The economic performance of grouper (Serranidae) and snapper (Lutjanidae) fisheries in Saleh Bay, Indonesia

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Abstract. The legal basis of the management of grouper and snapper fisheries in Saleh Bay is the Governor Regulation of West Nusa Tenggara No. 32 of 2018. This study adopted a Data Envelopment Analysis (DEA) approach to measure the efficiency level of the fishing capacity of small-scale fisheries in Saleh Bay, Indonesia. The analysis showed that the hand line vessels were more profitable than the bottom-longliners. The study results indicated the fishery performance had an average technical efficiency level (TE) of 0.627. The fishing trips and the number of hooks are significant variables affecting technical inefficiency. The use of the fishing gear (including the number of hooks) was strongly influenced by the level and expectations of individual income relative to other fishermen. Therefore, the existing management measures focused on achieving biological indicators should be strengthened through public awareness, co-management, and law enforcement.
Key Words: data envelopment analysis, inefficiency, small-scale fisheries, technical efficiency.

Introduction. Saleh Bay, located in the West Nusa Tenggara (WNT) Province, is one of the 10 fishing grounds of Indonesia. It is one of the best producers of grouper (Serranidae) and snapper (Lutjanidae) in Indonesia. This area also plays an important role in providing for the livelihoods of 5188 fishermen living along the coastline (BPS Sumbawa 2019; BPS Dompu 2019). The fisheries are the backbone of the economy of local communities and have an important economic value at provincial and national levels. However, the total landings of the reef or demersal species have slightly declined over the last decade due to destructive fishing practices and an increase in fishing efforts, leading to overfishing (Agustina et al 2018a).

Current local government policy has focused on preventing overfishing and destructive fishing techniques by initiating technical measures to manage fisheries resources. Legally, this policy is stipulated under the WNT Governor Regulation No. 32 of 2018 on the Action Plan for Sustainable Management of Grouper and Snapper Fisheries in Saleh Bay and the adjacent waters from 2018-2023 (WNT 2018). This intervention is expected to be an instrument in controlling overfishing, and in reducing the activities damaging to coral reef ecosystems as habitat for reef fish, including groupers and snappers in the bay. These regulations are now in the realm of fisheries policy at the local level. However, potential resistances are encountered when the policy objectives are not in line with those of target actors, such as small-scale fishermen. This situation, therefore, leads to the low effectiveness of the regulation in practice (Efendi et al 2020).

Policy impact assessment on small-scale grouper and red snapper fisheries management at the local level in the limit reference point has received much less attention, particularly in the context of socio-economic aspects. Subsequently, research concerning grouper and snapper fisheries, especially in Indonesia, is dominated by biological approaches, estimation of stock status, bioeconomic, and fishing techniques (Prasetya 2010; Tadjuddah et al 2013; Wahyuningsih et al 2013; Yulianto et al 2015; Bawole et al 2017; Patanda et al 2017; Agustina et al 2018a; Agustina et al 2018b; Tirtadanu et al 2018; Agustina et al 2019; Ernaningsih et al 2019; Setiawan et al 2019; Khasanah et al 2019a; Khasanah et al 2019b; Amorim et al 2020; Halim et al 2020). Every policy is expected to encourage the improvement of the techno-socio-economic conditions of the fisheries business. The fisheries regulations should be in place to guarantee the sustainability of fish stocks and generate economic benefits for key resource users. On the other hand, the challenge to scientists is to develop a solid methodology that uses biology and economic indicators to develop a framework management strategy evaluation (Aranda et al 2006). The performance information is required as input to evaluate the effect of the regulation and to measure the success of the management strategy. Therefore, this study aims to measure the economic efficiency level for grouper and snapper fisheries management in Saleh Bay and also study the factors that influence the fishing efficiency in the economic performance of small-scale fisheries.

Material and Method

Description of the study sites. This study was conducted in Saleh Bay, West Nusa Tenggara, as presented in Figure 1. The bay is one of the important locations in WNT waters, where the catch makes a significant contribution to the total production of reef fisheries (KKP 2020). Based on BPS Sumbawa and BPS Dompu (2019), the average total annual landings for grouper and snapper between 2009 and 2018 were 4048 tons and 3107 tons, respectively (Table 1). Agustina et al (2018a) reported that the fishing gears used by fishermen to catch grouper and snapper in Saleh Bay of Sumbawa Island were dominated by spear gun (36%), bottom long-line (34%), hand line (15%), troll line (6%), boat lift-net (6%), trap (2%) and set gillnet (1%). The research location is focused on 3 fishing villages, namely Labuan Kuris, Labuan Sangoro, and Labuan Jambu (Sumbawa Regency), which are the main landing sites for grouper and snapper fishing vessels around the bay.

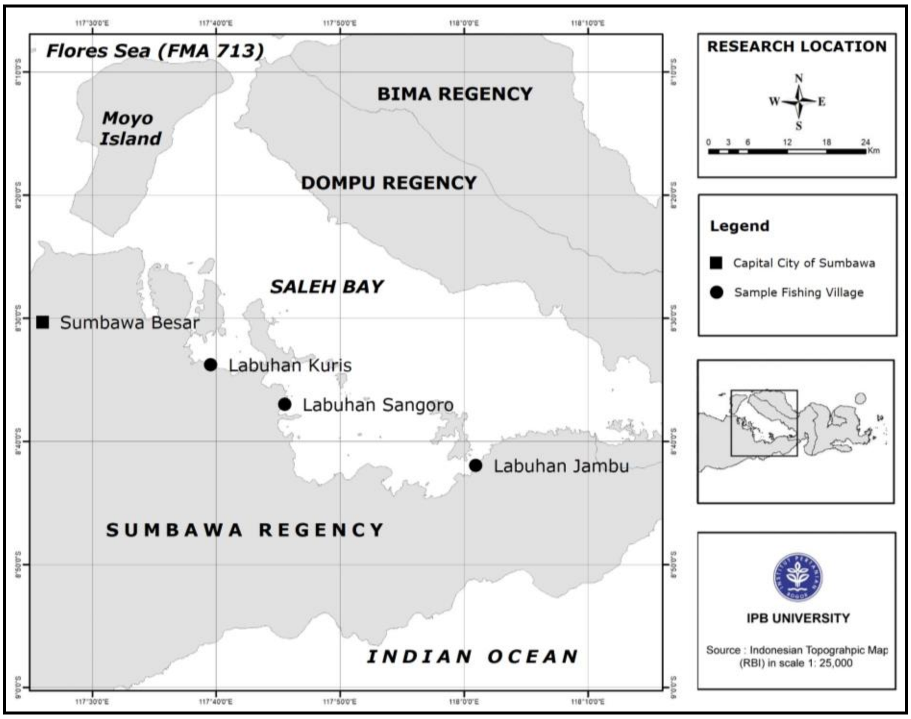

Figure 1. The location of Saleh Bay, West Nusa Tenggara.

Table 1

Total landings of grouper and snapper in Saleh Bay

Year	*Grouper (tons)*	*Snapper (tons)*	*Total (tons)*
2009	3773.13	3059.41	6832.54
2010	3347.70	3279.53	6627.23
2011	3766.35	1951.12	5717.47
2012	3224.11	3077.22	6301.33
2013	4089.62	3546.21	7635.83
2014	4401.09	2956.67	7357.76
2015	4442.51	2854.74	7297.25
2016	3797.56	3090.83	6888.39
2017	5652.77	2892.00	8544.77
2018	3992.30	4360.70	8353.00
mean	4048.71	3106.84	7155.56

Note: sources: BPS Sumbawa (2019); BPS Dompu (2019).

Data collection and data analysis. In this study, we used the purposive sampling method to collect data based on main landing sites. The survey was carried out from August to December 2019. This study focused on the two most important fishing gears targeted at grouper and snapper fisheries: handlines and bottom long lines. 402 fishermen from these villages rely on grouper and snapper fisheries. On average, the fishermen spent around 23 days at sea per month, in one-day fishing trips. For Data Envelopment Analysis (DEA), we have selected 40 respondents consisting of 24 fishermen who operated the bottom longline fishing gear and 16 fishermen who operated the hand lines. These fishermen were categorized as small-scale fisheries, with a fishing boat size of less than 5 gross tonnage (GT), overall length overall of vessels (LOA) ranging from 2.5 to 20 m, and an engine power between 5-30 HP (Table 2).

Table 2

Summary statistics of fishing gears characteristics in study sites

Specification of fishing gear	*Study sites*					
	Labuhan Jambu		*Labuhan Sangoro*		*Labuhan Kuris*	
	Mean	*Range (Min-Max)*	*Mean*	*Range (Min-Max)*	*Mean*	*Range (Min-Max)*
Length overall of fleet (m)	7.0	3-14	8.5	7-20	6.3	2.5-13
Size of fleet (GT)	1.8	1-4	1.7	0.5-3	1.3	1-2
Engine power (HP)	19.4	5-25	20.8	5-30	9.4	5-30
Bottom-longline						
Hooks size	8	7-9	7	6-8		
Number of hooks per operation	257	200-300	252	100-400		
Depth of operation (m)	67	45-90	75	30-240		
Fishing time per trip (hour)	12	11-14	12	7-15		
Hand line (dropline)						
Hooks size	10	8-10			13	13-13
Number of hooks per operation	50	38-70			2	1-2
Depth of operation (m)	48	30-70			43	35-50
Fishing time per trip (hour)	10	7-12			16	13-16

The economic performances of grouper and snapper fisheries were measured using technical efficiency (Berkes et al 2001; Aranda et al 2006) by employing the DEA approach developed by Charnes et al (1978). The analysis was conducted with the help of 40 fishermen, and was carried out by interviews involving the filling of socio-economic questionnaires. An input-oriented DEA model based on the assumption of variable returns to scale (VRS) was used in evaluating the efficiency of grouper fisheries in Saleh Bay. Coelli (2008) stated that the value of VRS type DEA is obtained using the following formula:

$TE = \min \theta$; subject to: $-y_i+Y\lambda \geq 0$; $\theta x_i - X\lambda \geq 0$; $\lambda \geq 0$.

Where: θ - the technical efficiency (TE) of decision-making units (DMU); y_i - output (revenue); x_i - input used, which consists of fuel, supply, and operational costs, such as feed, ice, oil, ship repairs and maintenance, as well as painting; λ - the efficient projections on the frontier. The use of input, output and quantitative data in the form of value (USD) makes it possible for the DEA analysis to be carried out (Portela 2014; Pinello et al 2016). The value of θ=1 means that the DMU is efficient, while a θ value less than 1 implies inefficiency. The procedure for the analysis method uses the DEA technique performed with the Frontier Analyst-Banxia software.

The level of inefficiency of ships is determined using the following function (Battese & Coelli 1995):

$U_i=\delta_0 + \delta Z_i + w_i$

Where: U_i - the inefficiency; θ - exp(-U); δ - parameter; i - fishermen 1, 2,... 40; Z_i - variables that affect inefficiency; w_i - error term. The independent variables consist of the experience of fishermen (EXP), family dependents (HOUSEHOLD SIZE), number of trips (TRIP), fishing boat size (GT), and the number of hooks (NUM OF HOOK).

This multiple linear regression of the inefficiency function was tested for 3 classical assumptions (i.e., normality test, autocorrelation test, and homoscedasticity test), using the online statistical analysis program available at www.apps.swanstatistics.com.

Results and Discussion. The technical efficiency analysis computed through the DEA model from the average revenue and cost structures data for the two main fishing gears, i.e., bottom longline and hand line (a total of 40 respondents), is presented in Table 3.

Table 3

Summary statistics of input and output variables used in the Data Envelopment Analysis

Variable	*Bottom longline*		*Hand lines*	
	Mean	*Standard Deviation*	*Mean*	*Standard Deviation*
Output				
Revenue per trip (USD)	24.26	5.3	30.96	9.03
Input (costs per trip in USD)	9.44	1.31	5.8	1.01
Fuel cost (USD)	2.29	0.4	2.02	0.66
Personal cost (USD)	2.6	0.87	2.27	0.69
Running cost (USD)	4.55	1.03	1.51	0.28

Note: the exchange rate is 14139 IDR per USD in 2019 (The Indonesia Central Bank 2020).

The DEA analysis results give an overview of the level of the technical efficiency scores in Saleh Bay, ranging widely from 0.264 to 1, with a mean technical efficiency (θ) score of 0.627 or 62.7%. Figure 2 shows the distribution of the technical efficiency scores of the 40 surveyed fishermen, in which 5 fisheries had an efficiency score of 1 or 100%. The remaining sample fishermen had efficiency scores below 0.9. Meanwhile, based on specified fishing gears, the hand line (or drop line; locally called "tomba") had an average technical efficiency score (0.783) greater than the bottom long line (0.523). Therefore, fishermen operating a hand line have an average output value (revenue) higher than that achieved using long lines, whereas the average input costs incurred are much lower than those obtained from the long line (Table 3).

DEA is also used to calculate potential improvements in the efficiency scores by reducing inputs or increasing output (Cooper et al 2004). Generally, it was observed that the efficiency of grouper and snapper fisheries in Saleh Bay is improved by reducing inputs. The policy of limiting the size of grouper and snapper in Saleh Bay by using the controlling inputs (costs), which is a policy instrument, led to the emergence of more efficient results. With efforts to reduce fuel costs by 33.86%, personal costs by 29.29%, and other operational costs by 36.85%, the fishing activities in Saleh Bay are expected to get more efficient results.

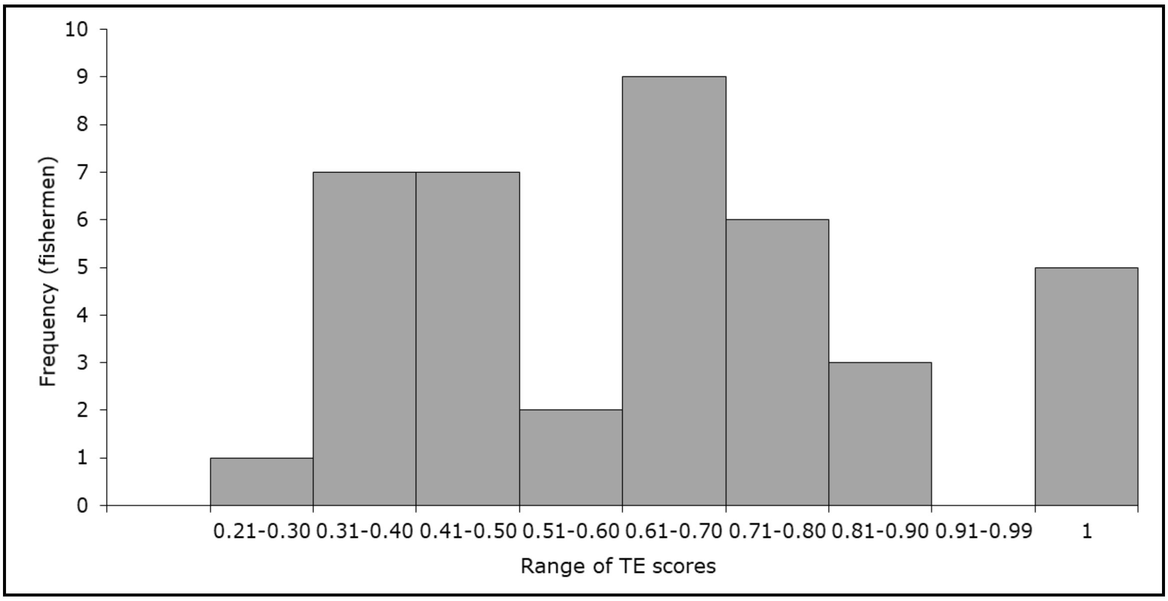

Figure 2. Distribution of the technical efficiency (TE) scores for grouper and snapper fisheries.

The results from the DEA analysis are known factors causing inefficiencies that need to be controlled. Based on stepwise regression, we have 6 independent variables that significantly influence the inefficiency of grouper and snapper fisheries in Saleh Bay, with a 95% confidence level and a determination coefficient of 57% (Table 4). Results show that individual fisherman inefficiency is positively associated with the number of trips and the number of hooks. In other words, both variables have adverse effects on the technical efficiency (Jamnia et al 2015). The results suggest that the experience and fishing trips variables were considered statistically not significant related to technical inefficiency at a 0.1 level of significance. In contrast, the coefficients of the remaining three variables had a highly significant impact on technical inefficiency ($p<0.05$).

Table 4

Parameter estimates of the technical inefficiency function

Variable	*Coefficient*	*t Stat*	*P-value*
Intercept	1.207995368	3.3822	0.0018
EXP	-0.011522696	-1.8570	0.0720
HOUSEHOLD_SIZE	-0.209906547	-4.3693	0.0001*
TRIP	0.017551143	1.7147	0.0955
GT	-0.306808074	-2.6110	0.0133**
NUM_OF_HOOK	0.001634987	4.0670	0.0003*
F value	8.8313		
F critical value in the table	2.4936		
R Square (R^2)	0.57		

Note: * - significance at $p<0.01$; ** - significance at $p<0.05$.

The analysis suggests that fisherman experience, the number of family members (household size), and boat size have a significant impact on technical efficiency. Fishermen with more experience in fishing techniques were found to be more efficient than their counterparts. The experience variable refers to skill, educational level, indigenous or local ecological knowledge, and others, for increasing fishing productivity. This factor had a positively significant impact on technical efficiency. These results are consistent with the findings of Squires et al (2003), Sesabo & Tol (2007), and Jeon et al (2006). Fishermen with more fishing experience have a better knowledge of the fishing ground, weather patterns, currents, tides, and bottom conditions (Squires et al 2003). Skilled fishermen in Saleh Bay usually apply local knowledge based on natural signs such as mountain positions to determine fishing grounds. Likewise, fishermen with a larger household size tend to be relatively more efficient than those with a smaller household. They are extremely efficient because they need to fulfill the household needs, with several dependents in the family. The estimated coefficient of household size is highly significant ($p<0.01$) and negatively associated with technical inefficiency, implying that this parameter positively affects technical efficiency. The coefficient of gross tonnages (GT) also had a negatively significant impact on technical inefficiency ($p<0.05$). This means that the boat size can improve technical efficiency.

This study also identifies some determinants affecting fishing inefficiency. The inefficiency model results suggest that both the number of trips and the number of fishing hooks have been identified as the most important fishing inefficiency factors in Saleh Bay. The expectations were that increasing the number of trips and the number of hooks would increase the amount of fish harvest. However, the coefficient for the fishing trips was not according to the expectations. The study results indicate that the variable has positive signs and a statistically significant impact on technical inefficiency ($p<0.01$). In the context of fisheries facing overfishing, especially for grouper and snapper fisheries in Saleh Bay, the increasing effort (fishing trips) causes the fishing ground to be at a farther distance, thereby resulting in longer trips. Fishermen who spend more trips at sea are more inefficient because they tend to incur significantly higher costs for fuel, supplies, and other operational costs. These results also indicate that the number of hooks has an effect on fishing efficiency ($p<0.01$) and has a positive sign, causing lesser efficiency.

The trip limitation option leads to an increase in the costs of fishing, but not enough to increase resources and, consequently, the profits gained by fishermen (Nielsen et al 2006). Therefore, the technical measures must be combined with current management interventions (under Governor Regulation) to increase the technical efficiency of the fisheries.

Although the Governor Regulation issuance marks a change in the management regime from open to limited access, the implementation is considered ineffective in practice, due to the weaknesses of law enforcement and compliance. The extent of enforcement of regulation involves the surveillance and detection of violators by adding more inspection personnel and patrol activities. The Provincial Government needs to strengthen management institutions by setting strict regulations and providing sanctions (Command-and-Control regimes) appropriately for offenders including actors and rent seekers in destructive fishing practices. Besides legality, ease of implementation also depends on how the enforcement (top-down process) will merge with the existing local institutional management structure (Anderson 1989). Therefore, the greater involvement of local communities and managers in the form of co-management is suggested. The greater participation of resource users in the management process will lead to an increased compliance level as having legitimacy (Jentoft 2000; Hatcher & Pascoe 2006). The successful implementation of grouper and snapper fisheries policy highly depends on the social and cultural conditions of local communities and their understanding and compliance with the rules (Busilacchi et al 2012). Sutinen & Kuperan (1999) have also found that the main cause of management failure in fisheries is non-compliance. This strategic change is expected to increase the degree of fishermen compliance in the decision-making process of using non-destructive fishing gear. Successively, changes in behavior will trigger the growth of awareness and collective action among other fishermen, which will strengthen the efforts to control resources. Consequently, an important approach is the establishment of fishermen institutions, including local communities and surveillance groups (locally called "Kelompok Masyarakat Pengawas" or its acronym "POKMASWAS"). These institutions play a role in economic empowerment activities that are beneficial to fishermen and increase their capacity and awareness in implementing a strategy for sustainability.

The results showed that the degree of compliance of fishermen with management rules is low due to the poor awareness of the rules. The issuance of new rules based on the minimum size limitation (output control) of grouper in Saleh Bay became rules for the changing behavior of fishermen. However, practicing the new regulation in this area is considered as rule-in-form (normative), rather than rule-in-use, this being a technical problem (Ostrom 2005). The implementation of the regulation was still not optimal since many fishermen did not fully understand the contents of the regulations and had different perceptions in complying with the governor regulation, even though the information on management measures can also be obtained from fish collectors and socialization from the local government and NGOs. Based on interviews, the perceptions of fishermen about the management rules vary: strong agreement (27.5%), agreement (10%), and somewhere in neutral (62.5%). Although their knowledge about the policy significantly improved, the acceptance of fishermen still poses a challenge. From a biological aspect, fishermen agree with the importance of the sustainability of fish resources; however, in reality, fishermen are faced with economic rationality that forces them to catch all sizes (includes undersized species) for local consumption, to cover costs for their fishing activities, such as fuel and supplies. It seems that the benefits of this policy are still not perceived by fishermen, even though their support should be considered as the key critical factor for implementing the regulation effectively (Pita et al 2020). Therefore, a tactical step is needed regarding the intensively increasing public awareness about sustainable fisheries on government regulations and the importance of fish resources sustainability, which guarantee an increase in welfare. The involvement of collectors or traders in determining the size of catch to be traded (minimum legal size) needs to increase its effectiveness, particularly in ensuring that the fishermen comply with the existing rules. In the empirical situation and conditions in Saleh Bay, the existence of middlemen seems to have escaped the reach of current policies, where supervision is only implemented in the upstream subsystem of the supply chain and not in the downstream. With some institutional engineering through economic policies, it is believed that collecting agents will be able to enforce the implementation of a sustainable fisheries resource management and practices. Furthermore, the government should provide economic and non-monetary incentives to affected fishermen, such as the provision of environmental friendly fishing gear, alternative income sources, insurance programs, access to finances, etc. Incentives play an important role in improving the compliance behavior of fishermen (Hatcher & Pascoe 2006) within the framework of stock sustainability and fishermen protection (Law No. 7 of 2016).

Conclusions. This study has estimated the economic indicators of grouper and snapper fisheries in Saleh Bay based on DEA analysis. On average, the technical efficiency score of these fisheries was 0.627, with 5 fisheries having an efficiency score of 1 or 100%. A policy that aims to change the behavior of the system needs to be designed to target leverage point elements. The management interventions imposed on these elements will have a systemic impact on others. Based on the results, the technical measures that are recommended and should affect the technical inefficiency are: fishing trips limitation and the regulation of the number of hooks. These measures need to be combined with the current policies expected to reduce fishing inefficiency, thereby effectively implementing the regulations, assuming law enforcement, compliance and co-management at the local level. Lastly, the government should provide economic incentives for affected fishermen.

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