

Fishing capacity and technical efficiency of tuna fisheries in Kupang, Indonesia

¹Soraya Gigentika, ²Tri Wiji Nurani, ²Sugeng H. Wisudo, ²John Haluan

¹ Programme of Marine Fisheries Technology, Postgraduate Program of Bogor Agricultural University, Bogor, Indonesia; ² Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, Bogor Agricultural University, Bogor, Indonesia. Corresponding author: S. Gigentika, sorayapsp43@yahoo.co.id

Abstract. Tuna fish landing activities in Kupang is highly intensified that it is on an alarming level for the sustainability of tuna resources. From information of tuna fishing capacity in Kupang, it is expected to note the current pressure for tuna fishing activities. Fishing gears which are used to catch tuna in Kupang are troll line, handline, and pole and line. This study aims to assess the capacity of tuna fishing activity by measuring its technical efficiency and the use of three types of tuna fishing gear based on vessel size group (GT). Data Envelopment Analysis (DEA) approaches was used to conduct the analysis of fishing capacity. The results showed that there were a number of tuna fishing units which were inefficient in the use of fishing capacity and had exceedingly used the production inputs. However, pole and line fishing vessel with the size of \leq 20 GT has been efficient in the use of fishing capacity and production inputs. **Key Words**: DEA, capacity utilization, variable input utilization, troll line, handline, pole and line.

Introduction. Tuna is a commodity which is highly demanded by fisheries industry and import-export industry. This is due to its quality of meat which is highly nutritious and contains all kinds of nutritional elements. According to the Warta Ekspor (2012), Department of Health, Education and Walfare stated that tuna has a high protein content (22.6 to 26.2 g/100 g of meat), low fat (0.2 to 2.7 g/100 g of meat), and minerals, calcium, phosphorus, iron and sodium, vitamin A (retinol), and vitamin B (thiamin, riboflavon, and niacin). Meanwhile, Indonesia took part as well as tuna supplier in world market. One of the areas in Indonesia supplying tuna resource is Kupang, East Nusa Tenggara Province.

Kupang has two fishing ports which are used as tuna landing port, namely Coastal Fishing Port (CFP) Tenau and Fish Landing Base (FLB) Oeba. Tenau CFP is a fish landing sites for fishing vessels with the size of 10-30 GT, while Oeba FLB is for fishing vessels with the size of 3-10 GT. This is due to the depth of ports basin and the height of pier provided by each fishing port. Fishing units which land tuna in Tenau CFP and Oeba FLB are troll line, handline, and pole and line. Both troll line and handline fishing unit use vessel with the size of ≤ 10 GT, while pole and line uses vessel with the size of 5-40 GT.

Tuna fish landing activity in Kupang happens almost every day with the average number of vessels between 2 to 10/day. The number of vessel per day which landing tuna in Kupang is affected by the number of fishing trip for each type of fishing unit. In general, troll line fishing unit and handline fishing unit operate in 2 to 14 days, while pole and line fishing unit operates in 1 day (one day fishing). The amount of the catch landed is between 500 kg to 3 tons per trip for one fishing unit of handline and troll line, and between 500 kg to 7 tons per trip for pole and line fishing unit. This conditions, if were to happen for a long period, would impact on tuna fishing pressure. ISSF (2012) states that fishing pressure will result in reduced production.

Indian Ocean, Sawu Sea, Flores Sea and the Timor Sea are often used as fishing area by tuna fishermen in Kupang. However, tuna population in these water areas is indicated to be pressured. Ningsih et al (2015) state that yellowfin tuna in Flores Sea is indicated to have fishing pressure, this is evidenced by the enormous number of juvenile tuna caught in that area. In part of the research conducted by Nurani et al (2008, 2012) also indicates that tuna in Indian Ocean of southern Java is indicated to be pressured. Ministry of Marine and Fisheries of the Republic of Indonesia regulation Number 45 year 2011 states that yellowfin tuna, bigeye tuna, and albakora have experienced fishing pressure in some areas of Indonesia.

Tuna fishing pressure measurements can be performed with fishing capacity. Fishing capacity is the maximum capital stock available in the fishery that can be used fully on a maximum efficient conditions, technically at the time and specific market conditions. As for the capital stock of fisheries activity is a function of the specifications of the vessel, fishing gear, and engine power. Capital stock is a manifestation of the effort measured from the amount of fishing (trip) or the number of days at sea (fished day). Based on these aspects, the capacity of fisheries can also be described as the level of possible effort, the capacity of effort, maximum potential effort, and the potential capacity of fishery (Kirkley & Squires 1998; Kirkley & Squires 1999).

Fishing capacity is important to consider in fishing activities due to excess in fishing capacity will provide a serious threat to the sustainability of fish resources, it can even lead to global fisheries crisis. Overcapacity occurs when output capacity exceeds the desired output or the target of the output at industry level. Target level of output, which is the target of fishing capacity, is the maximum number of fish in a certain time period (year, season) that can be produced by a fishing fleet if used fully. In more detail, the excess in fishing capacity will lead to three issues, namely: 1) Unhealthy performance of fisheries sector that the problem of poverty and the degradation of resources and the environment becomes more persistent; 2) Potential intense pressure to exploit fish resources for sustainability beyond its sustainable point so that the existing fleet can continue to operate, and when the business profits are diminishing and scattered to many fleet, the reduction of the fleet will be difficult to perform in both politically and socially; and 3) Triggers inefficiency and economic waste of resources, in addition to cause complications in the management of fisheries, especially in open access situation (Kirkley & Squires 1998).

Measurement of capacity can be conducted in order to determine the level of used capacity (capacity utilization - CU). The CU value can represent a proportion of the available capacity used, where CU generally refers to the proportion of used potential capacity and measured as the ratio of actual output and output capacity. CU is measured as the ratio of technical efficiency (TE) output and capacity output, where the ratio is correcting for the bias that may appear due to probability of the actual output which produced inefficiently (Kirkley & Squires 1999; Fare et al 1989).

This study aims to assess tuna fishing capacity with fishing capacity utilization level measurements and technical efficiency for three types of tuna fishing gear by vessel size group (gross tonnage - GT).

Material and Method. This research was conducted at Kupang, East Nusa Tenggara Province, Indonesia (Figure 1). The study was conducted in March and April 2015. The data used in this study was the daily arrival data of fishing vessel for 12 months in 2014. The data was obtained from the management of Tenau CFP and Oeba FLB. Based on these data, there were 106 of troll line fishing vessel, 113 of handline fishing vessel and 45 of pole and line fishing vessel which landed tuna in Kupang in 2014. Furthermore, Data Envelopment Analysis (DEA) approach will be used to analyze the fishing capacity. According to Tingley et al (2002), DEA approach can be used to calculate the fishing capacity.

DEA approach using panel data model with multi input is consisted of fixed inputs and non fixed inputs, single output, and multi output. Forwards are displayed the inputs and outputs that are used in this study:

- Fixed input: the dimensions of the vessel for each type of fishing gear, which consists of length (LOA), breadth (B), and the ship engine power;
- Non fixed input: the number of crews, as well as the needs of fuel and ice block in one trip of fishing operation;



- Single output: the total of all types of fish that can be caught and landed for each type of fishing gear.

Figure 1. Location of Tenau coastal fishing port and Oeba fish landing port in Kupang, East Nusa Tenggara province, Indonesia (Source: GIA 2013 edited).

The first step needs to perform for this analysis is to determine the vector output as u and vector input as x. In addition, there are also output m, input n, and j fishing unit. Input is divided into fixed input (x_f) and non fixed input (x_v) . Furthermore, the capacity output and utilization value of the input value are calculated using the following equation (Fare et al 1989):

 $TE = Max \theta$.

$$\begin{array}{l} \theta, z, \lambda \theta, z, \lambda \\ \theta_{1} u_{jm} \leq \displaystyle \sum_{j=1}^{J} z_{j} u_{jm} \qquad (\text{output compared to DMU}) \\ \displaystyle \sum_{j=1}^{J} z_{j} x_{jn} \leq x_{jn} \qquad n \in x_{f} \\ \displaystyle \sum_{j=1}^{J} z_{j} x_{jn} = \lambda_{jn} x_{jn} \qquad n \in x_{v} \\ \displaystyle z_{j} \geq 0 \qquad j = 1, 2, \dots, J \\ \lambda_{jn} \geq 0 \qquad n = 1, 2, \dots, N \end{array}$$

Description:

- z_j = variable intensity for observation
- $\hat{\theta}_1$ = the value of technical efficiency, or the proportion by which output is increased in production conditions at full capacity level
- $\lambda_{jn} = \text{average utilization of input variables (input variable utilization rate, VIU)} \\ \text{which is the ratio of input optimum use of } x_{jn} \text{ toward the utilization input} \\ \text{from } x_{in} \text{ observation}$

Technical efficiency capacity output (TECU) is then defined by doubling $\theta 1^*$ with the actual production. The formula used for calculating the TECU is:

$$\text{TECU} = \frac{u}{\theta_1^* u} = \frac{1}{\theta_1^*}$$

Furthermore, capacity utilization (CU), based on the output of the observation, then calculated using the formula:

$$CU = \frac{\theta_2^* u}{\theta_1^* u} = \frac{\theta_2^*}{\theta_1^*}$$

If the CU value is equal to 1 then it indicates that the production has been at full capacity, whereas if the CU value of less than 1, it indicates that the fishing unit has the potential to increase production without requiring capital expenditures for the procurement of new equipment. However, if the value of the CU is more than 1, it indicates that there has been over capacity.

Results and Discussion. Tuna fishing activities in Kupang was performed by using troll line fishing gear, handline, and pole and line. These fisihing gears were operated by using vessel which varies in size. The vessel was then grouped based on the size to simplify the efficiency calculation in this study. Troll line fishing unit are grouped into two categories, namely troll line with vessel of ≤ 5 GT and 6-10 GT. The same goes to handline fishing unit, as for the pole and line fishing unit was grouped into three, namely ≤ 10 GT, 11-20 GT, and 21-30 GT.

In this study, vessel was used as DMU (decision making unit). Fixed inputs used in this study were the gross tonnage (GT), length, width, and depth of ship (meter), and the engine power (HP). While variable inputs consist of a number of the crew, fuel consumption and ice block. Output consists of single output, namely the total catch for each type of fishing unit.

In the calculation of the alleged fishing CU rate for troll line vessel with the size of ≤ 5 GT, 60 samples of units (DMU) were used. The average value of CU for these fishing unit is 0.73. The number of vessels with a value of CU = 1 is 24 units; CU ≤ 0.7 is 7 units; CU value < 0.7 is 29 units; and there are no vessel with CU >1 (Figure 2). Meanwhile, 46 units sample of troll line fishing vessel with a size of 6-10 GT were used as DMU. The average value of CU for those fishing unit is 0.74 (Figure 2). The results obtained were 20 of troll line fishing vessel with a size between 6-10 GT have a value of CU = 1; 6 units have a value of CU ≥ 0.7 ; and 20 units have a value of CU <1 (Figure 2). There is no troll line fishing vessel which has a value of CU >1.



Figure 2. Level of capacity utilization (CU) for troll line fishing unit in Kupang, Indonesia.

The result of the calculation for variable input utilization (VIU) rate showed that the average value of VIU for the number of crew (VIU crew), fuel consumption (VIU fuel), and the use of ice block (VIU ice) on troll line fishing vessel with the size of ≤ 5 GT were 0.93, 0.89, and 0.98 respectively (Figure 3). Based on the number of vessel, troll line fishing vessel with crew number VIU = 1 was 34 units, crew number VIU ≥ 0.7 was 23 units, and crew number VIU <0.7 was 3 units (Figure 3). Furthermore, the number of troll line fishing vessel with VIU = 1 for fuel consumption was 32 units, fuel consumption VIU ≥ 0.7 was 24 units, and fuel consumption VIU <0.7 was 4 units (Figure 3). The number of troll line fishing vessel with VIU = 1 for ice block was 34 units, ice block VIU ≥ 0.7 was 23 units, and ice block VIU <0.7 was 3 units (Figure 3).



Figure 3. Level of variable input utilization (VIU) capacity for troll line fishing unit in Kupang, Indonesia.

In troll line fishing vessel with the size of 6-10 GT, the average value of VIU for the number of crew (VIU crew), fuel consumption (VIU fuel), and the use of ice block (VIU

ice) were 0.93, 0.81, and 0.89 respectively (Figure. 3). The number of troll line fishing vessel with the size of 6-10 GT with crew number VIU = 1 was 29 units, crew number VIU \geq 0.7 was 12 units, and crew number VIU <0.7 was 5 units (Figu. 3). Meanwhile, the number of troll line fishing vessel with fuel consumption VIU = 1 was 25 units, fuel consumption VIU \geq 0.7 was 6 units, and fuel consumption VIU <0.7 was 15 units (Figure 3). The number of troll line fishing vessel with VIU = 1 for ice block was 31 units, ice block VIU \geq 0.7 was 9 units, and ice block VIU <0.7 was 6 units (Figure 3).

CU estimation results on handline fishing vessel in Kupang showed that the average value of CU was 0.67 for vessel size of ≤ 5 GT and 0.78 for vessel size of 6-10 GT. The calculations showed that 20 units of handline fishing vessels with a size of ≤ 5 GT had a value of CU = 1, 5 vessels had a value of CU ≥ 0.7 , and 30 units had a value of CU < 0.7 (Figure 4). Meanwhile, the number of handline fishing vessel with a size of 6-10 GT with a value of CU = 1 was 28 units, 9 unit had a value of CU ≥ 0.7 , and 21 units had a value of CU < 0.7 (Figure 4).



Figure 4. Level of capacity utilization (CU) for handline fishing unit in Kupang, Indonesia.

Estimation of VIU for handline fishing vessel in Kupang showed that the average value of VIU for production inputs of the number of crew (VIU crew), fuel consumption (VIU fuel), and the use of ice block (VIU ice) on fishing vessel with the size of ≤ 5 GT were 0.96, 0.92, 0.90 respectively. There were 39 units of handline fishing vessel with the size of ≤ 5 GT with crew VIU value = 1, 15 units had crew VIU value ≥ 0.7 , and 1 unit that had crew VIU value <0.7 (Figure 5). The number of handline fishing vessel with fuel VIU value = 1 was 34 units, VIU fuel value ≥ 0.7 was 13 units, and VIU fuel value <0.7 was 8 units (Figure 5). Meanwhile, 33 units of those handline fishing vessels had ice block VIU value = 1, 15 units had ice block VIU ≥ 0.7 , and 7 units had ice block VIU<0.7 (Figure 5).

Handline fishing vessels with a size between 6-10 GT had an average value of VIU inputs for number of crew (VIU crew), fuel consumption (VIU fuel), and ice block (VIU ice) of 0.97, 0.94, and 0.95 respectively. The number of handline fishing vessels with VIU fuel value = 1 was 42 units, VIU fuel value \geq 0.7 was 15 units, and VIU fuel value <0.7 was 1 unit (Figure 5). Meanwhile, 40 units of handline fishing vessels had VIU fuel value = 1, 16 units had VIU fuel value \geq 0.7, 2 units had VIU fuel value <0.7 (Figure 5). Furthermore, the handline fishing vessel with VIU ice value = 1 was amounted to 47 units, VIU ice value \geq 0.7 was amounted to 6 units, and VIU ice value <0.7 was amounted to 5 units (Figure 5).



Figure 5. Level of variable input utilization (VIU) capacity for handline fishing unit in Kupang, Indonesia.

The variation of CU score for pole and line fishing vessel in Kupang was found in the vessel with size of 21-30 GT. While the vessel with the size of ≤ 20 GT had an average value of CU = 1. The DMU used for the estimation was 42 vessels of pole and line. In pole and line fishing vessels with the size of 21-30 GT, 21 units had a value of CU = 1, 1 unit had a value of CU ≥ 0.7 , and 15 units had a value of CU < 0.7 (Figure 6). The average value of CU for pole and line vessels was 0.76.



Figure 6. Level of capacity utilization (CU) for pole and line fishing unit in Kupang, Indonesia.

Not different with the previous CU estimation, the estimation VIU for pole and line fishing vessels also obtained results that pole and line fishing vessel with the size of \leq 10 GT and 11-20 GT have efficiently utilized the production inputs. Pole and line fishing vessels with a size between 21-30 GT had an average value of VIU for production input of crew

number (VIU crew) of 0.99, VIU value for fuel consumption (VIU fuel) was 0.93, and the value of VIU for ice block (VIU ice) was 0.92. VIU estimation results of pole and line fishing vessels with the size of 21-30 GT in Kupang showed that 33 fishing vessel have a crew VIU value = 1, 4 fishing vessel have a crew VIU value \geq 0.7, and no fishing vessel have crew VIU value <0.7 (Figure 7). Meanwhile, the number of fishing vessel with fuel consumption VIU value = 1 was 29 units, VIU fuel value \geq 0.7 was 4 units, and VIU fuel value <0.7 was 4 units (Figure 7). The number of handline fishing vessel with VIU ice value = 1 was 28 units, VIU ice value \geq 0.7 was 6 units, and VIU ice value <0.7 was 3 units (Figure 7).



Figure 7. Level of variable input utilization (VIU) capacity for pole and line fishing unit in Kupang, Indonesia.

The results showed that 60% of troll line fishing vessels with the size of ≤ 5 GT and 58.49% of troll line fishing vessels with the size between 6-10 GT have not been using their utilization rates efficiently. Similar things happened to 63.64% of handline fishing vessels with the size of ≤ 5 GT and 51.72% of handline fishing vessels with the size between 6-10 GT, as well as 43.24% of pole and line fishing vessels with the size of 21-30 GT. Pole and line fishing vessels with the size of ≤ 10 GT and 11-20 GT have been using the capacity utilization efficiently. In this study, there is no tuna fishing unit in Kupang which has excess of fishing capacity (CU>1). Therefore, inefficient of utilization rate of tuna is the problems on tuna fishing unit in Kupang.

CU value <1 means that fishing capacity of tuna fishing units in Kupang are indicated under fishing or the utilization effort are still not optimal. This is due to the use of traditional fishing techniques which is necessary to improve the technology so that the productivity of the tuna fishing unit in Kupang will be increased. Tsitsika et al (2008) suggest that a reduction in the size of the fishing fleet will reduce the capacity of overfishing. Furthermore, Pascoe et al (2001) state that limiting the number of fishing gear and restrictions on the allowable catch can help in reduction of fishing capacity. Thus, the utilization of tuna that has not been efficient in this study can be overcome by increasing the size of the fishing fleet. Nugraha & Hufiadi (2013) state that repairing or enhancing the life of the ship (ship rejuvenation) is one way to improve the efficiency of ship economically. Meanwhile, ships which are not efficient or have a low efficiency can be considered to be no longer operated.

The research conducted by Wiyono (2012) shows the fact that the inefficient utilization rate on a fishing unit will impact to the inoptimal use of production inputs in the process of fishing operation. Similar things happen in this research that some troll line and handline, as well as pole and line vessel with the size of 20-30 GT are indicated to have exceeding use of production inputs.

VIU estimation results in this study demonstrate that the necessary attention to production inputs used by tuna fishing unit in Kupang is needed due to indication of

excess in production inputs (VIU value <1) of tuna fishing activities in Kupang. Vestergaard (2005) states that fish resources are not only threatened by excess in fishing capacity, but also the excess input. Excess in production input is caused by high competition among fishermen to get as many tuna as possible. Wiyono (2012) states that the fishermen have tried to improve the ships capability to augment or enhance the production inputs to compete with other fishermen. However, Aranda (2009) states that the over improvement of vessel ability has consequences for gradual exhaustion of resources and shortening the fishing season. Fare et al (2000) state that reducing the excessive use of production inputs can make production input to be more efficient.

Conclusions. Tuna fishing activities in Kupang using troll line, handline, and pole and line, showed that there were a number of vessels which were inefficient in the use of fishing capacity and had exceedingly used the production inputs. However, pole and line vessel with the size of ≤ 20 GT has been efficient in the use of fishing capacity and production inputs. Therefore, tuna fishing units in Kupang need to increase production and reductions in the use of production inputs.

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Soraya Gigentika, Programme of Marine Fisheries Technology, Postgraduate Program of Bogor Agricultural University, Indonesia, Bogor, Kampus IPB Darmaga Bogor, 16680, e-mail: sorayapsp43@yahoo.co.id Tri Wiji Nurani, Bogor Agricultural University, Faculty of Fisheries and Marine Science, Department of Fisheries Resource Utilization, Indonesia, Bogor, Kampus IPB Darmaga Bogor, 16880, e-mail: triwiji@hotmail.com Sugeng Hari Wisudo, Bogor Agricultural University, Faculty of Fisheries and Marine Science, Department of Fisheries Resource Utilization, Indonesia, Bogor, Kampus IPB Darmaga Bogor, 16880, e-mail: wisudo1966@gmail.com

John Haluan, Bogor Agricultural University, Faculty of Fisheries and Marine Science, Department of Fisheries Resource Utilization, Indonesia, Bogor, Kampus IPB Darmaga Bogor, 16880, e-mail: jhaluan@yahoo.com This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

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