a), in small-scale or artisanal fisheries, quota restrictions could be difficult to enforce on an individual fishers basis, thus, community fishing rights may be the best alternative way. Specifically, organizing fishers into groups with community ITQs and with some TURFs rights may be practical and an efficient way to proceed (Arnason, 2009; Arnasaon, 2015b). These could offer other means of controlling the fishing effort by making fishers within a specific community behave as if property rights for a fishing ground exist. When the fishers access to or use the coastal area that is restricted to a small group within communities, the community therefore can determine how to harvest fish from the fishing ground and to whom the fish is allocated.

Due to time and funding limitations, this study analyzed only a few years' fisheries data. It would be useful if the fisheries data had not been disaggregated into coastal and offshore fisheries. More detailed and comprehensive research studies need to be conducted to fix the Schaefer model because more fisheries data could lead to better estimation by the model.

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