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MULTI CONNECTIVITY SOCIAL-ECOLOGICAL SYSTEM OF SPINY LOBSTER FISHERIES (CASE STUDY: GUNUNGKIDUL REGENCY, YOGYAKARTA, INDONESIA)

MULTI KONEKTIVITAS SISTEM SOSIAL-EKOLOGI PERIKANAN LOBSTER (STUDI KASUS: KABUPATEN GUNUNGKIDUL, PROVINSI DAERAH ISTIMEWA YOGYAKARTA, INDONESIA)

Putri Agil Lestari[*1)], Luky Adrianto[2,3)], Zairion Zairion[2,3)] and Andi Zulfikar[4)]

[1)] Coastal and Marine Resources Management Study Program, IPB University
[2)] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University
[3)] Center for Coastal and Marine Resources Study (PKSPL), IPB University
[4)] Faculty of Fisheries and Marine Sciences, Maritim Raja Ali Haji University

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ABSTRACT

Spiny lobster fisheries production, provides a fairly high economic value compared to other fisheries commodities in Gunungkidul Regency. The high selling value of spiny lobsters is one of the main factors that encourage fishermen to carry out their fishing activities massively, so it can have a negative impact on the environment and spiny lobster stocks in the waters. This study aims to map the interaction and connectivity of the social-ecological system (SES) of lobster fisheries on the coast of Gunungkidul Regency. The analysis method utilized is Social-Ecological Network Analysis (SENA) with R stundio tools and Cytoscape version 3.9.1. Data were obtained from in-depth interviews using questionnaires with key informants based on purposive sampling techniques. The results of the analysis showed that there were 94 elements and 216 relationships in the basic network model of multi SES lobster fisheries. The key variables that most affect the lobster fishing network are fishing season, fishing activity, lobster stock, and fishermen's income. There needs to be synergy between the resources system (RS), resources unit (RU), resources actor (RA), and resources governance (RG) such as monitoring and evaluation from RG to other systems in order to create optimal and sustainable lobster fisheries management.

Keywords: Gunungkidul regency, multi connectivity, social-ecological system, spiny lobster.

ABSTRAK

Produksi perikanan lobster memberikan nilai ekonomi cukup tinggi dibandingkan komoditas perikanan lainnya di Kabupaten Gunungkidul. Nilai jual lobster yang tinggi menjadi salah satu faktor utama yang mendorong nelayan melakukan kegiatan penangkapannya secara masif, sehingga dapat berdampak buruk bagi lingkungan dan stok lobster di perairan. Penelitian ini bertujuan untuk memetakan interaksi dan konektivitas sistem sosial-ekologi (SES) perikanan lobster di pesisir Kabupaten Gunungkidul. Metode analisis yang digunakan yaitu *Social-Ecological Network Analysis* (SENA) dengan *tools R studio* dan *Cytoscape* versi 3.9.1. Data diperoleh dari hasil wawancara mendalam menggunakan kuesioner bersama para informan kunci berdasarkan teknik *purposive sampling*. Hasil analisis menunjukkan bahwa terdapat 94 elemen dan 216 hubungan pada model jejaring dasar multi SES perikanan lobster. Variabel kunci (elemen) yang paling mempengaruhi jejaring perikanan lobster adalah musim penangkapan, aktivitas penangkapan, stok lobster, dan pendapatan nelayan. Perlu adanya sinergitas antara sistem sumberdaya (RS), unit sumberdaya (RU), pengguna sumberdaya (RA), dan sistem tata kelola sumberdaya (RG) seperti pemantauan dan evaluasi secara berkala dari RG ke sistem lainnya agar tercipta pengelolaan perikanan lobster yang optimal dan berkelanjutan.

Kata kunci: Kabupaten Gunungkidul, lobster, multi konektivitas**,** sistem sosial-ekologi

[*] *Corresponding author: Putri Agil Lestari, putriagillestari12@gmail.com*
Institution and its address: Coastal and Marine Resources Management Study Program, IPB University; Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University

INTRODUCTION

Indonesia is one of the largest spiny lobster producers in Southeast Asia (Waluyo & Arifin, 2021). Spiny lobster resources can be found in almost all Indonesian waters, especially the southern waters of the Indian Ocean which are included in the State Fisheries Management Area of the Republic of Indonesia (WPPNRI) 573. Spiny lobsters in the southern waters of Java are interconnected and distributed starting from the Sunda Strait, Binuangeun, Palabuhanratu, Pangandaran, Cilacap, Kebumen, Gunungkidul, until Pacitan, East Java (Waluyo & Arifin, 2021). There are three coastal districts that have high spiny lobster production in the Special Region of Yogyakarta Province, are Kulon Progo Regency, Bantul Regency, and Gunungkidul Regency which have the longest coastline in the Yogyakarta Special Region Province (along ±70 km) (Putri *et al*., 2022).

Spiny lobster (*Panulirus* spp.) is one of the genera of Palinuridae family with high economic value in the international market (Damora *et al*., 2018). The coast of Gunungkidul Regency has nine spiny lobster producing areas, ranging from the West to the East including Gesing Beach, Ngrenehan Beach, Baron Beach, Drini Beach, Ngandong Beach, Siung Beach, Nampu Beach, Sadeng Beach, and, Purwosari Beach. Ngrenehan Beach, Baron Beach, and Drini Beach are beaches with a fairly high number of spiny lobster catches (almost reaching 30% of the total catch in Gunungkidul Regency) (Tirtadanu *et al.,* 2022). The composition of spiny lobster catches in Gunungkidul Regency in 2020 was 51% for pronghorn spiny lobster (*Panulirus penicillatus*), ornate spiny lobster (*Panulirus ornatus*) by 17%, painted spiny lobster (*Panulirus versicolor*) about 16%, and scalloped spiny lobster (*Panulirus homarus*) with contribution 10% (Suadi *et al.,* 2020). The high selling value of spiny lobsters is one of the main factors that encourage fishermen to carry out fishing activities continuously, so that this can have an adverse impact on the environment and the condition of spiny lobster stocks in the waters (Suman *et al.,* 2019).

Spiny lobster resources are strongly influenced by various ecosystem components such as water quality and also social components such as communities as resources actor (McGinnis & Ostrom, 2014). Community involvement with spiny lobster resources on the coast of Gunungkidul Regency, cannot be separated from the social-ecological system (SES), so a holistic view is needed to see the attachment between these components to encourage sustainable fisheries development. The existence of spatially interconnected, open, shared, and unreported spiny lobster fisheries has the potential for low availability of adequate data (data poor fisheries), including connectivity data. Based on this, the concept of SES approach is considered important in spiny lobster fisheries management.

Social-ecological system (SES) is a holistic approach between ecological systems that are closely related to and influenced by one or more social systems (Biggs *et al.,* 2022). Conceptually, multi connectivity SES of spiny lobster fisheries in Gunungkidul, will connect and assess between two or more SES connectivity at different research locations, including Ngrenehan Beach, Baron Beach, and Drini Beach. This study refers to the Ostrom (2009) framework which consists of sub-system of SES including resources system, resources unit, resources actor, and resources

governance which produces an output from the interaction from the four sub-systems of SES and is influenced by the presence of an external factor. Many studies on SES have been carried out in several ecosystems such as seagrass SES by Sjafrie (2016), SES of urban fisheries in estuarine by Taylor & Suthers (2021), and SES of Gulf Waters by Munawar (2020). However, among these studies there has not been a study on multi SES of spiny lobster fisheries on the coast of Gunungkidul Regency.

The integration of SES connectivity for spiny lobster fisheries is an important matter to study, so that the interactions and influences between one coastal location and another on the ecological system can be identified. There needs to be a study related to mapping SES of spiny lobster resources management as a result of the many interactions and relationships that occur in the social and ecological components on the coast of Gunungkidul Regency. The aim of this study is for mapping the interaction and connectivity of the social-ecological system of lobster fisheries on the coast of Gunungkidul Regency, Special Region of Yogyakarta.

RESEARCH METHODS

Study Period and Area

This research was conducted from November 2022 to January 2023 on the coastal area of Gunungkidul Regency, Special Region of Yogyakarta Province. The study was conducted at three spiny lobster landing sites which include Ngrenehan Beach, Baron Beach, and Drini Beach which are administratively located in three villages and two sub-districts. Ngrenehan fish landing base is located at Ngrenehan Beach, Kanigoro, Saptosari, Gunungkidul. Baron fish landing base is located at Baron Beach, Kemadang, Tanjungsari District, Gunungkidul Regency. Drini fish landing base is located at Drini Beach, Banjarejo, Tanjungsari District, Gunungkidul Regency (Figure 1).

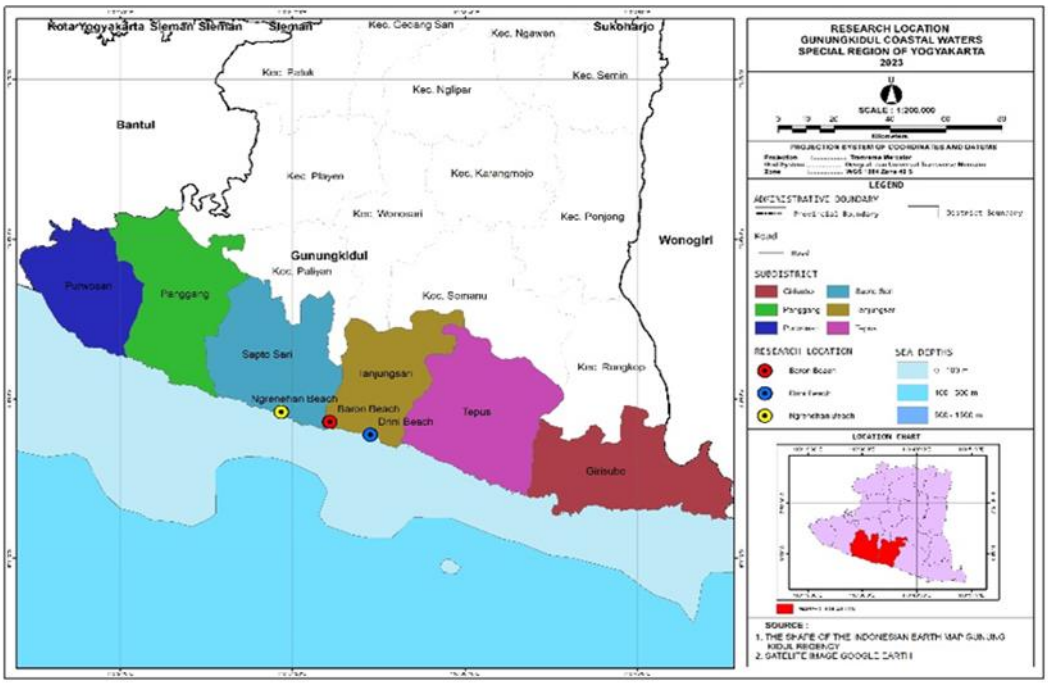


Figure 1. Spiny lobster Research Location in Gunungkidul Regency

Data Collections

The data in this study consists of primary data and secondary data. Primary data were obtained through direct observation, in-depth interviews using structured questionnaires and focus group discussions (FGDs) on fishermen and spiny lobster collectors by purposive sampling (finding key informants) on each beach as well as elements of the Marine and Fisheries Agencies (DKP) of Gunungkidul Regency and Special Region of Yogyakarta Province. Spiny lobster fishermen sampling is carried out by purposive sampling. Purposive sampling is an approach to find key informants who have a lot of information, using this approach several potential respondents are contacted or as initial contacts in helping to get other respondents through recommendations. Purposive sampling techniques, pay attention to certain criteria which include the relationship with the research topic, interests, willingness, concern for spiny lobster resource management, have special expertise and are key person, have good communication skills, are willing to be interviewed, understand problems related to spiny lobster fisheries, fishermen who have the main purpose of catching spiny lobsters and most of their catches is a spiny lobster, also is still classified as the age of the labor force or still actively carrying out spiny lobster fishing activities on the coast of Gunungkidul Regency.

The number of fishermen and collectors who were respondents in this study consisted of boat and non-boat fishermen (land or cliff fishermen) as many as 22 fishermen respondents and two big collectors at Ngrenehan Beach, 25 fishermen respondents and one big collector at Baron Beach, and 10 fishermen respondents, two big collectors, one small collector at Drini Beach (based on 10% of spiny lobster fisherman population on each beach) also one person from the Regional Agency, in this case is the Marine and Fisheries Agency of Gunungkidul District. These respondents are considered representative to represent the data, because it reach 10% of the population. Secondary data is obtained through regional statistics books from Marine and Fisheries Agency Gunungkidul District and Special Region of Yogyakarta Province as well as related scientific books or journals.

Data Analysis

Identification of The Basic Model of Connectivity Network of Social-Ecological Systems

Social-ecological system (SES) analysis of spiny lobster fisheries, uses the social-ecological network analysis (SENA) method which interactions and relationships between various social and ecological dimensions are first captured by identifying the basic network model of SES. Determination of the basic network model using the Ostrom framework, which is divided into sub-system of SES including resources system, resources unit, resources actor, and resources governance. SENA analysis was conducted to identify and analyze patterns of relationships, interactions and connectivity of SES (Munawar, 2021) at three different research location points. Components in the network (nodes) form an interaction and connectivity (edges) (Figure 2).

SENA identification process uses a variety of sources both from primary data (observations, interviews using questionnaires) and secondary data (official government reports, literature studies

or from several related previous publications). The measures in SES analysis starts from entering variables from the results of in-depth interviews obtained into the DIA diagram editor tools then run on R Software and R studio in the igraph and statnet packages as well as cytoscape 3.9.1 version to simulate the SES multi connectivity model. The type of network used is directed network (network with the direction of influence). The identification of the basic network is mainly focused around the elements and relationships associated with spiny lobster fishing activities in Gunungkidul District.

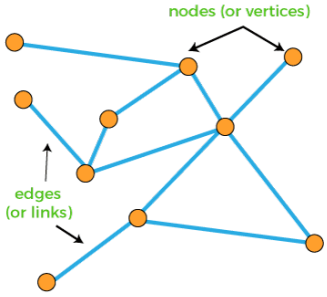


Figure 2. Edges and Nodes in SENA (Kluger *et al.*, 2015)

The Metric Value of Social-Ecological Systems Network

Network metrics are measured at two levels: the network level (the entire network) and the node (elements) also edge (connectivity/relationships) level.

a) Network level

Social network size: this analysis relates to how many members in a social network are symbolized in spheres (nodes, vertices, or actors).

- Density is the proportion of relationships (ties, edges, arc or relation) observed in social networks. The following formula is used (Biggs *et al*., 2022; Munawar, 2021):

$$\text{Density (}\textit{directed network}\text{)} = \frac{L}{k\,(k-1)} \quad (1)$$

Information:

L: the number of relationships observed in the network

k(k-1): is the maximum possible number of relationships between actors

- Network components: subgroups to which all actors are directly or indirectly connected.
- Network grouping coefficient: measures the tendency of networks to form relationship groupings

b) Node and edge levels

- Centrality: measures the central actors in the network by direction (directed network), considering the direction of the arrows into the element (in degree), out (out degree) and the total of both (total in and out degree). There are three ways to calculate the relationship value in this study, there are centrality degree (Cd), centrality betweenness (Cb), and centrality cluster or community detection (Cc) (Biggs *et al*., 2022).

  Centrality degree (Cd) is the number of connections a node has. Cd will calculate the weight of a node based on the number of edges formed between node (i) and other nodes. Calculating the value of centrality degree (Cd) is estimated using the following formula (Biggs *et al*., 2022; Munawar, 2021):

$$\text{Cd (ni)} = \frac{\sum_1^j eij}{N-1} \quad (2)$$

Information:

Cd (ni): centrality degree (ni) in the network (degree).

A: the number of corresponding nodes in the network (ni).

N : total number of nodes in the system

Eij : the edge between node (i) and node (j)

Centrality betweenness (Cb) calculates the weight of each node based on how much node (i) passes through by two other nodes based on their shortest path. The value of centrality betweenness (Cb) is estimated using the following formula:

$$\text{Cb (ni)} = \frac{\sum gjk\ (ni)}{gjk} \quad (3)$$

Information:

Cb (ni): centrality betweenness node (ni) in the network (edge point)

∑gjk (ni): the shortest number of paths through a node (ni)

gjk : Total number of shortest paths between (j) and (k) nodes

Centrality cluster (Cc) or community detection is one way to measure the value of centrality in a social network that focuses on how close an actor is to all other actors. Cc will calculate the weight of centrality of a node based on the shortest number of distances between node i and other nodes. Community detection is estimated using the following formula:

$$\text{Cc (ni)} = \frac{N-1}{\sum_{j\neq i}^{n} d\ (ni,nj)} \quad (4)$$

Information

Cc (ni) : centrality cluster

d (ni,nj) : distance between nodes (ni) and (nj)

N : the number of nodes in the network

- Social cohesion is a measure of connectedness between actors based on frequency, power and direct relationships (Wasserman and Faust, 1994). It is calculated using the following modularity values:

$$mod(\vartheta) = \sum_{K=1}^{K} [fkk(\vartheta) - f_{kk}^{*} \quad (5)$$

Information:

ϑ ={C1,...Ck} is a candidate network partition and specifies the value fij= fij(ϑ) as the fraction of the origin network relation connecting Ci with nodes C*j*. f_{kk}^{*} is the expected value of the fkk (the k row and column of the sum f of the K x K matrix formed based on the fij input. Some of the community detection algorithm options in the R package are: walktrap, edge betweenness and propotion labels. The algorithm that produces the highest modularity value to be used in the analysis results.

RESULT AND DISCUSSION

Basic Model of Social-Ecological System Connectivity Network

The conceptual model resulting from the interaction between sub-system of SES of spiny lobster fisheries on the coast of Gunungkidul Regency was known to be very complex. This complexity is formed because of the high dependence of the relationship between the social system and the resources system (ecology) that occurs. The basic SES network at Drini Beach, Baron Beach, Ngrenehan Beach (Figure 3), and SES multi connectivity as a whole in all three beach locations (Figure 4) were mapped based on sub-system of SES. The resources system (RS) includes ecosystem areas that contain various kinds of aquatic resource life (biotic and abiotic), thus forming a system that influences each other. RS usually a place or activity for resource utilization by fishermen. Resources unit (RU) is a unit of biotic resources that occupies an ecosystem and can be utilized by resources actor. Resources actor are actors in utilizing resources, generally to obtain economic benefits. Resources governance is a governance system such as policy makers from both government and private institutions who have concern for the existence of resources.

Spiny lobster resources are one of the important fishery commodities on the coast of Gunungkidul Regency. This is because the coastal geographical condition of Gunungkidul as a resource system is dominated by steep cliffs as the main habitat for spiny lobsters (Febriani *et al.*, 2014). There are at least five spiny lobster fishing grounds distributed, starting from sub-district Girisubo (Wediombo and Sadeng), sub-district Tanjungsari (Baron and Drini), sub-district Saptosari (Ngrenehan), sub-district Panggang (Gesing and Kesirat), sub-district Purwosari (Purwosari, Parangendog, Parangracuk), as far as Parangtritis Beach, that located in the southern part of Gunungkidul Regency. Generally, this location is often targeted by fishermen of Drini, Baron, and Ngrenehan beaches to catch spiny lobsters. It fishing ground is also influenced by water quality which can directly impact the abundance of spiny lobster stocks in nature (Tirtadanu *et al.*, 2021).

Types of spiny lobsters that are commonly caught on the coast of Gunungkidul Regency are pronghorn spiny lobster (*Panulirus penicillatus*), scalloped spiny lobster (*Panulirus homarus*), longlegged spiny lobster (*Panulirus longipes*), painted spiny lobster (*Panulirus versicolor*), and ornate spiny lobster (*Panulirus ornatus*) (Aisyah & Triharyuni, 2010). Pronghorn and scalloped Spiny lobsters are among the dominant types of spiny lobsters caught by fishermen while ornate spiny lobster is a type of spiny lobster that is rarely caught, but was highly sought after by fishermen, because it has a higher selling value. Spiny lobster as a resources unit was not only used as an export commodity, but also for consumption and processing into various types of various cuisines, one of which was by the restaurant industry. The restaurant industry stands because of the potential for tourism activities, which were not far from the fish landing site.

Spiny lobsters at Drini Beach, Baron Beach and Ngrenehan Beach were in great demand by local and non-local tourists, resulting in increased spiny lobster prices. The increase was directly proportional to the increasing income of fishermen and the number of operating vessels. However, this turned out to reduce the value of catch per unit effort (CPUE) and have an adverse impact on

coral ecosystems that were spiny lobster habitats (Febriani *et al.*, 2014). The spiny lobster fishery supply chain, starts from fishermen who catch spiny lobsters (using the help of boats and without boats or just throwing fishing gear from the top of the cliff) then sell the catch to small collectors, from small collectors to big collectors. Generally, big collectors usually receive a large amount of catch from sales from small collectors (there is no minimum sales quota). Furthermore, big collectors will export it to exporters in Jakarta before being exported to international markets such as China, Hongkong, and Vietnam.

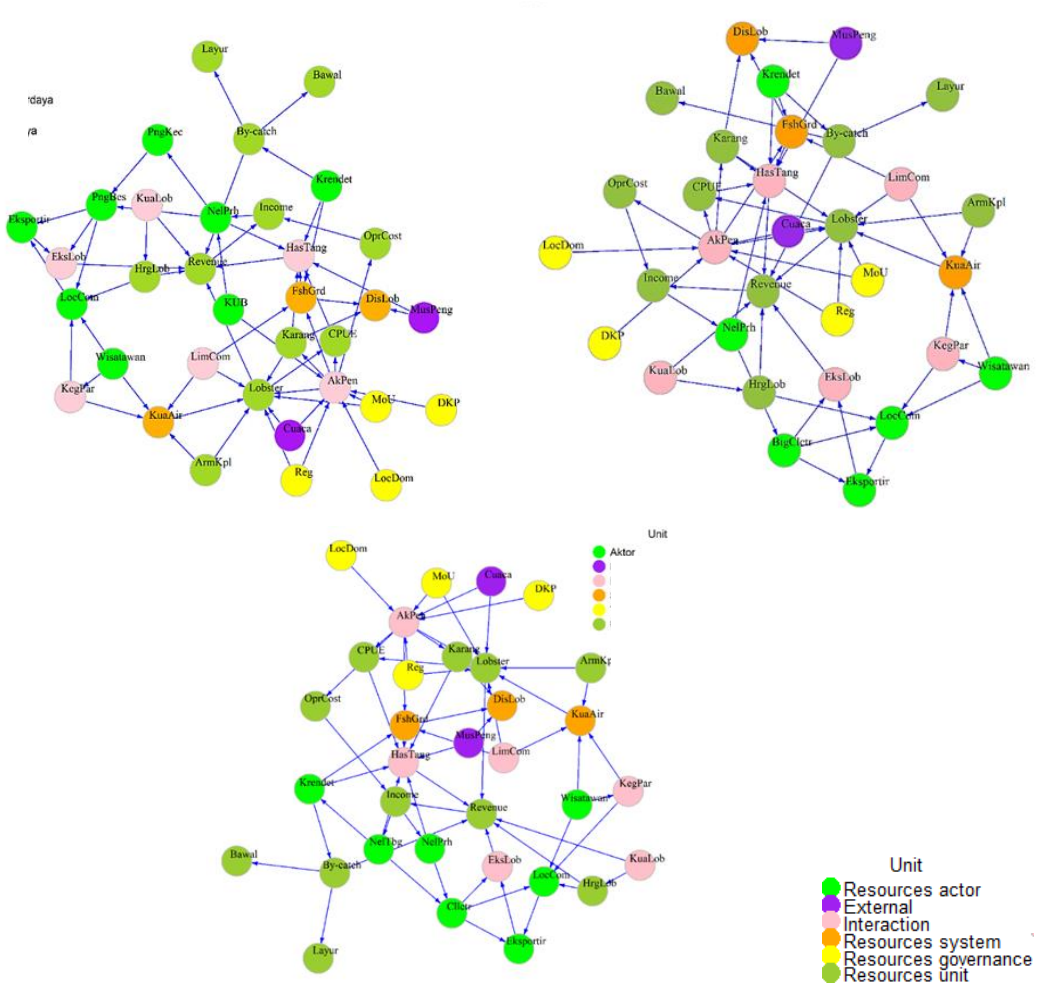
Gunungkidul fishermen usually catch spiny lobsters using Krendet and Renjos (modified by used nets into small pieces which are then ballast by fishermen) fishing gear. In addition, there was a fisheries joint business group (KUB), that becomes a forum or financier for fishermen if constrained by operational costs to went to sea, such as buying nets or fishing gear materials, ship fuel (fuel oil), and others. Though, spiny lobster fishing activities were strongly influenced by external factors such as weather and fishing season. This fishing season occurs around October to January along with the rainy season (Triharyuni & Wiadnyana, 2017). Outside of the fishing season, spiny lobsters were usually caught in few or no numbers. Another factor was that coastal fishermen of Gunungkidul Regency have local wisdom, which was not allowed for carried out fishing activities on Kliwon Tuesday. This also has an impact to the frequency of fishing fishermen, spiny lobster catches, CPUE value, also fishermen's net income (revenue) (Febriani *et al.*, 2014).

The components of resources governance there were quite a number of government agencies related to spiny lobster fisheries such as the Fisheries and Marine Agency of Gunungkidul District, the Fisheries and Marine Agency of Yogyakarta Special Region Province, academics or researchers, NGOs and regulations (national rules, regional rules, and local rules) that regulate the sustainability of their resources. Recently, the government of Gunungkidul Regency made a regional regulation in the form of a memorandum of understanding (MoU) with fishermen to agree that it was not allowed to catched puerulus (BBL) in all waters of Gunungkidul Regency. If this was violated, it will be subject to sanctions in the form of criminal acts or fines. This MoU began to be enacted on 12th of October 2022, not only applies to fishermen in Gunungkidul Regency but also applies for fishermen in Bantul and Kulonprogo Regencies. There was also a national regulation in the form of Regulation of the Minister of Marine Affairs and Fisheries Number 16th of 2022 related to the prohibition of catching puerulus. It is allowed to catch, but only for cultivation purposes, provided that cultivation was carried out in the same location as the BBL fishing location.

SES was built on relationships and interactions. Relationships and interactions between sub-system of SES are very important, to understand the behavior of a system (Ostrom, 2009). Drini, Baron, and Ngrenehan Beach which were part of the coast of Gunungkidul Regency have spatial and temporal interactions and connections that connect each other. In general, the three beach locations have SES interaction with almost similar activity patterns. Nontheless, the large number of operating vessels, the number of fishing gear used, the different types of spiny lobster fishermen (cliff fishermen and boat fishermen), the presence or absence of joint business groups (KUB) around

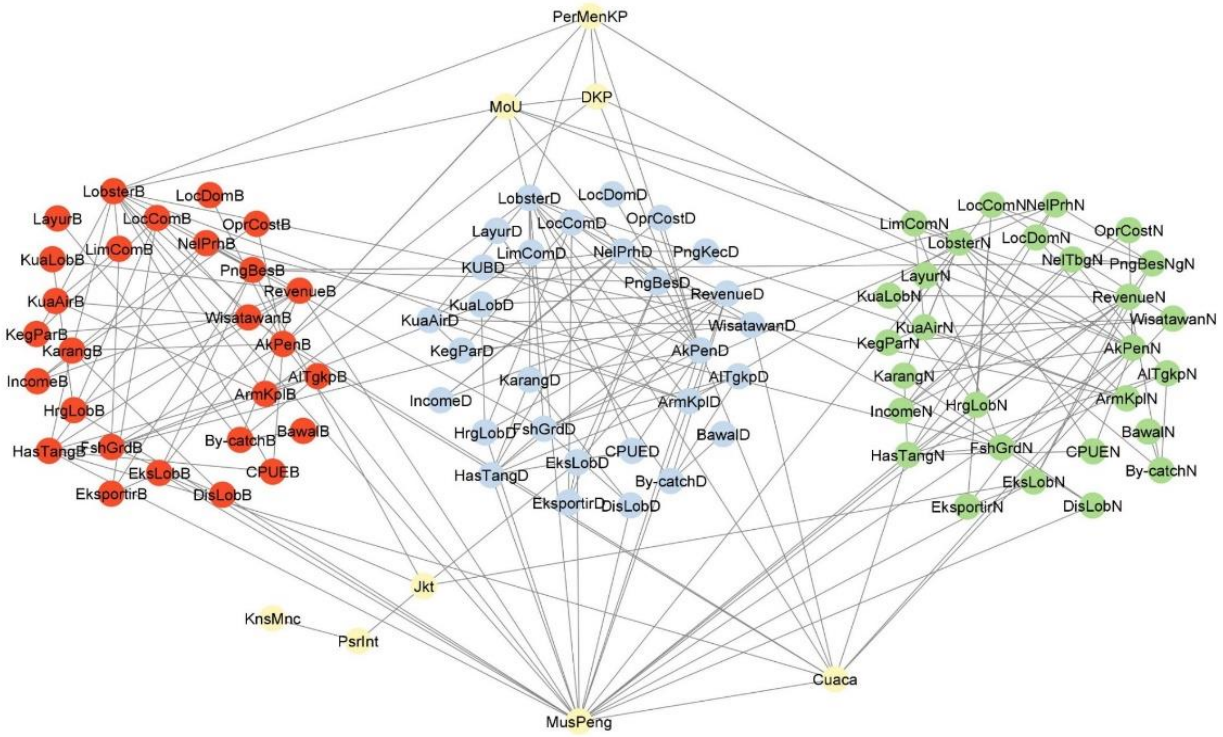
active fish landing sites, the number of collectors (small and big), were the differences in the pattern of fishery activities that occur on the three beaches. Cliff fishermen usually found more on Ngrenehan Beach while boat fishermen were found on Baron Beach which was the largest center of tourism activities in Gunungkidul Regency compared to Drini Beach and Ngrenehan Beach.

The catch of Ngrenehan fishermen spiny lobsters was generally more, when compared to the other two beaches because the geographical conditions were more dominated by cliffs or reefs which are the main habitat for spiny lobsters, the large fleet of ships operating, and the availability of adequate fishing gear. Collectors in this case become the key (connection) that connects fishery activities between Drini, Baron, and Ngrenehan Beach. There was also one big collector in Baron Beach who usually received fishermen's baskets or the proceeds from the sale of big collectors in Drini and Ngrenehan Beaches. Therefore, indirectly between one collector or collector at Drini, Baron, and Ngrenehan beaches are interconnected.



Description: Resources system includes fishing ground (FshGrd), Spiny lobster distribution (DisLob), water quality (KuaAir). Resources units include spiny lobster, coral, catch per unit effort (CPUE), fleet (ArmKpl), operational costs (OprCost), gross revenue (Income), Spiny lobster price (HrgLob), net income (revenue), by-catch (Layur and Bawal). Resources actor include boat fishermen (NelPrh), cliff fishermen (NelTbg), KUB, tourists, krendet, local industry (LocCom), small collectors (PngKec), big collectors (PngBes), exporters, and collectors (Cllctr). Resources governance includes regulations (Reg), memorandum of understanding (MoU), fisheries and marine agencies (DKP), local wisdom (LocDom).

Figure 3. SES Spiny lobster Basic Network Model at Drini (Top Left), Baron (Top Right), Ngrenehan Beach (Bottom Center)



Description: Red node (Baron Beach SES network), blue node (Drini Beach SES network), green node (Ngrenehan Beach SES network). Notes: Abbreviation information is in the figure 3 description.

Figure 4. Basic Model of Spiny Lobster multi SES Connectivity in Coastal Gunungkidul Regency

Connectivity of Social-Ecological Systems Based on Centrality Degree

Based on degree values, SES connectivity can determine how many variables one has a relationship or link with other variables in SES connectivity network. The size of node was based on how much it was related to other variables. This concept shows, that the greater the degree value of a variable, indicating that the variable was more important in a network system to connects other variables (Munawar, 2021). The value of centrality degree was estimated based on the number of relationships formed by one node with another node. In a system, there are at least one or two important variables (the core of the network) (Kluger *et al.*, 2015). There were two forms of relationships in the network of social-ecological systems of fisheries, that were out degree (the number of arrows pointing out) and in degree (the number of arrows pointing in). A change in one of the variables that has the highest degree value in a network, will have an impact on the system (Virapongse *et al.*, 2016). Therefore, the existence of these nodes becomes a key variable in the balance of relationships in the network. In Figure 6, the number of nodes was scaled based on the total degree value (the number of in and out arrows), the number of letters was scaled based on the out degree value while the darker color indicates the greater in degree value.

Descriptively, centrality degree in the SES network of Drini, shows that there were 34 components (nodes) and 60 relationships (edges), while in Baron were 32 components (nodes) and 56 relationships (edges), as well as 33 components (nodes) and 60 relationships (edges) on Ngrenehan Beach. The average density value of the three networks was 0.05 (the network was not

very dense), the modularity value was 0.46 and the network structure shows a random pattern (the assortavity value was close to 0). The main variables (nodes) that become the core of the network in spiny lobster fisheries on the coast of Gunungkidul Regency were spiny lobsters as resources unit, fishing activities (AkPen), and seasons (external factors) as nodes that arise from the interrelationship between resources unit and actors (fishermen).

AkPen nodes have the highest degree score in the network, which was 11 on Drini Beach and 10 on Baron and Ngrenehan Beaches. The next largest degree value was found in spiny lobster nodes of 10 on each beaches (Figure 5). As a result of multi cooperative network of SES spiny lobster fisheries (Figure 6), the fishing season (node MusPeng) becomes the core of the network in the spiny lobster fisheries system. This was in accordance with what has been stated by Triharyuni and Wiadnyana (2017), that spiny lobster fisheries were strongly influenced by the fishing season. The interconnectedness of the seasons can directly affect the presence of spiny lobster, fishing activity (AkPen), catches (HasTang), and other nodes.

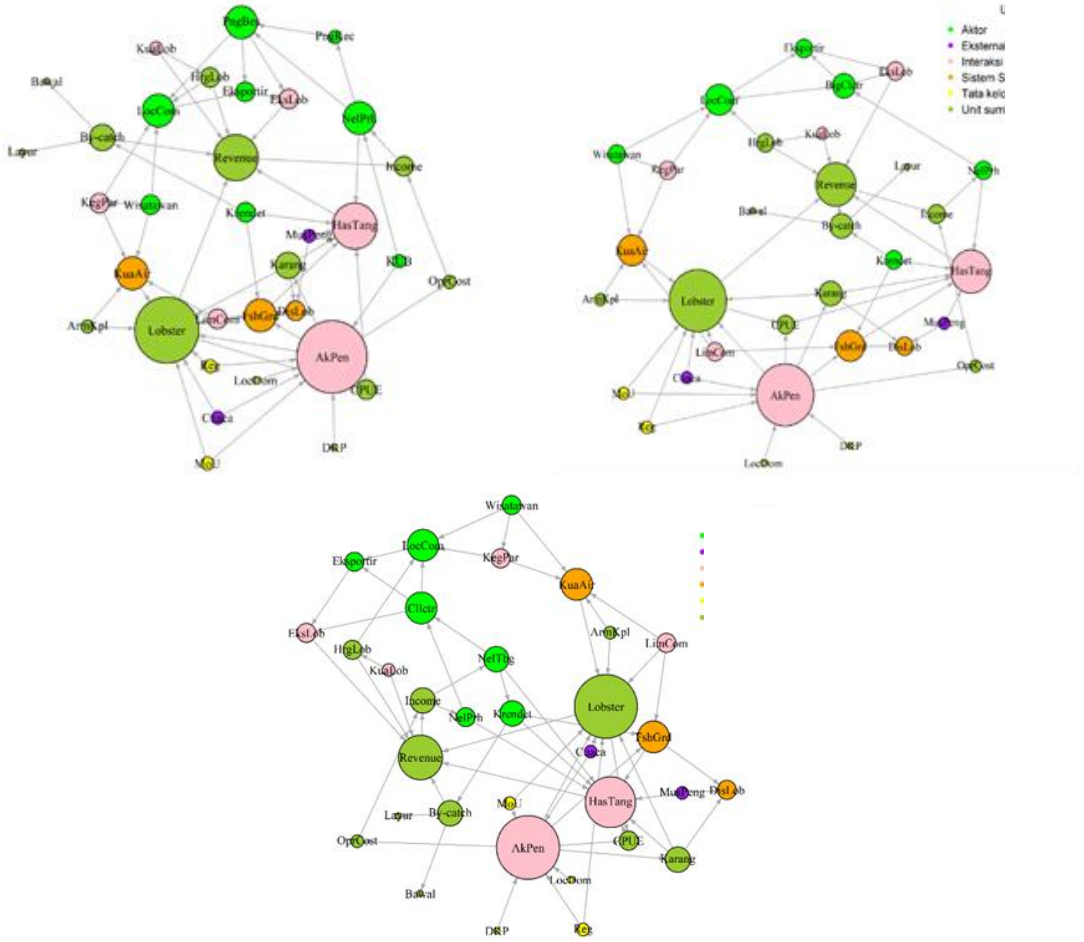


Figure 5. SES Connectivity Based on Degree Scores at Drini (Top Left), Baron (Top Right), and Ngrenehan (Bottom Center)

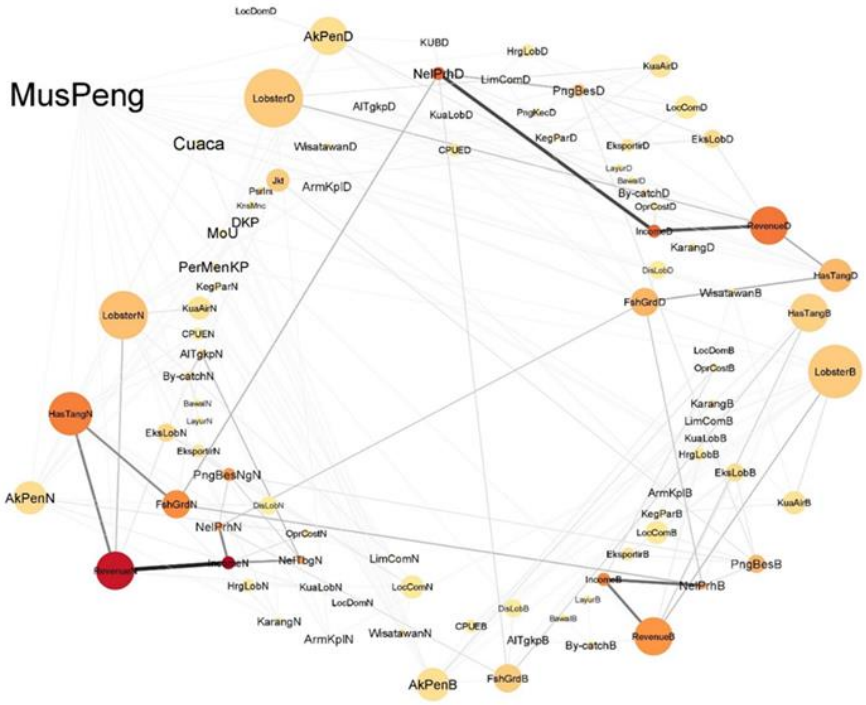


Figure 6. Multi Connectivity SES Spiny Lobster in Coastal Gunungkidul Regency

Connectivity of Social-Ecological Systems Based on Betweeness Values

The value of centrality betwenness, indicates a variable that acts as a liaison to other variables. The higher of the betweeness value of a variable, the more important the variable acts as a connecting path (Kluger *et al.*, 2015). The results of analysis in Drini Beach, show that the relationship between the income node and the boat fishing node (NelPrh) has a betweenness value of 152.00 and between the revenue node and the income node was 132.50. Baron Beach also shows almost the same thing. Another case with Ngrenehan Beach which shows that the node with the highest magnitude value was found in the income node with the NelTbg node of 293.00, and between the revenue node and the income node of 243.50. The value of these relationships was the highest aggregate value in the network of SES spiny lobster fisheries. The size of nodes and edges based on the magnitude of betweenness values in the network was presented in Figure 7.

Based on these results, it can be explained that there was a strong relationship between income, revenue, and NelPrh or NelTbg nodes. This indicates that fishermen's income was a central output from the existence of spiny lobster resources that were used directly by coastal fishermen in Gunungkidul Regency to support the economy and welfare of their families. Spiny lobster resources utilization activities were a form of interaction between the ecological system and the social system (Johnson *et al.*, 2019). Spiny lobster fishery business can grow in a positive or negative direction, one of which was determined by the existence of resource stocks. This was in line with the principles of fisheries management that sustainable and productive use of fishery resources, can ran well if it involves the active participation of all relevant parties as resource utilizers.

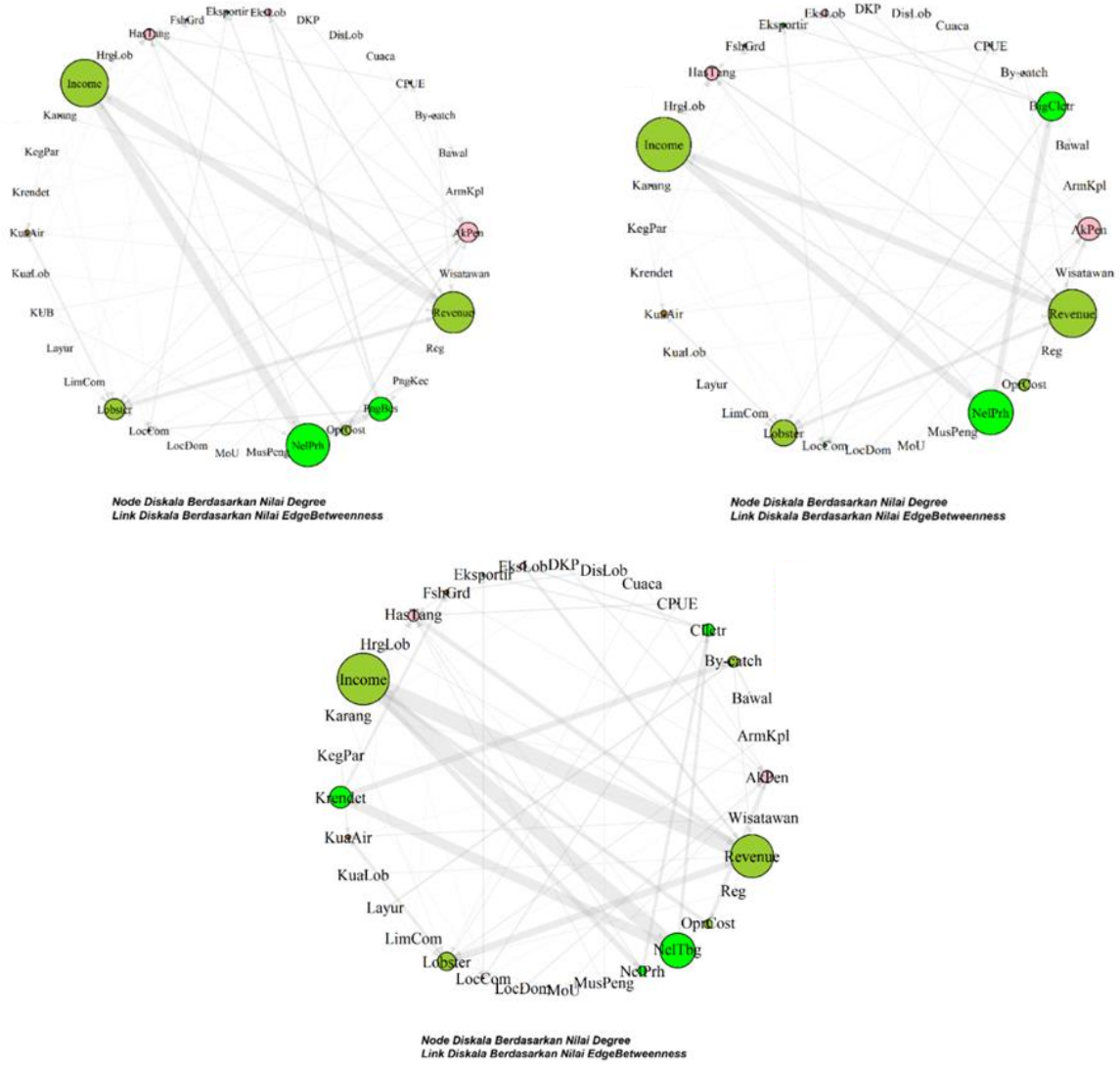


Figure 7. SES Connectivity Based on Betweeness Scores at Drini (Top Left), Baron (Top Right), and Ngrenehan (Bottom Center) Beaches

Connectivity of Social-Ecological Systems Based on Clustering Community

Clustering assessments naturally multiple group variables based on similarities in structure patterns and relationship characteristics. The clustering results show that there was a grouping in a SES network. Grouping was estimated based on the matrix of similarity of vertex values and edge betweenness (Munawar, 2021). Community detection was done using the walktrap algorithm. It has a higher modularity value compared to other algorithms. Community detection groupings on Drini, Baron, and Ngrenehan Beach were presented in Figure 10. The results analysis of the third coastal cluster show that there were five main groups in the SES network. Cluster one (I) includes income, OprCost, KUB, NelPrh, PngBes, PngKec, Exporter, Revenue, EksLob, Kualob, and HrgLob. Cluster two (II) includes LimCom, ArmKpl, KuaAir, LocCom, KegPar, tourists. Cluster three (III) includes DKP, LocDom, weather, Reg, AkPen, MoU, CPUE, and spiny lobster. Cluster four (IV) includes DisLob, MusPeng, krendet, karang, HasTang, FshGrd. The last cluster consists of by-catch (Bawal and Layur). The results of clustering on Baron and Ngrenehan beaches were not much different from

Drini Beach, the difference only lies in the variables of KUB, collectors, and types of Spiny lobster fishermen.

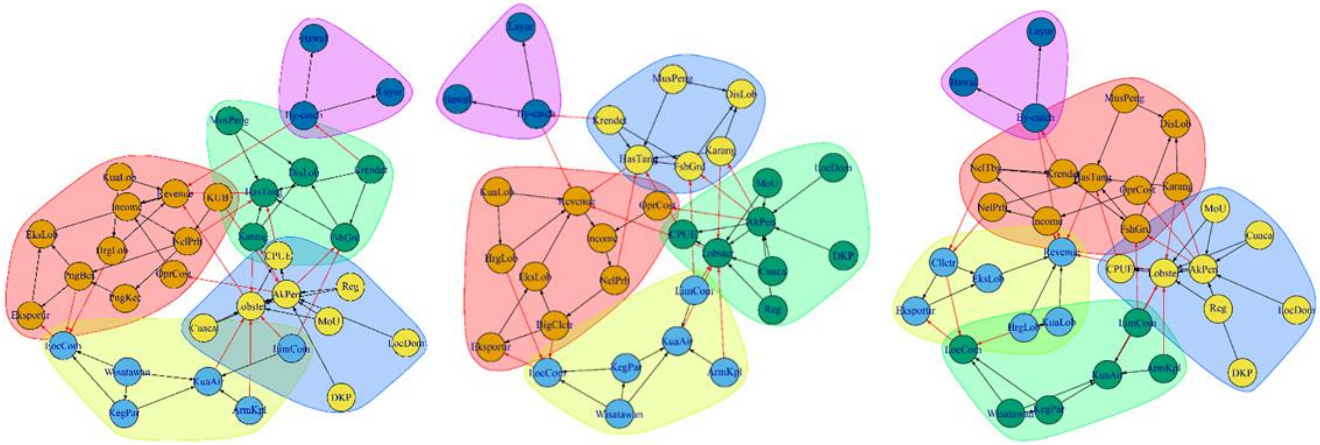


Figure 10. Cluster Community at Drini (Left), Baron (Middle), Ngrenehan (Right)

CONCLUSION AND SUGGESTION

Conclusion

In conclusion, there were 94 nodes (elements) and 216 edges (relationships) in the basic of multi SES network model of spiny lobster fisheries. The key variables that most affect the lobster fishing network are fishing season, fishing activity, lobster stock, and fishermen's income. There needs to be synergy between the resources system (RS), resources unit (RU), resources actor (RA), and resources governance (RG) such as monitoring and evaluation from RG to other systems in order to create optimal and sustainable lobster fisheries management.

Suggestion

Further research is needed on mapping the social-ecological connectivity of lobster fisheries as a whole at fish landing bases throughout Gunungkidul Regency for more comprehensive lobster fisheries management.

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