Trips Analysis of Swimming Crab Gillnets Based on Vessel Monitoring System

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Abstract. Gill net is an important traditional fishing net, which has the largest number in China. It is accounting for one third of the total vessel number. More than 60000 Chinese fishing vessels were equipped with Beidou terminals. They are similar to the VMS (Vessel monitoring system) system in the world. It can send information of time, speed, course and position of fishing boat. Its time and space resolution are high. The trajectories of fishing vessels are curved lines, and port area is plane. There is a spatial relationship between them. In this paper, the relationship between trajectories of fishing vessels and port surface is used to extract 15000 voyages of 56 fishing vessels. 16.91% of them had a voyage within one day. The fishing vessels with long trips come from Shengsi, Taizhou, Sanmen and Linhai. The trips of fishing vessel were concentrated in Shengsi, accounting for 84% of the total, and Taizhou accounted for 5.4%. The other port only had 10 to 40 vessel trips.

1. Introduction
The fuel price is increasing in fishing operations. While gillnetting has low impact fuel efficient fishing practices. It assumes significance globally for sustainable development of fisheries [1]. It is a typically commercial fishing gear for gillnets to be considered [2]. Gillnets consist of single, double or triple netting walls kept vertical by a floatline and a weighted groundline[3, 4], in which fish will gill, entangle or enmesh. They are considered to have fewer holistic environmental impacts than active fishing gears [5] and are used widely in fisheries throughout the world [6]. Gillnets are also used for assessing the ecological quality and monitoring fish communities [7]. Gillnet is the important traditional fishing net in China. It is about 180 thousand fishing vessels in China offshore, of which 54% are gillnets, And They catch more than 3 million tons, accounting for 23% of the total catch. Understanding the spatiotemporal behaviour of fishermen at the high scale is a key for instituting effective strategies for fishery management [8]. Vessel monitoring system is convenient means for fishing vessel monitoring. Fishery researchers can obtain important reference data from the system [9]. It can provide information on fishing activity at large spatial scales. Thought the analysis of the data, we can recognize vessel states, assess fishing effort, identify fishing grounds and so on [9, 10]. VMS is satellite-based surveillance systems [2], while in China it is based on Beidou satellite navigation system. And it has the functions of location navigation, short message, satellite communication and so on. It can be called Beidou Vessel monitoring system (BDVMS). The data accuracy is relatively high.
The time resolution is 3 minutes, and the spatial resolution is 10 meters [11]. China has implemented this system in 2006 to monitor fishing activities of offshore. It plays an important role in the management and rescue of fishing vessels.

In recent years, the export technology of living Portunus has appeared. It makes the processing of Portunus japonicus move from "frozen product era" to "live product era". Its market price has also increased hundreds of times. There is a big increase in demand. At the beginning of 2017, to protect the offshore fishery resources of China, two provinces launched the quota fishing experiment, of which Zhejiang province chose the swimming crab (Portunus trituberculatus) in North Zhejiang fishing ground to carry out the pilot project. Fishing is a key challenge in conservation and contemporary ecology. It is one of the human impacts. The accurate tracking of the spatial distribution is very important [12]. However, there are not any fishing logs or with uncertainty records in many fishing area. Better understanding of the fishing vessel is required in order to prioritize and enforce fisheries management and conservation measures. BDVMS data provide information about speed and position of fishing vessels.

In this paper, the trajectories of fishing vessels are curved lines, and port area is plane, through the spatial relationship analysis between them. We got more than 15000 fishing trips.

2. Methods

2.1. Data Sets

This study used BDMVS data from the Ministry of Agriculture and Rural Affairs for the fishing year 2017. It contains card No., position, time, speed, navigation and other information. The analysis was restricted to 56 gillnet fishing vessels in North Zhejiang fishing ground of East China Sea. It had about 3.67 million records.

Swimming crab fishing data came from Zhejiang fishery related departments. Fishing data were recorded by 8 fishing vessels in January, September to December in 2017. The information included date time, the start and end time of setting gillnet, the start and end time of hauling gillnet, catch weight of swing crab and name of the vessel.

2.2. Fishing Vessel Trip

The trajectories of fishing vessels are curved lines, and port area is plane. There is a spatial relationship between them. A vessel had more than one trip in a year, and it had different port to leave and arrive. During the vessel was in port, the state was set to 1, while during the boat was at sea the state was set 0 (Fig.1a).

![Figure 1](image1.png)

*Figure 1.* Tips extracting of all fishing vessels: (a) in port and at sea; (b) vessel trip extracting.

The black point singed for the vessel arriving into one port, and the circle singed for the leaving off one port (Fig.1a, 1b). Traversing the changes in the entry and exit of each fishing vessel in a year in the 56 fishing vessels, we can extract the tips of all the fishing vessels (Fig.1b).
3. Data Analysis
Through the analysis of spatial relationship between the track of a fishing vessel and the port, we got 15000 fishing trips. The departure time of each month was different. It was also existed in arrival time. From January to December (Fig.2), departed time gradually changed early. But arrival time gradually changed late except some special month (such as March, May, June and August).

![Figure 2](image)

**Figure 2.** Arrival and departure time of fishing vessel in every month: (a) departure time; (b) arrival time.

The duration of vessel trips were mainly within two days (Fig.3.a). There were 16.91% of the trips having the duration within one day. There were 38.87% of the trips having the duration from 1 to 2 days. There were 12.65% of the trips having the duration from 2 to 3 days. There were 80.80% of the trips having the duration less than 4 days. The duration of trips was about 91.67% within 10 days, 6.29% between 10 and 20 days, and 2.03% above 20 days. The descriptive statistics of duration of
the trips median was 1.256 days, mode was 0.395 days, kurtosis was 132.685 and skewness was 10.532.

Scatter Plot colored by smoothed densities were used to describe the number of trip days. From January to March (Fig.3b) and from June to August, there were some long time trips. While From September to December, there were not long time trips. The maximum density was about 1 day. The fishing vessels with long trips came from Taizhou, Sanmen, Linhai and Shengsi (Fig.3c), there long trip days at Xiangshan, Wenling and Zhoushan were few. Shengsi has the largest number of trips.

The fishing vessels with long trips come from Shengsi, Taizhou, Sanmen and Linhai. The trips of fishing vessel were concentrated in Shengsi, accounting for 84% of the total, and Taizhou accounted for 5.4%. The other port only had 10 to 40 vessel trips.

The arrival and departure ports of fishing vessel were Concentrated in several ports. There were 56 vessels in Shengsi, 37 vessels in Taizhou, 10 vessels in Linhai, 9 vessels in Sanmen, 6 vessels in Zhoushan, 6 vessels in Xiangshan and 4 vessels in Wenling. The trips of fishing vessel were concentrated in Shengsi, accounting for 84% of the total, and Taizhou accounted for 5.4%. The other port only had 10 to 40 vessel trips.

Table 1. The Trip number in every place.

| month | Linhai City | Sanmen County | Shengsi County | Taizhou City | Wenling City | Xiangshan County | Zhoushan City |
|-------|-------------|---------------|----------------|-------------|--------------|-----------------|--------------|
|       | out | in | out | in | out | in | out | in | out | in | out | in | out | in |
| 1     | 1   | 5  | 11  | 12 | 128 | 115 | 4   | 8  | 3   | 3  | 2   | 1  | 2   | 3  |
| 2     | 3   | 2  | 7   | 3  | 6   | 6  | 6   | 6  | 12  | 12 | 3   | 3  | 4   | 2  |
| 3     | 1   | 3  | 1   | 1  | 5   | 5  | 6   | 7  | 7   |    | 1   |    | 1   |    |
| 4     | 1   | 2  | 2   | 2  | 3   | 5  | 5   | 6  | 7   | 7  | 1   |    | 1   | 1  |
| 5     | 2   | 1  | 1   | 1  | 17  | 11 | 4   | 4  | 2   | 2  | 2   | 2  | 4   | 4  |
| 6     | 1   | 1  | 10  | 6  | 2   | 1  | 1   | 1  | 1   | 1  | 1   | 1  | 1   | 1  |
| 7     | 2   | 1  | 1   | 1  | 339 | 365 | 3   | 6  | 2   | 1  | 1   | 1  | 2   | 1  |
| 8     | 130 | 130| 32  | 28 | 4   | 4  | 2   | 2  | 2   | 2  | 4   | 4  | 4   | 4  |
| 9     | 251 | 251| 16  | 19 | 1   | 1  | 4   | 4  | 4   | 4  | 4   | 4  | 4   | 4  |
| 10    | 1   | 1  | 339 | 365| 3   | 6  | 2   | 1  | 1   | 1  | 2   | 1  | 2   | 1  |
| 11    | 245 | 246| 2   | 3  | 3   | 3  | 3   | 3  | 3   | 3  | 3   | 3  | 3   | 3  |
| 12    | 250 | 262| 1   | 2  | 1   | 1  | 1   | 1  | 1   | 1  | 1   | 1  | 1   | 1  |
| total | 34  | 10 | 38  | 32 | 1347| 1379| 86  | 86 | 11  | 1  | 20  | 19 | 37  | 36 |

In January There were some trip in or out at every port (Tab.1). In February the number reduced at every port. In March and April there were few trips at every port except Taizhou and Zhoushan. From May to July there were no trip in or out at Shengsi, Xiangshan and Zhoushan, and few at Linhai, Wenling and Taizhou. In August There were some trip in or out at every port except at Wenling. From September to December, There were no trip in or out at Linhai and Wenling, and few at Sanmen and Xiangshan. But there were many at Shengsi.

4. Discussion

China began installing SBNST in 2006, and nearly 60 thousand fishing vessels have been installed so far. China's offshore fishing vessels are mainly small-scale, and which have already been installed if it has installation conditions. However, the proportion of SBNST installations is still relatively low,
accounting for about 30% of fishing vessels. As other types of VMS, SBNST also has some defects and needs continuous improvement. Missing VMS records were pervasive and they would strongly influence the approach [13]. SBNST Mounted on a fishing vessel sometimes fails. It is unable to send back data or data error due to equipment failure, insufficient power supply, signal interference, etc. [14]. With the progress of China's dismantling small and old vessels, the popularity of SBNST will gradually increase. The improvement of the hardware and software technology of SBNST will also reduce the failure rate of the equipment. The state’s emphasis on quota fishing and the improvement of relevant laws and regulations can completely eliminate the phenomenon of artificially closing the SBNST. The development of the vessel's data mining technology will help to uncover further valuable information.

In this paper, 56 gillnetting VMS data were used to analysis fishing trip. When the fishing vessel enters a port to park or repair the vessel, the terminal is sometimes shut down. So there may be a loss of data. The parameters are set in the BSNT. When the speed of the vessel is low, the frequency of location information sending reduced. This speed is generally set to less than 0.5m/s. Net hauling, net setting, and cruising are all greater than this speed, so these missing data will not affect data analysis. These data are omitted in the article's data analysis.

Trips of vessels are often required in fishery management, fishing benefit calculation and resource surveys [15]. Fishing trips is the time of vessels from port leaving to returning. Through the analysis of the tip character, more useful result can be used for examining trends in fleet dynamics, fishing costs and fisher behaviour [16]. There were more than one hundred trips without fishing which counted for 6.7% of the all trips. They were mainly concentrated in March, May, June and July. From May to June, it was the closed fishing season. The trip in April was very special, because this month was before closed fishing season. Though the production efficiency was very poor, fisherman were still fishing out of the sea. In April, the fishermen caught shrimps and crabs in the nearby sea. They didn’t sell the catch at the time. Instead, they froze the catch as a stock for the closed fishing season. Because of the shortage of supply of aquatic products during the fishing season, the price will rise, which will make up for the loss of fishing.

Linhai and Sanmen are the port of registry for the demonstration vessel. In January, July and August, there were small number tips of vessels which came to these two ports for mooring or repairing. Some vessels fishing in Yushan fishing ground which is nearby Taizhou in the first half of the year then went to Taizhou to sell fishing catch. They repaired and maintained the vessels in Taizhou from June to July. Some vessels were also sold in Taizhou from August to October. Shengsi is the closest port to the northern Zhejiang fishing ground. It is a traditional port for demonstrating vessels to shelter from the wind and sells fishing. Therefore, from August to January of the next year, the proportion is relatively high. There were many trips to Shengsi in this period. Wenling is close to Linhai and Sanmen. In the first half of the year, a small amount of catch was sold in Wenling. Shipu Port of Xiangshan and Shenjiamen Port of Zhoushan are temporary sales and sheltered ports. There were some accidental trips. Fishermen often go to the sea early in the morning and return back in the evening, with fewer trips begin at night. So the hauling hours was mainly concentrated in the daytime. Departure time in the first half of the year was earlier than that in the second half of the year, while Arrival time in the first half of the year is later than that in the second half of the year, because daytime in the second half of the year is longer than that in the first half of the year, in Northern Hemisphere. Gillnet fishermen used to work during the daytime.

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