Dynamic spatial allocation of scalloped spiny lobster (Panulirus homarus) in the coast of Gunungkidul, Indonesia

A Damora¹,²,³*, L Adrianto⁴, Y Wardiatno⁴, A Suman⁵

¹Department of Aquaculture, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Indonesia
²Aceh Climate Change Initiative, Universitas Syiah Kuala, Indonesia
³Marine and Fisheries Research Center, Universitas Syiah Kuala, Indonesia
⁴Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University, Indonesia
⁵Research Institute for Marine Fisheries, Ministry of Marine Affair and Fisheries Republic of Indonesia, Cibinong, Indonesia

*Email: adamora@unsyiah.ac.id

Abstract. The Scalloped Spiny Lobster (Panulirus homarus) is the most caught species of the genus Panulirus in the coastal waters of Gunungkidul. As a result of the high economic value of this species, its catch rate continues to increase. The management of lobster fishery is less precise when using conventional bioeconomic models due to several things, among others are the distribution of its stock is spread according to spatial distribution, low levels of fish resource mobility and the tendency to be biased if the spatial aspects are not taken into account. Growth, mortality, and recruitment parameters are also highly dependent on environmental conditions albeit within a small distance. A spatial bioeconomic approach was carried out to assess a utilization optimization model, by taking into account the biological, ecological, and economic characteristics of this species' capture. This research was carried out in six lobster landing locations in Gunungkidul District, Yogyakarta, Indonesia. Catchability, fuel price, selling price, total cost, and total revenue from each lobster landing locations were identified to determine the dynamic spatial allocation of fishing effort. We found that the capture of P. homarus in four lobster landing locations (Gesing, Ngerenehan, Siung, and Sadeng) can be optimized during peak catch seasons, while in Gesing and Siung can be optimized during catch drought seasons.

1. Introduction

The genus of Panulirus in Indonesia has been the research objects, including the biological aspects and distribution [1, 2, 3, 4, 5, 6; 7, 8, 9], fishing characteristics [10, 11], stock assessments [12, 13], and economics [14]. Fisheries activities in Gunung Kidul District are dominated by pelagic fish. In 2012, the production of pelagic fish reaches 941.3 ton, while lobster's only reaches 82.4 ton. Nevertheless considering the production value, lobster holds the highest contribution to all fisheries commodities reaching IDR 14,237,862,604,00 [15]. Scalloped Spiny Lobster (Panulirus homarus Linnaeus 1758) is the most caught species covering 47% from six species of lobsters caught in the southern coastline of Yogyakarta Special District [10].

The high economic value of P. homarus encourages fishers to do fishing without considering the sustainability of the resources and environment as well. An indication is seen from the decline of...
lobster catch result in the south coastline of Java where the highest contribution coming from Gunungkidul [16]. The condition is worse by the lack of fisher’s support to control fishing, for instance by controlling the number of catch and fishing method.

The exploitation rate of *P. homarus* in the coast off Gunungkidul was a low captured-average length [1]. The high intensity of fishing has suppressed the larger *P. homarus* so that smaller *P. homarus* are captured more. The level of utilization of *P. homarus* also indicates the presence of overfishing condition so that management and conservation efforts are required to reduce the fishing pressure of this species, especially in exploiting young lobsters.

In conventional bioeconomic concepts, there are some models being references, such as Gordon-Schaefer's static and dynamic model, the dynamics of catch-fleet distribution based on the Smith model, production mortality model, and the age structure dynamics model. However, conventional bioeconomic models are applied for fish resource conditions that are assumed to have homogeneity in spatial distribution and fishing effort. On the other hand, the management of some types of demersal fisheries resources is less precise when using conventional bioeconomic models due to several things, among others are the distribution of its stock is spread according to spatial distribution, low levels of fish resource mobility and the tendency to be biased if the spatial aspects are not taken into account, growth, mortality, and recruitment parameters are highly dependent on environmental conditions albeit within a small distance [17]. The purpose of this research is to analyze the optimum utilization model using spatial bioeconomic of *P. homarus*. The result of this study is expected to give input to the more optimum management of *P. homarus* in the coast off Gunungkidul.

2. Materials and Methods

2.1. Site and time

Data collection was conducted on February 2013 to May 2014 in six lobster landing locations. The selection of location was based on information stating that those locations are used to be the landing and marketplace during the lobster harvest and drought season (Figure 2).

2.2. Data collection

Collection of primary data was conducted by using a structural interview method in two approaches, focus group discussion and interviewing the key informants. The deep interview questions cover the production activities which are lobster price, catch operational cost such as the fishing vessel, machine, fishing gear, fuel and needs of crews.

2.3. Data analysis

The analysis is based on the fact that conventional bioeconomic model which satisfies the dynamic pool assumption and thus homogeneity in the spatial distribution and fishing effort is assumed [17] is slightly not applicable for some types of demersal fish resources. The character of lobster resources is the stock is spreading out according to spatial distribution (Figure 2).

The bioeconomic analysis in this study applies this model:

\[ f_{khm}(t) = \text{dynamic spatial allocation of the fishing intensity of vessel type } m \text{ from port } h \text{ among fishing ground } k \text{ in time } t \]

\[ SAE_{khm}(t) = \text{allocation spatial of fishing effort} \]

\[ \text{DAYS} = \text{average number of effective fishing days per month} \]
\[ V_{hm}(t) = \text{number of fishing vessel type } m \text{ of the port which seasonally allocates their fishing effort to target species} \]

\[ P_k = \text{probability of finding the target species at a profitable level in fishing ground } k \]

\[ \text{quasi}_{khm}(t) = \text{quasi-rent of variable cost received by fishing vessel type } m \text{ of port } h \text{ in fishing ground } k \]

\[ D_{kh} = \text{distance to the fishing ground to port } h \]

\[ \text{Ø}_m = \text{weighing factor (fraction of distance) for fishing vessel type } m \]

Then, the cumulative economic rent received by vessel type \( m \) from port \( h \) over the fishing season is estimated by:

\[ \text{(3)} \]

### 3. Results and Discussions

#### 3.1. Spatial ecology characteristics

The character of lobster resources’ stock distribution is spreading out according to spatial distribution in waters. The spatial character of six lobster landing locations regarding the ecological condition in the waters is identified. The parameters used are coastal topography, ocean floor topography, population and catchability of \( P. homarus \).

**Table 1.** Ecological character of six lobster landing locations in coast off Gunungkidul, Indonesia.

| Parameter               | Gesing          | Ngerenehan      | Baron           | Ngandong        | Siung           | Sadeng          |
|-------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Coastal (beach) topography | Edge dominated by cliff | Edge dominated by cliff | Edge dominated by cliff | Beach shores with sand substrate | Stach stones with small cliff | Edge dominated by cliff |
| Ocean floor topology    | Sloping         | Medium          | Medium          | Medium          | Steep           | Steep           |
| Population density     | Low             | Low             | Low             | Medium          | Low             | Low             |
| Catchability            | 0.50            | 0.70            | 0.30            | 0.30            | 0.60            | 0.60            |

Table 1 shows that the habitat characteristic of \( P. homarus \) in Gunungkidul District is the edge with cliff consisted of limestone reefs. The edge topography tends to be escarp with stach formed by the erosion of frequent big waves. The hole in stones becomes the home of \( P. homarus \).

Lobster \( Panulirus \) juveniles tend to be solitary in small holes or their nest, but later on, they will live in groups [18]. The habit to live in groups is their strategy to defense against the predator [19]. The habitat of \( P. homarus \) is in shallow waters 1-90 m, particularly between1-5 m. This species usually lives in reef area, sometimes in a murky area [20, 8]. Figure 2 shows that the average fishing ground of lobster is in 10-50 meters depth. The denser contour line in the map, the steeper the topography. While the thinner the contour line, the shallower the topography. \( P. homarus \) is mostly caught in medium up to steep topography. However, the less catchability is also caused by vast fishing ground between each landing location. The more and bigger fishing ground, the bigger catchability.
Figure 1. Connectivity between the landing site and fishing site as a basic spatial bioeconomic concept in Gunungkidul, Yogyakarta, Indonesia.

In addition, there are several rivers whose estuary is the southern coast of Yogyakarta, but with low population density. This creates less impact to the surface runoff on the beaches in the south of Gunungkidul District. Muddy waters where *P. homarus* usually live, are mainly influenced by rainfall rather than by surface runoff. Therefore, this type of lobster is often found during the rainy season [21]. It can be seen from the peak season of lobster fishing from October to January at six lobster landing sites in Gunungkidul District, while in drought season the lobster fishing occurs from February to August. These seasons are similar to penaeid shrimps fishing season in Segara Anakan coastal area that located in the southern coast of Java too [22].

3.2. Spatial bioeconomic

The bioeconomic concept occurs from the assumption when fishing is unregulated, under normal circumstances, it will reach a balance where the profit of the fishing effort is equal to zero. As long as there is a profit in fishing effort, vessels will be stimulated to participate in the fishing effort and utilization of inventory and with the common property principle stating that no one could prevent it, causing everyone is free to take part in the sector [23].

The bioeconomic model consists of three main components, which are stock, market, and fishers. This model is divided into two parts, one of them is biology with fishery stock and the other is the social-economic component whose component consists of market and fishers. Bioeconomic concept portrays description of the circle of fishing activities conducted by fishers. Fishers who make the fishing effort *(f)* on a fishery resource stock will provide catch result *(C)* which will be sold to the market. Transactions in the market and making money (IDR) are ways for fishers to provide their livelihood and capital to engage in fishing [24].

The analysis of the spatial ecological character of the six lobster landing sites, a comparison of fishing characters was performed based on the difference in the number of fishing fleets and the
number of lobster fishing trips each month. Baron and Ngandong beaches have a much larger number of catches than the other four lobster landing sites. It is because of in both regions, the fishing population is larger. *P. homarus* itself is one of the target species considered as high-value and easily obtainable target compared to other species of lobsters. The fishing of this target species is also driven by market demand by middlemen who accommodate lobster catches. The local market of lobster in Gunungkidul District itself is dominated by only several middlemen and the biggest one is in Baron Beach. Middlemen’s domination causes the price largely determined by them.

Spatial fisheries management requires an understanding of the spatial characteristics of species studied with appropriate heterogeneity abundance in space and time and ecological interdependence within the ecosystem [25]. From ecological and economic characteristics, the spatial bioeconomic analysis was conducted to obtain optimization model of *P. homarus* lobster resource utilization in Gunungkidul District, covering dynamic spatial allocation and total cumulative economic benefit from six lobster landing sites (Table 2).

**Table 2.** Allocation of dynamic spatial and total revenue of *Panulirus homarus* fishing in Gunungkidul, Indonesia.

| Parameter                                                                 | Season | Lobster Landing Location |
|---------------------------------------------------------------------------|--------|--------------------------|
| Number of vessels $m$ from landing location $h$ (unit)                    |        | Gesing | Ngerenehan | Baron   | Ngandong | Siung | Sadeng |
| Number of the actual trip in landing location $h$ (trip)                  | -      | 30     | 65        | 60      | 8        | 13    | 36     |
| Dynamic spatial allocation of fishing intensity from vessel $m$ from port $h$ and in fishing ground $k$ in time $t$ (trip) | Peak   | 101    | 141       | 30      | 30       | 108   | 193    |
|                                                                          | Drought| 206    | 52        | 23      | 7        | 210   | -79    |
| Total cumulative revenue received by vessel $m$ from port $h$ in the specific fishing season (in thousand IDR) | Peak   | 8,314  | 18,315    | 11,563  | 14,750   | 7,959 | 11,310 |
|                                                                          | Drought| 5,250  | 3,087     | 4,725   | 1,380    | 5,400 | 870    |

Table 2 shows that the difference in the dynamic spatial allocation of the catch intensity of the six lobster landing sites, where during the fishing season Sadeng Beach has the largest allocation compared to the other five locations. It is because Sadeng Beach has the largest trip allocation. The great number of this allocation can be caused by several things, among others are the acceptance of the sale of *P. homarus* in this location is greater than in other locations and the catchability of *P. homarus* is sufficiently high.

Fishing lobsters on Sadeng Beach are not recommended during the drought season because of the estimation of benefit is slightly small. It is marked by a very small total cumulative economic profit. The small amount of profit earned is allegedly due to greater operational costs. Optimization of fishing in this season should be done at Gesing and Siung Beach as these two locations have dynamic spatial allocation and total cumulative economic profit estimates.

The environment, geography, and topography of a location may cause cost heterogeneity and revenue with other locations [26]. Cost and revenue form a specific location may also change due to the environmental damage and local ecosystem. This cost heterogeneity and revenues is also
influenced by an ecological factor of harvest system. Therefore, considering that each fishing ground has its own heterogeneity, a spatial approach is essential in harvesting lobster. However, one major thing is this research is not fully applying the ecological limits of *P. homarus*, but still applying economical limits assumptions.

4. Conclusion
Fishing efforts of *P. homarus* in four lobster landing sites (Gesing, Ngerenehan, Siung dan Sadeng) in Gunungkidul can be optimized during peak season, while Gesing and Siung beach in drought fishing season. Determination of lobster fishing trip quotas during the lobster fishing season in Gesing, Ngerenehan, Baron, Ngandong, Siung and Sadeng respectively 101, 141, 30, 30, 108 and 193 trips per month. The lobster fishing trip quotas during the drought season in Gesing, Ngerenehan, Baron, Ngandong, and Siung beaches respectively 206, 52, 23, 7 and 210 trips per month.

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