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

D S Efendi¹ ² ,*. L Adrianto¹ ³ , Yonvitner¹ ³ and Y Wardiatno¹ ³ ⁴

¹ Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Jl. Agatis, Kampus IPB Dramaga, Bogor 16680, Indonesia
² Directorate-General of Capture Fisheries, Ministry of Marine Affairs and Fisheries (MMAF), Jl. Medan Merdeka Timur No. 16, Jakarta 10110, Indonesia
³ Center for Coastal and Marine Resources Studies (CCMRS), IPB University, Kampus IPB Baranangsiang, Jl. Raya Pajajaran No. 1, Bogor 16127, Indonesia
⁴ Environmental Research Centre, IPB University, Jl. Lingkar Akademik, Kampus IPB Dramaga, Bogor 16680, Indonesia

*Corresponding author: dsefendi75@gmail.com, diding.efendi@kkp.go.id

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
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](image_url). 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. oliganthus, P. areolatus, Epinephelus coioides, E. fuscoguttatus, Cephalopolis miniata, Variola alibimarginata, 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\text{m}), length (size) at first capture (L\text{c}), average individual length (L\text{mean}), and optimum length (L\text{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\text{c}/L\text{m}>1 (expected value)
- Optimizing yield: when L\text{mean}/L\text{opt}=1 or >0.9.

The data required for LBSPR model are growth coefficient (K), asymptotic length (L\text{inf}), natural maturity rate (M), L\text{m}, L\text{95}, and M/K ratio), where on average L\text{95}=1.1 * L\text{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 |
| Resources | Catch per Unit Effort (CPUE) | CPUE data are not declining |
| | Size at first capture (L\text{c}) | L\text{c}>L\text{m} (size at maturity) |
| | | CPUE data are declining |
| | | CPUE data are declining |
| | | L\text{c}<L\text{m}, but <20% of catch immature |
| | | CPUE data are not available |
| | | L\text{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 | Identifiable impact (bottom fishing gear) | Serious impact (dredges) |
| Habitat | Impact of fishing gear on benthic habitat | Monitored and unpolluted | No monitoring or recovery plan, but polluted |
| | Negligible impact (mid-water, surface fishing gear) | Monitored or recovery plan, but polluted | Little information and no management plan |
| | Marine pollution of habitat | Type, quantity, and location of gear types lost are recorded and management plan in place | Little monitoring or control of discard |
| | Little | Little monitoring or control of discard |
| | Lost gear | Little | Little monitoring or control of discard |
| 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 | 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                                                                 |
|-------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Fishing methods               | All fishing methods and pattern are evaluated and changes monitored       | Better than target                                                               |
|                               | Adequate stock assessment is provided and precautionary approach is adopted | Between target and limit                                                         |
| Precautionary approach and sensitivity of stock assessment | Management plan is operational and reviewed annually                      | Beyond limit                                                                    |
| Management plan for fishery   | Management plan is operational, but irregularly reviewed                  |                                                                                  |
| Management of IUUF            | All fisheries are legal and regulated                                      |                                                                                  |
| Gear restrictions             | Gear restrictions and avoidance tactics are operational                   |                                                                                  |
| and avoidance tactics for non-target species | Development of gear restrictions and avoidance tactics in progress       |                                                                                  |
| Socio-economy                 | Total production data are available and total production are increasing   | Better than target                                                               |
| Productivity trend            | Income is increasing                                                       | Between target and limit                                                         |
| Income trend                  | Income is a little declining                                               | Beyond limit                                                                    |
| Sales trend                   | Data are available and sales are maintained or increasing                 |                                                                                  |
| Cost trend                    | Data are available and cost are maintained or increasing                  |                                                                                  |
| Employment (fishers) trend    | Data are available and fishers are increasing                             |                                                                                  |
| Participation                 | Mostly                                                                     | Better than target                                                               |
| Competition/conflict          | No conflict                                                                | Between target and limit                                                         |
|                               | Slightly increasing                                                        | Beyond limit                                                                    |

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:
\[ ORI = \frac{\sum_{i=0}^{n} RS_i W_i}{\sum_{i=1}^{n} W_i} \]  

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

\[ SRI = \lambda_R ORI_R + \lambda_H ORI_H + \lambda_I ORI_I + \lambda_S ORI_S \]  

where \( \lambda_R, \lambda_H, \lambda_I, \) and \( \lambda_S \) 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:

\[ FRI = \frac{\sum B_i SRI_i}{\sum B_i} \]  

where \( B_i \) 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 (\( L_{\text{mean}} \)) has been slightly larger, except \( Lutjanus malabaricus \). For example, \( Plectropomus leopardus \) and \( Epinephelus coioides \) fishes had an average size of 41 cm and 56 cm 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                  | \( L_{\text{mean}} \) (cm) | \( L_{\text{mean}} \) 2018/19 (cm) | \( L_c \) (cm) | \( L_m \) (cm) | \( L_{\text{opt}} \) (cm) |
|--------------------------|-----------------------------|-----------------------------------|---------------|---------------|--------------------------|
| *Plectropomus leopardus* | 37.39                       | 41                                | 29.02         | 38.83         | 45.81                    |
| *P. maculatus*           | 39.51                       | 45                                | 29.26         | 41.06         | 48.87                    |
| *P. olgicanthus*         | 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 (\( L_{\text{mean}} / L_{\text{opt}} \sim 1 \) 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          |
| *V. albiniconut*      | 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. maculatus* 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 2017 | 2018/19 | F/M 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    |
| *V. albiniconut*      | 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.

![Socio-economy (1.583) Resources (1.375)](image1)

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

![Socio-economy (1.000) Resources (1.000)](image2)

**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.

Acknowledgments
We acknowledge the support provided by the Ministry of Marine Affairs and Fisheries (PhD scholarship). We are grateful to the Country Director of Wildlife Conservation Society (WCS) and the staff and the fishers for providing their valuable data and information. We also thank Agus Hermansyah for helping to produce a research location map.

References
[1] Agustina S, Panggabean AS, Natsir M, Jimmi, Retnoningtyas H, and Yulianto I 2018 Profile of grouper and snapper fisheries stock in Saleh Bay, West Nusa Tenggara Province (Bogor: Wildlife Conservation Society) p 68
[2] BPS-Statistics of Sumbawa Regency 2019 Sumbawa in Figure 2019 (Sumbawa Besar: BPS) p 483 [in Indonesian]
[3] BPS-Statistics of Dompu Regency 2019 Dompu in Figure 2018 (Dompu: BPS) p 384 [in Indonesian]
[4] Amorim P, Sousa E, Jardim M, Azevedo, and Menezes G M 2020 Length-frequency data approaches to evaluate snapper and grouper fisheries in the Java Sea, Indonesia Fisheries Research 229 1-15
[5] Khasanah M, Nurdin N, Sadovyde Mitcheson Y and Jompa J 2019 Management of the grouper export trade in Indonesia Reviews Reviews in Fisheries Science & Aquaculture 28 1-15
[6] WNT (Government of West Nusa Tenggara) 2018 [Governor Regulation No. 32 of 2018 concerning action plan for sustainable management of snapper and grouper fisheries in Saleh Bay, Cempi Bay, Waworada Bay, and Sape waters 2018-2023] (Mataram: Provincial Secretariat) p 11 [in Indonesian]
[7] Efendi D S, Daud A R and Utomo D S 2020 *Policy impact assessment on grouper and snapper fisheries supply chain and small-scale fisheries economic in Saleh Bay: An agent-based modeling approach* (Unpublished Document-Project Report) (Jakarta: Conservation Strategy Fund Indonesia) p 60 [in Indonesian]

[8] Berkes F, Mahon R, McConney P, Pollinac R and Pomeroy R 2001 *Managing Small-Scale Fisheries, Alternative Directions and Methods* (Ottawa: International Development Research Centre) p 308

[9] Carvalho N, Van Amrooy R, Vassdal T and Dağtekin M 2020 *Techno-economic performance review of selected fishing fleets in Europe* (Rome: FAO Fisheries and Aquaculture Technical Papers) p 653

[10] Khasanah M, Nurdin N, and Jompa J 2019 Reproducive biology of three important threatened/near-threatened groupers (*Plectropomus leopardus*, *Epinephelus polyphekadion* and *Plectropomus areolatus*) in eastern Indonesia and implications for management *Animals* 9(643) p 18

[11] Agustina S, Panggabean A S, Natsir M, Retnoningtyas H, and Yulianto I 2019 Yield-per-recruit modeling as biological reference points to provide fisheries management of leopard coral grouper (*Plectropomus leopardus*) in Saleh Bay, West Nusa Tenggara *IOF Conference Series: Earth and Environmental Science* 278(012005) p 7

[12] Halim A, Loneragan N R, Wiryawan B, Hordyk A R, Sondita M F A, and Yulianto I 2020 Evaluating data-limited fisheries for grouper (Serranidae) and snapper (Lutjanidae) in the Coral Triangle, eastern Indonesia *Regional Studies in Marine Science* 38(2020)101388

[13] Efendi D S, Adrianto L, Yonvitner, Wardiatno Y and Agustina S 2020 The performance of stock indicators of grouper (Serranidae) and snapper (Lutjanidae) fisheries in Saleh Bay, Indonesia *AACL Bioflux* 13 2431-44

[14] International Council for the Exploration of the Sea 2018 ICES Technical Guidelines: ICES reference points for stocks in categories 3 and 4 *ICES* p 50

[15] Hordyk A, Ono K, Valencia S, Loneragan N and Prince J 2014 A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries *ICES Journal of Marine Science* p 15

[16] Prince J, Victor S, Kloulchad V, and Hordyk A 2015 Length based SPR assessment of eleven Indo-Pacific coral reef fish populations in Palau *Fisheries Research* 17 42-58

[17] Chong Lisa, Mildenberger T K, Rudd M B, Taylor M H, Cope J M, Branch T A, Wolff M and Stäbler M 2020 Performance evaluation of data-limited, length-based stock assessment methods *ICES Journal of Marine Science* 77 97-108

[18] Yeon I, Song M Y, Sohn M H, Hwang H J, Im Y J, Kim D H, and Zhang C I 2011 An ecosystem-based assessment of the Korean blue crab trammel net fishery in the Yellow Sea and management implications *Fisheries Research* 112 179-88

[19] Staples D and Funge-Smith S 2009 *Ecological approach to fisheries and aquaculture: Implementing the FAO Code of Conduct for Responsible Fisheries* (Bangkok: FAO Regional Office for Asia and the Pacific) p 48

[20] Zhang C I, Kim S, Gunderson D, Marasco R, Lee J B, Park H W and Lee J H 2009 An ecosystem-based fisheries assessment approach for Korean fisheries *Fisheries Research* 100 26-41

[21] Zhang C I, Hollowed A B, Lee J V and Kim D H 2011 An IFRAME approach for assessing impacts of climate change on fisheries *ICES* 68 1318-28

[22] Agustina S, Retnoningtyas R and Yulianto I 2019 *An evaluation of the implementation of the action plan for sustainable grouper and snapper fisheries management in West Nusa Tenggara province in the 1st year* (Bogor: Wildlife Conservation Society) p 17

[23] WCS 2020 *Evaluation of the Implementation of the Action Plan for Sustainable Grouper and Snapper Fisheries Management in West Nusa Tenggara (WNT) Province* (Bogor: Wildlife Conservation Society) p 4
[24] Booth H, Mardhiah U, Apolinardus B, Lia Y, Sarah D and Dwi L 2020 An integrated approach to tackling wildlife crime: Impact and lessons learned from the world’s largest targeted manta ray fishery Conservation Science and Practice e314 1–18

[25] Busilacchi S, Williams A J, Russ G R and Begg G A 2012 Complexity of applying minimum legal sizes (MLS) of retention in an indigenous coral reef fishery Fisheries Management and Ecology 19 233–44

[26] Haya L O M Y and Fujii M 2020 Assessment of coral reef ecosystem status in the Pangkajene and Kepulauan Regency, Spermonde Archipelago, Indonesia, using the rapid appraisal for fisheries and the analytic hierarchy process Marine Policy 118 1-11