

Fishing methods and fishing season of the tropical lobster fisheries of Southern Java, Indonesia

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Abstract. *Setyanto A, Sumarno, Wiadnya DGR, Prayogo C, Kusuma Z, West RJ, Tsamenyi M. 2023. Fishing methods and fishing season of the tropical lobster fisheries of southern Java, Indonesia. Biodiversitas 24: 778-783.* Tropical lobster fisheries represent a relatively small-scale but valuable export industry in Indonesia, but in many ways may fall within the category of Illegal, Unreported and Unregulated (IUU) fisheries. The absence of useful fisheries information means the management strategies and plans to manage the fisheries is severely limited. This research aimed to provide information about the fishing gear, methods, and fishing season of the fisheries, as a precursor to the development of fisheries management strategies. The study was conducted at Watukarung, Pacitan (East Java) and Baron, Gunungkidul (Yogyakarta). Fisheries data on lobster catch, fishing methods and fishing effort were collected through direct observation and interviews with fishers, fishery officers and port managers. Catch data were analyzed using ordinations technique to determine the fishing season. Lobsters were captured in various fishing gears throughout the year, but fishers targeting lobsters primarily used specialized lobster nets deployed by small boats and “krendet” (traps) deployed from cliff-tops as well as from small boat. The main fishing season for lobsters was from November to February each year. Future research needs to investigate fishing capacity and population parameters before any comprehensive fisheries management can be undertaken.

Keywords: Baron, East Java, Gunungkidul, krendet, Pacitan, Watukarung, Yogyakarta

INTRODUCTION

World fisheries management has been prompted by industrial and large-scale fisheries (Schuhbauer and Sumaila 2016). Since the emergence of an overfishing problem in the early twentieth century (Ferguson-Cradler 2021), the management which take into account small-scale fisheries (hereafter SSF) has become a major concern of world fisheries (Smallhorn-West et al. 2022). Despite being common in national fisheries, there are important in socio-economic and food security (Spanier et al. 2015). However, the fisheries are more vulnerable due to declining ecosystem health and climate change (Stacey et al. 2021). Their rights to the resources are being marginalized and disadvantaged, so that need to be secured by justice in the blue economy initiative (Jentoft et al. 2017). Their contribution to global fisheries data in general are underestimated (Bartley et al. 2015). They are great spatial-temporal variation, multi gears and multispecies, wide dispersal of fishing activities, and uncertainty of landings (Halim et al. 2018). They may consider illegal, unregulated, and unrecorded for some reason (Saputra 2020; Song et al. 2020).

At the global level, Indonesian lobster production shows an increasing trend (Phillips and Pérez-Ramírez 2019). Not only consumption size, but Indonesian lobster production also includes wild lobster seeds, which are of particular economic concern to the country (Jones et al. 2019). The SSF is dominant in Indonesia fisheries. Among

them is a lobster fishery. It has economic, social, and ecological importance. South Java lobster fishery is the most influential contributor to lobster production in Indonesia (Nurfiarini and Wijaya 2019; Nurfiarini et al. 2019; Setyanto et al. 2020).

The SSF are generally very flexible and adaptive because they are used to changing conditions such as weather, fish prices and catches. In such conditions they, can carry out fishing activities by upholding and increasing fishing effort, changing fishing targets, and looking for new fishing areas (Ekawaty et al. 2020). It is considered an adaptive strategy to uncertainty. The single species approach in fisheries management has neglected the species composition of the catch, which is a consequence of the adaptive fishing methods of small-scale fisheries actors. The application of this approach will result in the design of an ineffective management strategy. It is very important to understand fishing operations and identify their impact on the stocks of fish resources being exploited. The behavior of small-scale fishermen is reflected in fishing operations which can be understood by identifying certain groups with the same and common characteristics (Humphries et al. 2019).

Therefore, understanding the behavior of small-scale coastal fishermen in allocating fishing gear in relation to external and internal factors is crucial for the effectiveness of management. The main problem is how to determine fishermen effort in adapting to external e.g., weather and fish prices (Zhou et al. 2014; Zhang et al. 2022) and

internal factors, such as competition among fishermen (Lee and Viswanathan 2022). Studies on the dynamics of fishing gear allocation in relation to external and internal factors have been widely carried out. However, this is still rarely done in the tropics.

The preliminary study is proposed to draw concern of developing an understanding of the decision-making behavior of fishers in allocating fishing gear. Herein, studies on exploitation methods and fishing season are hypothesized to be fundamental to improve the understanding and management of the SSF. This study examined fishing gear allocation in SSF in Baron Gunungkidul of Yogyakarta, Indonesia. The study site was chosen because it is representative of lobster small-scale coastal fisheries of Indonesia. The study examined the dynamics of fishing gear allocation by analyzing seasonal fishing trips and catch by fishing gear. The aim was to assess fishing method and seasonal variability of the fishers in allocating fishing gear in response to external factors. Finally, the relevance of the results to management of the SSF will be discussed.

MATERIALS AND METHODS

Study area

Two study sites were chosen for this research based on their known lobster landings. They were Baron, Gunungkidul of Yogyakarta province and Watukarung, Pacitan of East Java province (Figure 1). Tropical lobsters

are landed at both ports by fishers using a variety of fishing gears and methods.

The South Coast of Java, including Gunungkidul and Pacitan, is separated from the central agricultural areas by a limestone mountain range. The geographical location of Gunungkidul is between $7^{\circ} 46' - 8^{\circ} 09'$ of South Latitude and $110^{\circ} 21' - 110^{\circ} 50'$ of East longitude. And Pacitan is $7^{\circ} 55' - 8^{\circ} - 17'$ south latitude and $110^{\circ} 55' - 111^{\circ} 25'$ of east Longitude. Karstic landscape is distinct scenery found in the regions. Based on the Schmidt-Fergusson climate classifications, Gunungkidul is classified as “slightly seasonal” with 14-33% rainfall during wet months or rainy season, while Pacitan is “seasonal” with 33-60%. Agro-climatic zones of the two locations are different. Gunungkidul is “seasonally dry” (rainfall is less than 100 mm/month for 5-8 months), while Pacitan is “permanently moist” (rainfall is less than 100 mm/month for 0-4 months) (Whitten et al. 1996). The attitude of land varies between 0-500 m above sea level. The temperature ranges from 27° C to 32° C.

Located along the south coast of Java, both sites' reefs are classified as ‘continental fringing reefs attached to large island (Java). Baron and Watukarung are small fishing landings located at a relatively protected small bay with medium black sandy beach. The beach is quite flat, but the waves are strong within, which could reach further to land during high tide. The existence of such landing sites along the south coast is patchy due to the geomorphological conditions of the coast, which are hilly and cliffy.

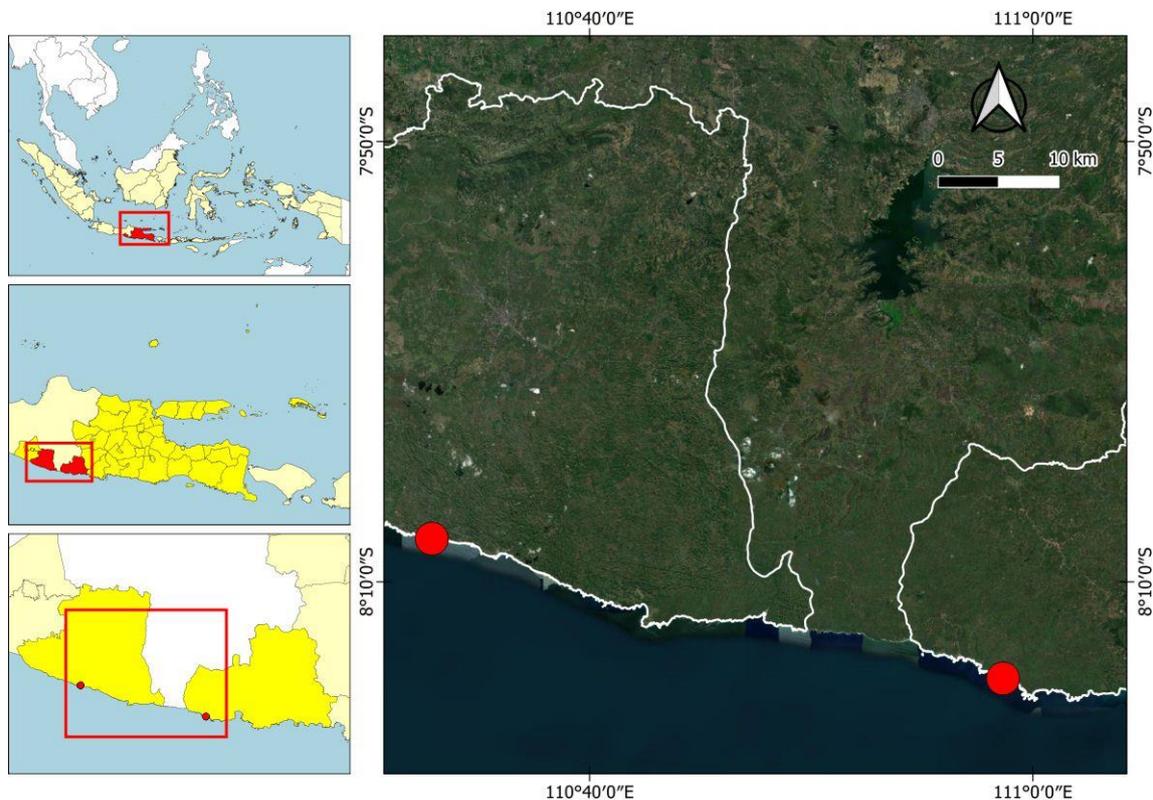


Figure 1. Study locations of Baron, Gunungkidul of Yogyakarta and Watukarung, Pacitan of East Java (red stars) of Java Island of the Republic of Indonesia

Fishing activity in these two locations is quite recent compared to other areas along the south coast of Java, such as Cilacap (Central Java), Indramayu (Banten), and Banyuwangi (East Java). Sea tenure is absent in both areas. But there are explicitly dynamic and adaptive norms and institutions regarding fishery tenet (Courtney et al. 2017). Marine catches of both landings consist of big and small pelagic fishes such as tuna, bonito, scads, and sardines, demersal fishes such as rays and pomfrets, and crustaceans including shrimps, crabs, and lobsters. Lobsters are among the most valuable commodities. And it is caught by local small-scale fishers. Most of the fishers are financed by buyers or collectors for their fishing activities and their daily live need.

Data collections

The study was conducted over three consecutive years, from 2010 to 2012. A range of data was collected and here we specifically report on the fishing gears and methods, as well as the catches landed at study locations. Other aspects of the fishery have been summarised elsewhere (Setyanto 2015). Information on the South Java Lobster fisheries at the two landing sites was both primary, in the form of interviews, and secondary, in the form of existing fisheries statistics kept at these local ports. Interviews were conducted with individual fishers and government officers and in group situations using previously prepared questions. Secondary data on these lobster fisheries were in the form of fisheries statistics books, reports, annual summaries, thesis, maps and catch reports made available from local Marine Affairs and Fisheries (MAF) offices (e.g., MAF in Yogyakarta Province, MAF in Gunungkidul Regency, and MAF in Pacitan Regency). Some information was also available at nearby universities (Gadjah Mada University, Yogyakarta and Diponegoro University, Semarang-Central Java).

Data analysis

General fishing seasons are figured and described from fisheries offices' annual and monthly catch production records. Lobsters' fishing season were estimated in more detail by looking at catches landed by species. Catch record data were copied from landings areas or auction offices. The data were then transferred into and analyzed using Principal Component Analysis (PCA). PCA is used to observe a temporal variation in species of catches landed. The similarities between two groups of variables (i.e., months and catch species) were demonstrated in the construction of PCA biplot. The relatively important species assemblages within each month were determined by constructing vector plot. The PCA was run using Statistics Program for Social Science (SPSS) 16.0.

Ordinations technique, that is PCA was used to analyse catch data. This technique is used to display the relative position of points (the species and the months), which allows investigation of pattern of variation and relationships among the points (Das et al. 2022). In other words, PCA was used to show temporal variation in species or catches compositions.

RESULTS AND DISCUSSION

Fishing gear and method

The South Java region has large numbers of fishers that operate small-scale fishing but overall generate large volumes of catches. Small fiberglass outrigger boats (~6m) are the major fishing vessels used by South Java fishers, including the lobster fishers. Fiber boat are preferred by fishers over wooden boat, as they are considered expensive and difficult to repair. Most fishing boats are powered by long shaft 5 horsepower motors located on the side of the boat. Lobster fishing is undertaken seasonally using specific gear –locally called lobster gillnets and krendet or hoop nets (described below). The other main fishing gears used in the region include (based on local names): Pomfret net, tuna-like species net, tuna-like species line, shrimp net, shark line, hair tail net, hair tail line and octopus hand line. Fishing gears such as sero (scoop net), throw net and hand line are considered alternative gears which do not generate major income for fishers, but are used for daily food and pocket money. The fisheries statistics book is unlikely classify those gears based on their local names but make used of a very general classification, such as: surface gill net, bottom gill net, drift gill net, mini long line, long line, hand line and another trap net (Table 1).

The South Java lobster fisheries consist of two main forms of fishing: fishing from small boats using gillnets; and fishing from the shore (cliff-tops) using krendets (baited entanglement traps) that are thrown and retrieved by hand. Some boat fishers use both fishing gears. The krendets (Figure 2A) are constructed with metal wire, bent on a 0.5-1.0 m diameter of circle, with a PE net of mesh size of 50-75 mm. A nylon rope attached across the middle of the metal wire is used to attach bait, such as marine snails, small crabs, or pieces of fish. Another nylon rope is used for retrieving the net. Small rocks and lumps of coral are used to keep the krendet fixed to the sea bottom. Lobster gill nets (Figure 2B) are about 80-100 m in length and 0.8-1.0 m in height and have a mesh size of 50-75 mm. The head rope of the net was fitted with plastic bottles or rubber floats and the foot rope was weighted down with small pieces of metals. The nets are anchored with stones that are placed at the corners of the nets. Both krendets and gill nets are generally set overnight.

One form of lobster fishing is hand fishing using the krendet traps from the cliffs along the South Java shorelines (Figure 3.A, left). This requires good climbing and balancing skills and is a dangerous and difficult form of fishing resulting in occasional falls and deaths of these specialized fishers. The fishers are locally called *cliff krendeters*. They mostly fish individually but also work in groups when fishing in difficult and dangerous fishing areas. This cliff-based fishery for lobsters can operate at any time during the year. Fish or mollusc are used as a bait in the krendet. The krendets set from cliff are deployed from the cliff top. Krendets or lobster net deployed from boat they are deployed as a longline set with multiple krendets or lobster nets joined by a mainline. Krendet set individually they set with individual surface floats.

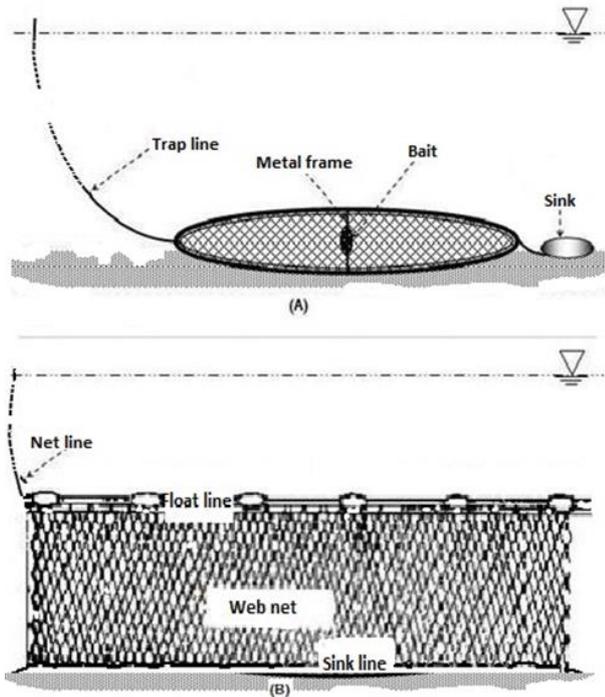


Figure 2. Design of krendet (A) and lobster net (B)

Boat lobster fishers can use both krendets (Figure 3.A, left) and gillnets (Figure 3.B). These fishers depart in fishing vessels from the fishing ports at around 4-5 am and return between midday and mid-afternoon. The trip to the fishing grounds can take between 20 min and 2 hours. There are generally two to three fishers working on each fishing vessel. They typically spend approximately 5 to 7 h recovering the gill net and/or krendets out of the water, collecting the lobsters and placing the gillnet back into the water krendets are taken back to shore to be re-baited before returning to the water in late afternoon. Broken gillnet and krendets are also taken home to be fixed. The lobster boat fishery generally operates through the summer rainy season, during relatively calm periods (Milton et al. 2014). There are often long periods when the fishing vessels cannot operate as sea conditions are too rough.

Lobster fishers using both methods return to fishing ports and local markets around midday or mid-afternoon and generally sell their live lobsters directly to middlemen, called *bakul* and/or *pengepul* (collector). These middlemen usually maintain seawater tank facilities to keep the lobster alive until they are exported (e.g., to Hong Kong), usually through a specialized live-export company (e.g., in Jakarta, Surabaya, Pacitan and Denpasar). Lobster gill nets and krendets exclusively target lobsters, but several other fishes (teleosts), molluscs, and crustaceans are caught as by-catch.

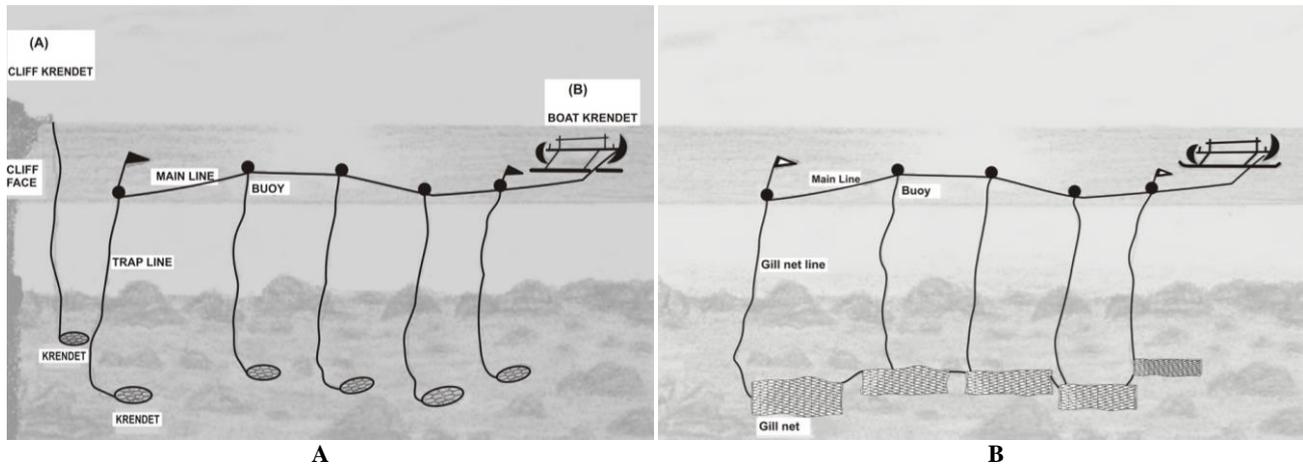


Figure 3. A. Illustration cliff krendet (left) and boat krendet (right) fishing method. B. Illustration of lobster gill net fishing method

Table 1. Fishing gear operated by small-scale fisher of South Java (collected from landing site of Baron of Gunungkidul and Watukarung of Pacitan).

English name	Local name	Gear type	Target species
Lobster net	<i>Jaring lobster</i>	Bottom set gill net	lobster
Lobster hoop net	<i>Krendet</i>	Entangling hoop net	lobster
Pomfret net	<i>Jaring bawal</i>	Drift gill net	Pomfret
Tuna-like species net	<i>Jaring tongkol</i>	Surface gill net	Tuna like species
Tuna-like species line	<i>Pancing tongkol</i>	Mini long line	Tuna like species
Shrimp net	<i>Jaring udang</i>	Trammel net	Shrimp/prawn
Shark line	<i>Pancing hiu</i>	Mini long line	Shark/rays
Hairtail net	<i>Jaring layur</i>	Surface gill net	Hairtail
Hairtail line	<i>Pancing layur</i>	Vertical hand line	Hairtail/
Octopus line	<i>Pancing gurita</i>	Hand line	Octopus

The lobster fishing season was investigated, relative to other fishing seasons, by analyzing frequencies of daily catches landed by species recorded at Baron Landing Places. Catch species or catch categories were based on the Baron catch data records, which were then compiled as shown in Table 2. Some categories are not based on a scientific classification but are commonly named groups, such as a “mixed species” category, which can include groupers, squids, swimming crabs and anchovies. Catches categorized as mixed are usually small quantities and considered by-catch to a targeted species. Mixed catches do not go to collectors but is sold at a local market. Local officials often start a new catch category when it is landed regularly in relatively high volume. For example, in 2012, “octopus” started to be recorded in the catch book record of Baron Landing place, as there were increasing demands for, and catches of octopuses. Even though octopus was targeted in other areas, such as Banyuwangi, Jember, Blitar and Malang, where it was a valuable catch and one of the main fishing targets of the fishers, records for octopus were not kept at Baron Landing place until 2012. The development of the octopus’s fishery in Pacitan and Gunungkidul began when local collectors introduced fishing gears and fishing methods for octopus to local fishers and lent the fishers octopus fishing gears. Also, they invite lobster fishers from other areas to deliver their expertise of knowledge to local fishers. It could be a sign of the establishment of patron-client relationship.

Fishing season

There is temporal difference in the structure of the species landed within a year (Figure 4). There are 13 species or categories of catch recorded as a data matrix. The months are available as explanatory information. These species are found clustered in three different vectors representing different fishing seasons. The first cluster is a fishing season for lobsters, octopuses, hair tails, king mackerels, prawns, frigates, mix species, and black

pomfret, which occur temporally between November and February. The second cluster is for: snappers, silver pomfret, sharks, giant catfish, and rays which appears in August, September, October, and March. The period from April to July has no fisheries categories recorded. This cluster confirms that there is an off-season in the fisheries in South Java. These results indicate that lobsters' fishing season is primarily from November to February. A low season occurs during August, September, October, and March. Finally, there are no landings of lobsters between May and August (Figure 4). These temporal differences in the fish species and categories landed at the Baron landing place may also reflect a temporal difference in the fishing gears deployed by South Java fisher. The most common type of lobster caught in southern Java is *Panulirus. Homarus (Scalloped Spiny Lobster/udang pasir)* followed by *P. penicillatus* (Pronghorn Spiny Lobster/udang batu), while the least caught was *P. polyphagus* (Mud Spiny Lobster/udang pakistan). On the other hand, on the North Coast of Java where *P. polyphagus* is the dominant catch (Setyanto et al. 2018, 2019, 2020).

Discussion

Lobster fishing gear and method

South Java lobster fisheries could be categorized as SSF considering their small capacity fishing boat and simple but diverse fishing gears, which operationally relatively low-capital investment and low-energy intensity (Halim et al. 2018). The fisheries may also be defined as multispecies due to its diversity of gears and target. Besides lobster gear, fisher may have 8 to 10 gears with different methods generally categorized as trap net, gill net, and long line. The boat is well-known as fiber boat because it is made from fiberglass with bamboo outriggers on both sides. The boat has dimension of about 9.5-10.5 m in length, 0.8 m in height and 1.5 m in width. The boat can land and load anywhere, including at any type of fishing port as there are no regulations such as port state measure upon the boat.

Table 2. Frequency of catches landed per day at TPI Baron during 2009-2011 (source of data: TPI Baron, Gunungkidul of Yogyakarta)

Months	Black pom frets	Silver pom frets	King mackerels	Snappers	Hairtails	Giant catfish	Frigates	Sharks	Rays	Mix	Lobsters	Prawns	Octopuses
1	29	1	3	8	11	9	11	2	4	20	18	16	n.a
2	20	0	10	12	9	12	18	2	3	15	23	19	n.a
3	21	1	4	25	2	20	32	9	13	38	13	18	n.a
4	19	6	0	12	1	9	17	1	5	20	12	10	n.a
5	18	1	1	8	3	7	5	1	4	11	13	10	n.a
6	0	0	1	2	0	4	0	2	3	4	3	1	n.a
7	3	0	1	3	0	7	0	4	9	5	5	9	n.a
8	1	0	11	15	0	14	10	0	7	20	5	5	n.a
9	2	0	9	11	4	14	15	7	13	19	6	4	n.a
10	11	0	4	11	8	13	48	10	7	27	8	4	n.a
11	4	0	12	16	26	8	22	5	6	36	28	6	13
12	15	0	10	0	14	0	10	1	1	10	15	15	14

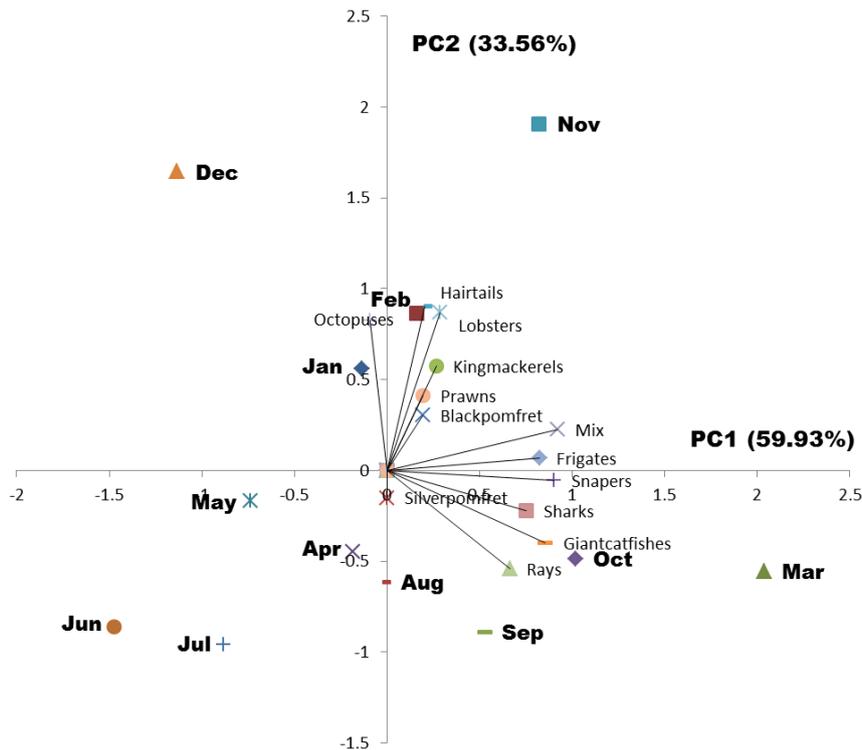


Figure 4. PCA biplot of relative fishing season by species categories at Baron, Gunungkidul of Yogyakarta. PCA reduces data by geometrically projecting them onto lower dimensions called principal components (PCs). Two axes or principal components (PC 1 (59.93%) and PC 2 (33,56%)) were used as they captured most variations of the point of the data

Krendet and gill nets are passive fishing gear. During fishing operation, the gears are laid down on the surface of sea bottom at the lobster's fishing ground. The fishing ground's depth ranges from a depth of 1 meter to a deep of 100 meters. One set of fishing gear of krendet may consist of about 50 to 150 units, while a set of gill nets is around 5 to 30 pieces. Krendets or gill nets set from the boat are deployed using a longline system (Figure 3 and Figure 4). On every fishing trip, there are 2 or 3 fishers on boat. A lobster fishery is one day fishing. Fisher goes fishing before sunrise and get back just about noon time. The cliff krendeter, on the other side, fisher is used for fishing individually, deploying 5 to 20 krendets set separately.

South java lobster fisheries, having its fishing gear and its fishing method, could give the idea on how to estimate their fishing effort. An appropriate unit of effort for lobster fisheries could be a gear unit per trip. Unit of boat, number of fisher and trip alone will lead to an underestimate of the effort as a boat could have tens to hundreds of unit of fishing gear owned by 2-3 fisher. Not only for lobster fisheries, may it also be applied to other fisheries which are regarded as small-scale. Presumably, total effort given by every fisher may turn tenfold of those lobster fishers as every local fisher has approximately 8 to 10 gear types. Under these circumstances, it is very urgent to count a proper effort of SSF for better fisheries management in emerging countries like Indonesia as they are the majority compared to other fisheries categories. These fisheries involve many fishers, which are widely dispersed over large areas. The fisheries capture hundreds of species with a variety type of fishing gear. The fisheries provide food and income for

majority of people. Many are poor and marginalized in their community (Azmi 2021).

Consequently, within those states, over-capacity issues in SSF are likely common in countries like Indonesia. The impact of overcapacity on the resources and its environment is known to be massive. Likewise, their national production could be more than threefold from the official statistical data. It is because the fishery has been ignored in the management processes, which may prompt the engagement of illegal, unreported, and unregulated (IUU) fishing practices (Song et al. 2020). One excessive impact of IUU fishing is overcapacity which could lead to derelict lobster fishing gear. The approximate derelict fishing gears of south java lobster fisheries had been estimated as much as 0.3 per year (lobster fisher personal comm.). These gears may be lost or abandoned underwater, leading to a ghost fishing problem. This problem may be the case of lack of effective management of fishing capacity. Therefore, it is urgent need to develop strategies to reduce fishing capacity. It is stated that strategy of fishing capacity reduction of the already overcapacity fishery is on people related solutions (Pomeroy 2012), i.e., selective and species-specific fishing gear.

Another excessive impact of overcapacity in lobster fisheries would be selectivity of the fishing gear. It is affirmed that there is almost none for any type of baited trap to be 100% selective targeting just a single species (Butcher et al. 2012). To minimize unnecessary catches, pollution, and ghost fishing it was suggested that large escape vents of pots and restriction of hoop nets are compulsory (Butler et al. 2022). Accordingly south java

lobster trap known as krendet is unlikely to be selective and effective. Neither is lobster net (gill net), both gears entangle lobsters with disrespecting their size. Both gears are unlikely to fulfill *the ideal fishing gear* criteria of FAO Code of Conduct (1995). This may of consideration of input control management. But when reducing fishing capacity is difficult to achieve, strategic management for the fisheries focuses on developing fishing gear technology by promoting more selective and effective lobster's fishing gear.

Lobsters' fishing season

Lobster fishing season runs from November to February. Within this season there is also fishing season for octopuses, hair tails, king mackerels, prawns, frigates, mix species, and black pomfret. Fishers use specific fishing gear to catch one of those fishing targets. Compared to other fishing target, fishing for lobsters is more profitable. Lobster fishing season is congruent with the rainy or wet season in the region. Rainy season is influenced by humid breezes air masses from Asia and the Pacific Ocean that is brought by the northwest monsoon to the southern hemisphere (Boavida-Portugal et al. 2018). The northwest monsoon, also known as Australasia, usually flows from December through February (Tangang et al. 2020). Apparently, during this season, local fishers have begun to fish for octopus since lobster catch is decreasing and when it gives certain catches than lobsters.

Off-season for lobster take place in two periods of times. First, off-season for lobster but fishing season for others such as snappers, silver pomfret, sharks, giant catfish, and rays which appears in August, September, October, and March. It depicts that lobster fishers can still do fishing activities whenever there are other fishing seasons in the area. Second, off-season for all fishing activities where there are no landings from April to July. During this season, they may farm and run their farmland and livestock. If they do not have it, they may become a migrant worker or farms labourer. Another choice is that during off-season, they spent most of the time fixing and repairing fishing gear, boats, and machines. Having no job to earn money they may still get an easy, simple, and quick loan from local creditor. So that they are not only able to fulfill their daily need for their family but also do some preparation for the following fishing seasons. Here we may find the role of patron-client relationship that becomes a social importance for SSF communities (Ferrol-Schulte et al. 2014).

Previous studies have shown a correlation between lobster population and environmental factors such as sea level, sea surface temperature, and southern oscillation index (SOI) (Boavida-Portugal et al. 2018). It is believed that every geographical different has their own physical and biological process maintaining species diversity and overall community structure within temporal and spatial scale (Hopkins et al. 2021). Knowing fishing season ones may be able to predict temporal and spatial operation of various fishing gears, which is important for developing better fisheries management strategies upon output and input control.

In conclusion, south Java fisher has been exploiting lobster by deploying lobster net and krendet net. Overcapacity with an excessive impact of ghost fishing could be critical if management strategy, i.e., input control is absence. Gear technology modification is necessary to promote sustainable lobster fishing gear.

A study on fishing methods and fishing season could provide the best study on any available information in the fisheries, which may turn out into output and input control management strategies. Future study on fishing capacity catches relative composition and abundance, gear allocation, and biological assessment to deliver comprehensive information for better management strategies are compulsory.

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