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Stock Performance and Fishers' Perception of Grouper and Snapper Fisheries in the Saleh Bay, Indonesia

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***Abstract*— The legal basis of managing grouper and snapper fisheries in Saleh Bay is the Governor Regulation of West Nusa Tenggara No. 32 of 2018. This study aims to assess stock performance and understand fishers' perception of the regulation. In this study, we used length-based assessment, perception analysis, and Rapid Appraisal for Fisheries technique. The overall results showed that the implementation of the governor fisheries management regulation was still not optimal, although the potential spawning ratio (SPR) of most fish stocks has higher than the threshold, being over 20% (SPR limit reference point), except *Epinephelus coioides*. However, fishers had diverse perceptions of the governor regulations and had not fully complied with the most important ones. These included the minimum size of catch and the allowed type of fishing gear. Therefore, we identify four management strategies to improve a more sustainable fisheries management are: an intensive program to increase public awareness about sustainable fisheries needs to be conducted, the policy to limit the legal size must be enforced and should be adopted as provincial regulation in the future, the surveillance capability and law enforcement of destructive fishing practices (bombs and potassium) should be strengthened, stakeholder participation should be engaged, and social institutions of the fishing community should be empowered by co-management. This study also highlights the urgency of establishing a combination of market-based management (e.g., seafood certification) and a closed fishing season in spawning aggregation areas to complement existing fishery management.**

***Keywords*— Grouper; snapper; effectiveness of regulation; overexploitation; sustainability.**

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I. INTRODUCTION

The Saleh Bay West Nusa Tenggara (WNT) is a productive fishing ground for grouper and snapper in Indonesian waters. Historical fisheries' data from the last ten years indicated average annual production of eight thousand tons of seafood with five thousand small-scale fisheries (SSF) live along its coastline [1], [2]. However, the total landings of these species have declined slightly over a decade. Some fish stocks were reported overfishing [3] due to higher fishing rates and degradation of habitats [4].

The government of WNT has attempted to address this problem by enacting a Governor Regulation (*Peraturan Gubernur* or its acronym *PERGUB*). A new policy regulates the restriction of minimum legal size (MLS), fishing gear, and a ban on destructive fishing practices. The management initiatives of the government to maintain the sustainability of fish stocks should be appreciated. However, in the planning process of this policy, the government has not incorporated the socio-economic aspect [5].

The government recently regularly evaluates the indicators to measure the impacts of regulation at least once a year. The fisheries indicator used to ex-post evaluation was stock status [6]. A key question is how best to make the regulatory policy work effectively, considering fisheries management sustainability solely as a biological concern without considering the socio-economic dimension. Further, it is questionable how sustainable fisheries status can be evaluated under data-poor situations.

However, while socio-economic aspects have critical importance in considering the successful fisheries' policy implementation, the study on these means is currently not widely conducted [3], [7]. Most of these fisheries face challenges, such as a lack of social-ecological data and poor management [8]. The previous studies, particularly in

Indonesia, focus on these fisheries' biological and ecological perspectives [9]–[17].

This study helps fill these gaps, evaluating performance policy actions and their implementation based on an interdisciplinary approach [18] under data-limited conditions. This study aims to assess biological performance, understand fishers' perception of sustainable fishing, and design alternative strategies to improve the effectiveness of the policy in the future. This study is essential for making recommendations to improve the successful implementation of fisheries policy. This effort is expected to achieve the Sustainable Development Goal (SDG) 14, specifically regarding the sustainable use of marine resources and SSF [19].

II. Material and Methods

A. Location

This study was conducted in Saleh Bay, as shown in Fig. 1. The bay has a significant contribution to the total production of reef and demersal fisheries in WNT [10], [20], [21]. The research is focused on three fishing villages: Labuan Kuris, Labuan Sangoro, and Labuan Jambu (Sumbawa Regency). These areas are known as the main landing sites for grouper and snapper fishing vessels in the bay.

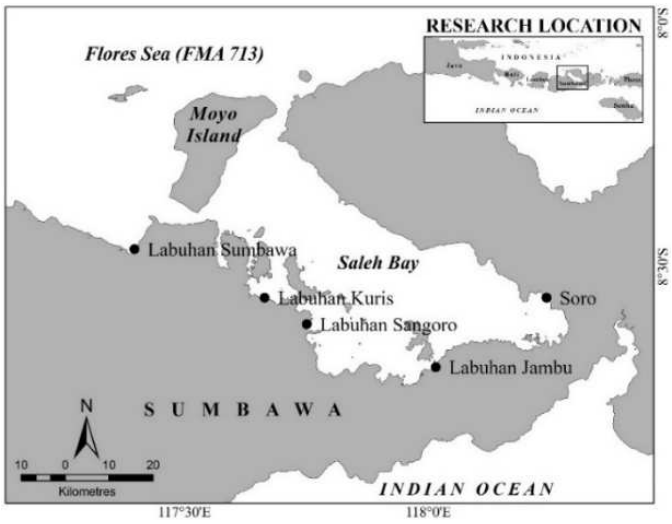

Fig. 1 Study Area

B. Data Collection

The research data consisted of primary data and secondary data. In-depth interviews were conducted with 40 respondents at the study site using a questionnaire to obtain information about fishers' perceptions and the Rapid Appraisal for Fisheries (RAPFISH) technique. The survey was carried out between August and December 2019. This study used size-composition data of the four dominant species published by the Wildlife Conservation Society (WCS). The four of the 11 species managed by governor regulation are *Plectropomus leopardus, P. maculatus*, *Epinephelus coioides*, and *Lutjanus malabaricus*. The other secondary data were collected through studies of the literature from relevant sources.

C. Data Analysis

This study involved three analytical methods: length based (LB) analysis, perception analysis, and RAPFISH analysis (Fig. 2). LB analysis is one method used to determine the fish stock status [22], whereas perception analysis can help to improve effective fisheries management measures [23]. We evaluated the sustainability status and identified sensitive factors influencing sustainability using the RAPFISH analysis [24]. These methods are valuable tools for assessing the fisheries' status under data-poor conditions [25], [26], [27].

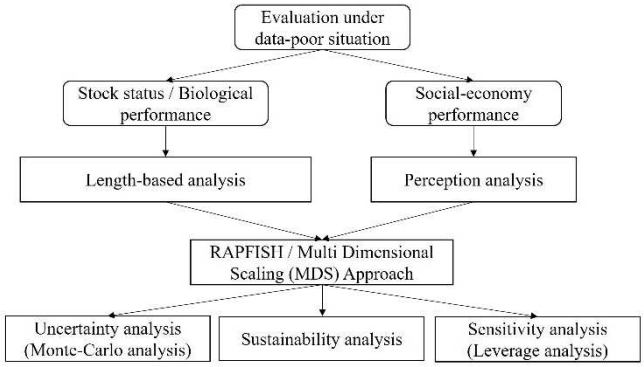

Fig. 2 Stages of the Research Analysis

1) Length-based Analysis: In this study, we applied two methods: the length based indicators (LBI) estimated by the equation considered by the International Council for the Exploration of the Sea (ICES) [22] and the potential spawning ratio (LBSPR) analysis described by Hordyk et al. [28]. This method can be applied to manage size selectivity in many SSF in Indonesia [29].

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}). The biological parameters were calculated using the R package software TropFishR [30]. LBI was used to classify the stock status by conservation and optimal yield and was based on a formula and reference point [22]:

- Conservation status: when $L_c/L_m > 1$ (expected value)
- Optimizing yield: when $L_{mean}/L_{opt} \sim 1$ or >0.9, where $L_{opt} = 2/3\ L_{inf}$.

Meanwhile, the data required for the LBSPR model are length compositions of catches and life-history parameters such as the asymptotic length (L_{inf}), growth coefficient (K), natural maturity rate (M), L_m, L_{95}, and M/K ratio, where on average $L_{95}=1.1 \times L_m$ [21]. The SPR was calculated by an online tool available at www.barefootecologist.com.au/lbspr.

The LBSPR method provides simple management reference points [31] and can assist precautionary management decisions of the fisheries [32]. However, the model has limitations and depends on the equilibrium assumption and the large uncertainty in the life-history parameters, so that the model's validity may be positively biased. The model estimates for the status of stock may have resulted in overestimation or underestimation [21].

2) Perception Analysis: A survey for fishers' perceptions was performed using questionnaires with 11 statements to investigate the fishers' responses to fishery resources, fishing activities, and management in the study area. The

respondents' agreement level was measured using a Likert–type scale consisting of five options: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, and (5) strongly agree [33].

The fishers' perception was assessed using descriptive statistics [34], [35]. We applied a nonparametric statistical tool, the Spearman rank correlation test, to assess the statistically significant level of the relationship of the responses for the respondents' responses for each of the 11 statements. Statistically, the differences were considered significant at $P < 0.05$.

3) RAPFISH Analysis: This analysis assists in diagnosis using multidimensional scaling (MDS), which maps out the different perceptions (ordinance) between one unit of fisheries and another [36]. The development of this method relies on semi-quantitative (ecological) and qualitative (social) data based on the reference points, "bad" and "good"[37]. Initially, the technique consists of six dimensions: ecology, economics, social, technology, ethics, and institutions [38].

In this study, the approach applied to assess sensitive factors influencing sustainability was based on leverage analysis [39] using the R program of RAPFISH 3.1 software (www.rapfish.org). This technique is focused on the ecological, economic, social, and institutional dimensions (Table I) with a determination score that ranges from 0 (bad) to 10 (good). The model's validation was performed using differences between the MDS score and the Monte Carlo analysis of less than 5% [40].

TABLE I
LEVERAGE ATTRIBUTE OF EACH DIMENSION IN RAPFISH

Dimension	Leverage Attribute	Scoring Guidelines
Ecological	Exploitation status, change in species, Fish size, Immature catch, Trend in CPUE (catch per unit effort)	0 (bad) to 10 (good)
Economic	Discount rate of fish productivity rate, Marketing system, Commodity, Alternative livelihoods, Ownership, Change of profitability	0 (bad) to 10 (good)
Social	Social network, Socialization, Local environmental knowledge, Participation, Conflict status, Fishing community (fishers)	0 (bad) to 10 (good)
Institutional	Regulation, Compliance/legality, Surveillance and monitoring (MCS), Destructive fishing, Community based/local institution, Mitigation of habitat damage	0 (bad) to 10 (good)

Modified from Pitcher et al. [24], [38]

III. RESULTS AND DISCUSSIONS

A. Fish Stock Condition

After establishing MLS regulations, the mean length of fish of all groupers became slightly larger. For example, *Plectropomus leopardus* and *Epinephelus coioides* fishes had average sizes of 42cm and 56cm, respectively. In contrast, the average length of *Lutjanus malabaricus* was decreased compared with that in the previous year. The length of the fish sampled in the study area is presented in Table II.

TABLE II
LENGTH OF THE FISH SAMPLED

Species	Sample Size (Fish)	L_{mean} (cm)	L_{inf} (cm)	L_m (cm)	L_c (cm)	L_{opt} (cm)
Plectropomus leopardus	1498	42	71.94	38.83	29.02	45.81
Plectropomus maculatus	941	44	76.55	41.06	29.26	48.87
Epinephelus coioides	814	56	110.21	56.95	39.50	71.45
Lutjanus malabaricus	1225	55	85.56	45.37	50.00	54.88

However, all grouper species presented worse states for conservation and optimized yield indicators compared with suggested reference points (Table III). The size of all grouper species is still below the reference point at optimal conditions. The situation indicated that many fishes are caught while still immature, demonstrating overexploitation. The only *Lutjanus malabaricus* had $L_c/L_m > 1$ in both of 2 years, indicating that immature fish were well conserved.

TABLE III
INDICATION OF STOCK STATUS COMPARED TO SUGGESTED REFERENCE POINTS

Species	Conservation	Optimal Yield
Plectropomus leopardus	0.75	0.82
Plectropomus maculatus	0.71	0.81
Epinephelus coioides	0.69	0.74
Lutjanus malabaricus	1.03	1.02

In addition, the status of all fish stocks is moderate, except *Plectropomus maculatus* species (Table IV). This fish stock status is reflected by the SPR value, which is below 20%. This species has been overexploited with an SPR value of 0.15. The result shows that under-sized catches were common.

The SPR value decreased compared with that in 2017 (initial), which is 0.22 (22%). Meanwhile, an improvement in the SPR value after establishing PERGUB was found in *Plectropomus leopardus*, shifting from 0.24 to 0.25 and in *Plectropomus maculatus*, from 0.21 to 0.30.

The results also revealed that fishing mortality is higher than natural mortality for all species, except *Plectropomus maculatus,* which may be overfishing. The high intensity of fishing pressure is also caused by the continual increase in the domestic and international demand for grouper [9], [13], [21], [41]. Besides, the price is relatively high compared with that of others.

TABLE IV
ESTIMATION OF SPAWNING POTENTIAL RATIO AND FISHING MORTALITY-NATURAL MORTALITY RATIO

Species	SPR	F/M
Plectropomus leopardus	0.25	1.40
Plectropomus maculatus	0.30	0.86
Epinephelus coioides	0.15	1.60
Lutjanus malabaricus	0.25	1.20

B. Fishers' Perception of Fishery Activities and Management

The analysis of the data obtained from the study areas showed that fishers have various perceptions of fishery status and management. Fig. 3 demonstrates the diversity of fishers' perception and provides baseline information for ex-post evaluation [42]. It is significant at the 0.05 level ($P < 0.05$) ($a = 0.05$; $Z½\alpha = Z0.025 = 1.96$).

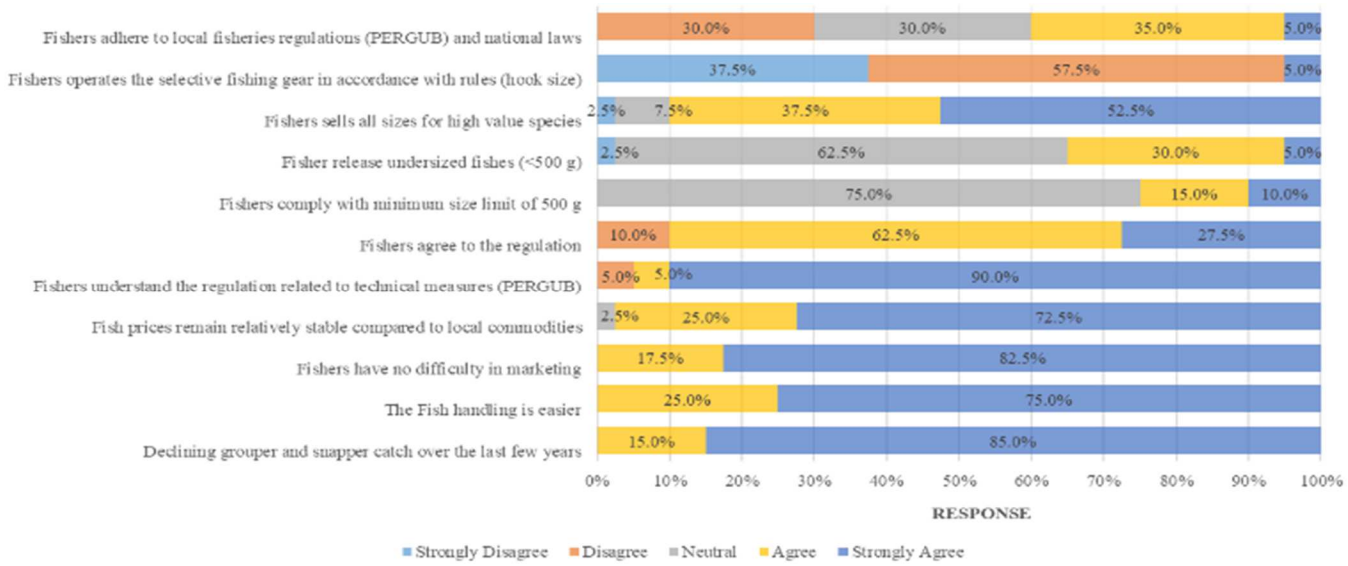

Fig. 3 Survey Responses for Each Statement

Based on the survey, 85.0% of fishers stated that they strongly agree that the abundance of grouper and snapper in Saleh Bay has decreased in the last four years. The fishers' first-hand knowledge of these species is consistent with the Catch per Unit Effort (CPUE) trends [43]. The CPUE declined from 3.35 individuals per trip in 2017 [4] to 1.5 individuals per trip or 3.5 kg per trip in 2019 [44] due to the increase in fishing intensity and presence of many active fishers. The high intensity of fishing is caused by the increasing demand for grouper as an export commodity [3], [32], [45].

Most fishers (82.5%) stated that they have not a serious problem with the marketing system. Fishers usually sell their catch to the local middlemen (fish collectors), who act as price-maker. The price tends to relatively stable (especially the coral grouper, which is relatively high compared with that of other fish, particularly for "plate-size" or those weighing 500-1000 g per individual).

Public perceptions of management rules vary from strongly agree (27.5%), agree (10%), and somewhere in between (62.5%). Many fishers do not fully understand the policy, although the local government and civil society have informed this law. They are faced with an economic reality that forces them to catch fish of all sizes to cover operational costs. That is why the implementation of PERGUB is still not optimal.

Overall, fishers in Saleh Bay have different perceptions on complying with the PERGUB, from agree-strongly agree (40% of respondents), neutral (30%), to disagree (30%). An economic motivation may cause non-compliance with the policy [46] by 40% among fishers. It is thus an ongoing challenge to improve the level of compliance with the regulatory policy.

C. Strategy for Increasing Effectiveness

Fig. 4 presents the results of the RAPFISH analysis of each dimension. In general, the grouper and snapper fisheries in Saleh Bay have average sustainability (MDS) scores ranging from 51 to 60%, considered 'less satisfactory' [27]. No dimensions achieved a 'good' performance level over the 70% threshold, and all thus need improvement strategies [47], particularly for the social and institutional fields with an average score below 55.68%.

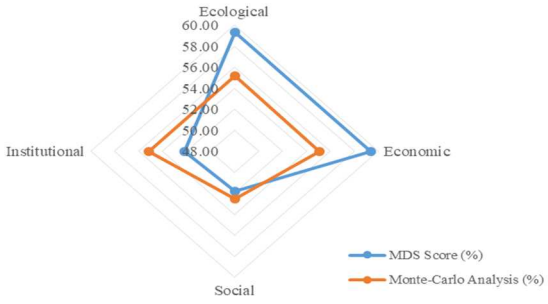

Fig. 4 Kite Diagram Expressing MDS Scores and Monte-Carlo Analysis

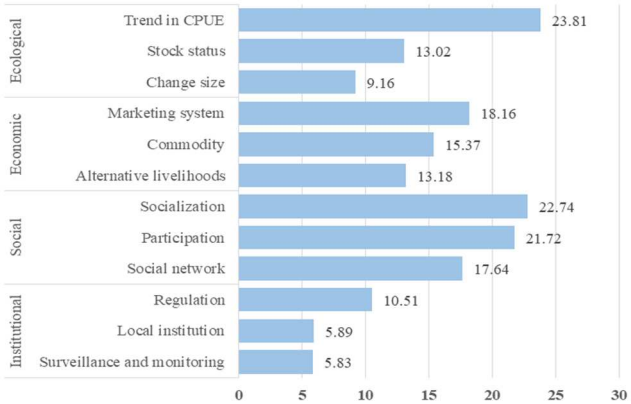

Fig. 5 Three Dominant Attributes of Each Dimension Based on Leverage Analysis

Based on the leverage analysis, the three most sensitive attributes for each field. These factors influence potential improvement strategies to reach a sustainable status (Fig.5). Regarding the ecological dimension, it is observed that the CPUE trend, stock status, and changes in the size of the fish caught promote ecological sustainability. A combination of a

closed fishing season and a closed area, especially in fish spawning aggregation sites, is recommended to complement conventional fishery management measures [3], [48], mainly to protect juveniles.

The three most sensitive attributes are the marketing system, commodity, and alternative livelihoods from an economic dimension. In the context of the marketing system, it was observed that middlemen have an essential role in the supply chain, particularly to increase the fishers' compliance and seafood sustainability outside of the public government process. Many fishers have patron-client relationships with middlemen and the decision-making process by fishers is inevitably influenced by them. So, the development of a non-state market-driven governance system is urgently promoted include a seafood certification program [39], [49].

The analysis also observed that the institutional dimension's three priority attributes are the regulations, local institutions, and surveillance. Therefore, the existing enforceable policy should be adopted to provincial regulation (Peraturan Daerah). In this process, the provincial government and the House of Representatives (DPRD) should be involved stakeholders through public consultation. The regulation must also be supported by more operational rules at the local level.

The other attribute of institutional dimensions is surveillance and law enforcement. Strict law enforcement against the practice of destructive fishing through marine patrols and strengthening the Community Surveillance Groups (POKMASWAS) are urgently needed to more effectively enforce the laws [50], [51]. This is in line with previous studies (e.g.[52]) showing that patrol frequency significantly impacts compliance and enforcement in implementing the regulation. The law enforcement agents need to be synergized with providing incentives schemes [53], [54].

Lastly, the key drivers of the social dimension are socialization, participation, and social network. The local group plays an imperative role in the implementation of PERGUB to reach sustainability. Hence, the strategy of improvement of public awareness [55], capacity building for key resource users [27], [56], [57], and stakeholder' participation are highly required. The stakeholders' participation in developing and implementing the policy should be engaged in co-management frameworks [58]–[67].

IV. Conclusions

The current challenges facing the effectiveness of the policy regulation in Saleh Bay are related to the biological (stocks status) and social ones. The fish stocks status has improved after implementing the regulations, where the SPR indicator of the most species has higher than SPR threshold of 20% (moderate status). However, when under data-poor conditions to performing fish stock status with sufficient confidence, a multidisciplinary approach should be considered. In this study, the indicator of social and institution was "less satisfactory" performance (below 60% threshold) and have remained a challenge. All thus in need of improvement strategies. The strategies are proposed related to changing fishers' behavior regarding their compliance with the regulation, such as enhancing public awareness and participation and strengthening surveillance and law enforcement.

The study has limitations related to data, time, and area. It is possible to get an inaccurate analysis of the stock assessment model because the ex-post evaluation of a policy requires relatively time-series data. Therefore, the research area should be extended to include data-rich fisheries of the ongoing data collection programs.

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References

[1] BPS-Statistics of Sumbawa Regency, *Sumbawa Regency in Figure 2019*. Sumbawa: BPS-Statistics of Sumbawa Regency, 2019.

[2] BPS-Statistics of Dompu Regency, *Dompu Regency in Figure 2019*. Dompu: BPS-Statistics of Dompu Regency, 2019.

[3] D. S. Efendi, L. Adrianto, Yonvitner, Y. Wardiatno, and S. Agustina, "The performance of stock indicators of grouper (Serranidae) and snapper (Lutjanidae) fisheries in Saleh Bay, Indonesia," *AACL Bioflux*, vol. 13, no. 5, pp. 2431–2444, 2020.

[4] S. Agustina, A. S. Panggabean, M. Natsir, Jimmi, H. Retnoningtyas, and I. Yulianto, *Profile of Grouper and Snapper Fisheries Stock in Saleh Bay, West Nusa Tenggara Province*. Bogor: Wildlife Conservation Society, 2017.

[5] H. Retnoningtyas *et al.*, "Stakeholder participation in management planning for grouper and snapper fisheries in West Nusa Tenggara Province, Indonesia," *Mar. Policy*, vol. 128, no. February, p. 104452, 2021, doi: 10.1016/j.marpol.2021.104452.

[6] T. Yildiz and A. Ulman, "Analyzing gaps in policy: Evaluation of the effectiveness of minimum landing size (MLS) regulations in Turkey," *Mar. Policy*, vol. 115, no. January, p. 103829, 2020, doi: 10.1016/j.marpol.2020.103829.

[7] N. Carvalho, R. Van Anrooy, T. Vassdal, and M. Dagtekin, *Techno-economic performance review of selected fishing feets in Europe*, FAO Fisher. Rome: FAO, 2020.

[8] A. Tilley, P. Herrón, S. Espinosa, J. L. Angarita, and S. Box, "Predicting vulnerability to management changes in data-limited, small-scale fisheries," *Mar. Policy*, vol. 94, no. May, pp. 39–45, 2018, doi: 10.1016/j.marpol.2018.04.013.

[9] P. Amorim, P. Sousa, E. Jardim, M. Azevedo, and G. M. Menezes, "Length-frequency data approaches to evaluate snapper and grouper fisheries in the Java Sea, Indonesia," *Fish. Res.*, vol. 229, no. March, p. 105576, 2020, doi: 10.1016/j.fishres.2020.105576.

[10] S. Agustina, A. S. Panggabean, M. Natsir, H. Retroningtyas, and I. Yulianto, "Yield-per-recruit modeling as biological reference points to provide fisheries management of leopard coral grouper (*Plectropomus leopardus*) in Saleh Bay, West Nusa Tenggara," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 278, no. 1, 2019, doi: 10.1088/1755-1315/278/1/012005.

[11] M. Khasanah, N. N. Kadir, and J. Jompa, "Reproductive biology of three important threatened/near-threatened groupers (*Plectropomus leopardus*, *Epinephelus polyphekadion* and *Plectropomus areolatus*) in eastern Indonesia and implications for management," *Animals*, vol. 9, no. 643, pp. 1–18, 2019.

[12] Mudjirahayu, R. Bawole, U. N. W. J. Rembet, A. S. Ananta, F. Runtuboi, and R. Sala, "Growth, mortality and exploitation rate of *Plectropomus maculatus* and *P. oligocanthus* (Groupers, Serranidae) on Cenderawasih Bay National Park, Indonesia," *Egypt. J. Aquat. Res.*, vol. 43, no. 3, pp. 213–218, 2017, doi: 10.1016/j.ejar.2017.09.002.

[13] M. Patanda, S. H. Wisudo, D. R. Monintja, and B. Wiryawan, "Sustainability for reef fish resource based on productivity and

susceptibility in Wangi-Wangi Island, Southeast Sulawesi, Indonesia," *AACL Bioflux*, vol. 10, no. 4, pp. 861–874, 2017.

[14] R. Bawole, M. Rahayu, U. N. W. J. Rembet, A. S. Ananta, F. Runtuboi, and R. Sala, "Growth and mortality rate of the napan-yaur coral trout, *Plectropomus leopardus* (Pisces: Serranidae), Cenderawasih Bay National Park, Indonesia," *Biodiversitas*, vol. 18, no. 2, pp. 758–764, 2017, doi: 10.13057/biodiv/d180245.

[15] Ernaningsih, Asbar, Danial, A. Hasrun, and M. Jamal, "Population dynamics and exploitation rate of coral grouper *Plectropomus leopardus* in the Sarappo Islands, Pangkep Regency, South Sulawesi," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 253, no. 1, p. 10 p, 2019, doi: 10.1088/1755-1315/253/1/012028.

[16] Muis, R. Kurnia, Sulistiono, and Taryono, "Coral reefs status and fish species in coastal waters of Spelman Straits, southeast Sulawesi, Indonesia," *AACL Bioflux*, vol. 12, no. 5, pp. 2020–2029, 2019.

[17] D. S. Achmad, S. A. Ali, Sudirman, and Y. N. Indar, "The gonad maturity development and spawning season of orange-spotted grouper (*Epinephelus coioides*) at Kwandang Bay, Gorontalo Province, Indonesia," *AACL Bioflux*, vol. 12, no. 2, pp. 642–649, 2019.

[18] M. Erauskin-Extramiana, S. Z. Herzka, G. Hinojosa-Arango, and O. Aburto-Oropeza, "An interdisciplinary approach to evaluate the status of large-bodied Serranid fisheries: The case of Magdalena-Almejas Bay lagoon complex, Baja California Sur, Mexico," *Ocean Coast. Manag.*, vol. 145, pp. 21–34, 2017, doi: 10.1016/j.ocecoaman.2017.05.005.

[19] A. Said and R. Chuenpagdee, "Aligning the sustainable development goals to the small-scale fisheries guidelines: A case for EU fisheries governance," *Mar. Policy*, vol. 107, no. March, p. 103599, 2019, doi: 10.1016/j.marpol.2019.103599.

[20] M. Natsir, T. Ruchimat, S. Agustina, and I. Yulianto, "Application of global positioning system tracker to detect the fishing ground location and effective effort in artisanal fishery," *Sensors Mater.*, vol. 31, no. 3, pp. 803–814, 2019, doi: 10.18494/SAM.2019.2238.

[21] A. Halim, N. R. Loneragan, B. Wiryawan, A. R. Hordyk, M. F. A. Sondita, and I. Yulianto, "Evaluating data-limited fisheries for grouper (Serranidae) and snapper (Lutjanidae) in the Coral Triangle, eastern Indonesia," *Reg. Stud. Mar. Sci.*, vol. 38, p. 101388, 2020, doi: 10.1016/j.rsma.2020.101388.

[22] ICES, "ICES reference points for stocks in categories 3 and 4," *ICES Tech. Guidel.*, no. February, p. 50, 2018.

[23] S. Mavruk, İ. Saygu, F. Bengil, V. Alan, and E. Azzurro, "Grouper fishery in the Northeastern Mediterranean: An assessment based on interviews on resource users," *Mar. Policy*, vol. 87, no. July 2017, pp. 141–148, 2018, doi: 10.1016/j.marpol.2017.10.018.

[24] T. J. Pitcher and D. Preikshot, "RAPFISH: A rapid appraisal technique to evaluate the sustainability status of fisheries," *Fish. Res.*, vol. 49, no. 3, pp. 255–270, 2001, doi: 10.1016/S0165-7836(00)00205-8.

[25] L. Chong *et al.*, "Performance evaluation of data-limited, length-based stock assessment methods," *ICES J. Mar. Sci.*, vol. 77, no. 1, pp. 97–108, 2020, doi: 10.1093/icesjms/fsz212.

[26] É. A. Jimenez, R. S. L. Barboza, M. T. Amaral, and F. Lucena Frédou, "Understanding changes to fish stock abundance and associated conflicts: Perceptions of small-scale fishers from the Amazon coast of Brazil," *Ocean Coast. Manag.*, vol. 182, no. March, p. 104954, 2019, doi: 10.1016/j.ocecoaman.2019.104954.

[27] É. A. Jimenez, J. G. Gonzalez, M. T. Amaral, and F. Lucena Frédou, "Sustainability indicators for the integrated assessment of coastal small-scale fisheries in the Brazilian Amazon," *Ecol. Econ.*, no. November, p. 106910, 2020, doi: 10.1016/j.ecolecon.2020.106910.

[28] A. Hordyk, K. Ono, S. Valencia, N. Loneragan, and J. Prince, "A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries," *ICES J. Mar. Sci.*, vol. 72, no. 1, pp. 217–231, 2014, doi: 10.1093/icesjms/fsu004.

[29] J. Prince, S. Creech, H. Madduppa, and A. Hordyk, "Length based assessment of spawning potential ratio in data-poor fisheries for blue swimming crab (*Portunus* spp.) in Sri Lanka and Indonesia: Implications for sustainable management," *Reg. Stud. Mar. Sci.*, vol. 36, p. 101309, 2020, doi: 10.1016/j.rsma.2020.101309.

[30] T. K. Mildenberger, M. H. Taylor, and M. Wolff, "TropFishR: an R package for fisheries analysis with length-frequency data," *Methods Ecol. Evol.*, vol. 8, no. 11, pp. 1520–1527, 2017, doi: 10.1111/2041-210X.12791.

[31] J. Prince and A. Hordyk, "What to do when you have almost nothing: A simple quantitative prescription for managing extremely data-poor fisheries," *Fish Fish.*, vol. 20, no. 2, pp. 224–238, 2019, doi: 10.1111/faf.12335.

[32] Y. J. Sadovy de Mitcheson *et al.*, "Valuable but vulnerable: Over-fishing and under-management continue to threaten groupers so what now?," *Mar. Policy*, vol. 116, no. February, pp. 1–10, 2020, doi: 10.1016/j.marpol.2020.103909.

[33] J. Agar, M. Shivlani, C. Fleming, and D. Solís, "Small-scale fishers' perceptions about the performance of seasonal closures in the commonwealth of Puerto Rico," *Ocean Coast. Manag.*, vol. 175, no. March 2018, pp. 33–42, 2019, doi: 10.1016/j.ocecoaman.2019.03.025.

[34] I. Cahyadinata, A. Fahrudin, Sulistiono, and R. Kurnia, "Perception and participation of fishermen in the sustainable management of mud crabs on the outermost small island (Case study: Enggano Island, Bengkulu Province, Indonesia)," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 9, no. 4, pp. 1330–1336, 2019, doi: 10.18517/ijaseit.9.4.7287.

[35] Y. Hayati, L. Adrianto, M. Krisanti, W. S. Pranowo, and F. Kurniawan, "Magnitudes and tourist perception of marine debris on small tourism island: Assessment of Tidung Island, Jakarta, Indonesia," *Mar. Pollut. Bull.*, vol. 158, no. June, p. 111393, 2020, doi: 10.1016/j.marpolbul.2020.111393.

[36] A. Fauzi, *Teknik Analisis Keberlanjutan*. Jakarta: PT Gramedia Pustaka Utama, 2019.

[37] Suharno, N. Anwar, and E. Saraswati, "A technique of assessing the status of sustainability of resources," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 250, no. 1, pp. 1–5, 2019, doi: 10.1088/1755-1315/250/1/012080.

[38] T. J. Pitcher *et al.*, "Improvements to Rapfish: A rapid evaluation technique for fisheries integrating ecological and human dimensionsa," *J. Fish Biol.*, vol. 83, no. 4, pp. 865–889, 2013, doi: 10.1111/jfb.12122.

[39] L. O. M. Yasir Haya and M. Fujii, "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," *Mar. Policy*, vol. 118, no. July 2019, p. 104028, 2020, doi: 10.1016/j.marpol.2020.104028.

[40] S. Handayani, D. G. Bengen, I. W. Nurjaya, L. Adrianto, and Y. Wardiatno, "The sustainability status of mangrove ecosystem management in the rehabilitation area of Sayung coastal zone, Demak Regency, Central Java Indonesia," *AACL Bioflux*, vol. 13, no. 2, pp. 865–884, 2020.

[41] E. A. Babcock, A. Tewfik, and V. Burns-Perez, "Fish community and single-species indicators provide evidence of unsustainable practices in a multi-gear reef fishery," *Fish. Res.*, vol. 208, no. July, pp. 70–85, 2018, doi: 10.1016/j.fishres.2018.07.003.

[42] A. Gkargkavouzi, S. Paraskevopoulos, and S. Matsiori, "Public perceptions of the marine environment and behavioral intentions to preserve it: The case of three coastal cities in Greece," *Mar. Policy*, vol. 111, no. November 2019, p. 103727, 2020, doi: 10.1016/j.marpol.2019.103727.

[43] M. A. Messias *et al.*, "Ethnoecology of Lutjanidae (snappers) in communities of artisanal fisheries in northeast Brazil," *Ocean Coast. Manag.*, vol. 181, no. March, p. 104866, 2019, doi: 10.1016/j.ocecoaman.2019.104866.

[44] D. S. Efendi, L. Adrianto, and Y. Wardiatno, "Analisis bioekonomi spasial perikanan kerapu dalam kerangka pengelolaan perikanan di Teluk Saleh," vol. 10, no. 3, pp. 338–351, 2020.

[45] M. Khasanah, N. Nurdin, Y. Sadovy de Mitcheson, and J. Jompa, "Management of the grouper export trade in Indonesia," *Rev. Fish. Sci. Aquac.*, vol. 28, no. 1, pp. 1–15, 2020, doi: 10.1080/23308249.2018.1542420.

[46] P. Herrón, L. C. Kluger, G. A. Castellanos-Galindo, M. Wolff, and M. Glaser, "Understanding gear choices and identifying leverage points for sustainable tropical small-scale marine fisheries," *Ocean Coast. Manag.*, vol. 188, no. May, p. 105074, 2020, doi: 10.1016/j.ocecoaman.2019.105074.

[47] T. J. Pitcher, D. Kalikoski, K. Short, D. Varkey, and G. Pramod, "An evaluation of progress in implementing ecosystem-based management of fisheries in 33 countries," *Mar. Policy*, vol. 33, no. 2, pp. 223–232, 2009, doi: 10.1016/j.marpol.2008.06.002.

[48] Y. Sadovy de Mitcheson, P. L. Colin, S. J. Lindfield, and A. Bukurrou, "A decade of monitoring an Indo-Pacific grouper spawning aggregation: Benefits of protection and importance of survey design," *Front. Mar. Sci.*, vol. 7, no. November, pp. 1–23, 2020, doi: 10.3389/fmars.2020.571878.

[49] K. L. Thomas Travaille, J. Lindley, G. A. Kendrick, L. B. Crowder, and J. Clifton, "The market for sustainable seafood drives transformative change in fishery social-ecological systems," *Glob. Environ. Chang.*, vol. 57, no. November 2018, p. 101919, 2019, doi: 10.1016/j.gloenvcha.2019.05.003.

[50] S. Jentoft *et al.*, "Working together in small-scale fisheries: harnessing collective action for poverty eradication," *Marit. Stud.*, vol. 17, no. 1, pp. 1–12, 2018, doi: 10.1007/s40152-018-0094-8.

[51] S. Wallner-Hahn and M. de la Torre-Castro, "Early steps for successful management in small-scale fisheries: An analysis of fishers' managers' and scientists' opinions preceding implementation," *Mar. Pollut. Bull.*, vol. 134, no. September 2017, pp. 186–196, 2018, doi: 10.1016/j.marpolbul.2017.07.058.

[52] H. Booth, U. Mardhiah, B. Apolinardus, Y. Lia, D. Sarah, and L. Dwi, "An integrated approach to tackling wildlife crime : Impact and lessons learned from the world ' s largest targeted manta ray fishery," *Conserv. Sci. Pract.*, no. October, pp. 1–18, 2020, doi: 10.1111/csp2.314.

[53] M. M. Islam, M. Nahiduzzaman, and M. A. Wahab, "Fisheries co-management in hilsa shad sanctuaries of Bangladesh: Early experiences and implementation challenges," *Mar. Policy*, vol. 117, no. March, p. 103955, 2020, doi: 10.1016/j.marpol.2020.103955.

[54] C. N. T. Quynh, S. Schilizzi, A. Hailu, and S. Iftekhar, "Fishers' preference heterogeneity and trade-offs between design options for more effective monitoring of fisheries," *Ecol. Econ.*, vol. 151, no. May, pp. 22–33, 2018, doi: 10.1016/j.ecolecon.2018.04.032.

[55] D. S. Efendi, L. Adrianto, Yonvitner, Y. Wardiatno, and Muis, "The economic performance of grouper (Serranidae) and snapper (lutjanidae) fisheries in Saleh Bay, Indonesia," *AACL Bioflux*, vol. 13, no. 6, pp. 3556–3565, 2020.

[56] I. Cahyadinata, Nusril, and Gushevinalti, "Descriptive, correlation analysis and analytical hierarchy process of coastal community empowerment of Bengkulu City, Indonesia," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 10, no. 3, pp. 1304–1310, 2020, doi: 10.18517/ijaseit.10.3.2659.

[57] J. G. Mason, J. Alfaro-Shigueto, J. C. Mangel, L. B. Crowder, and N. M. Ardoin, "Fishers' solutions for hammerhead shark conservation in Peru," *Biol. Conserv.*, vol. 243, no. February 2019, p. 108460, 2020, doi: 10.1016/j.biocon.2020.108460.

[58] M. Semitiel-García and P. Noguera-Méndez, "Fishers' participation in small-scale fisheries. A structural analysis of the Cabo de Palos-Islas Hormigas MPA, Spain," *Mar. Policy*, vol. 101, no. November 2017, pp. 257–267, 2019, doi: 10.1016/j.marpol.2018.04.009.

[59] R. S. Pomeroy and N. L. Andrew, "Small-scale fisheries management: Frameworks and approaches for the developing world," in *Small-Scale Fisheries Management: Frameworks and Approaches for the Developing World*, R. S. Pomeroy and N. L. Andrew, Eds. Oxfordshire and Cambridge: CAB International, 2011, pp. 1–247.

[60] R. H. Roa-Ureta, J. Henríquez, and C. Molinet, "Achieving sustainable exploitation through co-management in three Chilean small-scale fisheries," *Fish. Res.*, vol. 230, no. June, p. 105674, 2020, doi: 10.1016/j.fishres.2020.105674.

[61] K. E. Pellowe and H. M. Leslie, "The interplay between formal and informal institutions and the potential for co-management in a Mexican small-scale fishery," *Mar. Policy*, no. August, p. 104179, 2020, doi: 10.1016/j.marpol.2020.104179.

[62] M. Léopold, O. Thébaud, and A. Charles, "The dynamics of institutional innovation: Crafting co-management in small-scale fisheries through action research," *J. Environ. Manage.*, vol. 237, no. July 2018, pp. 187–199, 2019, doi: 10.1016/j.jenvman.2019.01.112.

[63] L. d'Armengol, M. Prieto Castillo, I. Ruiz-Mallén, and E. Corbera, "A systematic review of co-managed small-scale fisheries: Social diversity and adaptive management improve outcomes," *Glob. Environ. Chang.*, vol. 52, no. July, pp. 212–225, 2018, doi: 10.1016/j.gloenvcha.2018.07.009.

[64] U. Muawanah *et al.*, "Review of national laws and regulation in Indonesia in relation to an ecosystem approach to fisheries management," *Mar. Policy*, vol. 91, no. August 2017, pp. 150–160, 2018, doi: 10.1016/j.marpol.2018.01.027.

[65] J. Kurien, "Collective action and co-management initiatives in post-disaster Aceh, Indonesia," *Marit. Stud.*, vol. 16, no. 1, 2017, doi: 10.1186/s40152-017-0075-3.

[66] M. C. Medeiros, R. R. D. Barboza, G. Martel, and J. da S. Mourão, "Combining local fishers' and scientific ecological knowledge: Implications for comanagement," *Ocean Coast. Manag.*, vol. 158, no. February, pp. 1–10, 2018, doi: 10.1016/j.ocecoaman.2018.03.014.

[67] A. M. Cisneros-Montemayor, M. J. Zetina-Rejón, M. J. Espinosa-Romero, M. A. Cisneros-Mata, G. G. Singh, and F. J. Fernández-Rivera Melo, "Evaluating ecosystem impacts of data-limited artisanal fisheries through ecosystem modelling and traditional fisher knowledge," *Ocean Coast. Manag.*, vol. 195, no. February, 2020, doi: 10.1016/j.ocecoaman.2020.105291.