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Analysis of CPUE and Fishing Capacity of demersal fisheries in Kema 2, North Sulawesi, Indonesia

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Abstract**—** *Capture fisheries should be a sustainable economic activity aspect to provide good benefits to future resources. Sustainable marine fisheries resources exploitation requires a utilization rate lower than their availability. Therefore, the exploitation rate should not achieve the recovery ability of the resources in certain time. In fishing activities, for instance, there is a guideline not to catch fish over the Total Allowable Catch (TAC), 80% of the MSY. Information on the potency and the fishing capacity of tuna fisheries can be useful for the sustainable management of the resources. Also, this information can be used as a consideration for further management of the potency.*

There are two purposes of the study: (1) to analyze the CPUE (catch per unit effort) of demersal fisheries in Kema 2, North Sulawesi, for prediction of their potency, and (2) to analyze the efficiency of fishing capacity of the demersal fisheries in Kema 2, The study was done in two stages. The first was done by analyzing the potency using CPUE method (Shaefer models) to obtain the MSY, optimum effort and TAC (total allowable catch); and the second was done by analyzing the fishing capacity of demersal fisheries using DEA method to estimate the efficiency level of the fishing boats and devices in Kema 2.

The result showed that the potency of demersal fisheries in Kema 2 was 71,700 tons per year and the optimum effort was 72,964 trips. Fishing capacity in demersal fisheries occurred in Kema 2 for the last 12 years was inefficient, especially for 2001. This may be caused by some factors such as trip operation, fishing duration, oil consumption, crew and operational cost. So, to manage the demersal resources in Kema 2, the TAC should be 57,520 tons per year. Based on the result, to increase the fishing efficiency, we should take into account of above factors. We suppose that the good means is reducing trip operation, fishing duration, oil consumption, crew and operational cost.

Keywords**— *CPUE, MSY, TAC, Fishing Capacity, Kema 2***

I. INTRODUCTION

Capture fisheries is an economic activity that has high contributions to the production of marine fisheries in North Sulawesi Province. Kema 2 is a part of North Sulawesi Province geographically located at N 1°23'23" - 1°35'39" and E 125°1'43" - 125°18'13".

Demersal fish is one of the fisheries commodities in Kem 2 having economic value. It can be exported as fresh fish several countries. Since demersal fish has become an export commodity, fishing activities of the local fishermen is increasing. Nevertheless, there is no information on the potency of demersal resources.

Control on fishing effort is one of the approaches to manage the fisheries resources relating to restrictions on the fishing capacity or the amount of fishing gears. The goal is to increase catches and fishing industry's economic performances through reduced effort or excessive fishing capacity. The issue of managing fishing capacity has developed along with the developing attention to the phenomenon of the excess spread in fishing inputs and overcapitalization in world fisheries (Loftas 2001; Yu and Yu 2007).

II. RESEARCH METHOD

a. CPUE Analysis

Catch estimates could be used to illustrate a fsiheries development using Catch Per Unit Effort method. This study employed a production model to estimate demersal stocks in Kema 2 the relationship between the catch (C) and fishing effort (f). The assumption underlying this relationship is the catch per unit effort (CPUE) with a mathematical model of Gulland (1983):

C/f = a bf…………………………………………… (1)

C = af-bf2 ………………………………………… (2)

Optimum effort (fopt) can be obtained by following equation :

fopt (Effort MSY) = -a/2b ………………………… .(3)

by substitution equation (3) into equation (2) will be obtained the maximum sustainable catches (CMSY),

CMSY = -a2/4b …………………………………… (4)

FOpt (EffortMSY) = -0.5 x a/b ……….…………… (5)

b. Fishing capacity analysis

Data Envelopment Analysis (DEA) was be used to calculate the fishing capacity with the approach (Fare, et al.,1989, 2000; Gréboval, 2003).). Data Envelopment Analysis is a mathematical analysis program for estimating the technical efficiency of production activities simultaneously. The analysis uses panel data model with multi-input and single output. In fisheries applications, DEA has advantages in terms of its ability to estimate the capacity under the implementation constraints of certain policies, such as the Total Allowable Catch (TAC), taxes, regional distribution or vessel size, catch restrictions at certain times (when the pollution, for example), and those of other socio-economic development.

The unit of observation is fishing boat and input and output data based on yearly trips of boat (input) and its caught (output). DEA approach used in this study was the minimization of inputs (input oriented) and the maximization of output (output oriented). This approach is used to measure how many outputs are produced by a number of fishing vessels without any reductions and how many inputs (effort) should be induced to have stable amount of output (catch). To estimate the technical efficiency of fishing effort over the last 12 years 1999-2010 (long term) using input minimization approach with the assumption that there J effort (trip), where j = 1, 2, ... J; j =12) as an input with an output from the catch by using a model assuming constant returns to scale (CRS) with the formula (Kirkley and Squires 1999):

$$TE = Max\ \theta$$

$$\theta u_j \leq \sum_{j=1}^{J} z_j u_j \qquad \text{.................................(6)}$$

$$\sum_{j=1}^{J} z_j x_{jn} \leq x_{jn}, n \in \alpha$$

$$\sum_{j=1}^{J} z_j = 1$$

$$\sum_{j=1}^{J} z_j x_{jn} = \lambda_j x_{jn},\ n \in \hat{\alpha}$$

$$z_j \geq 0, \lambda_{jn} \geq 0 \,\forall\, n \in \hat{\alpha}$$

where j = 1,2, ..., J is the year of observation as decision making units. Thus there are 12 years of observation or J = 12 and n = 1,2, .., n inputs (n = 1).

Description: TE, technical efficiency for years to j; □, the measurement value for each observation (□ 1); UJ, output for the year-to-j is an output (catch); xjn, the n-th input is used, consisting of a fixed input (the amount of effort each fishing gear); □ j, the level of use of the n-th input variable; ZJ, intensity of use of variables.

III. RESULT AND DISCUSSION

a) Analysis of CPUE

Catch per unit effort (CPUE) is a ratio commonly used to eliminate temporal and regional trends in fish stock abundance. The “catch” portion of the measure may be expressed as the number or weight of the entire catch, a selected subset of the catch, or a particular species in the catch. The “effort unit” portion of the rate usually refers to the time a uniformly designed and employed piece of fishing gear is deployed in the water. In the absence of uniform gear use, CPUE could be applied as a coarser scale utilizing whatever effort data is available.

Table 1. Demersal fish catches (tonnes) and effort (trips) during the period of 12 years

Year	**Catch**	**Effort**	**CPUE**
	(ton)	**(trip)**	**(ton/trip)**
1999	56626.29	42660	1.327386076
2000	56330.51	37200	1.514260887
2001	56561.36	31500	1.795598571
2002	51667.07	30160	1.713098972
2003	52481.57	34940	1.502048226
2004	59489.15	48000	1.239357188
2005	59869.08	50185	1.19296762
2006	59327.46	52240	1.135671133
2007	60459.08	53600	1.12798041
2008	63721.62	60230	1.057971443
2009	60233.98	90580	0.664981011
2010	68236.79	116840	0.584019043
Total	705004.60	648135	14.85534058
Mean	58750.38	54011.25	1.237945048

Intercept (a) = 1.96536983

Slope (b) =-0.0000135

CMSY = -a2/4b = 71700.918 ton

FOpt. = -a/2b = 72964.301 trip

TAC = 0.8 * MSY = 57360.734 ton/year

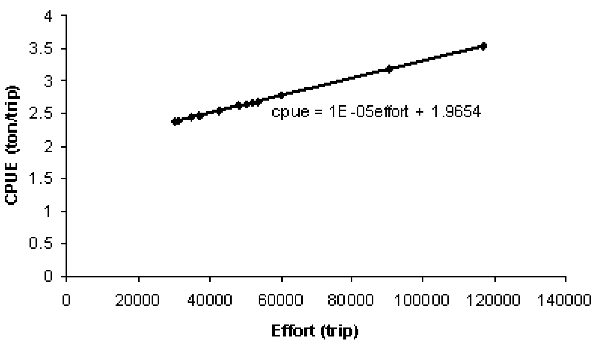


Fig.1. Relationship between effort (trip) and CPUE (tons/trip)

Figure 1 shows that there is a tendency of increased effort (trip) will increase the catch per unit effort as well (tons / trip). The analysis above shows that CMSY occur at 71700.918 tonnes while the optimum effort occurred at 72964.301 trip. Total Allowable Catch (TAC) demersal fish in Kema 2 is suggested to run 57360,734 tons / year so that these resources remain intact

b) Fishing Capacity Analysis

The analysis was based on the period of 1999 to 2010 for efficiency comparison between gear types and input approaches that are constant returns to scale (CRS) and analysis of the efficiency of the same type of fishing gear with the output approach which is variable returns to scale (VRS).

(1) Assessment of long-term efficiency (over time) Measurement of fishing capacity can be done in the long term and short term. DEA method for long term used time series data and a decision making unit (DMU) is year. The output variable is the actual catch, while the input variable is mean effort (trip) per year. The results will provide information on the status of the inputs used to achieve the absolute efficiency.

Demersal fishing activities around Kema 2 in the last 12 years fluctuated in terms of efficiency. Since 1999-2001 there was a trend for levels of efficiency and in subsequent years (2002-2010) showing a pattern of decreasing in the level of inefficiency. In 2001 the fishing activity had an efficiency value of 1 meaning that the effort spent was in accordance with the catches obtained. The fluctuation in the level of annual efficiency of demersal fisheries in Kema 2 is presented in Figure 2.

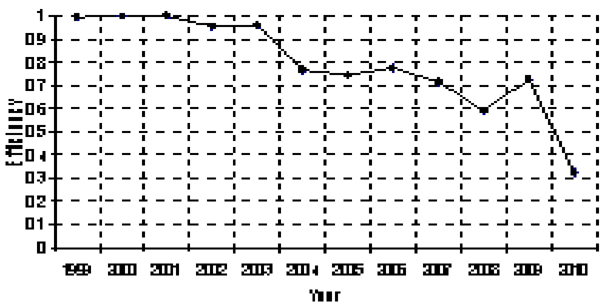


Fig.2. The efficiency of demersal fisheries in Kema 2

Figure 2 illustrates that within the last 12 years the efficiency value of the demersal fisheries in Kema 2 from year to year tends to decrease. The highest efficiency level (has a value equal to 1) occurred in 2001. The relative efficiency of demersal fisheries can be used to determine the exploitation condition of demersal fish in the waters of Kema 2 by multiplying the actual efforts used and the relative efficiency in order to obtain the target capacity (Table 2 and Figure 3).

Table 2. Efficiency score, actual effort, targeted effort and excess in capacity of demersal fisheries in Kema 2

Year	Score	Actual	Target	Excess in Capacity	
	Efficiency	Effort	Effort	Trip	%
1999	0.993	42660	42361.38	-298.62	0.16
2000	0.998	37200	37125.60	-74.40	0.04
2001	1.000	31500	31500.00	0.00	0.00
2002	0.954	30160	28772.64	-1387.36	0.76
2003	0.962	34940	33612.28	-1327.72	0.73
2004	0.766	48000	36768.00	-11232.00	6.15
2005	0.745	50185	37387.83	-12797.18	7.01
2006	0.776	52240	40538.24	-11701.76	6.41
2007	0.714	53600	38270.40	-15329.60	8.40
2008	0.589	60230	35475.47	-24754.53	13.56
2009	0.726	90580	65761.08	-24818.92	13.59
2010	0.325	116840	37973.00	-78867.00	43.19

In the last seven years (2004-2010), an increase in the number of efforts was sufficiently large in that the capacity increased significantly. Excess input of the largest fishing effort occurred in 2010 which reached 43.19%. The excess of actual effort against target effort is presented in Figure 3.

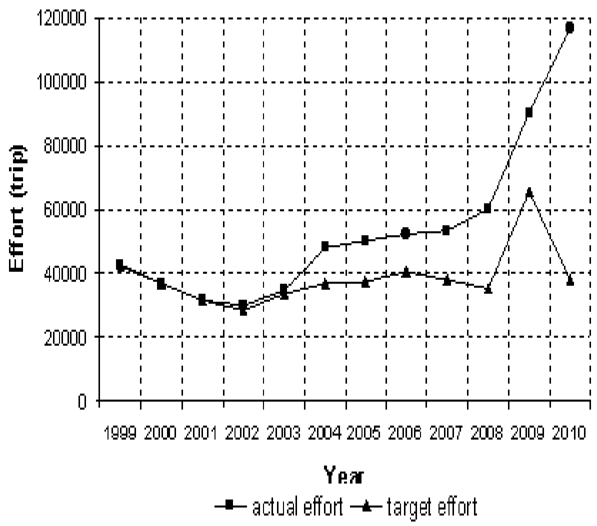


Fig.3 Comparison of actual effort and target effort of demersal fisheries in Kema 2

Figure 3 shows the difference between actual effort and target effort since 2004 to 2010 increase indicating that there was an excess in the capacity of demersal fisheries in Kema 2. It could also be seen that the difference between the target effort and actual effort is negative. Excess in number of trips could cause high pressure on the resources which could interfere with the recruitment process. If the number of actual efforts equals to the target effort then there will be 100% efficiency. Year 2001 is the year in which the amount of actual efforts equals to target efforts or the value of efficiency equals to 1, so the number of trips could be used as a reference to determining the policies for the following years.

Nine demersal fishing boats were tested for their efficiency. The results are presented in Figure 4.

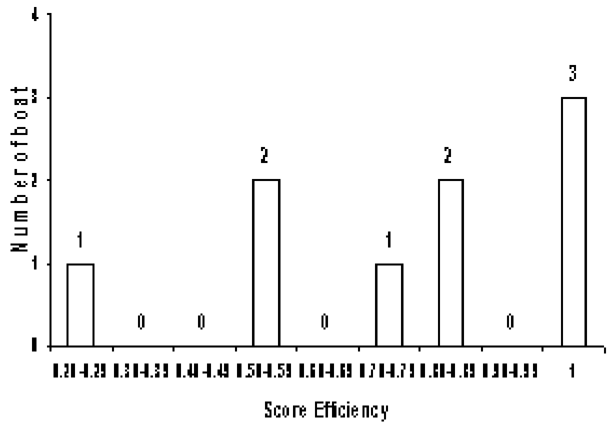


Fig.4 The efficiency of demersal fishing boat in Kema 2

Figure 4 shows that among those nine demersal fishing boats tested, only three boats have an efficiency of 1. Subsequent analysis focused only on the other six boats.

(2) Sort-term efficiency (inter-boat) assessment

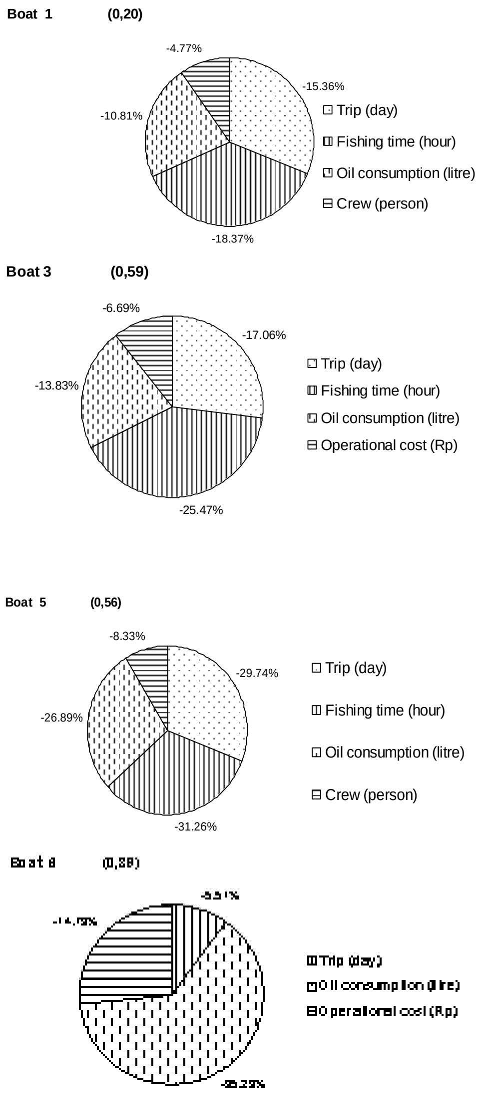
DEA efficiency analysis, in addition to long-term with the variable year as a DMU, this study also measured the efficiency of short-term nature. The analysis of a short-term efficiency was carried out by comparing the efficiency of each boat, the DMU of the tuna fishing boat itself. Input variables were trip (day), fishing time (hour), oil consumption (liter), crew (person) and operational cost (Rp). While the output variable used was demersal fish catch per boat.

Demersal fishing boat can increase the efficiency by making changes in the input variables used. The input variable adjustment is given in the Table 3 and Figure 5 below.

Table 3. Examples of demersal fishing vessels that need to be adjustment to improve efficiency

Boat		**Input**		**Deviation**	**Percentage**
1	**0,20**	**Actual**	**Target**		
Production (kg)		108			
Value of production (Rp)		1184500			
Trip (day)		27	22.85	-4.15	-15.36
Fishing time (hour)		7	5.71	-1.29	-18.37
Oil consumption (liter)		1430	1275.46	-154.54	-10.81
Crew (person)		3	2.86	-0.14	-4.77
Operational cost (Rp)		9745000	9745000	0	
3	**0,59**				
Production (kg)		250			
Value of production (Rp)		5207000			
Trip (day)		21	17.42	-3.58	-17.06
Fishing time (hour)		6	4.47	-1.53	-25.47
Oil consumption (liter)		1125	969.43	-155.57	-13.83
Crew (person)		2	2	0	0.00
Operational cost (Rp)		7688000	7173640	-514360	-6.69
5	**0,56**				
Production (kg)		326			
Value of production (Rp)		7422500			
Trip (day)		31	21.78	-9.22	-29.74
Fishing time (hour)		8	5.49	-2.51	-31.26
Oil consumption (liter)		1359	993.50	-365.50	-26.89
Crew (person)		3	2.75	-0.25	-8.33
Operational cost (Rp)		8067500	8067500	0	0.00
6	**0,89**				
Production (kg)		606			
Value of production (Rp)		12241000			
Trip (day)		25	23.62	-1.38	-5.51
Fishing time (hour)		6	6	0	0.00
Oil consumption (litre)		1435	929.52	-505.48	-35.23
Crew (person)		3	3	0	0.00
Operational cost (Rp)		9314000	7936489	-1377511	-14.79
7	**0,87**				
Production (kg)		852			
Value of production (Rp)		23597500			
Trip (day)		35	31.19	-3.81	-10.88

Fishing time (hour)	9	7.98	-1.02	-11.27
Oil consumption (liter)	965	965	0	0.00
Crew (person)	4	3.99	-0.01	-0.18
Operational cost (Rp)	9148500	9038182	-110318	-1.21
9 **0,74**				
Production (kg)	515			
Value of production (Rp)	7350000			
Trip (day)	35	27.189	-7.811	-22.32
Fishing time (hour)	9	6.849	-2.151	-23.90
Oil consumption (liter)	1326	1307.774	-18.226	-1.37
Crew (person)	4	3.424	-0.576	-14.40
Operational cost (Rp)	10441940	10441940	0	0.00



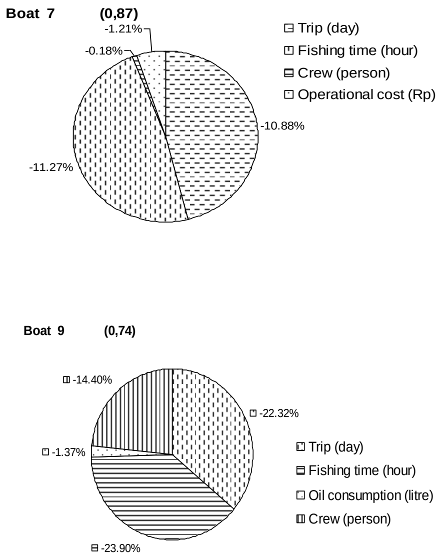


Fig.5. The potential for efficiency improvement each fishing boat

Based on Table 3 and Figure 5 shows that to improve the efficiency of demersal fishing vessels in Kema 2 the necessary arrangements in terms of fuel usage, trip operation, the number of crew, the time of arrest and operational costs as needed in each of the different ships.

IV. CONCLUSION

1. Potential demersal fisheries in Kema2 based on CPUE analysis was 71,700 tons per year and optimum effort was 72,964 trips, with a total allowable catch (TAC) of 57520 tons per year.
2. Fishing capacity for demersal fisheries along 12 last year was inefficient, especially in 2001. This may be

caused by some factors, such as fishing duration, trip operation, oil consumption, crew and operational cost. Based on the results, to increase the efficiency of fishing capacity we should take into account of these factors. The good means is by reducing fishing duration, trip operation, oil consumption, crew and operational cost.

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