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# Analysis of spiny lobster fishery sustainability the using ecosystem approach to fisheries management (EAFM) in Pulo Aceh

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ABSTRACT

The high exploitation rate due to increasing global demand caused spiny lobster vulnerable to overfishing. this study aims to assess the sustainability status of lobster fisheries, through the ecosystem approach to fisheries management (EAFM) and to examine the appropriate strategies to support the sustainability of spiny lobster fisheries in Pulo Aceh Islands, Aceh Besar district, Aceh Province. Indicators or domains used in this study are fish resources, habitats, and ecosystems, fishing techniques, economics, social, and governance, which consist of 27 attributes. Results show that the aggregate value of fish resources domain is 59.22 (moderate), habitat and ecosystem domain is 39.14, (poor), fishing technique domain is 28.62 (poor), the economic domain is 65 (good), social domain is 47.82 (moderate) and the institutional domain is 39.89 (poor). The overall aggregate value for the six domains is 46.61 (moderate), the sustainability status of the spiny lobster fishery in Pulo Aceh is in the moderate category. the fish resource domain and the economic domain are the main domains that provide a positive value for the sustainability of the lobster fishery in Pulo Aceh. However, to improve the status of lobster fisheries management in Pulo Aceh; should focus on domains that have low-value categories, which are; fishing techniques, habitats and ecosystems, and governance domain.

## Introduction

The high level of exploitation of spiny lobsters driven by the increase in global trade demand in the last few decades, thus caused spiny lobsters to be a species that is prone to overfishing. Indonesia is one of the exporting countries for Panulirus lobster in the world, it is necessary to make efforts to manage lobster capture fisheries (WWF, 2015). The spiny lobster stocks degradation resulted from a combination of natural and anthropogenic factors, such as overfishing and destruction of coral reef habitat due to the use of bombs and poison in reef fishing (Haris et al., 2013). Aceh is one of the main producers of spiny lobster in Indonesia (Hilal and Fachri, 2016).

Aceh province has been identified as one of the national priorities for lobster seed restocking, especially in the South West Coast region of Aceh (Nurfiarini et al., 2016). This is due to the high level of exploitation of lobsters in the coastal areas of Aceh, especially in archipelagic areas such as Simeulue Island, Simeulue District, and Pulo Aceh, Aceh Besar District (Edwarsyah, 2017) and (Tewfik, et al, 2008). The high level of exploitation of lobster in the waters of Pulo Aceh Islands; raises concerns about the sustainability of these economically important fishery resources. If the above problems continue, it is feared that it will accelerate the rate of the scarcity of lobster resources, which can affect the balance of the food chain in coastal ecosystems, especially in the waters of the Pulo Aceh Islands. As a result, it can reduce the carrying capacity of the environment and the capacity of the sea as a provider of fish resources, as well as harm small fishermen who live and earn a living in the Pulo Aceh District, Aceh Besar District. This study aims to evaluate the

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status of the spiny lobster fishery in Pulo Aceh Island, also to find out management strategies that could improve the sustainability of spiny lobster fishery in Pulo Aceh. Results from this study are therefore very important for the future programs for managing Spiny lobster in Aceh Province, as well as in other parts of the region.

## Material and method

### Location and time of research

This study was conducted at Pulo Aceh Islands, Aceh Province, about 12 nautical miles (northwest) from the mainland of Sumatera. The Pulo Aceh archipelago comprises 10 islands, with 2 inhabitant Islands; Breuh Island, and Nasi Island, and several tiny islands which are uninhabited. The islands only can be accessed by small boat and ferry from Banda Aceh. The islands are influenced by the Northeast Monsoon from November to February, which brings heavy rainfall and storms, and Southwest Monsoon during May to August. This study was conducted from August 2020 to February 2021, focusing on 4 villages in Breuh Island which is the fishers' main target is spiny lobster. The water quality sampling and fishers' interview location are shown in Figure 1.

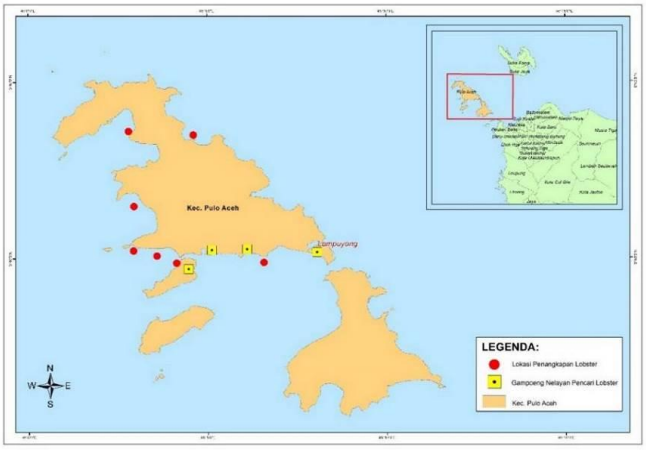


Figure 1. Research sites in Pulo Aceh Island, Aceh.

Figure 2. Carapace length & weight measurement.

### Data collecting method

Primary data retrieval for spiny lobster morphometric was obtained by measuring the lobsters landed during the research period at the lobster landing site and in lobster trader warehouses. Respondents to be interviewed were carried out by purposive sampling, especially fishermen that caught spiny lobster as their main target. Meanwhile, lobster measurements were carried out by census of *lobsters* caught by fishermen who had been previously selected. The lobsters used as samples were measured for carapace length using a caliper ruler with a scale of 1 (one) mm and weighed using a digital balance with an accuracy of 5 grams (Figure 2).

Interviews were employed to assess the characteristics of spiny lobster fisheries and fishers' households. Respondents were selected using the purposive sampling method and followed up interview was conducted In-Depth Interviews with key informants who are considered to have a broad knowledge of aspects of habitat, biology, fishing, trade, and fisheries management policies in Pulo Aceh and Fisheries Agency of Aceh Provinces.

Total 60 lobstermen as the main respondent, 3 traders, 1 Panglima laot, 5 Government officers as key informants were interviewed during this study. Secondaries data were collected from literature studies such as habitat and ecosystem status, and impact of climate change on the coral reef in Pulo Aceh waters, also policies related to lobster fisheries in Indonesia and Aceh Province.

### Data Analysis

Analysis of the six EAFM domains uses the flag modeling technique. The flag modeling technique is using the Multi-Criteria Analysis (MCA) method, where a set of criteria is constructed as the basis for analysis of the performance of fisheries management areas seen from the ecosystem approach to into fisheries management through the development of composite index (Adrianto et al., 2005). The criteria are grouped into; (1). Fish Resource Domain which consists of 6 attributes, (2). The Habitat and Ecosystem domain consists of 6 attributes, (3). Fishing Techniques Domain consists of 3 attributes, (4). Economic Domain which consists of 3 attributes, (5). Social Domain consists of 3 criteria, and (6). Governance Domain consists of 6 criteria. The total attributes of the six domains are 27 attributes. Statistical analyses were performed using MicrosoftExcell® software, which refers to EAFM Modul (Adrianto et al., 2014). The method used to analyze the suitable approach and strategy to increase lobster fisheries management status in Pulo Aceh in this study is using the Tactical Decision Analysis (TDA) method (Pratiwi, 2014). Data analysis used to see the effort to catch lobsters was carried out using the CpUE (Catch per Unit Effort) formula developed by Sparre and Venema (1998). Analysis of lobster species composition data using the formula

Ks = ni/N x 100% (Odum, 1971), where: Ks = Species composition; ni = the number of individuals of each lobster species, and N = the total number of individuals of all lobster species.

Composite value assessment in each domain ($C\text{-}_{DJ}$) based on the following formula:

$$C\text{-}_{Dj} = ns_{ij} \times br_{ij} \times sd_i,$$

where :

C-Dj = total EAFM value of one attribute in the domain
nsij = the score of the i- an indicator of the j- domain
brij = weight of the i domain of indicator ranking j
sdij = the density score of the i- indicator

Total composites value assessment of all domain (C-loc), using the following formula:

$$C\text{-}_{eafm} = AVE\ d_j : ns_{ij} \times br_{ij} \times sd_i$$

where :

$C\text{-}_{eafm}$ = EAFM domain aggregate composite value
$Ave_{dj}$ = arithmetic mean of j domain
$ns_{ij}$ = Score of the i- an indicator of the j- domain
$br_{ij}$ = weight of the i domain of indicator ranking j
$sd_{ij}$ = the density score of the i- indicator

Attributes Score is shown in Table 4 to Table 9. Weighting for attributes in each domain is based on the priority of issues in the domain, and scoring was determined based on the current condition of each attribute, compared with the ideal condition. The weighting value was carried out using a likelihood scale and a score based on a 1-3 Likert scale (Adrianto et al., 2005). Classification of scoring results, flag model, and status of each attribute shown in Table 1.

Table 1. Classification of attributes scoring results.

| Score Value | Flag model | Status |
|---|---|---|
| 1 | | Bad |
| 2 | | Moderate |
| 3 | | Good |

Table 2. Classification of domain scoring results.

| Value Range | Flag model | Description |
|---|---|---|
| 1-20 | | Bad |
| 21-40 | | Poor |
| 41-60 | | Moderate |
| 61-80 | | Good |
| 81-100 | | Very Good |

Steps to conducted Multi-Criteria Analysis (MCA) were weighing and scoring, Identifying the level of connectivity (density) among attributes, conducting simple composite analyses based on the arithmetic mean which is then displayed in the form of a flag model with the following criteria (Table 2).

Domains and attributes that have the smallest value showed the magnitude of the problem in fisheries management, thus need to be addressed immediately and prioritized in the management strategy and the steps of tactical efforts using tactical decision analysis will be determined based on these results.

**Attributes Connectivity (Density)**

Connectivity (density) between domains and indicators by determining the domain score from the results of cognitive mapping of the relationship among indicators. This linkage is one of the main characteristics of EAFM. The density score (connectivity) between EAFM attributes in this study is presented in Table 3.

Table 3. Density score of each attribute

| No | Attribute | Connectivity Score (Density) |
|---|---|---|
| 1 | Fish Resources domain | |
| 1.1 | CpUE | 22 |
| 1.2 | Catch size trend | 20 |
| 1.3 | Juveniles proportion | 18 |
| 1.4 | Catch composition | 15 |
| 1.5 | Range collapse lobster | 21 |
| 1.6 | ETP Species | 17 |
| 2 | Habitat and ecosystem domain | |
| 2.1 | Water quality | 18 |
| 2.2 | Coral reef ecosystem status | 23 |
| 2.3 | Mangrove's ecosystem status | 17 |
| 2.4 | Seagrass ecosystem status | 18 |
| 2.5 | Unique habitat | 17 |
| 2.6 | Climate's change | 16 |
| 3 | Fishing techniques domain | |
| 3.1 | *Destructive Fishing* | 24 |
| 3.2 | Fishing gear modification | 18 |
| 3.3 | Catch effectivity | 18 |
| 4 | Economic domain | |
| 4.1 | Fishermen households income | 20 |
| 4.2 | Saving ratio | 21 |
| 4.3 | Alternative income | 21 |
| 5 | Social Domain | |
| 5.1 | Participation rate | 15 |
| 5.2 | Marine resources use conflicts | 22 |
| 5.3 | Use of Traditional Knowledge | 25 |
| 6 | Domain Kelembagaan (K) | |
| 6.1 | Compliance with rules | 25 |
| 6.2 | Completeness of the rules of the game | 25 |
| 6.3 | Decision-making mechanism | 17 |
| 6.4 | Fisheries management plan | 22 |
| 6.5 | The level of policy and institutional synergy | 17 |
| 6.6 | Stakeholder capacity | 25 |

**Composite analysis**

Composite analysis of each domain was carried out to see the performance value of each domain. The composite value of a domain is determined from the average value of all attributes in each domain. Multiplying the attribute score and the density score will give the value of each attribute. These results will then be entered into the aggregate domain. Domain aggregate values are then converted into values with a scale of 1-100 (Adrianto et al., 2014).

## Results

**Fish resources domain**

The results of the composite analysis showed that the aggregate value of the fish resource domain was 59.22 (Table 4.). Indicators that fall into the good category include CpUE, the proportion of juvenile catch, catch composition, and response to the ETP species. Meanwhile, indicators that are classified as moderate in the fish resource domain are lobster size trends and lobster collapse range, where 63.3% of respondents who targeted lobsters stated that finding lobsters was getting more difficult and farther away. Based on the results of the composite analysis, the domain of fish resources in the management of lobster fisheries in Pulo Aceh is in the "moderate" category.

**Habitat and ecosystem domain**

The results of the composite analysis showed that the aggregate value of habitat and ecosystem domains was 39.14 (Table 5). Indicators included in the good category were water quality, indicators that are classified as moderate are the status of coral reef ecosystems and the presence of unique/special habitats. Meanwhile, indicators that are classified as low in the habitat and ecosystem domain are the status of mangrove ecosystems, seagrass ecosystems, and the impact of climate change. Based on these results, the habitat and ecosystem domain for lobster fisheries management in Pulo Aceh is in the "poor" category.

**Fishing techniques domain**

The results of the composite analysis showed that the aggregate value of the fishing technique domain was 28.62 (Table 6). There were no indicators that fall into the „good" category in this domain, indicators that are classified as moderate are the attributes of lobster catching effectiveness, while the attributes of destructive fishing and modification of fishing gear are in a low category. Based on these results, the domain of fishing techniques in the management of lobster fisheries in Pulo Aceh is in the "poor" category.

Table 4. The aggregate value of fish resources domain.

| Attribute | Attribute Score | Weight | Densities Score | Value |
|---|---|---|---|---|
| CpUE | 3 | 40 | 22 | 2640 |
| Catch size trend | 2 | 20 | 20 | 800 |
| Juveniles proportion catch | 2.5 | 15 | 18 | 675 |
| Catch composition | 3 | 10 | 15 | 450 |
| Range collapse lobster | 1.65 | 10 | 21 | 346.5 |
| ETP Species | 2.83 | 5 | 17 | 240.55 |
| Total | 15.48 | 100 | 113 | 5287.05 |
| Means | 2.58 | | 18.83 | 881.18 |
| Minimum value | | | | 100 |
| Maximum value | | | | 8700 |
| Aggregate | | | | 59,22 |

Table 5. The aggregate value of habitat and ecosystem domain.

| Habitat and Ecosystem Domain | Attribute Score | Weight | Densities Score | Value |
|---|---|---|---|---|
| Water quality | 3 | 25 | 18 | 1350 |
| Coral reef ecosystem status | 2 | 15 | 23 | 690 |
| Mangrove's ecosystem status | 1 | 15 | 17 | 255 |
| Seagrass ecosystem status | 1 | 15 | 18 | 270 |
| Unique's habitat | 2 | 20 | 17 | 680 |
| Climate changes impact | 1 | 10 | 16 | 160 |
| Total | 10 | 100 | 109 | 3405 |
| Means | 1.67 | | 18.17 | 567.50 |
| Minimum value | | | | 100 |
| Maximum value | | | | 8700 |
| Aggregate | | | | 39.14 |

Table 6. The aggregate value of fishing techniques domain.

| Fishing techniques domain | Attribute Score | Weight | Densities Score | Value |
|---|---|---|---|---|
| Destructive fishing | 1 | 40 | 24 | 960 |
| Fishing gear modification | 1 | 35 | 18 | 630 |
| Catch effectiveness | 2 | 25 | 18 | 900 |
| Total | 4 | 100 | 60 | 2490 |
| Means | 1 | | 20 | 830 |
| Minimum value | | | | 100 |
| Maximum value | | | | 8700 |
| Aggregate | | | | 28.62 |

**Economic domain**

The results of the composite analysis of the economic domain aggregate value yielded a value of

65 (Table 7). The attributes were included in the good category in this domain are fishery household income and savings ratio, while the alternative income attributes were in the moderate category. Based on these results, the economic domain in the management of lobster fisheries in Pulo Aceh is included in the "good" category.

**Social domain**

The results of the composite analysis showed that the aggregate value of the social domain produces a value of 47.82 (Table 8). Attributes that have a high score in this domain are the conflict in the use of fisheries resources, the attribute of the use of local wisdom or Traditional Ecological Knowledge (TEK) is in the medium category and the level of community participation is low. Based on these results, the social domain in lobster fisheries management in Pulo Aceh is included in the "moderate" category.

**Governance domain**

The results of the composite analysis show that the aggregate value of the governance domain produces a value of 39.89 (Table 9). No attribute has a high score in this domain, the attributes that are included in the moderate category are the completeness of the rules of the game, decision-making mechanisms, synergy of policies and institutions, and the capacity of key stakeholders. The attributes of the level of compliance of the parties and the availability of the Fisheries Management and Action Plan get a low score. Based on these results, the value of the institutional domain in the management of lobster fisheries in Pulo Aceh is included in the "poor" category.

**Sustainability status**

The results of the analysis of the aggregate composite index of all of these domains indicate that only one domain has a good value, which is the economic domain, 2 (two) domains are included in the moderate category; fish resource, and social domain. Habitat and ecosystem domains, fishing technique domains, and institutional domains are included in the "poor" category. The composite value diagram for each domain can be seen in Table 10., and the flow chart in Figure 3.

Table 7. The aggregate value of the economic domain.

| Economic domain | Attribute Score | Weight | Densities Score | Value |
|---|---|---|---|---|
| Fisher HH income | 3 | 40 | 20 | 2400 |
| Saving ratio | 3 | 35 | 21 | 2205 |
| Alternative income | 2 | 25 | 21 | 1050 |
| Total | 8 | 100 | 62 | 5655 |
| Mean | 3 | | 21 | 1885 |
| Minimum value | | | | 100 |
| Maximum value | | | | 8700 |
| Aggregate | | | | 65.00 |

Table 8. The aggregate value of the social domain.

| Social domain | Attribute Score | Weight | Densities Score | Value |
|---|---|---|---|---|
| Participation level | 1 | 40 | 15 | 600 |
| Marine resources use conflict | 3 | 35 | 22 | 2310 |
| Local wisdom use | 2 | 25 | 25 | 1250 |
| Total | 6 | 100 | 62 | 4160 |
| Mean | 2 | | 21 | 1387 |
| Minimum value | | | | 100 |
| Maximum value | | | | 8700 |
| Aggregate | | | | 47.82 |

Table 9. The aggregate value of the institutional domain.

| Institutional domain | Attribute Score | Weight | Densities Score | Value |
|---|---|---|---|---|
| Compliance | 1 | 25 | 25 | 625 |
| completeness of the rules of the game | 2 | 25 | 25 | 1250 |
| decision-making mechanisms | 2 | 15 | 17 | 510 |
| Spiny Lobster Management Plan | 1 | 15 | 22 | 330 |
| The synergy of policies and institutions | 1.5 | 10 | 17 | 255 |
| the capacity of key stakeholders | 2 | 10 | 25 | 500 |
| Total | 9.5 | 100 | 131 | 3470 |
| Mean | 1.58 | | 21.83 | 578.33 |
| Minimum value | | | | 100 |
| Maximum value | | | | 8700 |
| Aggregate | | | | 39.89 |

Table 10. Aggregate composite value all domain

| Domain | Composite value | Description |
|---|---|---|
| Fish resources | 59,22 | Moderate |
| Habitat and ecosystem | 39.14 | Poor |
| Fishing techniques | 28,62 | Poor |
| Social | 47.82 | Moderate |
| Economic | 65.00 | Good |
| Institutional | 39.89 | Poor |
| Aggregate | **46.61** | **Moderate** |

## Discussion

Results showed factors or attributes that affect the sustainability status of spiny lobsters fishery in Pulo Aceh is the status of mangrove ecosystems and seagrass ecosystems, the impact of climate change (Coral Bleaching), destructive fishing methods, modification of fishing gear, low level of stakeholder participation (especially fishermen), low level of compliance to regulations, the low synergy between institutions and the absence of a lobster fishery management plan (RPP) and its derivative plan (Action Plan). This is in line with the results of the research by Teteleptal et al. (2017), which states that the factor that makes a major contribution to the sustainability of lobster fisheries is bycatch which is caused by fishing techniques that have a high level of fishing effectiveness and low community involvement in fisheries management.

The strategy to improve lobster fisheries management in Pulo Aceh for the short term is focused on indicators of habitat and ecosystem domains, fishing techniques, and governance domains, considering that these three domains have "poor" indicator values based on EAFM reference point (Adrianto et. Al, 2014). The follow-up strategy emphasizes indicators that have moderate values. The formulation of tactical steps for the habitat and ecosystem domain are; 1). rehabilitation of mangrove and seagrass ecosystems in Pulo Aceh, 2). prohibition of conversion of mangrove and seagrass ecosystems and 3). the existence of special rules regarding fishing in the location of the seagrass ecosystem which is the nursery ground habitat for the spiny lobster species. Tactical steps for the fishing technique domain are; 1). intensive socialization and communication regard to destructive fishing, 2). increase supervision of law enforcement, and 3). prohibition of the use of hookah compressor fishing in Pulo Aceh.

It is estimated that at least 80 or 90 percent of conflicts in transitional democracies are resolved by informal or traditional justice systems. According to Dashlibroon and Zamani (2020) in the Journal of Critical Reviews, the non-governmental and customary justice system handles almost all conflicts, especially conflicts over marine resource use (Tungale, 2008), so that the existence of local wisdom, if used appropriately and appropriately, can reduce conflicts over resource use and support sustainable fisheries. Social domain tactical steps include; 1). Increase stakeholder participation in the preparation of regulations related to marine resources use, 2). community involvement in every development planning phase, 3). Adoption of national rules on destructive fishing to become part of local customary law (vice versa) and 4). Strengthening Panglima Laot institutions and enforcement of marine customary law. The institutional domain tactical steps include; 1). Involvement of stakeholders (especially fishing communities) in the preparation of regulations related to marine resources use, 2). The social and cultural approach in implementing the preventive legal approach, 3). facilitate the formulation of the lobster Fishery Management Plan (RPP) and the lobster Fishery Management Action Plan (RAPP) at the Aceh Province level, and 4). capacity building of key stakeholders (fishermen, traders, Panglima Laot institutions, Aceh Marine and Fisheries Agency officers, fisheries law enforcement officers) on sustainable fisheries management, both conceptual and practices. Lastly, the absence of a lobster fishery management plan makes a significant impact to lobster fisheries governance (Paulus, et. al, 2020).

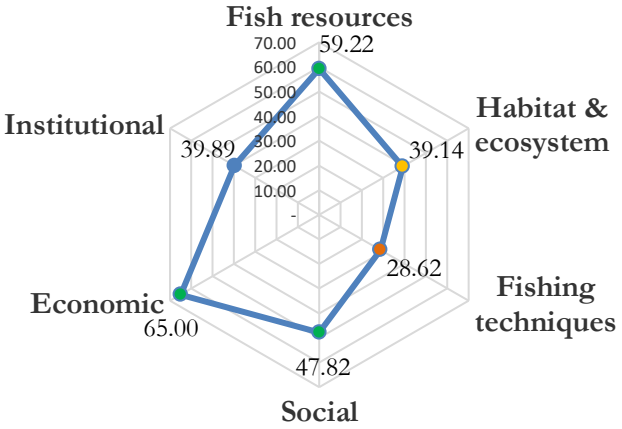


Figure 3. Kite diagram of composite results of the Pulo Aceh lobster fishery using EAFM

## Conclusion

This study has documented the baseline information for spiny lobster fisheries at Pulo Aceh, Aceh Besar District, Aceh Province, and shown the result that the sustainability status of the spiny lobster fisheries in Pulo Aceh is in the moderate category. Based on the results of the composite scores from the 6 EAFM domains studied, it can be concluded that the fish resource domain and the economic domain are the main domains that provide a positive value for the sustainability of the lobster fishery in Pulo Aceh. However, to improve the status of lobster fisheries management in Pulo Aceh should focus on domains that have low value, which is; fishing techniques, habitats, ecosystems, and institutions governance.

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