Study on the Temporal and Spatial Distribution Characteristics of Aquatic Traffic Accidents

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Abstract—The study of the characteristic of aquatic traffic accidents is significant for avoiding accidents effectively and guiding the supervision of water traffic safety and the search and rescue of water accidents. In this paper, the temporal and spatial characteristics of aquatic accidents from the aspects of accident occurrence and accident consequences were studied. The results indicated that the total number of verified distress incidents has significant temporal and spatial distribution characteristics; the number of verified distress incidents in coastal areas is significantly higher than that of inland rivers; the main causes of water accidents include collisions, stranding, fires and windstorm, all of which have a significant temporal distribution. In terms of accident consequences, the number of general danger is significantly higher than that of other levels of risk, and there is a significant temporal distribution characteristics on four danger levels. The main types of ships in distress are transporting ships, agricultural vessels, fishing boats and official ships. The number of transporting ships and fishing boats both fluctuated greatly in some months; there was no difference on the temporal distribution for the number of agricultural vessels and official ships in a year. There is no significant linear relationship between the number of distressed people and ships; the number of people in distress on the four types of ships all showed a certain time distribution characteristics; the number of deaths and disappearances in the main rivers rose sharply in June. By analyzing the temporal and spatial distribution characteristics of accidents and their consequences, this paper provides a basis for the relevant authorities to optimize the prevention and control of water accidents, the layout of water search and rescue forces and the timeliness of target searches.

1. Introduction

With the rapid development of water transportation and the increasing development and utilization of oceans in recent years, the risks and threats of water traffic accidents have also increased, and the tasks and pressures of water traffic safety supervision and target search and rescue have increased significantly. Water traffic safety supervision and search and rescue are important components of the national emergency system for public emergencies. It is vital to understand the characteristic of maritime traffic accidents for improving the capability of safety supervision and search and rescue.
The distribution of water traffic accidents, the causes and consequences of accidents have always been the focus of research on water traffic safety [1-2]. Water traffic accidents occur in a water traffic system composed of people, ships, and environment. The coastal waters are relatively busy, with little space for manoeuvres and a large proportion of accidents. The open sea environment has huge space for maneuvering, and the proportion of accidents is small [3]. The cause analysis of water traffic accidents is mainly to use statistical analysis and data mining methods to excavate various accident factors and the correlation between accidents from a large number of accident cases [4-6]. Major accidents often involve human factors [4, 7-8]. Many studies have shown that human errors and violations of rules and regulations account for more than eighty percent of water traffic accidents [7]. Research on the consequences of water traffic accidents has always been the focus of the analysis of water traffic accidents [9]. Heinrich conducted statistical analysis based on five hundred and fifty thousand accidents and classified the accidents according to their severity, it is found that for every three hundred and thirty accidents, the ratio of the number of serious injuries, minor injuries and non-injury accidents is 1:29:300 [10]. Analysis of water traffic accident is an important method to improve traffic safety [8]. Although the research on water traffic accidents has been a long history, its development is still lagging behind that of road traffic accidents [11] and aviation accidents [12].

The objective of this study is to analyze the temporal and spatial characteristics of aquatic accidents from the aspects of accident occurrence and accident consequences. Specifically, this study aims to answer the following questions. (1) Regarding of accidents, does the number of distress on water have a time effect and a space effect in a year? What are the main causes of distress and are there time effects? (2) In terms of accident consequences, is there a significant time rule for the risk level of accidents? Is there a significant difference in the number of ships in distress each month? What types of ships are in distress? Is there a time rule for the number of distress for each type of ship in distress? Is there a significant difference in the number of people in distress each month? Are there significant differences in the number of people in distress on different types of ships in distress? Is there a time rule for the number of people in distress on each type of ship in distress? Is there a law of spatial distribution of the number of dead and missing persons?

2. DATA AND METHODS

2.1. Data
This paper collected data on water traffic accidents from January 1, 2014 to March 31, 2020 from the database of China Search and Rescue Center of Ministry of Transport of the People's Republic of China, and obtained seventy-six accident monthly data. The data not only provides detailed information on the accidents consequences of ships and personnel, but also records the causes of accidents. The information in each accident report is very helpful to evaluate the consequences of the accident between the person and the ship in distress.

2.2. Methods
Descriptive statistics method was used to demonstrate the temporal and spatial characteristics of aquatic accidents from the aspects of accident occurrence and accident consequences. To describe the degree of dispersion of accident data, statistical analysis of standard deviation were conducted.

3. Temporal distribution of water accidents

3.1. Temporal Distribution of accidents happened
In recent years, the China Maritime Search and Rescue Center has received an average of 250 distress alerts per month, and the actual number of verified distress incidents is shown in Fig. 1. The number of distresses exceeded the monthly average number of distresses for six months of the year (distributed in April, August, September, October, November, and December), and reached its lowest value in February.
The main causes of water accidents include collisions, stranded, fires and wind damage. The number of collision accidents cyclically fluctuated, with the lowest value in February, and the number of collisions in other months was significantly higher than stranded, fire and wind disasters, it is consistent with the accident rule that every accident is evolved from the unsafe behavior of countless people or the unsafe state of things proposed by previous studies [10]. Stranding had its highest value in December. Fires occurred most frequently in September. The wind disaster occurred at most in August (see in Fig. 2).

![Figure 1. The number of verified distress incidents on water](image1)

![Figure 2. The number of incidents with different causes of distress](image2)

### 3.2. Temporal Distribution of accident consequences

In Fig. 3, the number of general danger is significantly higher than that of other levels of risk, and the lowest value occurred in February, and in April, August, September, October, November and December all showed high values, which followed the same temporal pattern as the total number of verified distress incidents. The lowest values for Greater danger occurred in February and the highest values in October. The highest number of major danger occurred in May, and extraordinary danger occurred at least three times in June, July and August.
Figure 3. The number of occurrences of different risk levels

3.2.1. Ships in distress
The number of ships in distress per month and the total number of verified distress incidents showed the same temporal distribution from January to August, both of which showed the lowest value in February, the number of ships in distress fell back in September and October (see in Fig. 4).

The main types of ships in distress are transporting ships, agricultural vessels, fishing boats and official ships (see in Fig. 5). The number of transporting ships in distress is significantly larger than other types of ships. The number of transporting ships and fishing boats both fluctuated greatly in some months. The number of transporting ships fluctuated the most in August, with the number ranged from 80 to 158 and appeared at the lowest value in February; the number of fishing boats in distress was the lowest in May and July, and increased sharply in August and the following months. There was no difference on the temporal distribution for the number of agricultural vessels and official ships in a year.

Figure 4. The number of ships in distress per month

Figure 5. The number of different types of ships in distress per month
3.2.2. People in distress
The number of people in distress increased significantly in May and fluctuated the most in a year. This phenomenon is diametrically opposed to the trend of the number of ships in distress. After August, the number of people in distress showed a slowly changing trend that decreased month by month (see in Fig. 6).

Due to the largest number of transporting ships, the number of people in distress is also the highest among the four types of ships in distress (see in Fig. 7).

Distressed persons on fishing boats showed the lowest value in July and the highest value in September and October (see in Fig. 8). The number of agricultural vessels in distress was the highest in July (see in Fig. 9). Official ships are only in distress in March, April, June, July and December throughout the year, and there are no official ships in distress in other months (see in Fig. 10).
4. Spatial distribution of water accidents

4.1. Spatial Distribution of accidents happened
The number of distress in coastal areas is significantly higher than that of inland rivers (ie, main rivers, tributaries, lakes and reservoirs). The number of distress in coastal area showed the same temporal distribution as the total number of verified distress incidents, the number of distress was the smallest in February and increased significantly in the second half of the year. The main stream of rivers had the lowest number of distress in February and October. Tributaries, lakes and reservoirs have stabilized at no more than 20 occurrences in each month (Fig. 11).
4.2. Spatial Distribution of accidents consequences

Coastal areas have the largest number of distress, and the number of deaths and missing persons is also significantly higher than that of inland waters.

There was a sudden increase in the number of deaths and disappearances in the main rivers in June. This was due to the sinking of the "Oriental Star" passenger ship that occurred at 21:30 on June 1, 2015, resulting in 454 people in distress. Due to the squall line weather, the accident occurred suddenly, coupled with the difficulty of search and rescue, 12 people were successfully rescued after nearly half a month. This incident reflects two problems in China's traffic safety emergency: 1. early warning, accident prevention and control capabilities is inadequate; 2. Poor timeliness in searching for marine targets in distress. No significant difference in the number of deaths and disappearances of tributaries, lakes and reservoirs in each month (see in Fig. 12).

![Figure 12. The number of deaths and missing persons in different sea areas](image)

5. CONCLUSIONS

Traffic accident data is the basis for the analysis of water traffic accidents. This paper collected data on water traffic accidents from the database of China Search and Rescue Center to find the temporal and spatial characteristics of aquatic accidents from the aspects of accident occurrence and accident consequences.

In terms of accident occurrence, the number of verified distress incidents in coastal areas is significantly higher than that of inland rivers (ie, main rivers, tributaries, lakes and reservoirs) and increased significantly in the second half of the year. Therefore, the supervision of vessels in coastal area should be strengthened in the second half of the year so as to promptly investigate the risk. In addition, it is necessary to increase search and rescue equipment to ensure the fastest possible rescue. Collisions were lowest in February, and the number of collisions in other months was significantly higher than the number of stranded, fires and windstorms. Therefore, there is a need to improve the detection capability of a wide range of ships, which can be achieved by integrating information technologies such as the AIS, electronic nautical charts of ships, satellite remote sensing and others.

About the consequences of the accident, both the number of general and greater danger levels have higher values from August to December. Major grades have the highest number of occurrences in May, and extreme risks appear at least 3 times in June, July and August. Authorities should focus on water transport safety in May, June, July and August. The number of ships in distress showed the same temporal distribution with the number of verified distress incidents from January to August, and dropped in September and October. The main types of ships in distress are transporting ships, agricultural vessels, fishing boats and official ships. Transporting ships fluctuated the most in August, and the number of fishing vessels in distress increased sharply in August and the following months. There is no significant linear relationship between the number of distressed people and ships. The number of people in distress on the four types of ships all showed a certain time distribution characteristics. The sudden increase in the number of deaths and disappearances in the main rivers in
June reflects two problems in traffic safety emergency: 1. inadequate risk warning and accident prevention and control, 2. poor timeliness in searching for marine targets in distress.

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