Modeling of habitat suitability for sea cucumber ranching in Sintok Island, Karimunjawa National Park, Indonesia

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Abstract. Increasing demand for marine resources, such as sea cucumber, has led to widespread interest in their conservation, one of which is sea ranching. This study sought to identify habitat suitability for sea cucumber *Holothuria scabra* ranching. The proposed location was Sintok Island, one small island part of Karimunjawa Archipelagos. The HSI (Habitat Suitability Index) model was used to identify potential sites for sea cucumber ranching. Twelve habitat factors were used as input variables for the HSI model: sediment classification, water temperature, salinity, pH, dissolved oxygen, depth, transparency, current, depth, organic matter and chlorophyll-a of the sediment, seagrass density, and tide. The weighting of each habitat factor was defined through the Delphi method. Sediment classification and seagrass density were the most and less important condition affecting the HSI of *H. scabra* in the different study areas with weighing index of 0.2191 and 0.015 respectively. The HSI of Southern Station (Station 1) was relatively low (0.79-0.81), meaning the site was not suitable for sea ranching of *H. scabra*. In contrast, the western (Station 2) and the northern part (Station 3) of Sintok Island, were preferable sites, suitable as habitats for restoration efforts in sea ranching.

Keywords: HIS, *Holothuria scabra*, ranching, Sintok Island.

1. Introduction
Indonesia is known as one of the largest sea cucumber exporting countries in the world [1], one of the species exported is *Holothuria scabra* (Sandfish). This species could be found in Lampung, Thousand Islands, Karimunjawa Islands, the coast of Madura, Java, Bali, Sumba, Lombok, Aceh, Bengkulu, Bangka, Riau and surrounding areas, Belitung, Kalimantan, Sulawesi, Maluku, and Papua [2]. Sea cucumbers are caught continuously regardless of their size and age to meet high market demand. The absence of stock management will have an impact on population decline in nature around the world. The sea cucumber is currently proposed to be included in the Appendix II category of Convention on International Trade in Endangered Species (CITES) because its population is decreasing and even declared extinct locally [3]. This high exploitation may be caused by several factors, such as the sea cucumber being easy to find in shallow waters, high economic value, large trade volume, but not balanced with culture efforts. The application of culture method for sea cucumber could also be used in conservation, such as sea ranching. This effort could increase production, reduce overfishing, help restore populations in nature, and provide supplies with good quality and sustainability as well as conservation.
Utilization of coastal waters for marine culture and sea ranching can be categorized as suitable or appropriate and unsuitable or inappropriate areas. This depends on the presence or absence of limiting factors for the biota to be cultivated. Common limiting factors include physical, chemical, and ge-oceanographic factors that act as habitat factors that support the survival of sea cucumbers [4]. Marine culture and sea ranching for sea cucumber, especially H. scabra will be optimal if carried out in areas that have relatively small limiting factors naturally so that it can be categorized that the above factors are supporting factors. This limiting factor greatly affects the level of suitability of an area. The suitability of the location for the implementation of cultivation affects the results to be obtained.

The Karimunjawa National Park (KNP), a nature reserve that has an original ecosystem and a rich diverse coral reef, seagrass, and mangrove, is managed by Karimunjawa National Park Authority (KNPA). Sintok is a privately owned island with an area of 21 Ha with a circumference of 1,625 m. In the zoning system of the KNPA, the northern waters include in the marine protection zone and the southern waters could be utilized as tourism. Proposed as an ecotourism destination, one tourism object is sea cucumber ranching, to improve tourist awareness on conservation. Therefore, this research needs to be carried out to determine a suitable location for sea cucumber sea ranching in the Sintok Island, Karimunjawa National Park based on habitat factors that support the life of sea cucumbers.

2. Materials and Methods
This research was conducted on Sintok Island, Karimunjawa National Park. There are three stations (three sub-station each) (Figure 1). The station selection was based on the proposed objection of sea cucumber ranching establishment in Sintok Island, i.e. as ecotourism, and based on KNPA zonation. The northeast water was not selected since it is more open area and faces strong current and waves [5] which are not suitable for tourism. Observation of seagrass density was done using the LIPI method [6] during low tide with a 50 cm x 50 cm quadrant transect. Line transects are drawn perpendicular to the shoreline starting from the first point where seagrasses are found and up to 100 m towards the sea. Observations were made every 10 m to the 100 meter using a quadrant transect placed to the right of the line transect. The distance between line transects is 50 m parallel to the shoreline. There were three substations with a distance of 100 meters. Measurements of water quality, such as temperature, salinity, brightness, depth, pH, and dissolved oxygen were carried out in situ in the column layer of seawater along with observations of seagrass density. Sediment samples were taken using a sediment core randomly along the transect line for analyses of grain size, chlorophyll–a, and organic matter. The sediment is then put into a ziplock and placed in a cool box for further analyses in the laboratory. The water quality measurement and sediment samples taken were triplicated, and the average results were used for further analyses.

Analysis of water suitability using the Habitat Suitability Index (HSI) model [7]. There are 12 habitat factors used as variables (n), namely sediment classification, salinity, temperature, depth, pH, dissolved oxygen, brightness, current velocity, tides, organic matter, seagrass density, and chlorophyll–a. The final result shows a quality index that ranges from 0 (very unsuitable) to 1 (very suitable). The suitability index (SI/Suitability Index) was based on literature related to water quality conditions that met the criteria for the cultivation of sea cucumbers [8-17]. Parameters that give a stronger influence as a limiting factor for sea cucumbers are given a higher value. The largest value is 1 (strongly agree) while the smallest is 0 (strongly disagree). The results of the Conformity Index (SI) are then presented in the form of a diagram (Figure 2).

Determination of the weight value of each variable (Wi) was calculated using the Delphi Method and Analytic Hierarchy Process (AHP) [7, 20]. The Delphi Method is used to collect and consider data based on expert opinions sourced from the literature. While the Analytic Hierarchy Process (AHP) is used to compare a pair of objects so that if there are n objects, there will be C(n,2) comparisons. Determination of the weight value of each variable (Wi) is carried out by a hierarchical structure model, scoring matrix, calculating priority weights, and calculating the consistency index (CI/Consistency Index) based on the relationship between sea cucumbers and their habitat factors. If CR (Consistency Ratio) $< 0.1$, then the answer is considered consistent so that the resulting solution will be optimal. The results of the weights of each variable (Wi) are presented in Table 1.
**Figure 1.** Proposed sea ranching location for *Holothuria scabra*.

**Figure 2.** Suitability index for sea ranching of *Holothuria scabra* of water quality parameter sediment classifications (a), salinity (b), temperature (c), depth (d), pH (e), dissolved oxygen (f), water transparency (g), current speed (h), tide (i), total organic matter (j), seagrass density (k), and chlorophyll-a (l).
Table 1. Weight Value (Wi) Habitat of Holothuria scabra.

| Variable          | Parameter             | Weight Value |
|-------------------|-----------------------|--------------|
| 1                 | Sediment classification| 0.2191       |
| 2                 | Salinity              | 0.2133       |
| 3                 | Temperature           | 0.1514       |
| 4                 | Depth                 | 0.1068       |
| 5                 | pH                    | 0.0736       |
| 6                 | Dissolved oxygen      | 0.0736       |
| 7                 | Brightness            | 0.0510       |
| 8                 | Current speed         | 0.0360       |
| 9                 | Tide                  | 0.0252       |
| 10                | Total organic matter  | 0.0202       |
| 11                | Seagrass density      | 0.0150       |
| 12                | Chlorophyll–a         | 0.0150       |

HSI was built with following formula:

\[
\text{HSI} = \frac{1}{\sum_{i=1}^{n} W_i} \sum_{i=1}^{n} S_i W_i
\]

SI<sub>i</sub>: Suitability Indeks Habitat variable of –i
W<sub>i</sub>: Weight of habitat variabel of –i
N: Number of habitat variabel
I: Variabel (1, 2, ..., n)

ArcMap 10.5 is used to create model HSI maps. The HSI values are given a different color on the map based on the results of calculation (0.79–0.91) namely red (0.79–0.81), orange (0.81–0.83), yellow (0.83–0.85), light blue (0.85–0.87), blue (0.87–0.89), and dark blue (0.89–0.91).

3. Results and Discussion

Sintok Island is located at 5°46’33” – 5°47’10” South Latitude and 110°30’33” – 110°30’54” East Longitude with an island area of 21 Ha with a circumference of 1,625 m. In the zoning system of the Karimunjawa National Park Office, the northern part of the Sintok Island waters is used as a Marine Protection Zone while the southern part of the island is used as a Marine Tourism Utilization Zone. Sintok Island has a barrier reef that surrounds the island. This causes the current inside the barrier to tend to be quieter compared to the current outside of the barrier.

Observations of physical and chemical water quality parameters from three stations showed that the highest value in Station 1 was only salinity, which was 35.1 ppt. The high results at Station 2 were pH (8.17), temperature (32.3°C), organic matter (74.11%), chlorophyll–a (1.85 mg·g<sup>–1</sup>), and current velocity (0.05 m·s<sup>–1</sup>). The highest result was dissolved oxygen (10.94 mg·L<sup>–1</sup>) and temperature (25°C). The lowest value in Station 2 was only chlorophyll–a (0.1 mg·L<sup>–1</sup>). The low values in Station 3 were pH (8.09), and organic matter (3.08%). Meanwhile, the results of brightness, sediment classification, and tides showed the same results at all observation stations.

The same highest HSI value was found in S2T1 and S2T2 (0.91) and was marked in dark blue color on the map. While the smallest HSI value was found at S1T2 (0.79) and was marked in red on the map (Figure 3; Table 2).
Table 2. Habitat Suitability Index for Sea ranching of *Holothuria scabra*.

| Station/Substation | HIS Value |
|--------------------|-----------|
| S1T1               | 0.87      |
| S1T2               | 0.79      |
| S1T3               | 0.81      |
| S2T1               | 0.92      |
| S2T2               | 0.92      |
| S2T3               | 0.91      |
| S3T1               | 0.89      |
| S3T2               | 0.90      |
| S3T3               | 0.90      |

Figure 3. Habitat Suitability for Sea ranching of *Holothuria scabra* in Sintok Island, Karimunjawa National Park, Indonesia.

Generally, the bottom substrate in the waters of Sintok Island is sand that has coral fragments with a rare to medium density of seagrass and the brightness reaches the bottom. Sintok Island is an uninhabited island so it is still safe from anthropogenic pressure due to human activities. This island does not have a river flow and does not have a mangrove forest ecosystem, only has a coastal forest. The highest density of seagrass found at the study site was in S2T1, S2T2, and S2T3 with very dense density criteria. The species of seagrass found at the research site were *Thalassia hemprichii*, *Cymodocea rotundata*, *Halodule uninervis*, and *Halophila ovalis*. *Enhalus acoroides* were also found, but in small numbers, only concentrated at one point, and did not enter the observation transect. Three habitat characteristics need to be considered in the cultivation of sea cucumbers (*H. scabra*) [21], namely depth, the density of seagrass vegetation, and size and nutrient content of the bottom substrate of the waters. Shallow waters with moderate seagrass density conditions will allow sunlight to reach the bottom which directly supports the growth of seagrass and microalgae. This situation makes the sea cucumbers move more freely but still protects the sea cucumbers from predators. The function of seagrass in sea cucumber cultivation other than as a shelter is as food and food traps for sea cucumbers [22]. This is in accordance with what was found at the research site where the waters of Sintok Island are shallow waters with seagrass beds with a fine sand substrate.

*H. scabra* prefers to immerse themselves into the substrate during the day and reappear on the surface in the afternoon as a form of their adaptation to sunlight [2, 23, 24]. This is what causes the water
substrate in the form of sand to be an important factor in the success of *H. scabra* cultivation. Sea cucumbers tend to like substrates that have a high organic matter content and do not like muddy substrates because they are anoxic or lack oxygen. In addition, to allow sunlight to reach the bottom. The depth of the waters affects the technical aspects in aquaculture activities, such as the installation of sea pens or cages, monitoring and management processes [22, 24]. Depths that are too shallow at low tide will also cause sea cucumbers to stress due to overheating. The depth of the water affects the costs required for investment in aquaculture containers [2]. The deeper the waters at the cultivation site, the higher the cost, because the equipment and materials used, will tend to be more.

As a deposit feeder, sea cucumbers seek food from the bottom of the water, in the form of organic matter, detritus, and plankton in the substrate. Therefore, sea cucumbers prefer a substrate that has a high organic matter content, such as a muddy sand substrate with coral rubble. Chlorophyll--a contained in phytoplankton and aquatic plants also include the food of sea cucumbers.

Sea cucumbers are stenohaline animals, meaning they cannot tolerate low salinity. This is used as one of the important considerations in the cultivation of sea cucumbers. That a decrease or increase in salinity beyond the physiological capabilities of sea cucumbers will result in death [24]. At a salinity of 20-25 ppt, sea cucumbers will become stressed, there will be a decrease in immunity and changes in physiological functions. In the long term, it will result in a decrease in the rate of growth and lead to death. Sea cucumbers will die if exposed to salinity < 20 ppt in less than 48 hours. The results of salinity measurements at the research site show optimal results for the cultivation of sea cucumbers, which is about 35 ppt. Salinity at the study site tends to show the same value, which can be caused by the absence of a river at the study site so that it does not allow for a meeting of freshwater and seawater.

The temperature at the Sintok Island showed the optimal temperature for sea cucumber cultivation which ranges from 25-32°C. Temperature affects the metabolic activity and breeding of sea cucumbers [22]. Temperatures <23°C will slow down growth, while temperatures >32°C will cause stress because it's too hot for sea cucumbers and will cause a decrease in dissolved oxygen levels in the waters.

The source of dissolved oxygen in the waters is the result of the diffusion process from free air and the results of the photosynthesis process of plants in these waters [25]. The depth of the water also affects the dissolved oxygen content. The dissolved oxygen level at the surface will be higher because of the process of diffusion between water and air and the process of photosynthesis. Dissolved oxygen is needed for marine biota for respiration, metabolism for growth, and reproduction. The role of dissolved oxygen levels in the waters also functions in the process of reducing and oxidizing chemicals into simpler compounds as nutrients for biota. The process of exchanging dissolved oxygen and food needed by marine life, including sea cucumbers, is carried by currents in waters [22]. Currents that are too strong will damage cultivation support facilities, such as cultivation containers or cages. In addition to damaging the facilities, currents that are too strong will also damage the habitat of the sea cucumbers and cause stress for the sea cucumbers. Current conditions at the research site tend to be calm because of the barrier reef around the island.

The analysis of the suitability of the waters with the HSI model carried out at the research location showed moderate to good conditions. Station S2T1 and Station S2T2 are categorized as the most suitable points for *H. scabra* sea ranching in this study which are marked in dark blue on the HSI map. This is the point with the highest density of seagrass and organic matter among other points in the research location. While Station S1T2 is categorized as the most unsuitable point for *H. scabra* sea ranching in this study because the lowest HSI value is marked in red on the HSI map. The incompatibility of Station S1T2 is due to the low organic matter and density of seagrass which is included in the category of rare seagrass. The less-dense seagrass density is thought to affect the low organic matter because they act as a sediment trap, in turn, will be a food source for sea cucumbers. In addition, the less dense seagrass provides less protection for sea cucumbers from predators. The higher the density of seagrass, the more organic matter will be trapped at the bottom of the water [26]. This data provides information that the condition of Sintok Island is quite good for the habitat of *H. scabra* in which water quality was met with requirements needed for *H. scabra*.

Water suitability analysis is useful as an initial step in the process of preparing spatial plans and developing small islands and can prevent conflicts of interest in the use of space in resource utilization among stakeholders. Although the results have shown alternative locations that can be implemented for
cultivation activities and prospective conservation for *H. scabra* [13], management steps remain an important aspect to ensure the sustainability of cultivation and ensure the sustainability of natural resources at the same time. This is done so as not to cause new problems, such as environmental degradation in the future.

4. Conclusion

The water conditions of the western part of Sintok Island are categorized as the most suitable point for *H. scabra* cultivation with pH 8.16, dissolved oxygen 11.25 mg.L⁻¹, salinity 35 ppt, temperature 32.2°C, brightness 100%, organic matter 74.11%, chlorophyll–a 1.82 mg.g⁻¹, current velocity 0.05 m.s⁻¹, tide 0.87 m, depth 0.65 m, seagrass density 444.36 indiv.m⁻², and sediment classification in the form of sand. Based on the HSI model, points S2T1 and S2T2 are the most recommended points for *H. scabra* cultivation in the waters of Sintok Island which are shown in dark blue on the map.

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