An evaluation of grouper and snapper fisheries management policy in Saleh Bay, Indonesia

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Abstract. In the policy context, managing grouper and snapper fisheries resources for sustainability is a big challenge due to the complexity of small-scale fisheries in Saleh Bay. This study implemented two analytical methods: length-based analysis and ecosystem approach to fisheries assessment to evaluate the performance of the implementation of the grouper and snapper fisheries management in Saleh Bay. The results showed after policy implementation, the mean length of species has been slightly larger and three species already reached the spawning potential ratio (SPR) target reference point. However, two of the 11 species regulated had SPR values below the limit reference point, which indicated that these species are currently fished at unsustainable levels. Overall, the assessment of fishery risk index indicated the risk status of this fisheries in the category of moderate risk, 1.185, in which two dimensions need to be improved: socio-economy and habitat. Therefore, this study highlighted leverage points to achieve 'good' performance level, such as socialization program intensively, enforcing regulation to provincial regulation, strengthening the surveillance and law enforcement of destructive fishing practices, empowerment of local institutions by co-management, and rehabilitation of coral reef ecosystems.

Keywords: ecosystem approach; effectiveness of regulation; performance; tactical decision

1. Introduction

The Saleh Bay West Nusa Tenggara (WNT), is a productive fishing ground for grouper and snapper in Fisheries Management Area 713, with regard to total annual fish landings [1]. Based on the historical fisheries data in the last ten years indicated average annual catch landings of four tons for grouper and three tons for snapper in this area [2, 3]. The most recent statistics reported the average catch of grouper and snapper in Saleh Bay was 7,594.6 tons per year. These fisheries also play an important role in providing the livelihoods of coastal and small island communities [1, 4, 5], especially for 5,188 fishers who live along its coastline. Therefore, the small-scale grouper and snapper fisheries are the backbone of the local communities' economy and have significant economic value at provincial and national

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levels. However, the total landings of the coral reef or demersal species have slightly declined over a decade, which leads to overfishing [5]. In line with the dynamics of environmental development, the phenomenon of the declining production in this fish species started in this area. Several studies have shown that this phenomenon is a result of higher fishing rates and the increasing damaged coral reef ecosystem habitats [5]. The damaged coral reefs are due to the high intensity of fish bombing, the use of poisoning and destructive gear, and also the intense fishing rate in response to the high domestic and international demand for groupers. It is clear to all parties that this condition leads to overfishing practices and poses a major threat to the sustainability of the entire fishing industry.

In line with this, the WNT government attempt to address these severe problems through Governor Regulation No 32/2018 concerning Action Plan for Sustainable Management of Snapper and Grouper Fisheries in Saleh Bay, Cempi Bay, Waworada Bay, and Sape Waters 2018-2023. This new policy stipulates the control of fishing activities through a minimum legal size (MLS), restrictions on fishing gears, and the regulation of the fishing season, as well as the banning of destructive fishing practice [6]. This policy is the first management measure of grouper and snapper fisheries initiated by local government in Indonesia. Nevertheless, the implementation of this regulation is faced with resistance and potential non-compliance challenges from small-scale fishers that depend on fishing, so that it will be affected the successful management in this area [7].

This study attempts to evaluate the effectiveness of small-scale grouper and snapper fisheries policy in both ecological and social-economic aspects. From existing literature (e.g., [10-13]), there are currently not widely conducted and often receive much less attention [7-9]. Most of the researchers were only focus on the biological model. Therefore, it is necessary to analyse and design the best way to manage fisheries by considering the leverage points that influence the regulations' effectiveness. This study aims to evaluate performance for sustainable grouper and snapper fisheries management in Saleh Bay, and also design potential alternative strategies to improve the effectiveness of the policy for future purposes.

2. Material and methods

2.1. Location

This study was conducted in Saleh Bay, WNT (figure 1). The bay is home to a variety of fish resources in WNT Province, where fisher's catches make an essential contribution to the total landings of reef fisheries. The research location is focused on five fishing villages along the Saleh Bay, namely Labuan Sumbawa, Labuan Kuris, Labuan Sangoro, Labuan Jambu (Sumbawa Regency), and Soro (Dompu Regency), which are the main landing sites for grouper and snapper fishing vessels.

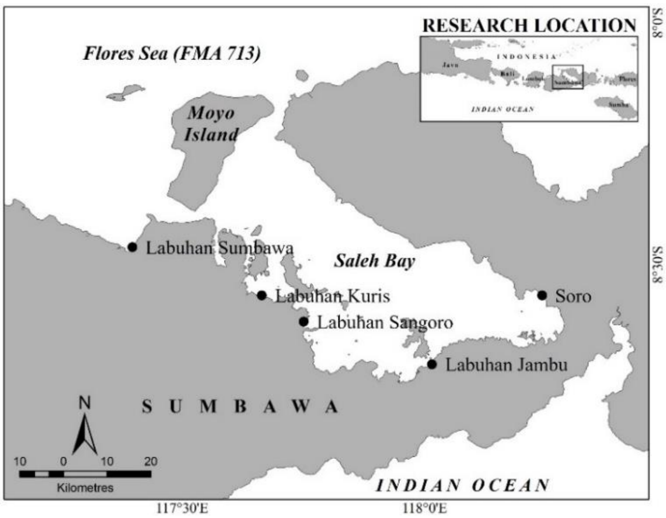

Figure 1. The location of Saleh Bay, West Nusa Tenggara.

2.2. Data collection

The research data consisted of primary data and secondary data. In this study, primary data were collected by semi-structured interviews and observation. A total of 50 respondents were selected by purposive sampling. The respondents represented all key actors who have experience of working within the grouper and snapper fisheries. They are 40 fishers, five middlemen, three fisheries officers, one surveillance group leader, and one civil society to obtain information about attributes and indicators of ecosystem approach included fish resources, habitat, socio-economic conditions, and institution. The survey was carried out between August and December 2019. Meanwhile, the secondary data were obtained from the literature of relevant sources. Information on biological characteristics of eleven grouper and snapper species such as size-composition and length-frequency (total length) data were obtained from unpublished Wildlife Conservation Society (WCS) and reported to the WNT Government. The eleven species regulated by governor regulation are *Plectropomus leopardus, P. maculatus, P. oligacanthus, P. areolatus, Epinephelus coioides, E. fuscoguttatus, Cephalopolis miniata, Variola albimarginata, V. Louti, Cromileptes altivelis*, and *Lutjanus malabaricus*. The fish landings data used for this study were the data from January-December 2019, which collected total of 14 days per month.

2.3. Data analysis

2.3.1. Length-based analysis. Length-based analysis is one of the methods used by the International Council for the Exploration of the Sea (ICES) to determine the stock and exploitation status of marine resources [14]. In this research, we applied two methods: the length-based indicators (LBI) estimated by the equation considered by ICES 2014 [14] and the length-based spawner per ratio, or called "spawning potential ratio" (LBSPR) analysis described by Hordyk *et al*. 2015 [15]. LBI analysis used the data of length at maturity (L_m), length (size) at first capture (L_c), average individual length (L_{mean}), and optimum length (L_{opt}) for 11 species individually under the Governor Regulation. LBI used to classify the stock status by conservation and optimal yield and based on formula and reference point (expected value) [14]:

- Conservation status: when $L_c/L_m>1$ (expected value)
- Optimizing yield: when L_{mean}/L_{opt}~1 or >0.9.

The data required for LBSPR model are growth coefficient (K), asymptotic length (L_{inf}), natural maturity rate (M), L_m, L_{95}, and M/K ratio), where on average $L_{95}=1.1 * L_m$ [16]. The LBSPR method has better performance to estimates stock status for data-limited fishery [17]. The SPR was calculated from WCS data.

2.3.2. Ecosystem approach to fisheries (*EAFA*). The EAFA is a useful tool for assessing the impacts of fishing on ecosystem [18] and vice-versa (the impacts of ecosystem on fisheries), using appropriate indicators and benchmark/reference points [19]. In this study here, we adopted an ecosystem approach according to a Tier 2 (a qualitative assessment or semi-quantitative) developed by Zhang *et al*. due to data-poor situations [18, 20]. Indicators for each dimension (resources, habitat quality, institution, and socio-economy) were identified in table 1.

Table 1. Dimensions, indicators, and status of indicators relative to target and limit reference points.

Dimension	Indicator	Indicator status		
		Better than target	Between target and limit	Beyond limit
Resources	Catch per Unit Effort (CPUE)	CPUE data are not declining	CPUE data are declining	CPUE data are not available
	Size at first capture (L_c)	$L_c>L_m$ (size at maturity)	$L_c<L_m$, but <20% of catch immature	L_m unknown or >20% of the catch immature

Dimension	Indicator	Indicator status		
		Better than target	Between target and limit	Beyond limit
	Maximum age or age at maturity	Low risk (<10, <5, respectively)	Medium risk (10-25, 5-10, respectively)	High risk (>25, >10, respectively)
	Adult habitat overlap with juvenile	Lower	Medium	High or no data
	Population structure/ number spawning population	Constant	Declining	Unknown or sharply declining
	By-catch	By-catches are being monitored and controlled for all fisheries	By-catches are being monitored and controlled for some fisheries	Little monitoring or control of by-catch
	Discard	Discard are being monitored and controlled for all fisheries	Discard are being monitored and controlled for some fisheries	Little monitoring or control of discard
Habitat	Impact of fishing gear on benthic habitat	Negligible impact (mid-water, surface fishing gear)	Identifiable impact (bottom fishing gear)	Serious impact (dredges)
	Marine pollution of habitat	Monitored and unpolluted	Monitored or recovery plan, but polluted	No monitoring or recovery plan, polluted
	Lost gear	Sufficient knowledge of type, quantity, and location of gear types lost and management plan in place	Type, quantity, and location of gear types lost are recorded and management plan in place	Little information and no management plan
	Critical habitat closure or gear restrictions	Operational	Under development/planning	No restriction and protection
	Recovery of physically damaged habitat	Artificial reefs have recovered damaged habitat	Artificial reefs have partially recovered damaged habitat	No recovery
	Coral reefs ecosystem conditions	>70%	50-70%	<50%
Institution	Restricted access	Fixed access, little latent effort exists (<30% of licenses inactive)	New entrants can be licensed >30% latent effort in fishery	Open access
	Fishing monitoring and sampling	Observer program in place, sampling for all fisheries data	Monitoring and sampling for a limited number of fisheries	Negligible monitoring and sampling

Dimension	Indicator	Indicator status		
		Better than target	Between target and limit	Beyond limit
	Fishing methods	All fishing methods and pattern are evaluated and changes monitored	Fishing methods and patterns are evaluated for main methods and some geographical areas	Main fishing methods and pattern are not evaluated
	Precautionary approach and sensitivity of stock assessment	Adequate stock assessment is provided and precautionary approach is adopted	Inadequate stock assessment is provided but precautionary approach is adopted	Inadequate stock assessment and precautionary approach is not adopted
	Management plan for fishery	Management plan is operational and reviewed annually	Management plan is operational, but irregularly reviewed	Management plan is not operational
	Management of IUUF	All fisheries are legal and regulated	Some illegal fisheries exist	Little regulation exists
	Gear restrictions and avoidance tactics for non-target species	Gear restrictions and avoidance tactics operational	Development of gear restrictions and avoidance tactics in progress	Few gear restrictions and avoidance tactics
Socio-economy	Productivity trend	Total production data are available and total production are increasing	Total production data are monitored and declining	No monitoring for total production and data are declining
	Income trend	Income is increasing	Income is a little declining	Income is significantly declining
	Sales trend	Data are available and sales are maintained or increasing	Data are available and sales are slightly declining or slightly changing	Data are not available or sales are significantly declining
	Cost trend	Data are available and cost are maintained or increasing	Data are available and cost are slightly increasing or slightly changing	Data are not available or cost are significantly increasing
	Employment (fishers) trend	Data are available and fishers are increasing	Data are available and fishers are declining or slightly changing	Number of fishers is significantly decreasing
	Participation	Mostly	Several	No participation
	Competition/ conflict	No conflict	Slightly increasing	Drastically increasing

Modified from Zhang *et al.* [20]

The approach has determined risk indices of fishery such as an objective risk index (ORI), species risk index (SRI), and fishery risk index (FRI) [20]. The ORI was defined as:

$$ORI=\frac{\sum_{i=0}^{n} RS_i W_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

where RS is the risk score for indicator "i", W is the weighting factor for indicator "i". The SRI was defined as:

$$SRI=\lambda_R ORI_R+\lambda_H ORI_H+\lambda_I ORI_I+\lambda_S ORI_S \quad (2)$$

where λ_R, λ_H, λ_I, and λ_S are the weighting factor for ORI_R (risk indices for resources), ORI_H (habitat), ORI_I (institution), and ORI_S (socio-economy), respectively. The FRI can be calculated from Equation:

$$FRI=\frac{\sum B_i SRI_i}{\sum B_i} \quad (3)$$

where Bi is the biomass (biomass index) for species "I". All scores divided into 3 categories by 'traffic lights' color:

- green zone (range from 0 to 1.16) if performance is satisfactory,
- yellow zone (1.16-1.63) if moderate,
- red zone (1.63-2) if not satisfactory [19, 20].

3. Results and discussion

3.1. Fish stock status

The government expressly regulated fishing activities through the Minimum Legal Size (MLS) instrument for the sustainability management of grouper and snapper species in Saleh Bay. This fishing control technique aimed to achieve control of the reproductive size of the fishes. After policy implementation, the mean length of fish (L_{mean}) has been slightly larger, except *Lutjanus malabaricus*. For example, *Plectropomus leopardus* and *Epinephelus coioides* fishes had an average size of 41cm and 56cm respectively. In contrast, the average length of the *Lutjanus malabaricus* species has declined compared to the previous year, from 56 cm to 55 cm. The average length, length at first capture, and length at maturity of grouper and snapper species in study area are presented in table 2.

Table 2. Length of the fish sample.

Species	L_{mean} 2017 (cm)	L_{mean} 2018/19 (cm)	L_c (cm)	L_m (cm)	L_{opt} (cm)
Plectropomus leopardus	37.39	41	29.02	38.83	45.81
P. maculatus	39.51	45	29.26	41.06	48.87
P. oligacanthus	37.94	43	28.86	39.67	46.96
P. areolatus	35.42	40	27.89	35.45	41.21
Epinephelus coioides	52.93	56	39.50	56.95	71.45
E. fuscoguttatus	46.49	53	35.17	57.78	72.66
Cephalopolis miniata	26.90	31	23.42	25.21	27.74
Variola albimarginata	30.45	33	27.78	30.37	34.44
V. louti	34.34	41	25.16	30.56	34.69
Cromileptes altivelis	31.83	34	26.68	29.07	32.73
Lutjanus malabaricus	56.15	55	26.68	45.37	54.88

Source: Agustina *et al.* [1], Agustina *et al.* [22] WCS [23]

However, all grouper species presented a worse state for conservation and optimized yield indicators compared to suggested reference points as shown in table 3. The majority of groupers species (70%) are still below the reference point at optimal conditions (L_{mean} /L_{opt} ~ 1 or 0.9). This situation indicated that many fishes are caught during immature (juvenile) conditions, demonstrating overexploitation [14]. In contrast, red snapper is above the reference point in both conservation and optimal yield, indicating immature fish are well conserved.

In addition, the fish stock status of *Epinephelus coioides* and *E. fuscoguttatus* are overexploited. This status is reflected by the Spawning Potential Ratio (SPR) value, which is below 20% (limit reference point) and shows that under-sized catches were common (table 4). Overall, from the 10 grouper species, 3 species already reached the SPR target reference point (30%), i.e., *Plectropomus maculatus, V. louti,* and *Cromileptes altivelis* [23].

Table 3. Indication of stock status compared to suggested reference points.

Species	Conservation	Optimal Yield
Plectropomus leopardus	0.75	0.82
P. maculatus	0.71	0.81
P. oligacanthus	0.73	0.81
P. areolatus	0.79	0.86
Epinephelus coioides	0.69	0.74
E. fuscoguttatus	0.61	0.64
Cephalopolis miniata	0.93	0.97
Variola albimarginata	0.91	0.88
V. louti	0.82	0.99
Cromileptes altivelis	0.92	0.97
Lutjanus malabaricus	1.03	1.02

After the PERGUB was established, the SPR value showed a significant increase for *P. areolatus* and *C. miniata*, demonstrated by the change of exploitation status from "overexploited" in the initial year to "fully-exploited" in recent year, and for *P. maculates* and *Cromileptes altivelis* demonstrated by the change of exploitation status from "fully-exploited" to "under-exploited". However, the SPR value of *E. coioides* and *L. malabaricus* showed a declining trend from this period due to the high exploitation of small fish, most of them were caught using spear guns. The results also revealed that fishing mortality (F) is higher than natural mortality (M) or F/M ratio >1 for all species, except *P. maculatus*, *V. louti*, and *Cromileptes altivelis* which may be overfishing [table 4]. The high intensity of fishing pressures is also caused by the continual increase in the domestic and international demand for grouper, which is an essential economic commodity, and the price is relatively high compared to other fish.

Table 4. Estimation of spawning potential ratio and fishing mortality-natural mortality ratio.

Species	SPR		F/M	
	2017	2018/19	2017	2018/19
Plectropomus leopardus	0.24	0.25	1.63	1.40
P. maculatus	0.21	0.30	1.13	0.86
P. oligacanthus	0.21	0.25	1.50	1.00
P. areolatus	0.19	0.20	1.07	1.00
Epinephelus coioides	0.22	0.15	1.13	1.60
E. fuscoguttatus	0.05	0.06	2.21	2.20
Cephalopolis miniata	0.19	0.22	2.13	1.10
Variola albimarginata	0.20	0.25	2.07	1.12
V. louti	0.43	0.80	1.50	0.92
Cromileptes altivelis	0.28	0.44	0.88	0.50
Lutjanus malabaricus	0.38	0.25	0.88	1.20

Source: Agustina *et al.* [1], WCS [23]

3.2. Ecosystem approach to fisheries

Kite diagrams from grouper and snapper fisheries are presented in figure 2 and figure 3. Figure 2 illustrates the major challenges facing grouper fisheries is the socio-economic dimension for grouper fisheries. This fishery has the highest score of ORI (1.583) related to social-economic dimension, whereas the ORI values of resources dimension, habitat dimension, and institution are 1.375, 1.385, and 0.929 respectively. Meanwhile, ORI value for snapper ranged from 0.929 to 1.385 (see figure 3), which the highest risk of ORI was habitat dimension (the species significantly has associated with coral reef). The estimated SRI values for grouper and snapper are 1.285 and 1.056, respectively. Based on these values, we calculated the FRI value of 1.185 using Equation 3. The indicator falls in the yellow zone; thus, special attention is needed to improve fisheries performance.

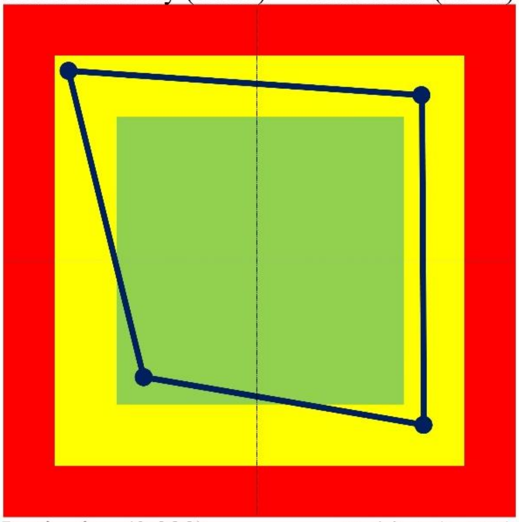

Figure 2. Kite diagram of ORI values for grouper fishery.

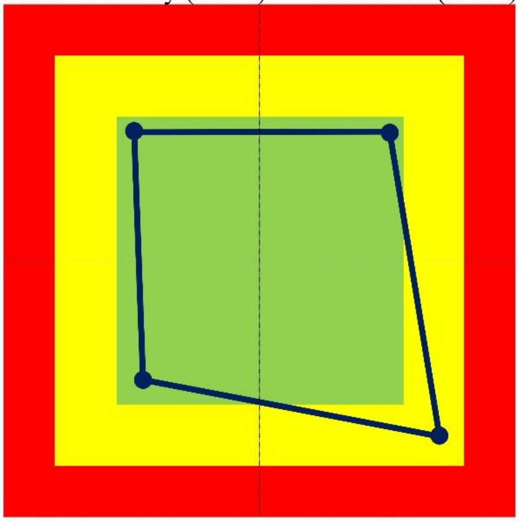

Figure 3. Kite diagram of ORI values for snapper fishery.

The FRI performance in 2019 for these fisheries was lower than those in 2017 (1.706), indicating the fishery has reduced the risk level from the red zone in 2017 to the yellow zone in 2019. These results showed that management of grouper and snapper fisheries has been improved. However, policies and regulations governing grouper and snapper fishing techniques is not effective enough to encourage the growth of sustainable aquatic resource management, especially in the context of small-scale fisheries. A policy which basically aims to change the behaviour of the system needs to be designed to target elements which are the leverage point. Hence the improvements are necessary for attributes of each dimension to increase 'good' performance.

The intervention imposed on these elements will have a systemic impact on others. The effective policy requires substantial efforts to improve fishers' compliance with the existing rules, such as gear restriction and size limits. The strategic change of surveillance by adding marine patrol activities [24] and more personnel is expected to increase the degree of fishers' compliance in the decision-making process of using non-destructive fishing gear. Successively, changes in behaviour will trigger the growth of awareness and collective action among other fishers, which will strengthen the efforts to control aquatic resources [7]. Therefore, a tactical step is required in the form of the Governor Regulation Campaigns to increase public awareness and understanding and further encourage the participation of fishermen and collectors in fish resources sustainability will ensure improvement in the effectiveness of this regulation [13]. In this study, it was observed that the involvement of collectors or traders in determining the size of catch to be traded is one of the market-based management actions (market-driven) that needs to increase its effectiveness, particularly in ensuring that the fishers comply with the existing rules. In this context, the collectors need to provide guidance to member fishers to avoid prohibited fishing practices that pose a risk to fishers' safety and legal consequences associated with violation. As an implication, fisheries policies are designed not only to include fishers as the main target but also other agents who are closely related and bounded. In the empirical situation and conditions in

Saleh Bay, the existence of collectors seems to have escaped from the reach of the current policies; where supervision is only implemented in the upstream subsystem of the supply chain and not the downstream. With a little 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.

In other hand, policy instruments of limitation catch and fishing gear for grouper and snapper fisheries in Saleh Bay must be enforced. The regulation needs to be adopted or passed by the provincial House of Representatives (DPRD) to Provincial Regulation (*Peraturan Daerah* or its acronym *PERDA*), which have a higher legal standing than PERGUB. The regulation also must be supported by more operational rules at the local level and participation of local communities and fisheries managers in co-management arrangements [25]. These institutions play a role in economic empowerment activities that are beneficial to fishers and increase their capacity and awareness in implementing a strategy for sustainability. Furthermore, the achievement of grouper and snapper fisheries sustainability in Saleh Bay requires targeted efforts through the rehabilitation of coral reef strategies [26]. This activity is carried out to ensure the recovery of damaged coral reefs by destructive fishing practices and its sustainable use. It also focused on the location of damaged coral reefs that have the potential for spawning sites. One of the activities needed to be implemented is coral reef transplantation.

4. Conclusion

Evidence shows an increase in average length and SPR values of grouper and snapper species after the policy implementation. However, the FRI evaluation results indicate that these fisheries' status is in the yellow zone and has remained a challenge. To achieve the long-term sustainability of these fisheries, the tactical decisions needed to be considered, such as enhancing public awareness and compliance, enforcing the regulation, strengthening the surveillance and law enforcement, empowering local institutions in the co-management context. We also recommended preventing habitat quality by closed fishing season and rehabilitation of coral reef ecosystems to prevent small-fish/immature.

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