The fishery of sea-cucumber Holothuridae in Kilbat Village, Central Maluku Regency, Indonesia

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Abstract. Sea cumber is one of the valuable high economic resources. Worldwide, most sea cucumber fisheries are ineffectively managed, leading to declining stocks and potentially eroding the resilience of fisheries. The local fishermen of Kilbat Village have been exploiting sea cucumber for a long time with un-proper management pan. This study was aimed to investigate the utilization of sea cumber and assess its sustainability, and propose a sustainable management strategy. Field observation was used to analyze sea cucumber utilization, the Rapid appraisal to Fisheries (Rapfish) approach was used to assess its sustainability, whilst DPSIR was applied to perform a sustainable management strategy. The result shows that the local sea cucumber fishermen utilize sea cucumber as a source of income and self-consumption. The average sustainability was 61.17% of 100% sustainable scale and considered as fair sustain with institutional dimension being unsustain. There are 8 strategies proposed for sea cucumber sustainable management with responses at D, P, S, and I level, A traditional indigenous knowledge (sasi) has been proposed for sea cucumber community-based fishery management.

1. Introduction

Sea cucumbers are among the members of thorny animals, living on the base of the sand substrate, muddy sand or in the reef environment, and areas with high organic matter [1, 2, 3]. Based on fisheries and trade data of worldwide sea cucumber fisheries, they are found to distribute in temperate areas of the Northern Hemisphere; Latin America and the Caribbean; Africa and the Indian Ocean; Asia; and Western Central Pacific [4, 5]. There are approximately 60 species of sea cucumber species found to distribute in Indonesia waters like eastern Java coast, Maluku, Irian, North Sulawesi, western coast of Sumatra, North Sumatra, Aceh, East Nusa Tenggara, West Nusa Tenggara [6].

For most of the Chinese and some other Asian countries like Korea and Japan, sea cucumbers are a traditional delicacy prized for their dietary and curative properties [7]. In the international seafood trade, the processed body wall, known as bêche-de-mer or trepang, has been a globally important trade commodity since the 16th century. The most valuable species Holothuria scabra, commonly known as sandfish, has an average market price of USD 303 kg⁻¹ with prices reaching as high as USD 668 kg⁻¹ for a premium grade-A product. Market prices across species (averaging USD 385 kg⁻¹) appear to have mostly increased six- to twelve-fold over the past decade [7, 8].
Throughout the world, 66 species of sea cucumbers are commonly exploited [9], and of particular importance in the Indo-Pacific [10]. Sustainably managing these fisheries has proven to be very difficult over the years. Worldwide, most sea cucumber fisheries are ineffectively managed, leading to declining stocks and potentially eroding the resilience of fisheries. Market demand currently exceeds global supply, and prices are rising [11]. Many sea cucumber fisheries worldwide have dramatically declined worldwide due to rapid overexploitation and ineffective management [12].

Sea cucumber has been exploited at some parts of Maluku i.e. at Morella Village [13], Porto and Warialau Village [14], Suli, Morela, Pelauw, at Central Maluku, and Southeast Maluku Regency [15]. Studies on some parts of Maluku have shown signs of unsustainable conditions of sea cucumber fisheries. Sea cucumber sustainability in Southeast Maluku and Central Maluku was in less sustainable condition due to customer attitude to sustainability, less involvement of government agency in the management, poor data condition, and the use of unfriendly fishing gear [15].

Bringing the sea cucumber industry under responsible and sustainable management is of utmost importance. The key elements of management are well known, but the practicalities of putting these in place are problematic [11]. The local community in Kilbat Village has exploited sea cucumber for more than 10 years with no sustainable management principles. This study aimed to assess the management of sea cucumber fishery at Kilbat Village and proposed sustainable sea cucumber management for small-scale sea cucumber fishery.

2. Materials and Method

2.1. Location and date of study
This research was carried out at Kilbat Village, Eastern Seram Regency of Maluku Province (Figure 1). The study was conducted between March to May 2020.

Figure 1. Map showing the study site (red circle)
2.2. Data collection
Data for sea cucumber fisheries practices was obtained through field observation and interviews with local sea cucumber fishermen and through focus group discussion (FGD). For FGD 15 respondents were chosen which consists of sea cucumber fishermen mix with village administrative and local community with depth experience with sea cucumber from this village. The analysis of sea cucumber fisheries was analyzed descriptively.

2.3. Sustainability analysis
For sea cucumber sustainable status, a questionnaire with the close question was distributed to sea cucumber fishermen to filled out. Attributes for sustainable analysis following [16, 17] with some modifications for small-scale sea cucumber fishermen from Kilbat Village. The analysis of MDS data was conducted using Microsoft Excel software following [18]. The sustainability classification for the small-scale fishery was categorized according to ecosystem-based fisheries management standards [19].

2.4. Sea cucumber sustainability strategy
The Driver-Pressure-State-Impact-Response (DPSIR) framework has been suggested as a useful approach in analyzing problems concerning the connectivity between human and natural systems. This approach offers a simple and essential structure for linking causal-effect relationships [20]. This concept is valuable in identifying the causal-loop relationship between community and ecosystem [21] and in this study was used to develop sustainable management plans for sea cucumber fishery [22, 23].

The small-scale sea cucumber fishermen from Kilbat Village exploiting sea cucumber is a driving factor (D) variable in this study using traditional goggles. The high demand and price for sea cucumber are considered as pressure (P) in this study. The state variable (S) is the component within the system of sea cucumber fishery and in this study are the two most sensitive attributes affecting sea cucumber sustainability. These attributes were obtained from the Leverage analysis of Rapfish assessment result [18, 24]. The impact (I) is the predicted outcome from the pressure against the component within the system. The response (R) component is the attempt conducted in the form of a program or strategy to overcome the impact and it can be at the level of D, P, or S.

3. Results and Discussion

3.1. Sea cucumber utilization
Kilbat village is a small village with a total population by 2019 amounted to 853 individuals. This village is situated at the coastal waters of Central Maluku Regency. Majority (33.10%) work as a farmer and only 14.2% as fishermen. The sea cucumber fishery in this village is classified as small-scale fisheries, and with their fishing gear, vessel size, fishing technic, and investment capital, the fishermen belong to an artisanal fisher [25]. The sea cucumber is mainly harvested by the local fishermen and some fishermen from the neighboring village. Sea cucumber is harvested by gleaning through free diving mostly using traditional goggles, but there are a few that use the compressor.

The sea cucumber fishery in this village has been done for more than 15 years. Of 11 species found in this village, the main target species are Holothuria scarba, H. atra, Stichopus ananas, and S. variegatus. Depend on the species and the size, the price of sea cucumber at the village level range from IDR 70,000 – IDR 600,000 kg-1 dry weight. The sea cucumber harvested is sold to a local trade collector, who will buy it and send it to Makassar or Surabaya market.
With high prices and demand, the local fishermen harvesting the sea cucumber almost every day. From an interview with local fishermen, they used to harvest more than 50 – 70 individuals per day, but at present time the harvest is decreasing to less than 35 individuals per day. This symptom indicates an unsustainable condition with probable cause due to high fishing intensity and no proper fisheries management.

### 3.2. The sustainability status

Rapfish ordination analysis for ecology sustainability status of sea cucumber, Holothuroidea, harvested by small-scale fishermen from Kilbat village shows that ecology sustainability status was 68.82% from 100% sustainable scale (Figure 2A). This ecology sustainability status is assumed fair sustain according to ecosystem-based fisheries management for small-scale fisheries [19]. This sustainability status is higher compared to the sustainability of sea cucumber from some villages from Central Maluku and Southeast Maluku Regency that have an average sustainable status of 54.41% [15]. The stress value measuring the goodness of fit of the analysis was 0.1452 which is less than 0.15 and considered good. The Monte Carlo Scatter Plot (Figure 1B) shows the stability of the analysis during the ordination as shown in the clumps form of the plot [24].

![Figure 2](image.png)

**Figure 2.** Ecology sustainability status of sea cucumber from Kilbat village

The same procedure to assess the sustainability status of sea cucumber fishery using the Rapfish analysis was also performed to social, economic, technology, and institutional dimensions for this fishery. The summary of the result was shown in Table 1. This table shows that the sea cucumber sustainable status varies between dimensions with the technology dimension having the highest sustainability status (77.66%), and the lowest one is the institutional dimension (38.22%) from a 100% sustainable scale.

From the ecosystem approach to fisheries management, the institutional dimension is considered unsustain [19]. Variables considered important in sustainable fisheries management like reporting, monitoring/evaluation, protection, management plan [17, 26], are not implemented in this fishery. This is not surprising since worldwide, most sea cucumber fisheries are ineffectively managed, leading to declining stocks and potentially eroding the resilience of fisheries. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) had listed some sea cucumber species in Appendix II for endangers and threatened species [27].
### Table 1. Summary of sustainability status of small-scale sea cucumber fishery

| Dimension     | Sustainability status | Stress | Square Correlation | Remarks     |
|---------------|-----------------------|--------|--------------------|-------------|
| Ecology       | 68.82                 | 0.1452 | 0.9486             | Fair sustain|
| Economy       | 56.24                 | 0.1533 | 0.9449             | Less sustain|
| Social        | 64.89                 | 0.1374 | 0.9503             | Fair sustain|
| Technology    | 77.66                 | 0.1431 | 0.9493             | Sustain     |
| Institutional | 38.22                 | 0.1437 | 0.9498             | Unsustain   |
| Average       | 61.17                 |        |                    |             |

3.3. **Sustainable management strategy**

For a sustainable management strategy for the small-scale sea cucumber fishery of Kilbat Village, the DPSIR was developed, an approach believed as a useful approach in developing an integrated sustainable management plan [22, 23]. Table 2 shows the most sensitive attributes towards sustainability of the small-scale sea cucumber fishery of Kilbat Village. The sensitive attributes are the attribute from leverage analysis and in this case the attribute that has a negative impact on sea cucumber sustainability.

### Table 2. The most sensitive attributes towards small-scale sea cucumber fishery

| Dimension     | Sensitive attribute                  | RMS value |
|---------------|--------------------------------------|-----------|
| Ecology       | Habitat/ecosystem                     | 3.53      |
| Social        | Sea cucumber size                     | 2.67      |
|               | Consumer attitude towards sustainability | 8.32     |
| Economy       | Change in fishing activity            | 5.86      |
|               | Other source of income                | 7.63      |
| Technology    | Equity in resources used              | 4.88      |
|               | Use of fish aggregating device        | 4.54      |
|               | Change in vessel capacity             | 3.88      |
| Institutional | Report                                | 4.75      |
|               | Monitoring/controling                 | 4.17      |

Based on sensitive attributes towards small-scale sea cucumber fishery sustainability, the sustainable management strategy was developed using the DPSIR framework. The framework consists of connectivity explaining the causal-loop diagram between the attributes and potential impact which might occur in the sea cucumber fishery system.

Easy access to sea cucumber habitats combined with their biological characteristics of slow growth, late age-at-maturity, and broadcast spawning reproductive strategy has made sea cucumbers especially vulnerable to overexploitation by fishers [27]. With habitat/ecosystem degradation, the high fishing intensity will decrease sea-cucumber density that will create less ability to reproduce. This condition in the longer term will cause an unsustainable condition for this fishery. Figure 3 show connectivity between sensitive attribute and possible impact happen, and response taken as a sustainable management strategy. Workshop and training is the major strategy for increasing awareness in exploiting the sea cucumber.
Consumer attitude is defined as how the community behavior towards the practice of one particular fishery. If the fishery comes from unsustainable fisheries practice and the community resists purchase, it will foster sustainability and vice versa [17]. The result shows that even small sea cucumber is harvested and sold to a local trader. Because they are a luxury food item and one that apparently delivers curative benefits, it is unlikely that the global market will wane over time, particularly if consumer affluence in China continues to rise [9]. Targeting seafood consumers to improve seafood sustainability such as through certification schemes and consumer awareness campaigns is considered important [28]. Figure 4 shows several management strategies like establish of Harvest Control Rule, workshop and training, partnership establishment, habitat rehabilitation proposed to be conducted.
Figure 4. Socio-economy management framework for sustainable sea cucumber fishery

The fish aggregating device in this case is the use of compressor as a supporting tool in the harvesting sea cucumber. The use of a compressor will enable the diver to dive deeper and spent more time harvesting sea cucumber hence they can harvest more sea cucumber compared to the free diver that using simple google which only dives to a depth of 2 m. Better fisheries management needs good quality data which come from reporting of all activities in the fisheries like the number in size of sea cucumber harvested, species composition, discard and/or by-catch. In this fishery, no such data is available, therefore, the unsustainable condition could arise from this poor data condition.

Monitoring, control, and surveillance (MCS) are critical for the success of marine conservation and management, but effective MCS remains challenging [29]. The initiation of Illegal, Unreported, and Unregulated (IUU) fishing has been widely recognized as a deterrent to the sustainable development and utilization of fisheries resources. The MCS is an important element in combating IUU fishing [30]. The
absence of the MSC in this fishery will certainly lead to an unsustainable sea cucumber fishery. Several management strategies were proposed i.e. workshops and training for the local community and local traders to increase the awareness of sustainable fisheries management, establishing harvest control rules and harvest strategy, data management improvement, establish MSC (Figure 5).

Figure 5. Technology and institutional management framework for sustainable sea cucumber fishery

4. Conclusion and Recommendation

4.1. Conclusion

Based on the results, it can be concluded that the sea cucumber fishery in Kilbat Village is considered a small-scale fishery. From the ecosystem approach to fisheries management, this fishery is conducting with no sustainable principles that leading to the unsustainable condition. Several management strategies prosed
are workshops and training to empower local sea cucumber fishermen and local trader awareness in sustainable fisheries management principles, establishing harvest control rules and harvest strategy for the fishery, establish monitoring, controlling, and surveillance, improve data management, market mechanism, and partnership.

4.2. Recommendation
There should be a more comprehensive study in this fishery including species composition, population biology of sea cucumber, the establishment of traditional community base management through sasi, and stock enhancement through pen culture.

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