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Assessment of lobster fisheries and sustainable management strategies: A case study of EAFM in Central Lombok – Indonesia

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Abstract. The exploitation of lobster resources in the waters of the Central Lombok Regency, Indonesia is not effectively managed, causing problems in terms of resource availability and sustainability of lobster fishing operations. This study aimed to assess the status of lobster fisheries management and policy strategies for sustainable lobster fisheries management. Data were collected in three lobster fishing centres: Teluk Awang, Teluk Bumbang and Teluk Gerupuk. Methods used were a structured interview technique with questionnaires, focus group discussions (FGDs) and public consultation. The status of the lobster fishery was analysed using the Ecosystem Approach to Fisheries Management (EAFM) indicators with six Domains. The lobster fishery management status was classified as "moderate" (aggregate score 50/100). The Fisheries Resources Domain scored 35, indicating that lobster stocks are in "poor" condition. Four dimensions had a "moderate" status: the Fisheries Technology Dimension (43), the Economic Dimension (48), the Social Dimension (53), and the institutional dimension (55). The Habitat and Ecosystem Dimensions was classified as "good" (67). Sustainable lobster fisheries management strategies include regulating fishing quotas, banning gears which catch lobster seed, and optimizing the use of selective fishing gear; establishing a working group for lobster management; managing water quality and zonation of lobster habitat; transfer of lobster farming techniques; and empowering community coastwatch groups.

1. Introduction

The coastal area of Central Lombok Regency is part of Indonesian Fisheries Management Area (FMA) 573 and has a high diversity of marine resources, one of which is the lobster stock [1]. The dominant type of lobster being exploited is the scalloped spiny lobster (*Panulirus homarus*). Spiny lobsters are an economically valuable fish stock with a relatively large demand from Asian, European and American countries [2]. Although this demand provides an opportunity for fishermen to make optimal use of lobster resources, the management of lobster fisheries has not been optimized so far, which has led to various problems, one of which is the capture of lobster seeds [2].

Sustainable management of lobster fisheries is important to maintain the availability of the resource and ensure the sustainability of operations. The Ecosystem Approach to Fisheries Management (EAFM) is a concept aiming to achieve socio-economic goals while considering ecosystems and



human-ecosystem interactions in a balanced manner through integrated, comprehensive and sustainable management [3]. This study was conducted to assess the performance of lobster fisheries in the Central Lombok Regency of West Nusa Tenggara (NTB) Province, and to develop intervention strategies to improve lobster fisheries management in a pilot site of the Indonesian Sea-Large Marine Ecosystem (ISLME) joint program between FAO and the Directorate General of Resource Management, Ministry of Marine Affairs and Fisheries (DGRM-MMAF). The study was carried out in cooperation with DGRM-MMAF. The results of this study are expected to help the government in developing the sustainable management of fisheries, especially the lobster fishery in Indonesia.

2. Methods

The study was conducted over 14 weeks from August to November 2019. The study area was under the jurisdiction of the Pujut District of Central Lombok Regency, and included three sites: Teluk Awang, Teluk Bumbang and Teluk Gerupuk (Figure 1). These three bays directly face the Indian Ocean and are the centres of the FMA 573 lobster fishery.



Figure 1. The three study sites: (A) Teluk Gerupuk, (B) Teluk Bumbang, (C) Teluk Awang.

Data were collected using a structured interview method with questionnaires, focus group discussions (FGDs) and public consultation. Structured interviews with lobster fishermen were conducted to determine the size of individuals, the species and the catch volume. In-depth interviews were also conducted with key informants. In addition, FGDs were conducted with lobster fishermen at the three locations. Public consultations were conducted with various stakeholders to confirm the results of the assessment.

The status assessment of lobster fisheries management used the Ecosystem Approach to Fisheries Management (EAFM) evaluation method with six domains and 32 indicators [3]. The domains assessed were the fisheries resources (stocks), habitat and ecosystems, fisheries technology, social, economic, and institutional domains. The results of the assessment of each domain and indicator were analysed using a multi-criteria flag modelling technique with composite indicators [3]. The calculation of composite indicators generated values for each domain, which were used to determine an overall composite value for the lobster fishery (Table 1). Intervention recommendations for improved fisheries management were developed by assessing the status of the lobster fishery management using the EAFM indicators. In addition, the results of the assessment will be used as a basis for determining problems and alternative management strategies.

Table 1. Criteria for aggregate composite rating on model flags

Range of Values		Flag Model	Description
Low	High		
1	21		Poor
22	41		Insufficient
42	60		Medium/Moderate
61	80		Good
81	100		Excellent

Sources: [3, 4]

The limitations in analysing the assessment of lobster management status at the study site were:

1. The stock analysis focused on lobster species exploited for both consumption and seed;
2. The volume of seeds harvested at the study site was greater than that of lobsters of a size suitable for consumption
3. The CPUE was calculated based on the scale of consumption-sized lobster production. Due to the lack of effort data, the CPUE values were determined based on the results of the interviews
4. Because the lobster fishery in central Lombok is a small-scale fishery, licensing is not a prerequisite for small-scale fishermen therefore, several indicators related to licensing and completeness of vessel documentation have the maximum scores
5. The best data available were used in the analysis, whether from secondary data, calculations or interviews
6. This study was conducted prior to the promulgation of regulation Permen KP No. 12 in 2020.

3. Results and Discussion

There were 1402 lobster fishermen at the study sites, including those who catch seed and/or consumption size lobsters [5]. Although several species of lobsters are caught in the study area (Table 2), the most commonly caught species (*Panulirus homarus*, *P. ornatus* and *P. longipes*) are caught both as seed and at consumption sizes. Consumption sized lobsters are caught by gill nets, traps, or diving with compressors, while lobster seed are caught using a fishing gear called a "pocong".

Table 2. Lobster species caught at the study site.

Species	Local Name	Common Name	IUCN Status
<i>Panulirus ornatus</i>	<i>udang mutiara</i>	ornate spiny lobster	<i>Least concern</i>
<i>Panulirus homarus</i>	<i>udang pasir</i>	scalloped spiny lobster	<i>Least concern</i>
<i>Panulirus longipes</i>	<i>udang batik</i>	longlegged spiny lobster	<i>Least concern</i>
<i>Panulirus versicolor</i>	<i>udang bambu</i>	painted spiny lobster	<i>Least concern</i>
<i>Panulirus penicillatus</i>	<i>udang batu</i>	stone lobster	<i>Least concern</i>

(Sources: www.iucnredlist.org; survey results, 2019)

3.1. Lobster Fishery Management Status

The composite values for the six Domains in the EAFM assessment of lobster fisheries management in Central Lombok (Table 3) show that the lowest composite value was obtained for the fisheries resources domain (insufficient) and the highest (good) was for the habitat and ecosystem domain. The resource domain has a high priority for fisheries management improvement interventions because the score is the lowest; but such efforts must be accompanied by interventions in the other domains because the indicators in each domain interact with each other.

Table 3. Composite Assessment of “Lobster Fisheries Management in Central Lombok Regency”.

Domain	Composite Value	Description
Fisheries Resources	35	Insufficient
Habitat and ecosystem	67	Good
Fishing Technology	43	Medium
Social	53	Medium
Economy	48	Medium
Institutional	55	Medium
Aggregate	50	Medium

3.1.1. Lobster Resources. CPUE values could not be calculated because only production data were available with no effort data; therefore, the CPUE score was derived from the interviews with lobster fishermen who reported a decreasing trend in consumption size lobster catch over the period 1994-2019. In 2018 and 2019, fishermen caught an average of 1-10 kg of lobster per trip; however, the fishermen often came home without any lobsters at all, especially those using bottom gillnets. Although lobsters are the prime target of bottom gillnet fishers, in fact most of the catch is comprised of reef fish. The ratio of target species (lobsters) to non-target species (all other catch) in bottom gillnet catches was around 1:100.

Lobsters are caught as seed and when they reach consumption size. Massive catching of lobster seeds began in 2012 due to the high market price. Fishermen find few lobsters that have reached consumption size (1 kg or more), and consider that one reason for this scarcity is the increasing number of fishermen. Consumption sized ornate spiny lobsters in particular are becoming much harder to find and fishermen are having to travel to more distant fishing grounds for consumption sized lobsters, increasing travel time. In 1994 lobster fishing grounds could be reached in 30 minutes; but by 2019, the fishermen had to travel for around two hours. Fishermen also said that ETP (endangered, threatened and protected species) had been taken in the past, especially turtles, but none had been harvested in the past two years.

The lobster stocks in Central Lombok can be described as experiencing growth and recruitment overfishing. Atmaja [6] stated that growth overfishing occurs when fish are caught before they have had a chance to grow, while recruitment overfishing occurs when fewer juveniles enter the fishery. Recruitment overfishing occurs in the Central Lombok lobster fishery because of habitat degradation. There is a need to educate fishermen on the status of lobster stocks in the Central Lombok coastal area as some coastal ecosystems are degraded due to tourism development. There is also a need to investigate the availability and status of lobster resources in the Central Lombok waters so that the data can be used to inform fishermen.

3.1.2. Habitat and Ecosystem Domain. The Habitat and Ecosystem Domain was classified in the Good category (green) with a composite score of 67. With the exception of the mangrove ecosystem and climate change indicators, the indicator scores were between 2 and 3. The low score for the status of mangrove ecosystems was due to a decrease in mangrove area over the past two decades. Field observations indicate that mangroves are being converted due to the development of tourism. The area of mangroves along the coast of Central Lombok was 325.79 hectares in 1999, but by 2006 it had decreased to 202.68 hectares. According to [7] species commonly found in Teluk Bumbang and Teluk Awang were *Rhizophora mucronata*, *R. apiculata*, *R. stylosa*, *Avicennia officinalis*, *A. alba*, *Sonneratia griffithii*, and *S. alba*. Rare mangrove species included *Bruguiera gymnorrhiza*, *B. sexangula*, *Ceriops decandra*, *C. tagal*, *Excoecaria sp.*, *Xylocarpus mollucensis*, *X. granatum*, *Aegiceras corniculatum*, *A. annulata*, and *Lumnitzera racemosa*. Mangrove ecosystem management should be a priority in Central Lombok. These coastal forests have important ecological functions as

nurseries, spawning grounds and feeding grounds, especially in relation to fisheries resources [8] and primary production to support aquatic foodwebs [9].

The climate change indicator score was poor because no studies have been conducted on climate change Central Lombok waters and the impact of climate change on lobsters is not certain. Although water quality in the study area is classified as good (Table 4), there are threats to lobster habitat and coastal ecosystems, including plastic waste and waste discharged from vessels. Teluk Awang has been designated a major domestic port area, with the risk of vessel discharges affecting water quality and thus habitat and ecosystem condition. Teluk Awang and Teluk Gerupuk are open access areas, while Teluk Bumbang has been declared as a conservation area.

Table 4. Habitat characteristics of lobster catching sites in Central Lombok.

Parameter	Teluk Bumbang [10]	Teluk Awang [10]	Gerupuk [11, 12]
Depth (m)	3.5 – 15.1	1.5 – 9.6	4.5 – 9.8
Brightness (m)	3.2 – 14	1.3 – 9	NA
Temperature (° C)	29.75 – 31.2	29.65 – 30.7	26.5 – 32.10
Salinity (‰)	32.59 – 33.24	32.06 – 32.97	26 – 35.75
pH	8.61 – 8.85	8.51 – 8.67	7.97 – 8.46
Dissolved O ₂ (mg / l)	5.81 – 8.89	5.51 – 6.65	5.67 – 10.26
Ammonia (mg / l)	0.001 – 0.037	0.001– 0.018	0.00 – 0.09
Nitrate (mg / l)	0.012 – 0.675	0.02 – 0.901	0.01 – 0.04
Phosphate (mg / l)	0.03 – 1.855	0.03 – 0.685	0.03 – 2.64
Chlorophyll-a	0 – 0.1601	0 – 1.548	0.00 – 0.46
Region status	Conservation area	Open access	Open access
Unique habitat	Abundance of seeds caught indicates spawning grounds/nursery grounds		

The highest seagrass cover reported in Central Lombok (43.6%) is on the Kuta coast, with a sandy substrate and a canopy height of 103 cm. Eleven seagrass species are reported from Central Lombok: *Enhalus acoroides*, *Thalassia hemprichii*, *Cymodocea rotundata*, *C. serulata*, *Halodule uninervis*, *H. pinifolia*, *Syringodium isoetifolium*, *Halophila ovalis*, *H. minor*, *H. spinulosa* and *Thalassodendron ciliatum* [7]. With regards to coral reefs, the three dominant substrate types reported are algae, hard corals, and soft corals, with similar proportions. Other types of substrates such as sand account for less than 10%. Hard coral diversity is quite high with 27 genera, dominated by *Acropora* (27%), *Porites* (25%), and *Montipora* (13%), with other genera accounting for less than 10% each [13]. The interviews indicate the presence of unique/special habitats in Teluk Awang, Teluk Bumbang, and Teluk Gerupuk, around rocky areas or coral reefs along the bay. These areas are strongly indicated as lobster spawning and/or nursery grounds, but they are not been managed properly because the fishermen use this unique/special habitat to catch lobster seeds in an unregulated manner.

3.1.3. Lobster Fishing Technology. The status of the Lobster Fishing Technology Domain in Central Lombok was classified as Medium with a composite score of 43 (yellow flag). Several indicators had a Poor score, due to the use of a modified fishing gear (*pocong*), which captures large numbers of juvenile lobsters. The gears used to catch consumption-sized lobsters are bottom gillnets, traps/lobster pots, and night diving with torches and compressors. Lobster fishing with compressors is a prohibited fishing method under Law No. 31/2004 and Law No. 45/2009 on the amendment of Law No. 31/2004 on Fisheries.

The modified bottom gillnets fitted with *pocong* cannot be considered as responsible fishing gears because the catch consists wholly of juveniles or lobster seed. Regulation Permen KP No. 56/2016 prohibits the fishing of lobsters weighing less than 200 g or with a carapace length less than 8 cm. The lobster catching capacity ratio value was < 1 due to the ineffectiveness of consumption size lobster fishing units. Despite daily lobster fishing effort, the catch has not increased.

Lobster traps (lobster pots) are highly selective, because any undersized lobsters caught can be returned alive and undamaged. Bycatch is relatively low and the impact on seabed biotic communities is very small [14, 15].

Bottom gillnets are a non-selective gear because the species caught are dominated by non-target species, with a 1:100 (target to non-target species) ratio. In addition, bottom gillnets with *pocong* attachments result in the catch of lobster seed. The mean carapace length at first maturity varies between species from 55 mm for painted spiny lobsters to 98 mm for ornate spiny lobsters [16].

Lobster fishermen in Central Lombok are classified as small-scale fishermen because the tonnage of the fishing vessels used is less than 5 GT with length over all (LOA) between 4.5 and 10 m. Permen KP No. 5/2019 on the amendment of Ministerial Ordinance No. 23 on Registration and Labelling of Fishing Vessels states that fishing vessels larger than 10 GT must be registered. Therefore, lobster fishermen are not required to have documents for their fishing vessels; they only need to have a fishing card as a legal document to carry out fishing activities. Lobster fishermen in Central Lombok also do not have a crew certificate or a certificate of expertise related to their fishing activities.

3.1.4. Social Domain. The Social Domain status was classified as "medium" with a composite value of 53 (yellow flag). The social characteristics of the communities in the three bays within the study area were homogeneous. Stakeholder participation had the lowest score. Communities believe there is a lack of government involvement in lobster resource management. Fishermen perceive that they are not part of the stakeholder group, so that their participation score was very low. Government and other stakeholders have made some efforts to support and improve the lobster fishery, but the extent, frequency and surveillance of these activities was minimal due to the limited human resources available. Community perceptions of stakeholder participation need to be improved, as participation is believed to help resolve conflicts and strengthen the local knowledge of fishers. According to [17], conflicts can be resolved through democratic and constructive means or by involving a neutral and impartial third party to help the parties to the dispute resolve the issue.

According to the lobster fishermen, only the village officials were involved in the socialisation of regulation Permen KP No. 56/2016 on the ban on catching and/or exporting lobster (*Panulirus* spp.), mud crabs (*Scylla* spp.), and blue swimming crabs (*Portunus* spp.) from Indonesian FMAs by the NTB Provincial Marine and Fisheries Service and NGOs. Meanwhile fisheries officers and the water police were involved in surveillance and enforcement of sanctions for fishermen who committed infractions.

Horizontal conflict does occur in the lobster fishery, for example a dispute between lobster fishermen in Teluk Bumbang and those in Gerupuk Bay, because the use of lights by lobster fishermen in Teluk Bumbang is seen as the reason for fewer lobsters migrating to Gerupuk Bay. There was a perceived vertical conflict between the lobster fishermen and the government because the fishermen who have been fishing for lobsters for 20 years as their main livelihood felt that their source of income has been taken away by the promulgation of Permen KP No.56 / 2016. The fishermen do not agree with the government that Permen KP No. 56/2016 is aimed at the conservation of lobster stocks and the sustainability of lobster fisheries, and hoped that this regulation would be reviewed.

Fishermen have good local knowledge of the lobster stocks based on fishing experience, for example they know when and where lobsters are spawning and foraging, but local knowledge is not being used to promote proper management of the lobster stock. The traditional practice of *awik-awik* is no longer used as it only applies within the territory of one village and does not apply between villages. Just over half of the respondents said that there were local rules applicable to lobster resource management, with the imposition of fines or social sanctions on those who break the agreement.

3.1.5. Economic Domain. The Economic Domain was classified as moderate with a composite value of 48 (yellow flag). Asset ownership had not declined, but just over half of the lobster fishing respondents were currently earning less than the regional minimum wage (called UMR), which was set at IDR 2,012,610/month in NTB Province in 2019. Lobster fishermen had productive assets such as boats and fishing gear; but over the past five years, the value of productive assets had mostly

decreased. Before the enactment of Permen KP No. 56/2016, the average income could exceed IDR 3,000,000/day when catching and selling lobster seeds. Since the enactment of Permen KP No. 56/2016, the average income from the catch and sale of lobsters was less than IDR 3,000,000/month, sometimes even as low as IDR 300,000/month. However, the total income of the fishers was often above IDR 2,000,000/month when income from other fishing activities (e.g. reef fish capture and sale) was included.

Generally, the majority of lobster fishing households did not have an awareness of the importance of saving, so the income earned was used to meet their consumptive needs. However, 31.58% of the respondents were saving 20-50% of their income each month. The reasons they gave for saving included health insurance, children's schooling needs, and preparation for urgent needs, whereas 68.42% of the respondents did not have any savings plans, with the reason given being that they did not have school-aged children.

Economic domain indicators in need of improved management were income and savings awareness. According to [18], factors contributing to the low income of fishermen include limited skills in conducting fishing activities, being in debt, and limited marketing opportunities for their catch. Very few lobster fishermen in Central Lombok admitted that they were in debt, so the government could focus on supporting lobster fishermen in terms of fishing technology and marketing of their catch so that lobster fishermen no longer feel the need to catch lobster seed.

Fishermen can potentially increase their income through activities that can provide added value, such as processed seafood products. Despite the potential for value-added enhancement, processing of fisheries produce was rarely undertaken at the study sites. Since the enactment of Permen KP No. 56/2016, the government has been trying to offer compensatory programs in the form of seaweed cultivation and floating cages for snubnose pompano growout, but the programs have not had lasting impacts, as there was a lack of ongoing integrated support in terms of technical mariculture skills as well as marketing. In addition, the response of fishermen to the aquaculture programs has been poor because the income from catching lobster seeds is greater than that from seaweed farming or snubnose pomfret growout.

3.1.6. Institutional Domain. The Institutional Domain was classified in the "medium" status category, with a composite value of 48 (yellow flag). In terms of the comprehensiveness of regulations, the lobster fishery in Central Lombok already has adequate regulations in place at both the national and local scales. However, compliance with the principles of responsible fisheries management, both formal and informal, was still low. The lobster fishery is dominated by the catch of juveniles (seed), despite the fact that the catch and sale of lobster seed is banned by Permen KP No. 56/2016, so that these activities are less frequent and conducted in secret. Fishermen consider the management plans being implemented by the government are not clear. The level of fishermen's compliance with the principles of responsible fishing is low and exacerbated by a lack of synergy between policies and institutions related to the lack of a clear program.

Law enforcement in relation to lobster harvesting limitations under Permen KP No. 56/2016 has been carried out by fisheries officers and water police. This rule has had an effect as respondents have stated that it is better to quit or not break the rules than to be arrested. There have been prison sentences for infractions in Central Lombok Regency, but irresponsible/illegal fishing for lobster seed still occurs. Surveillance and enforcement of the lobster fishery does have decision-making mechanisms, but they are not effectively implemented due to the limited facilities and infrastructure for surveillance and the implementation of lobster management activities. Synergy between agencies is still minimal, but communication is ongoing to establish/improve synergy in the management of the lobster fishery.

3.1.7. Gaps in lobster fisheries management. A gap analysis was conducted for each problem group to identify areas where government action in managing the lobster fishery was lacking in comparison to the conceptual model designed. This gap analysis indicated that the government could identify a

program of activities that should be implemented to improve the status of lobster fisheries management in Central Lombok Regency. Key areas for action identified included harvest regulations (e.g. quotas or fishing seasons); bans on the gear used to catch lobster seeds and development of appropriate lobster fishing gears; addressing environmental issues such as plastic waste and coastal development; improving the institutional framework and stakeholder participations (e.g. establishing a lobster fishery management working group); zonation to resolve horizontal conflicts between lobster fishermen and between sectors; technology transfer of lobster aquaculture (growout); marketing support for lobster and processed products; and improving surveillance and enforcement. The latter in particular through empowerment of community coastwatch groups (*pokmaswas*) to address the problem of poor compliance with responsible fisheries principles and regulations in lobster fisheries.

4. Conclusion

The overall EAFM status of lobster fishery management in Central Lombok Regency was in the Moderate category. Of the six EAFM domains analysed, the Fisheries Resource Domain had the lowest (Poor) status, while the Habitat and Ecosystem Domain was in the Good status category, and the remaining four dimensions had Moderate status. To improve the status of the fishery and the welfare of the lobster fishermen, lobster fishery management needs to be improved, with a multi-sectoral approach addressing the issues in all six Domains. Sustainable lobster fisheries management strategies proposed include regulating fishing quotas, prohibiting the excessive use of lobster seed fishing gear, managing water quality, optimizing the use of selective fishing gear, establishing a working group for lobster management, detailed zoning of lobster habitat areas, transfer of lobster growout technology, as well as empowering community coastwatch groups (*pokmaswas*).

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