Risk Analysis of Marine Dangerous Cases and Accidents in Weihai and Study on Their Preventive &Control Measures

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Abstract. The paper analyses the features of risks in marine dangerous cases and accidents that happened in Weihai, defines the levels of regional risks and draws the risk-region spatial distribution map with respect to the accident level, the risk-area spatial distribution, the type of vessel in danger, the period of time of accident happening and dangerous situation etc. through acquired remote-sensing images of Tiangong-2 (a Chinese satellite) and the statistical data on marine dangerous cases and accidents (MDCAs) in Weihai by using RS and GIS technology. On the basis of the features of risks in MDCAs in Weihai, the paper recommends some measures to prevent and control risks, for instance, design a three-level search & rescue network and improve the safeguard mechanism. The work will further enhance the Weihai marine search and rescue capability and foster development of the regional marine economy quickly and stably.

1. Background

In the Marine Search and Rescue Regulations of Shandong Province [1], its Section 6 provides that “the people’s governments at the county and above shall incorporate marine search and rescue into planning of national economic and social development, establish and improve the marine search & rescue system and emergency response mechanisms to enhance their marine ability to search and rescue” and its Section 9 provides “the marine search and rescue center established by the people’s governments of coastal cities and counties (city and district) shall be responsible for overall organization, coordination and command of marine search and rescue activities over sea under their jurisdiction”. In Weihai which lies in the coast of Yellow Sea, surrounded by sea in its three directions, with a total coastline of 977.80 km, the marine economy is central to its economic and social development, and the shipping, marine fishery and tourism have been growing rapidly. As a region with frequent marine dangerous cases and accidents (MDCAs) in China, 386 MDCAs have happened at sea under jurisdiction of Weihai from 2010 to 2017, including 3,118 victims. Though Weihai maintains a marine search & rescue center, the capabilities for marine search & rescue are clearly insufficient due to poorly-developed systems and mechanisms, shortage in specialized equipment and personnel, and deficient safeguarding measures. Currently, there is no standard to be complied with to build the marine search & rescue capacity at the city level, nor example for reference. To scientifically respond to high risks in MDCAs in order to effectively control and reduce injuries and deaths as well as property loss, the paper analyzes the features of risks in MDCAs in Weihai from multiple perspectives, recommends measures for risk prevention and control, and provides scientific basis to build and plan marine search
&rescue capacity in Weihai, which will play an important role in enhancing the city’s emergency ability of marine search &rescue.

2. Geographical Range under Research

The geographical range under research of this paper is the region where Weihai is responsible for marine search & rescue, Chinese waters between the south and north borders: the north border: N37° 28’ 06.18″ / E 121° 55’ 08.35″ and N38° 30’ 00″ / E 121° 55’ 08.35″ is connected sequentially and then extend to the due east along the latitude line N38° 30’ 00″; the south border: N36° 46’ 53.86″ / E121° 28’ 06.16″, N36° 46’ 54.02″ / E121° 28’ 18.25″, N36° 45’ 38.45″ / E121° 28’ 30.35″, N36° 44’ 35.90″ / E121° 27’ 37.75″ and N36° 34’ 00″ / E121° 30’ 27.35″ are connected sequentially and then extend to the due east along the latitude line N36° 34’ 00″.[2]

3. Data Acquisition and Pre-processing

3.1 Data from remote-sensing images

3.1.1 Selection of Data from remote-sensing images. Of nearly a thousand remote-sensing images over the researched geographical range and its surrounding taken by Tiangong-2 from January 1 2017 to August 1 2018, three are selected as original remote-sensing images to draw the base map for data analysis as shown in Figure 1 and Table 1. The criteria to select the original images are: 1) it is able to cover the researched region after image splicing and mosaic; 2) there shall be as less amount of cloud over the researched region as possible; 3) higher resolution.

Fig. 1. [3] original remote-sensing images

| Data Name | satellite | payload | product type | product level | spectrum range |
|-----------|-----------|---------|--------------|---------------|----------------|
| T2_MWI_VNI_IMG_20180311095551_20180311101245_L2_000_22_20180311201514_V211.tif | Tiangong-2 | Wide-band Imaging Spectrometer | image | Level 2 | visible and near-infrared spectrum range of Wide-band Imaging Spectrometer |
| T2_MWI_VNI_IMG_20180411152937_L2_000_22_20180412033514_V211.tif | Tiangong-2 | Wide-band Imaging Spectrometer | image | Level 2 | visible and near-infrared spectrum range of Wide-band Imaging Spectrometer |
| T2_MWI_VNI_IMG_20180531142608_L2_000_26_20180531142608_V211.tif | Tiangong-2 | Wide-band Imaging Spectrometer | image | Level 2 | visible and near-infrared spectrum range of Wide-band Imaging Spectrometer |
Data acquisition time | 2018-03-11 | 2018-04-11 | 2018-05-08
---|---|---|---
Space resolution | 100m | 100m | 100m
Coordinate system | WGS84 | WGS84 | WGS84
Map Projection | UTM | UTM | UTM

3.1.2 Draw the base map for data analysis. The original remote-sensing image is L2 data and possesses geographical information and geometrical calibration is completed between images. First, the image’s Data Ignore Value is set as 0 to remove image’s background value by using Edit ENVI Header of ENVI. Second, image mosaic is done by using Seamless Mosaic. Third, in the condition of the longitudes and latitudes of the outmost borders for the geographical range under research mentioned in 2.1, the mosaic images are trimmed regularly to remove messages irrelevant to the researched region. Finally, Segment Only Feature Extraction Workflow is used to extract the water and land borders within the researched region to finally create the data analysis base map files with geographic coordinate information as shown in Figure 2.

The data analysis base file is stored as a KML file from SHP format by the tool of Layer to KML of GIS, and KML and Layer Output Scale is 1000. The KML file is opened by Google Earth as shown in Figure 3. We find that the data analysis base file and Google Earth satellite map overlap well.

3.2 Statistical Data of MDCAs over the Years
The collected messages on MDCAs that had happened from 2010 to 2017 in Weihai are entered into an Excel file item by item, and the Excel Gauss Projection Conversion Formula is applied to convert the positional information on MDCAs from the form of longitude and latitude into the form of XY coordinates in meter. Then, the above-mentioned information is entered into different worksheets by year, and meanwhile Level I and Level II MDCAs over the years are collected and entered in two worksheets, creating 10 sheet files.

The Excel sheets are read into the software ArcGIS, and xy values of every sheet file are read respectively to form 10 events in GIS and then the event data are exported respectively as 10 shp files containing information of point elements. The point element in the shp file means the position of a MDCA.

4. Risk Analysis
4.1 Level of Accidents
Based on MDCA’s factors such as its nature, severity, controllability and scope of influence, the paper divides MDCAs into four levels: I (extraordinarily serious), II (serious), III (larger) and IV (ordinary). [4] Their divisions are presented in Table 2 in detail.
Table 2. [4] Division of MDCA level in Weihai

| Level of Accidents | Conditions for division                                                                                         |
|-------------------|---------------------------------------------------------------------------------------------------------------|
| Level I (extraordinarily serious) | • any marine abrupt incident that causes 30 and more deaths (including missing, the same below) or endanger the life of 30 people and above;  
• any marine abrupt incident that happen in a passenger ship or a chemical carrier and endanger the safety of the vessel or the life of onboard people;  
• Any marine abrupt incident that happens in a civil aircraft carrying 30 people and more at sea;  
• any marine abrupt incident of collision, stranding and fire that happens to a vessel of 10,000 tons and above and endangers the safety of the vessel and the life of onboard people;  
• any marine abrupt incident that urgently needs State Council to related regions, agencies or military forces to rescue;  
• any marine abrupt incident that may lead to extraordinarily serious social impact or hazard. |
| Level II (serious) | • any marine abrupt incident that causes deaths of more than 10 but less than 30 people or endanger the life of more than 10 but less than 30 people;  
• any marine abrupt incident that happens in a civil aircraft carrying less than 30 people at sea;  
• any marine abrupt incident of collision, stranding and fire that happens to a non-passenger or non-dangerous-chemical vessel ranging between 3,000 and 10,000 tons and endangers the safety of the vessel and the life of onboard people;  
• any marine abrupt incident that may lead to serious social impact or hazard. |
| Level III (larger) | • any marine abrupt incident that causes deaths of more than 3 but less than 10 people or endanger the life of more than 3 but less than 10 people;  
• any marine abrupt incident of collision, stranding and fire that happens to a non-passenger or non-dangerous-chemical vessel ranging between 500 and 3,000 tons and endangers the safety of the vessel and the life of onboard people;  
• any marine abrupt incident that a Chinese ship or a foreign ship carrying Chinese is missing;  
• other marine abrupt incident that lead to or may lead to larger social impact or hazard. |
| Level IV (ordinary) | • any marine abrupt incident that causes deaths of less than 3 people or endanger the life of less than 3 people;  
• any marine abrupt incident of collision, stranding and fire that happens to a non-passenger or non-dangerous-chemical vessel below 500 tons and endangers the safety of the vessel and the life of onboard people;  
• other marine abrupt incident that leads or may lead to general dangerous consequence. |

a As for number expressions in Table 2, the wording “and more” or “and above” includes the number there while the wording “and below” or “less than” does not include the number there.

Based on the conditions for accident level division defined in Table 2, statistical data concerning MDCAs in Weihai from 2010 to 2017 are compared item by item, and the obtained data on accident level are statistically analyzed, with the result shown in Figure 4. In the region, the ordinary accident outnumbers the others, accounting for about 69% of total accidents; the extraordinarily serious acci-
dent is the least, about 1%; the larger accident and the serious accident account for about 20% and 10% respectively. Also, MDCAs of the four levels show a trend to drop year by year.

![Fig. 4. Trending sketch of MDCAs in Weihai by level in the period 2010~2017](image)

Although the number of the serious and extraordinarily serious MDCAs is less than others, but they still deserve our attention, because they always threaten heavily the safety of people life and property though they are less. In Weihai, there were two extraordinarily serious MDCAs in 2010 but no for 2011 ~ 2017, 0.25 accident/year on average. Weihai had experienced 40 serious MDCAs for years 2010 ~ 2017, 5 accidents/year on average.

4.2 High-risk Region
On the condition that the marine functional zoning is constant in Weihai, the paper believes that the more MDCA happens, the higher the marine risk in the region. The shp file and the data-analysis base map generated in 3.2 are read in the software ArcGIS to superpose and display to generate the MDCA distribution map, as shown in Figures 5.

![Fig. 5. MDCA distribution map](image)

In the period 2010 ~ 2017, Weihai Marine Search &Rescue Center received 386 MDCA reports of which 84% happened within the region where Weihai is responsible for marine search & rescue. Weihai Marine Search & Rescue Center participates in dealing with any MDCA that happens to any vessel registered in Weihai out of the responsible region of Weihai, which mainly are fishing vessel in danger. With enhanced regulation to fishing vessels and a new responsible region for marine search and rescue divided by Shandong Maritime Safety Administration in which also determined the responsibilities of
all sub-bureaus within their responsible regions, Weihai MDCAs have mainly happened within its responsible region since 2014.

On the basis of the density and distribution of accident positions within the responsible region, it is known that, in the period 2010~2017, MDCAs showed a trend to decline progressively within the responsible region, and mainly distribute within 30 nautical miles to the coast which are within the responsible regions of Longyan and Shidao Marine Offices; serious MDCAs are distribute within 60 nautical miles to the coast which are within the responsible regions of Longyan and Shidao Marine Offices, most of which happened within 30 nautical miles to the coast. The most MDCAs happened within the responsible region of Longyan Marine Office where two extraordinarily serious MDCAs took place. This has relations with the facts that there are densely distributed ports, sea lanes and anchorages, many vessels navigating and complex navigation environment in this region.

The areas in 30 nautical miles to the coast in the responsible regions of Long Yan and Shi Dao Marine Offices are determined to have a high risk for MDCAs. The areas that are from 30 to 60 nautical miles to the coast within the responsible regions of Long Yan and Shi Dao Marine Offices and the whole responsible region of Ru Shan Marine Office are determined to have a medium risk. The other areas are determined to have a low risk.

Fig. 6. Sketch map of risk areas for MDCAs in Weihai

4.3 Type of Vessel with High Risk

In the period 2010~2017, the vessels in danger of MDCAs in Weihai include merchant ships, fishing boats, passenger ships, sailboats, scientific research ships, barges, workboats and yachts. Of these, fishing boats are in danger in the most quantity, accounting for about 61% of total in-danger vessels; the merchant ships follow it, accounting for about 36%; total in-danger ships of other types account for about 3%. As a result, Weihai marine search & rescue shall focus on fishing boats in the first place and then merchant ships. The statistic results of in-danger vessels are shown in Figure 7 by vessel type.

Fig. 7. Proportion of vessels in danger of MDCAs in the period 2010~2017 in Weihai
4.4 Period of Time with High Risks
Weihai stands in the north China where it is colder in winter. The accident incidence is low from January to April every year during which people stay home to escape cold and celebrate the holidays including the New Year’s Day and the Spring Festival and therefore no ship goes to sea basically. For the period from May to August which is the fishing-off season, it is mainly merchant and passenger ships that are navigating at sea and the probability for MDCAs is low because both are safer and their sailors are well qualified. The period from September to December is the high-risk period of time during which MDCA rises suddenly. Due to ending of the fishing-off season, many fishing boats go to sea fishing. And since the Thanksgiving and Christmas of western countries take place in the period, the quantity of vessels for foreign trade and export is on the rise and navigating vessels increase. All these result in more complicated navigation environment, the fishing boats are low in safety, and therefore the probability for MDCAs is higher.

4.5 Main Dangerous Situations
Dangerous situation shows how MDCA performs and one MDCA corresponds to one dangerous situation. Based on the results from statistical analysis of dangerous situations of MDCAs in the period 2010 ~ 2017 in Weihai as shown in Figure 8, injury is the major dangerous situation in the region, accounting for about 41% of total accidents; in addition, damage to machinery, collision, damage from touching, water ingress into ships and ship sinking/self-sinking are common dangerous situations, accounting for 14%, 13%, 8%, 6% and 6% respectively. Injury, damage to machinery, collision and damage from touching are still main dangerous situations in the region though they showed an obvious trend to decline year by year. Other dangerous situations have remained steady in the amount. Wind damage has not happened since 2012, dragging did not happened in 2010 ~ 2015 but occurred in 2016, and dragging accident increased in 2017.

![Fig. 8. Proportion of dangerous situations of MDCAs in the period 2010 ~ 2017 in Weihai](image)

5. Recommendations to Measures for Risk Prevention and Control

5.1 Plan a Three-level Search & Rescue Network
Based on the level of risk areas in MDCAs and their spatial distribution in Wei-hai, it is planned to establish a search & rescue network consisting of three levels: comprehensive search & rescue base, search & rescue base and search & rescue station.

The comprehensive base shall be capable to berth large search & rescue vessels and take off and land search & rescue planes which may be built with the planned Chengshantou Level-1 Emergency Equipment Warehouse. The comprehensive base shall have functions for organization and coordination, also concurrently used as Weihai Marine Search & Rescue Command Center, Weihai Marine Search & Rescue Training and Drill Base, and Weihai Scientific Popularization Base for Marine Search & Rescue, and the responsible region of it covers all of Weihai waters.
It is recommended to plan to build 3 search & rescue bases respectively located at the responsible regions of Longyan, Shidaoshan and Rushan Marine Offices which may be built in combination with the planned Level-2 emergency equipment warehouse. The bases shall have functions to berth search & rescue emergent vessels, store and maintain/repair search & rescue equipment etc.; have an emergency temporary command station for marine search & rescue and provide medical aid services.

It is recommended to build search & rescue stations at bathing beaches, marinas and passenger liners etc. to support existing rescue forces, which will have functions to store, maintain and repair research & rescue equipment, be provided with high-speed yachts and water scooters mainly used to deal with drowning accidents quickly.

5.2 Improve Safeguard Mechanisms
It is recommended to further improve the safeguard mechanism for Weihai marine search & rescue on interagency coordination, funding, propaganda, drill and professional training etc. It is recommended to establishing a sound management and coordination mechanism under the leadership of the city government involving Beihai Rescue Bureau of MOT, the Maritime Safety Administration, the Ocean and Fishery Bureau, the Port Authority and Blue Sky Rescue (BSR) etc. It is recommended that Weihai City Government appropriate special funds, and improve the search & rescue compensation and reward mechanism.

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