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Application of Global Positioning System Tracker to Detect the Fishing Ground Location and Effective Effort in Artisanal Fishery

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Information on the fishing ground location and effective effort plays important roles in fishery management. Using this information, we could conduct the analysis of fishery spatial management and effort standardization. A global positioning system (GPS) tracker and a GPS logger have been well developed and allow a wide range of applications in many sectors because the sensors and logger have become more affordable with good resolution and high accuracy. In this study, we intend to use the GPS tracker in capture fishery application to obtain details about the fishing ground location and as an effective method for artisanal grouper fishery. Eight GPS tracers were installed on 10 boats for grouper fishery in Saleh Bay, West Nusa Tenggara Province, Indonesia. On the basis of the GPS position, we could plot their fishing ground and also measure the distance for each trip and the time required for each fishing operation. Results of this study showed that the fishing grounds of grouper fishing boats were 5–10 nautical miles from the fishing landing port and mostly at the western part of Saleh Bay. In general, speargun and hook and line (troll line and handline) fishers had different fishing grounds, where speargun fishers tend to fish within a marine protected area (MPA) and hook and line fishers tend to fish in the southern (outside) part of the MPA. From the results of this study, a similar analysis method could be utilized in Banyuwangi sardine fishery for the science and technology research partnership for sustainable developments project (SATREPS).

1. Introduction

The global positioning system (GPS) is a network of 24 satellites orbiting the Earth at an altitude of 12000 nautical miles.(1) The system was originally developed by the US government for military navigation,(2) but now anyone with a GPS device, be it a SatNav, a mobile phone or a handheld GPS unit, can receive the radio signals that the satellites broadcast. GPS technology has grown rapidly in all sectors to enable the production of GPS signal receivers as well as

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position transmitters with good resolution at a more affordable price. GPS tracker application has been widely applied in motor vehicles (e.g., cars and motorcycles) as well as for the transportation management of people or goods (transportation and expedition).

One of the needs in fishery management is spatial catch information; thus, the impact of fishery (fishing) on fish resources as well as on the fish habitat should be studied in detail. In addition, the fishery industry and consumers now also demand to know the origin of the catch information for catch traceability. This technology could improve the accuracy of fishing effort estimation and is essential for stock assessment analysis.[3] Spatial fishing information became increasingly important in modern fishery management. Detailed spatial fishing information will provide better management and harvest strategy formulation.

Groupers and snappers are considered important fishery commodities in Indonesia, both ecologically and economically. These fish are generally caught by small-scale fishers that operate in nearby reefs; thus, undertaking sustainable grouper and snapper fisheries is of paramount importance for their continuous supply. As one of the important sites for grouper and snapper fisheries nationwide, West Nusa Tenggara (NTB) Province will take the lead by providing an example on sustainable grouper and snapper management that can later be replicated in other parts of Indonesia.[4]

Using information on the fishing ground location and the duration of this fishing operation, which can be obtained by utilizing affordable GPS tracker technology, we could literally track a fisherman using GPS tracker devices.[5] The objectives of installing a GPS tracker in a fishing operation are to monitor the movement of fishing vessels, identify the fishing ground location, determine the pattern of the fishing operation, and increase efficiency with data catch for a detailed catch per unit of effort (CPUE).

2. Materials and Methods

2.1 GPS tracker installation

The study was conducted in West Nusa Tenggara–Indonesia (Saleh Bay Waters). SPOT TRACE was installed from November 2016 to March 2017 (5 months). Eight GPS trackers were installed in three different fishing gears, namely, handline, speargun, and long line, in four different villages (Labuan Kurisi, Labuan Sanggoro, Labuhan Bontong, and Labuhan Jambu). Figure 1 shows the installation process of the GPS tracker on a nonmetal pole on a grouper fishery fishing boat, in an open space to prevent shadowing by other objects and in a suitable place to minimize human interferences.

Figure 2 shows the study location, fishing gears targeting groupers, and GPS transmission location at 5 intervals. With the installation of the GPS tracker, information on the fishing grounds is collected with a participatory approach to fisheries in Saleh Bay.

2.2 Distance measurement and analysis

The distance was measured from 2 GPS locations using the following equation of the spherical law of cosines:

Fig. 1. (Color online) GPS tracker installation on small boat.

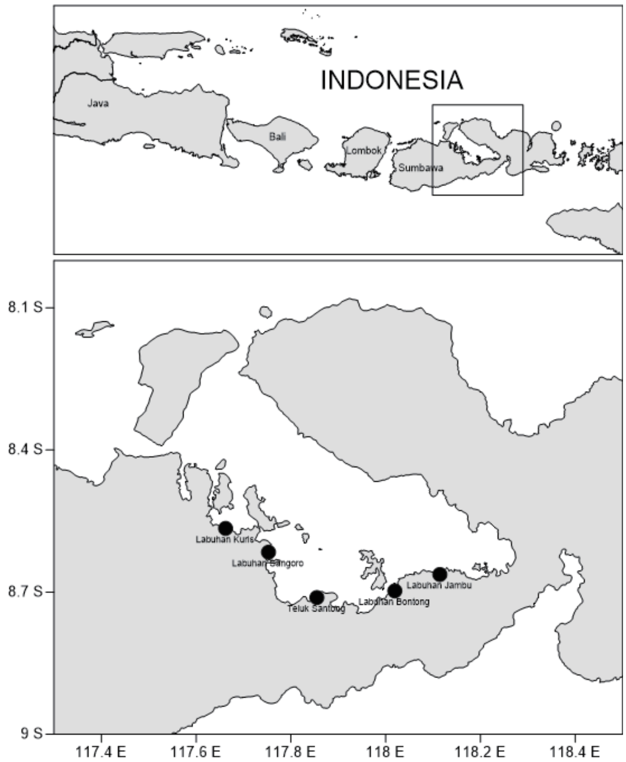

Fig. 2. Location of the study.

$$d = \text{acos}\,(\sin\varphi_1 \cdot \sin\varphi_2 + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \cos\Delta\lambda\,) \cdot R, \tag{1}$$

where d is the distance from two positions from points 1 (λ_1, φ_1) and 2 (λ_2, φ_2) measured in km, φ_1 is the latitude of the first location (in radian), φ_2 is the latitude of the second location (in radian), $\Delta\lambda = \lambda_2 - \lambda_1$ is the margin of longitude between points 1 and 2 in radian, and R is Earth's radius (mean radius = 6371 km), to allow distance calculation in Microsoft Excel using the data. We converted the radian into degrees using the following equation:

$$d = [\text{acos}(\sin(\text{lat}_1 \times \pi/180) \cdot \sin(\text{lat}_2 \times \pi/180)] + [\cos(\text{lat}_1 \times \pi/180) \cdot \cos(\text{lat}_2 \times \pi/180) \cdot \cos(\text{long2} \times \pi/180)] - [(\text{long1} \times \pi/180)) \cdot R]. \quad (2)$$

The distance of the fishing operation was then calculated for each trip to understand the grouper fishing operation and also to understand the effort for each individual vessel. Combining this information with catch monitoring, we determined the CPUE for grouper fishery in Saleh Bay, Sumbawa Island.

During the research, GPS locations were collected from the GPS tracker without further process and corrections, considering that the spatial resolution of the GPS is suitable for fisheries study. According to Ref. 8, the spatial error from a standard GPS in open water is varied from 6 to 30 m. Depending on the sources of error and accuracy for standard positioning services, it is varied from 10 to 15 m. The spatial error and accuracy could be accepted since this study does not require a high spatial resolution, different from detailed marine infrastructures, i.e., harbors and other marine building facilities that require high spatial resolutions. Another study also used the output data from the GPS without further spatial correction.(9)

2.3 Fishing intensity

Fishing intensity analysis was conducted using a grid with a length of 5 × 5 nautical miles^2 as shown in Fig. 3; the letter and code for each grid were standardized at the Research Institute for Marine Fisheries (RIMF), Jakarta. The fishing intensity in the dedicated grid represents 3 pieces of information, i.e., the number of catches from the participatory data collection, the number of fishing days on the grid from the participatory data collection of a trained enumerator through catch landing data collection, and fishing ground information interview.

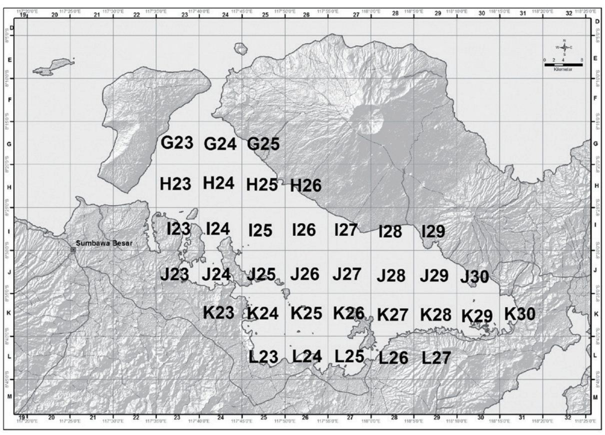

Fig. 3. Grid for fishing intensity analysis.

3. Results and Discussion

3.1 General information of Saleh Bay fisheries

Saleh Bay is administratively located in two districts in West Nusa Tenggara Province, namely, Sumbawa Regency and Dompu Regency. The Saleh Bay area covers ten subdistricts, namely, Kempo, Labuhan Badas, Lape, Manggalewa, Maronge, Moyo Hilir, North Moyo, Pekat, Plampang, and Tarano, where 27 villages are located. The total population living in Saleh Bay is around 67000 with a total of around 3800 registered fishermen, but there are more than 5800 fishermen actively fishing in Saleh Bay. This is because not all villages in Labuhan Badas and Pekat are included in Saleh Bay, but all fishermen living in these two subdistricts operate in Saleh Bay.

Saleh Bay is one of the important locations in NTB waters, where the catch of its fishermen contributes significantly to the total production of reef fisheries in NTB. Saleh Bay is part of fishery management area 713, where there are small islands and coastal ecosystems such as coral reefs, seagrass beds, and mangroves, which are important habitats of fish resources.

3.2 GPS tracker sampling data

All eight GPS trackers installed on the sample boats functioned appropriately in sending GPS locations from each particular boat. Tracking data sent at 5 min intervals include the position, speed, and time, which provide information on ship movements, that is, when the ship stops and makes new movements. This stop and new movements indicate that the boats carried out fishing activities.

Figures 4–7 show the results of tracking carried out during the study period, where grey dots indicate boat movements and black dots represent the location where the boat stops, indicating

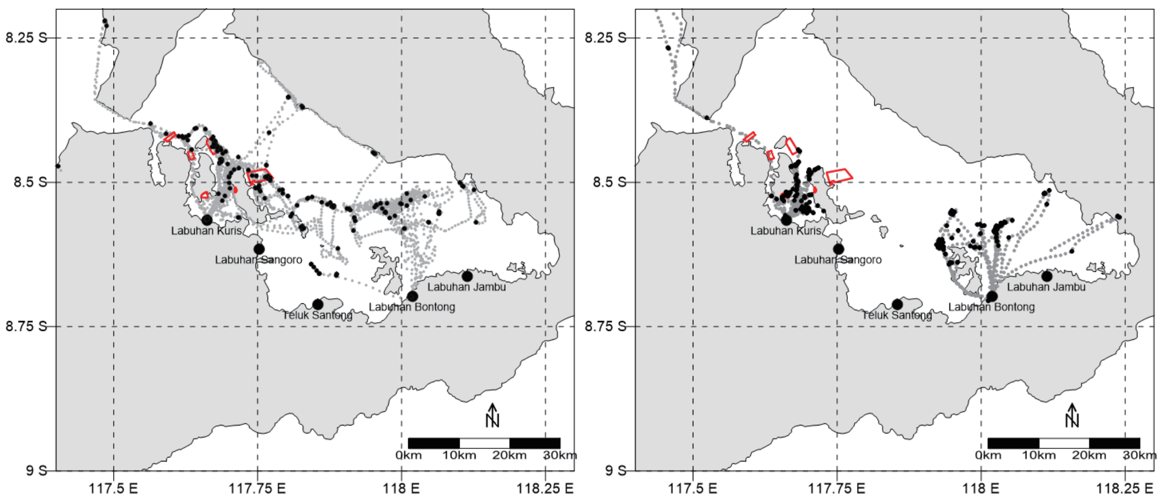

Fig. 4. (Color online) GPS position plot from sample boats 1 and 2 during five months of monitoring; grey dots indicate movements, black dots indicate fishing location, and red lines are borders of MPA's core zones.

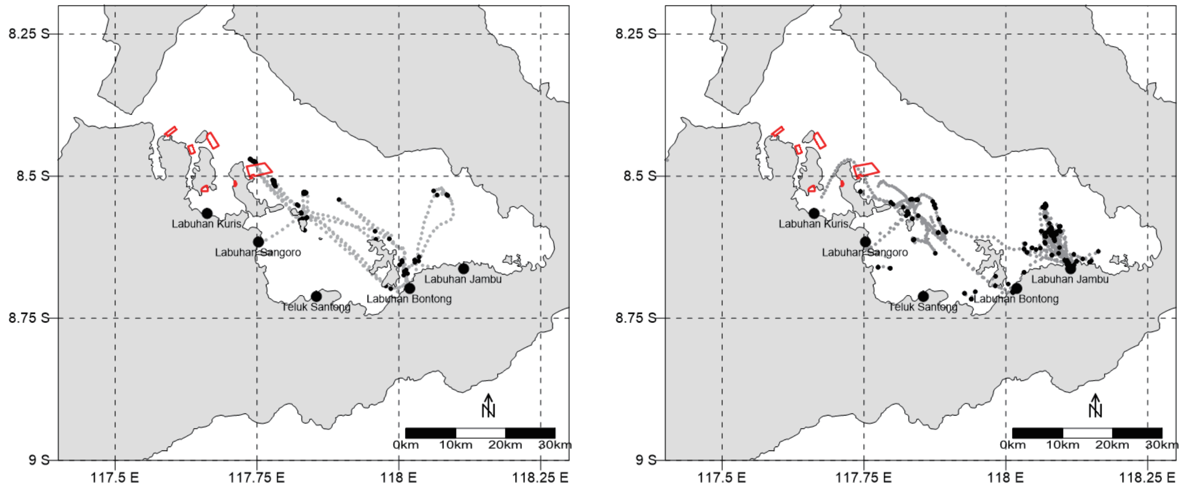

Fig. 5. (Color online) GPS position plot from sample boats 3 and 4 during five months of monitoring; grey dots indicate movements, black dots indicate fishing location, and red lines are borders of MPA's core zones.

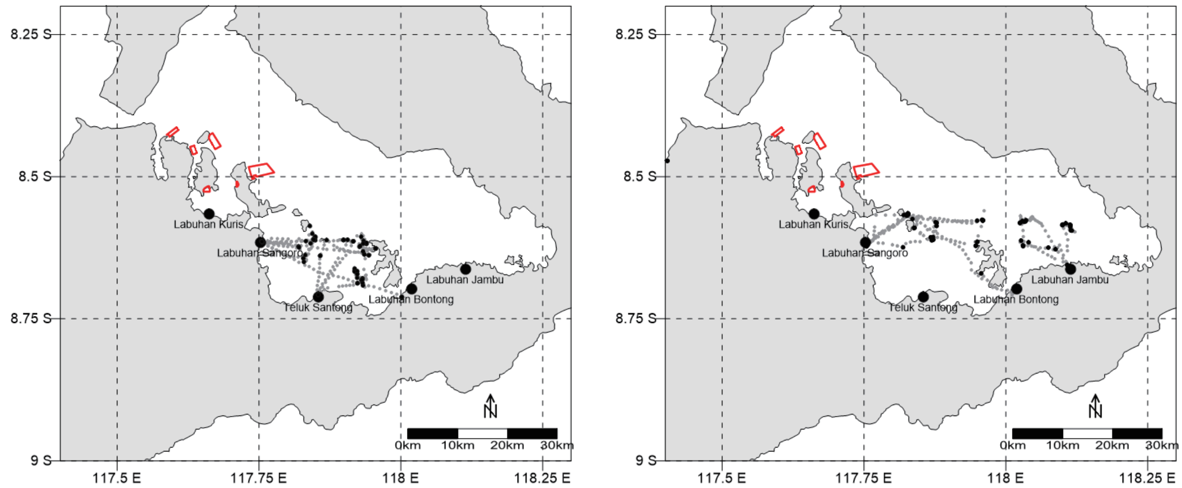

Fig. 6. (Color online) GPS position plot from sample boats 5 and 6 during five months of monitoring; grey dots indicate movements, black dots indicate fishing location, and red lines are borders of MPA's core zones.

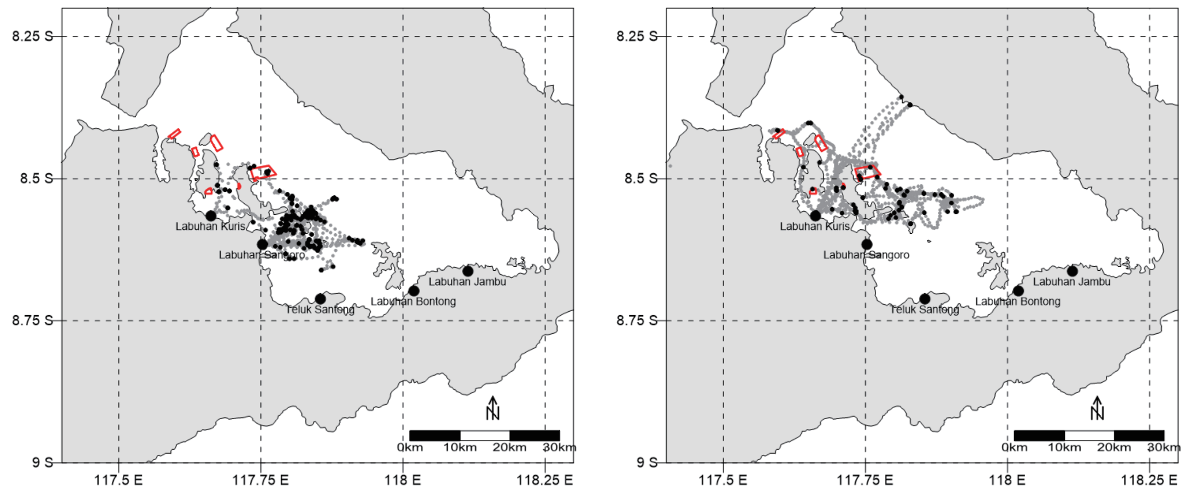

Fig. 7. (Color online) GPS position plot from sample boats 7 and 8 during five months of monitoring; grey dots indicate movements, black dots indicate fishing location, and red lines are borders of MPA's core zones.

the fishing location. The number of samples obtained from each sample boat varied, which was due to a different sampling period for each sample boat. Figure 4 shows that the highest number of samples was obtained from sample boats 1 and 2, considering that these two vessels were the first to actively participate in the installation of a GPS tracker. No further correction to the GPS information was conducted, including the GPS positions that were plotted and analyzed.

3.3 Fishing ground information

GPS tracker positions from sample boats 1 to 8 were analyzed and categorized into two different groups, namely, speargun and hook and line fishery groups, according to the sample vessel transmitting the data. The separated data were plotted and overlying with the core zone of a marine protected area was agreed upon to restrict fishing activities; this area is marked with a red grid line on the map. The results of ship movement and fishing operation analyses indicate that hook and line boats have a wider range of cruises than speargun boats. In the next section, this information will be analyzed further to determine in detail the fishing effort from these two fisheries.

In general, speargun and hook and line (troll line and handline) fishers have different fishing grounds. In Figs. 8 and 9, we can see that speargun fishery is mostly based on Labuhan Kuris and Labuhan Jambu, whereas hook and line fishery is mostly based on Labuhan Sanggoro and Labuhan Bontong. Speargun fishers from Labuhan Kuris operate in the northern part of Saleh Bay not far from their villages; they tend to fish within marine protected area (MPA) boundaries and sometimes inside the MPA. Speargun fishers from Labuhan Bontong also operate in the northern part and conduct fishing within the MPA. Speargun fishers from Labuhan Jambu have a different fishing ground and operate in the southern part far from the MPA, but closer to their villages.

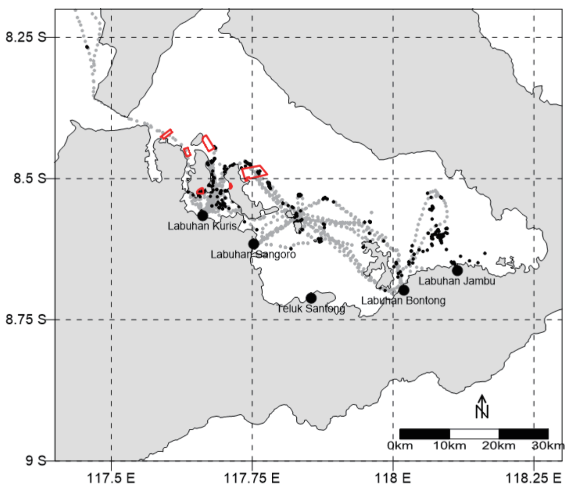

Fig. 8. (Color online) GPS position plot from speargun fishery during five months of monitoring; grey dots indicate movements, black dots indicate fishing location, and red lines are borders of MPA's core zones.

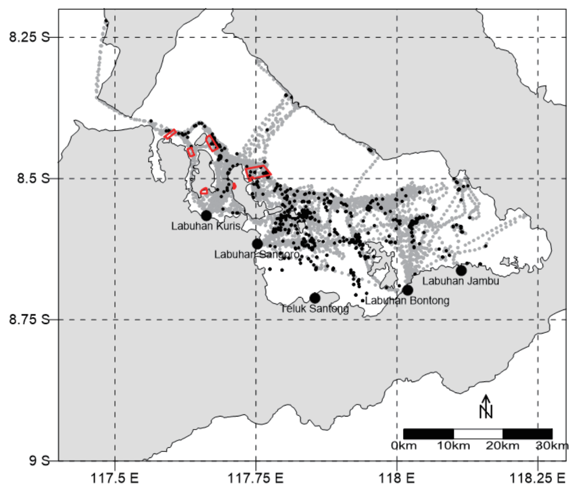

Fig. 9. (Color online) GPS position plot from hook and line fishery during five months of monitoring; grey dots indicate movements, black dots indicate fishing location, and red lines are borders of MPA's core zones.

Hook and line fishery is mostly based on Labuhan Kuris, Labuhan Sanggoro, and Labuhan Bontong. Its operation covers a wider area than that of speargun fishery. Similar to speargun fishers, hook and line fishers tend to fish within and inside the MPA. The main fishing ground of hook and line fishery is located on the southern part of MPA near Labuhan Sanggoro.

Information regarding fishing ground areas is very useful for the traceability of the catch and also for management and surveillance purposes. Through this information, the local fishing authority could understand the behavior of the fishers, the origin of the catch, and how the fishers utilize the fish stock. In terms of surveillance, the surveillance officer in Saleh Bay could detect whether some fishing operations are carried out at the edge of the conservation area. Occasionally, these two types of fisheries carry out operations inside conservation areas, which is actually prohibited. This understanding will lead to necessary measures from a management perspective, which are not only limited to law enforcement but also increase awareness and socialization among the fishers about the regulation inside the core zone of MPA.

3.4 Distance covered (effort) analysis

Effort analysis from each fishery was conducted using the distance of each fishery for each trip. Descriptive statistics and histograms were used to describe the results of distance analysis for two main groups, namely, hook and line fishery (Table 1 and Fig. 10) and speargun fishery (Table 2 and Fig. 11). The average distance of hook and line fishery is larger than that

Table 1
Descriptive statistic of distance for hook and line fishery.

Parameter (unit)	Value
Mean	38695
Standard deviation	34912
Range	133974
Minimum (m)	2
Maximum (m)	133976
Count	158
Confidence level (95.0%)	5486

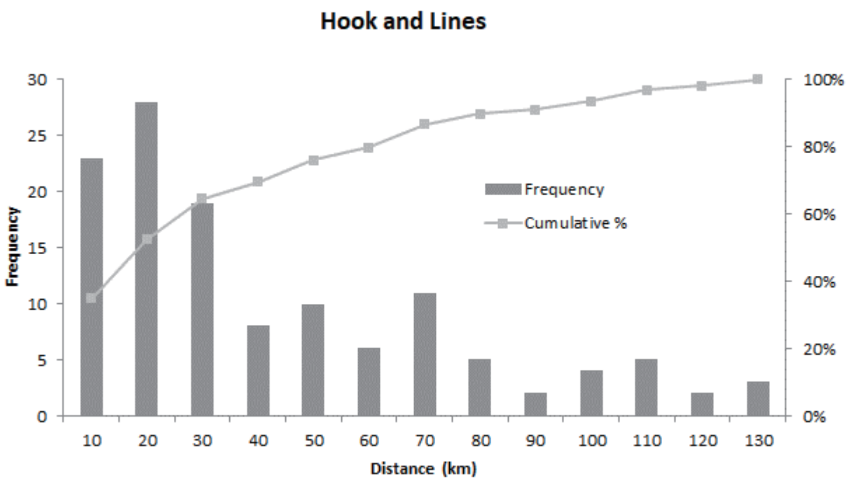

Fig. 10. Hook and line distance frequency histogram and the frequency cumulative.

Table 2
Descriptive statistic of distance for speargun fishery.

Parameter (unit)	Value
Mean	24733
Standard deviation	2729
Range	138060
Minimum (m)	2
Maximum (m)	138063
Count	93
Confidence level (95.0%)	5420

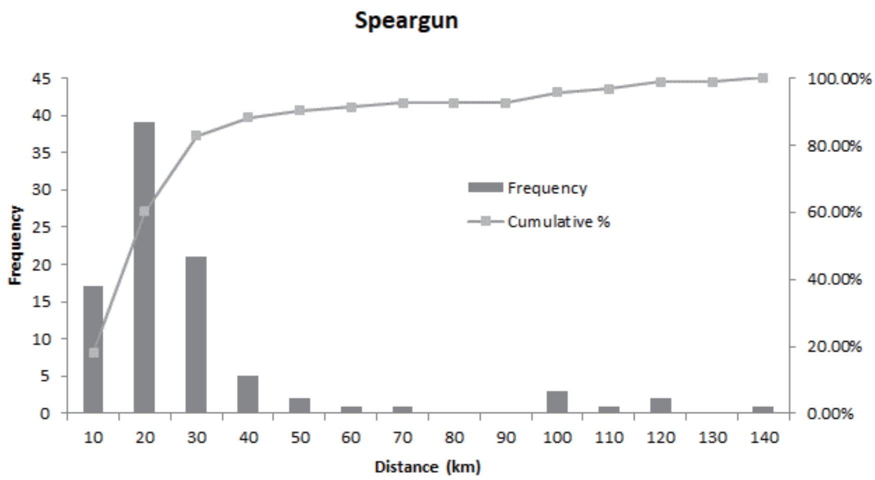

Fig. 11. Speargun distance frequency histogram and the frequency cumulative.

of speargun fishery. On average, hook and line fishery travels 38 km per trip with a maximum distance of 133 km per trip, whereas speargun fishery travels 24 km per trip with a maximum distance of 138 km.

Figures 10 and 11 show that 50% of the total distance of hook and line fishery covered in a single trip is less than 40 km; this data indicates that the fishing grounds of the fisheries are close to their villages. Sometimes, the fishers go to farther fishing grounds. A closer fishing ground will result in higher catch quality, lower fuel consumption, and lower cost.

3.5 Fishing intensity analysis

The total number of trips recorded during the monitoring period is 922. Catch effort from this monitoring is presented visually on the basis of the fishing area. Grouper and snapper fish in Saleh Bay are captured with six types of fishing gear, namely, boat lift net, trap, gillnet, speargun, handline trolling line, and bottom longline. The use of different fishing gears varies the effort to catch groupers and snappers, such that the standardization of fishing gear is carried out with fishing power index (FPI) analysis and the speargun as the standard fishing gear. The catch of the speargun is large, i.e., 49% of the total catch.

Figures 12 and 13 show the number of trips and the CPUE represented by the number of fish per trips for each grid. Similar to the GPS tracker information, the fishing operation is mostly around the MPA and the southern part of Saleh Bay near Labuhan Bontong. During the monitoring, grid L26 has the highest CPUE of 14 fish per trip, whereas grid I23 has the second highest CPUE of 11 fish per trip.

4. Discussion

The results of this study show that the fishing grounds of groupers and snappers for speargun and hook and line fisheries are close to the fishing landing port and mostly at the western part of Saleh Bay. The fishing intensity is similar to the result indicated in Ref. 6, and is mainly contributed by the surrounding fishing landing base.

The average distance of the hook and line fishing operation is larger than that of the speargun fishing operation. This is due to the operational aspect of each fishing gear; that is, a speargun fishing boat only stays in one place when the fishers conduct operation, whereas a hook and line fishing boat actively moves throughout the entire fishing operation according to Ref. 7; hook and line fishing gears, especially handline trolling lines, are moved around the fishing area throughout the fishing operation.

The GPS tracker shows good performance during the tracker operation; thus, this device is suitable for one-fishing artisanal fisheries. The only issue during the operation is the battery replacement after the operation, which requires minor training to resolve this issue.

Information on the fishing ground and distance covered by each operation could support the traceability of the catch origin and a detailed effort estimation analysis. Traceability requires detailed information on the location where the catch is conducted. A better effort estimation also supports an accurate stock assessment and a better harvest strategy formulation of fishery management.(3) In this study, the number of samples and also the amount of catch information during tracking should be increased, participatory data collection from the fisherman should be improved and better formulated, and the use of ICT could be incorporated during the fishing operation similarly to the study conducted in Mexico for artisanal fisheries.(6)

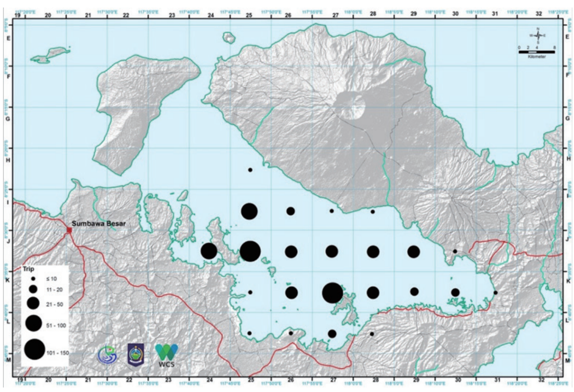

Fig. 12. (Color online) Distribution of number of trips obtained during monitoring.

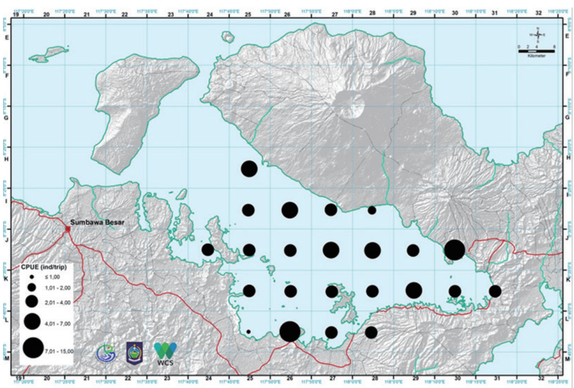

Fig. 13. (Color online) Distribution of total CPUE obtained during monitoring.

GPS tracker studies are continuously increasingly carried out in Indonesia and improved in terms of the number of samples and quality of data. The use of GPS information to achieve effective effort and obtain fishing grounds is still rarely applied in Indonesia. In a study, commercial deep-sea snapper fishery was combined with data from vessel monitoring systems (VMSs).(9) This paper will provide a new discussion on effort to calculate Indonesian fisheries, especially artisanal fishery.

5. Conclusions

The low-cost GPS tracker used in this study shows good performance and robust results for artisanal fisheries in a one-day operation. Information on the fishing ground location and effective effort obtained in this study is a breakthrough in Indonesian artisanal fisheries; this information could support the traceability of the catch, which is a mandatory requirement in the global market and supports a better data collection for accurate effort estimation and stock assessment. Tracking information also supports the spatial management of MPA, and a surveillance officer could use this information to increase the awareness of the fishers to avoid entering the core zone of MPA during a fishing operation. Better information and assessment will result in better fishery management to achieve a sustainable fishery exploitation.

Acknowledgments

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