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Determination of refuge places for oil tankers in emergencies in the Chinese Bohai Sea

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A R T I C L E I N F O

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A B S T R A C T

This study considered three major emergency scenarios for oil tankers: explosion and fire on board, oil leaking from the ship into the sea, and sinking of the ship. A total of 25 main harbors and 51 main anchorages along the Bohai Sea were considered as potential places of refuge (PoR) to which oil tankers could be towed in an emergency. Three categories of indicators including 18 criteria were constructed given a total of 76 potential PoR. For visualization and further evaluation, a GIS-based score mapping system was built using normalization and rectilinear grids covering the whole domain for each of the criteria. All criteria were weighted equally and were then overlapped to present an overview of the ranking of all PoR in the Bohai Sea under each scenario. The least ranked five PoR for each scenario included in the final findings should be avoided by decision makers when they face a decision on where to tow an oil tanker for sheltering in emergency conditions. This paper provides a quantitative assessment method for determining PoR to which oil tankers should be towed in emergency conditions and suggests appropriate PoR with high rankings for oil tankers in the Chinese Bohai Sea.

1. Introduction

According to the *Guidelines on Places of Refuge for Ships in Need of Assistance* issued by the International Maritime Organization (IMO), a place of refuge (PoR) refers to a location where a ship in need of assistance can be taken to enable it to stabilize its condition, thus reducing the hazards to navigation, human life, and the environment. As the only instrument and standard on PoR [1], the IMO guidelines were initiated following a serious of notorious oil spill accidents such as Erika in 1999, Castor in 2000 and Prestige in 2002 [2]. In the case of Prestige, one of its tanks burst in northwestern Spain while it was carrying 77,000 t of heavy oil in November 2002. The captain called for help but the Spanish, French, and Portuguese governments all refused to allow the ship to dock in their ports for fear of pollution of their coasts. As a result, the ship split in half and sank, releasing 20 million US gallons of oil into the ocean. The accident caused huge economic and ecological losses to the surrounding areas [3–5]. The estimation of short-term losses in all affected economic sectors amounts to almost €770 million [6], and the Spanish society placed a value of the environmental losses around €574 million [5]. Hence, a pre-designated PoR is needed to mitigate damage in future emergencies [7].

Such catastrophes sounded the alarm to coastal states. Since 2003, more and more countries have started to take measures to respond to the IMO guidelines. The EU has taken action to provide practical guidance for the competent authorities involved in managing a request for a PoR for ships by issuing EU Operational Guidelines on PoR. At the 3rd meeting of the EU Cooperation Group on PoR in 2015, a decision was made to test the guidelines using a practical case scenario. Under the terms of the community vessel traffic monitoring and information system (VTMIS) directive (Directive 2002/59/EC), EU member states

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Table 1
Details of all involved criteria and their normalization rules for the emergency response capacities-based indicator.

Label	Criteria	Data obtained	Description	Normalized score (0–100)
X_1	Rescue capability	Obtained from local MSA	Continuous data representing the quantity of rescue ships	The more rescue ships, the higher the score
X_2	Towing capacity	Obtained from local MSA	Continuous data representing the quantity of tugs	The more tugs, the higher the score
X_3	Firefighting capability	Obtained from local MSA	Continuous data representing the quantity of fireboats	The more fireboats, the higher the score
X_4	Protective suits for rescue team	Obtained from local MSA	Continuous data representing the quantity of chemical splash proof suits	The more chemical splash suits required, the higher the score
X_5	Capacity for containing oil	Obtained from local MSA	Continuous data representing the quantity of contaminated oil booms	The more oil booms, the higher the score
X_6	Capacity for trans-shipping oil	Obtained from local MSA	Continuous data representing the quantity of unloading pumps	The more unloading pumps, the higher the score
X_7	Capacity for cleanup of spilled oil	Obtained from local MSA	Continuous data representing the quantity of oil skimmers	The more oil skimmers, the higher the score

Note: MSA, Maritime Safety Administration.

have been required to designate "one or more competent authorities which have the required expertise and the power, at the time of the operation, to take independent decisions on their own initiative concerning the accommodation of ships in need of assistance." Some countries have taken further action in addition to the official directive to designate PoR. There have been two principal approaches to this problem [8]: First, some countries have clearly outlined PoR in advance. For example, Denmark designated a total of 22 sites along its coastline as potential PoR [9], and Latvia designated 7 coastal PoR including harbors and anchorages [10]. Second, other countries did not identify PoR but instead produced standard criteria and procedures that could guide endangered oil tankers to an appropriate place for sheltering. For instance, the United Kingdom maintains a list of approximately 800 potential sites as PoR, even including environmentally-sensitive areas [11]. The decision will be made under assessment of the contingent situation once accidents occur. The US has not designated potential PoR for oil tankers either, but guidelines for PoR decision-making have been issued by the National Response Team (NRT) including identification of important factors such as weather, sea state, tide and for consideration, and a decision-making process has been presented [12,13]. China has a high demand for imported crude oil, which mainly relies on marine transportation by oil tankers. In 2015 alone, 3.355 billion tons crude oil were imported. Accidents related to oil tankers have threatened the Chinese coasts in the past 30 years. According to the statistics [14], from 1990 to 2010, approximately 22,035 t were lost in Chinese waters, and 71 spills had a volume exceeding 50 t. However, China has neither designated potential PoR nor presented a decision–making process for oil tankers, which could result in chaos and inappropriate decision-making in the case of an emergency.

To our knowledge, quantitative selection methods for PoR for oil tankers are rarely available. Most previous publications have focused on legal aspects [15–17] or transboundary issues [18,19]. To our knowledge, no studies have covered quantitative assessments for PoR of oil tankers; thus, the technical method requires further discussion. To fill the research gap and to provide data of practical importance for Chinese coastal management, our study focused on how to determine PoR for oil tankers in emergencies in China with a focus on demonstrating a concrete methodology in the specific case of the Chinese Bohai Sea.

The Chinese Bohai Sea is one of the busiest sea areas in China, and shipping accidents remain frequent there [20]. Moreover, coastal regions of the Bohai Sea are economically developed, and the Bohai Sea is a semi-enclosed shallow sea with average and maximum water depths of 18 and 70 m, respectively. Due to its specific ecological and economic importance, it is highly vulnerable to oil spills of any size. Finally, given that the Bohai Sea is China's inland sea, it would not cause any disputes with neighboring countries when PoR were designated. Hence, the Bohai Sea was selected as an ideal area for our study.

2. Data and methods

In this study, three major scenarios were explored in which an oil tanker would need to be towed to a PoR for further assistance. These scenarios include explosion and fire on board without leakage of oil, oil leaking into the sea, and the risk of sinking. For each scenario, corresponding criteria to be examined were selected. In general, three major categories of indicators were considered by combining empirical evidence and the IMO guidelines: the emergency response capacities indicator, the environmental indicator, and the social indicator. Moreover, each type of indicator contained a variety of criteria: rescue capability, towing capacity, firefighting capability, protective suits for a rescue team, capacity for oil containment, capacity of trans-shipping oil, capacity for the cleanup of spilled oil, nature reserve areas, distance from the coast, wind speed, wave height, maximum ocean current velocity, slope degree, bathymetry, seabed material, population, tourist attractions, and mari/aquaculture (Tables 1–3). As the criteria considered in each scenario were not identical, the three scenarios and their corresponding criteria were explored as shown in Fig. 1.

2.1. Scenario 1: explosion and fire on board

When explosions and/or fires occur on oil tankers, the most urgent response must be to rescue of the crews. Hence, the rescue capacity was first considered and then the towing capacity and firefighting capability were considered. In order to obtain the emergency capabilities on the sea surface, inverse distance weighting (IDW) interpolation was used for the evaluation. The IDW method is a type of deterministic method for multivariate interpolation with a scattered set of points. It assumes that each input point has a local influence that diminishes with distance, and it weights the points closer to the processing cell greater than those farther away.

Moreover, the designated PoR under this scenario should be far away from densely populated areas because of the adverse social impacts [21] and because oil pollution can harm human health both in physically [22] and mentally ([23]. Thus, the influence of population density in every county around the Bohai Sea was taken into consideration. A threshold of 20 nautical miles from the coastlines was assumed. Outside this distance, it was thought that the oil would not pose a threat to human health.

2.2. Scenario 2: oil leakage into the sea

Once the spilled oil was observed on the sea surface, the oil combat

Table 2
Details of all involved criteria and their normalization rules for the environmentally-based indicator.

Label	Criteria	Data obtained	Description	Normalized score (0–100)
X_8	Nature reserve areas	Digitalize from database of nature reserves in China	Continuous data representing the distance from PoR to nature reserve areas	The farther from nature reserves, the higher the score
X_9	The distance from coast	Downloaded from Google Earth	Continuous data representing the distance from PoR to coast	The closer to the coast, the higher the score
X_{10}	Wind speed	Observed from HY – 2A satellite radar altimeter product	Continuous data representing annual average wind speed on the sea surface	The lower the wind speed, the higher the score
X_{11}	Wave height	Observed from HY – 2A satellite radar altimeter product	Continuous data representing the average of annual wave height on the sea surface	The lower the wave height, the higher the score
X_{12}	Maximum ocean current velocity	Simulated from General Estuarine Transport Model (GETM)	Continuous data representing the maximum ocean currents velocity	The lower the current velocity, the higher the score
X_{13}	Slope degree	Re-calculated from the change of bathymetry	Continuous data representing the seabed slope	The gentler the slope degree, the higher the score
X_{14}	Bathymetry	Digitalized from submarine topographic map in the East China Sea	Continuous data representing the depth of sea water	The shallower the depth, the higher the score
X_{15}	Seabed material	Digitalized from map of types of marine sediments in the East China Sea	Category data representing the bottom material of seafloor	It was assumed that the score of clay was 100, the score of silt was 70, the score of fine sand was 50, the score of coarse sand was 20, and the score of sand with gravel was 10

capabilities for the spill were first considered, such as the capacity for oil containment, capacity of trans-shipping oil and capacity of cleanup spilled oil. The protective suits that were prepared for the relief workers were also included because the exposure to the oil and the cleanup efforts could cause acute health problems [24].

The spilled oil has a huge influence on the surrounding environmental resources [25]. Based on previous experiences [26–28], oil contamination can cause a long-term impact on the ecology of the environment and can persist in the marine environment for many years after an oil spill. In order to reduce the possible impact of the spill on nature reserves, the PoR should be located far away from them. In this study, a threshold of 20 nautical miles was assumed, which was the distance from the nature reserves that could be influenced by the spilled oil. The areas inside the buffer were considered inferior to areas outside the buffer for designation as a PoR. Inside the buffer, the closer the site to the natural reserves; the less appropriate it was considered to be for oil tankers to take shelter. In contrast, all areas outside the buffer were thought to be appropriate for PoR. Moreover, commercial fisheries and tourism could also be strongly influenced by oil spill accidents [29]. The same threshold was assumed for tourist attractions and mari/aquaculture regions as for nature reserves.

The IMO guidelines suggested that the prevailing wind, current conditions, and depth should be considered for the evaluation of risks associated with the provision of PoR. The sea conditions, especially wind speed and wave height, would influence the decision-making to a large extent when an oil tanker needs shelter. However, the real-time data of wind and waves can only be determined in response to each specific future emergency. Therefore, it was difficult to consider these aspects given the dynamic nature of the marine environment. For this reason, previous data were used as a substitute for the instantaneous data. The annual average wind speed and wave height were used in the present work. The currents used here reflect real-time information; so the maximum current velocities from the simulation results of GETM were considered (further details of this model can be found at http://www.getm.eu/).

2.3. Scenario 3: risk of sinking

In this scenario, the potential PoR should be distant from nature reserves, commercial fisheries, and tourist attractions for the convenience of subsequent salvage of the ship and due to the potential spillage risk. In addition, other criteria such as slope degree, bathymetry, and seabed material of the Bohai Sea were also taken into account, since once an endangered oil tanker is confronted with a risk of sinking, the appropriate PoR would be located in areas with a gentle slope and shallow water for easier salvage. Moreover, the seabed material of the Bohai Sea is mainly clay, silt, fine sand, coarse sand, and sand with gravel. Generally, the larger the particle size of the seabed material, the more easily the spilled oil will permeate it. Hence, silt was thought to be preferable to the other sediments for the convenience of cleanup after the emergency, because it is difficult for fluids to permeate.

2.4. Harbors and anchorages

By design, harbors and anchorages have clear advantages as PoR; Latvia's pre-designated places were all harbors and anchorages. In this study, 25 harbors and 51 anchorages in the Bohai Sea (Fig. 2) were considered as potential options for PoR.

2.5. The gridding score system

In this study, diverse criteria with different metrics were taken into consideration. This study referenced the gridding technology in previous studies to respond to the cross-disciplinary nature of the work [30,31]. Subsequently, a gridding score mapping system was built using

Table 3
Details of all involved criteria and their normalization rules for the socially-based indicator.

Label	Criteria	Data obtained	Description	Normalized score (0–100)
X_{16}	Population	Digitalized from 2010 national-wide census of population of China	Continuous data representing population density of every county around the Bohai Sea	The lower the population density, the higher the score
X_{17}	Tourism	Investigated from LMO	Continuous data representing the distance from PoR to places of tourist attraction	The farther from tourist attractions, the higher the score
X_{18}	Mari/aquaculture	Investigated from LMO	Continuous data representing the distance from PoR to mari/aquaculture area	The farther from mari/ aquacultural areas, the higher the score

Note: LMO, Local Management Office.

a geographic information system (GIS) with the purpose of eliminating the cross-disciplinary effect.

Rectilinear grids were generated to cover the whole domain of the Chinese Bohai Sea. Each grid cell in the mesh was 1000 m × 1000 m. Every cell was then normalized for the individual criteria by allocating each cell with a score from 0 to 100 according to the value corresponding with it. The corresponding values were the true values of the criteria obtained from various sources as shown in Tables 1–3. Every cell score was calculated according to the same formula. Formula (1) was used for normalization of each grid cell,

$$K_i^j = (x_i^j - Min_i)/(Max_i - Min_i) \times 100, \tag{1}$$

where ***K*** is the score between 0 and 100, ***j*** represents the identifier of cell, ***min*** is the minimum value in terms of a specific criterion, ***max*** is the maximum value in terms of a specific criterion, ***x*** is the true value of the cell, ***i*** represents the identifier of criteria (from 1 to 18). The criteria were normalized respectively according to Formula (1). The criteria used to determine the score for each scenario indicator and label are listed in Tables 1–3. It was here assumed that all criteria used in each scenario were equally weighted. The normalized scores were summed to determine the overall performance of each potential PoR.

3. Results

3.1. Ranking scores for each individual criterion

As shown in Fig. 3, the whole Bohai Sea area was scored in terms of the selection criteria and subsequently normalized based on Formula (1). Compared with the zone in red, the zone in blue represented a higher score and thus an increased preference as a PoR.

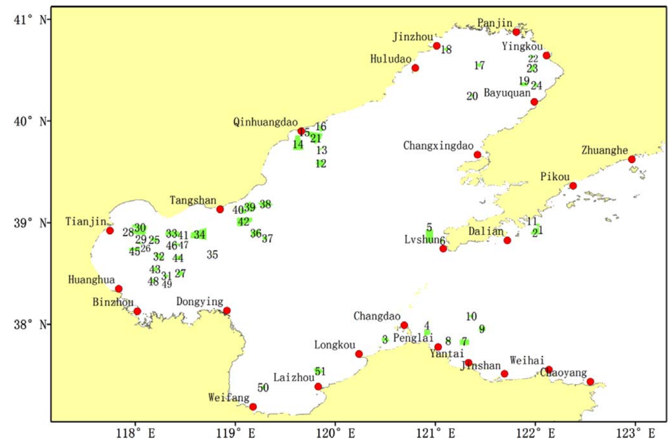

Fig. 2. All 76 potential places of refuge, including 25 main harbors and 51 anchorages in the Bohai Sea. The anchorages are labeled in green, and the harbors are labeled in red.

In general, for the seven criteria affiliated with the emergency response capacities indicator (Fig. 3 (X_1–X_7)), the highest-scored sites corresponded with the sites in which equipment storage units were located. The response capabilities diminished with distance because it would take more time to transport the facilities to more distant locations. Correspondingly, the farther the distance to the equipment storage units, the worse the response capabilities would be.

(Fig. 3 (X_{16})) shows that the impact of spilled oil on the local population is positively linked with the population density and negatively

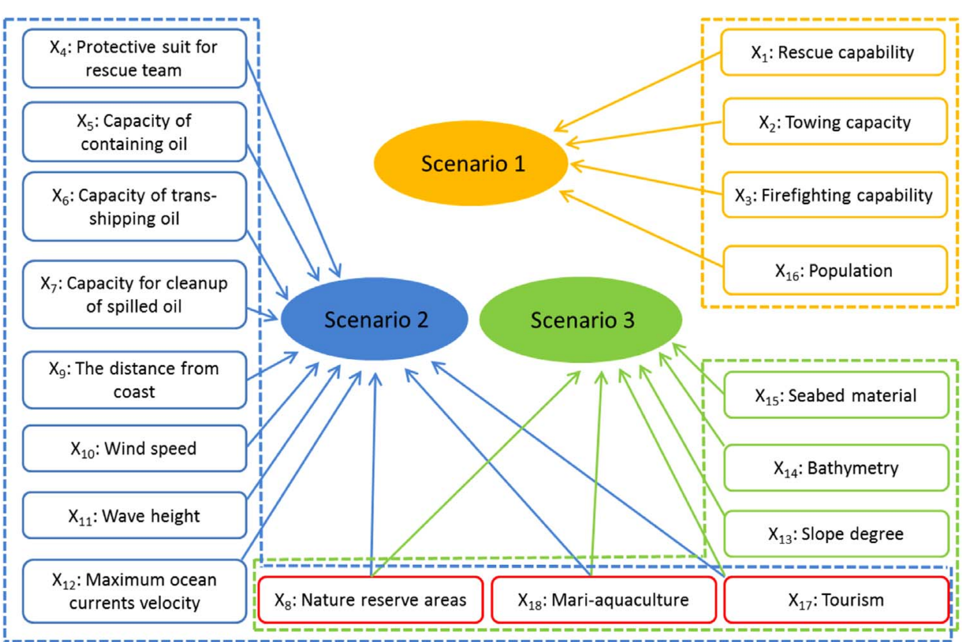

Fig. 1. Summary of the corresponding criteria for the three scenarios (a)Scenario1: explosion/fire on board, (b) Scenario 2: oil leaking into the sea, and (c) Scenario 3: risk of sinking.

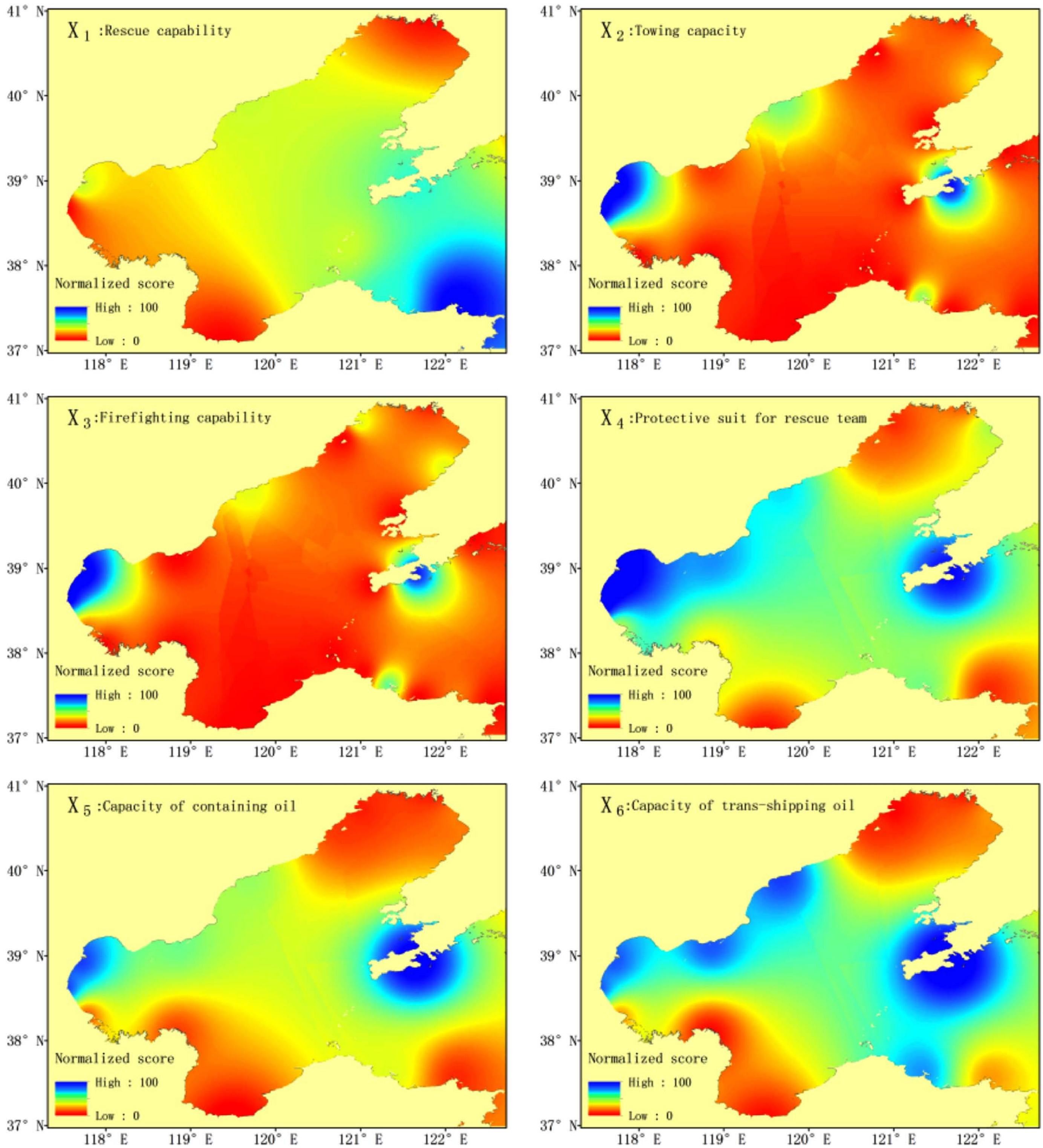

Fig. 3. Ranking scores in terms of each individual criterion for the entire Chinese Bohai Sea, blue areas should be considered as PoR, and red areas should not be considered as PoR.

linked with distance. Correspondingly, the score decreased gradually inside the assumed threshold distance of 20 nautical miles, and a hotspot was present in the upper part of the Bohai Strait, where the super city Dalian with a population greater than 6.9 million is located. A similar rule also applied to the following three criteria: nature reserve, tourist attraction, and mari/aquaculture (Fig. 3 (X_8, X_{17}, and X_{18})). These three criteria represent sensitive areas along the Bohai Sea, and regions were identified in the center of the score maps that were at least 20 nautical miles away from the sensitive areas.

3.2. Evaluation results for Scenarios 1–3

For the three scenarios, the selection results of the whole domain were obtained after overlapping scoring maps of selected criteria, and the results were also indicated by gradient color (Fig. 4). The harbors and anchorage sites in blue-colored zones could serve as PoR for oil

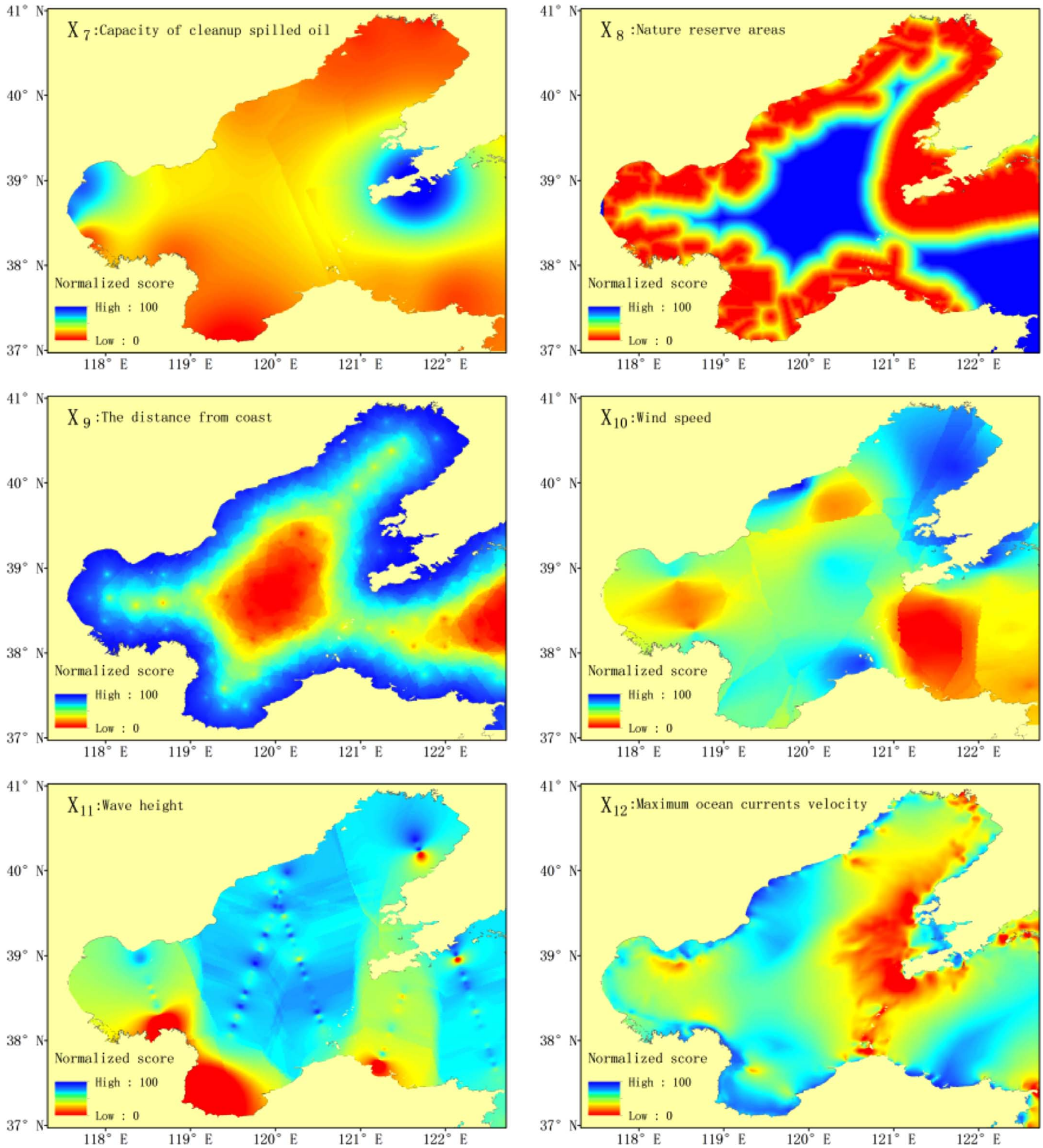

Fig. 3. (*continued*)

tankers, whereas those in red zones are not recommended.

Fig. 4(a)–(c) indicates that the suitable PoR would shift according to the scenario because different criteria were considered in each case. For Scenario 1 (Fig. 4(a)), the most appropriate places were near Tianjin or Dalian, including Tianjin Harbor, Anchorage 28, Anchorage 29, Dalian Harbor, and Anchorage 52. However, locations in the southwestern bay of the Bohai Sea were considered unsuitable as temporary shelters for oil tankers under Scenario 1. For scenario 2 (Fig. 4(b)), the most inappropriate sites to act as PoR were mostly located in the southwestern bay and the northeastern bay of the Bohai Sea. They were Anchorage 18, Panjin Harbor, Jinzhou Harbor, Weifang Harbor, and Anchorage 50. Under Scenario 2, nearly all potential PoR with negative performance were located close to the coasts. This is because three criteria (the presence of nature reserves, fisheries, and tourist attractions) were introduced into the evaluation, and all these sensitive resources are distributed along the coasts. It was suggested that an oil tanker leaking oil should be towed to a location distant from these sensitive resources to avoid subjecting them to pollution. For Scenario 3, Chaoyang Harbor

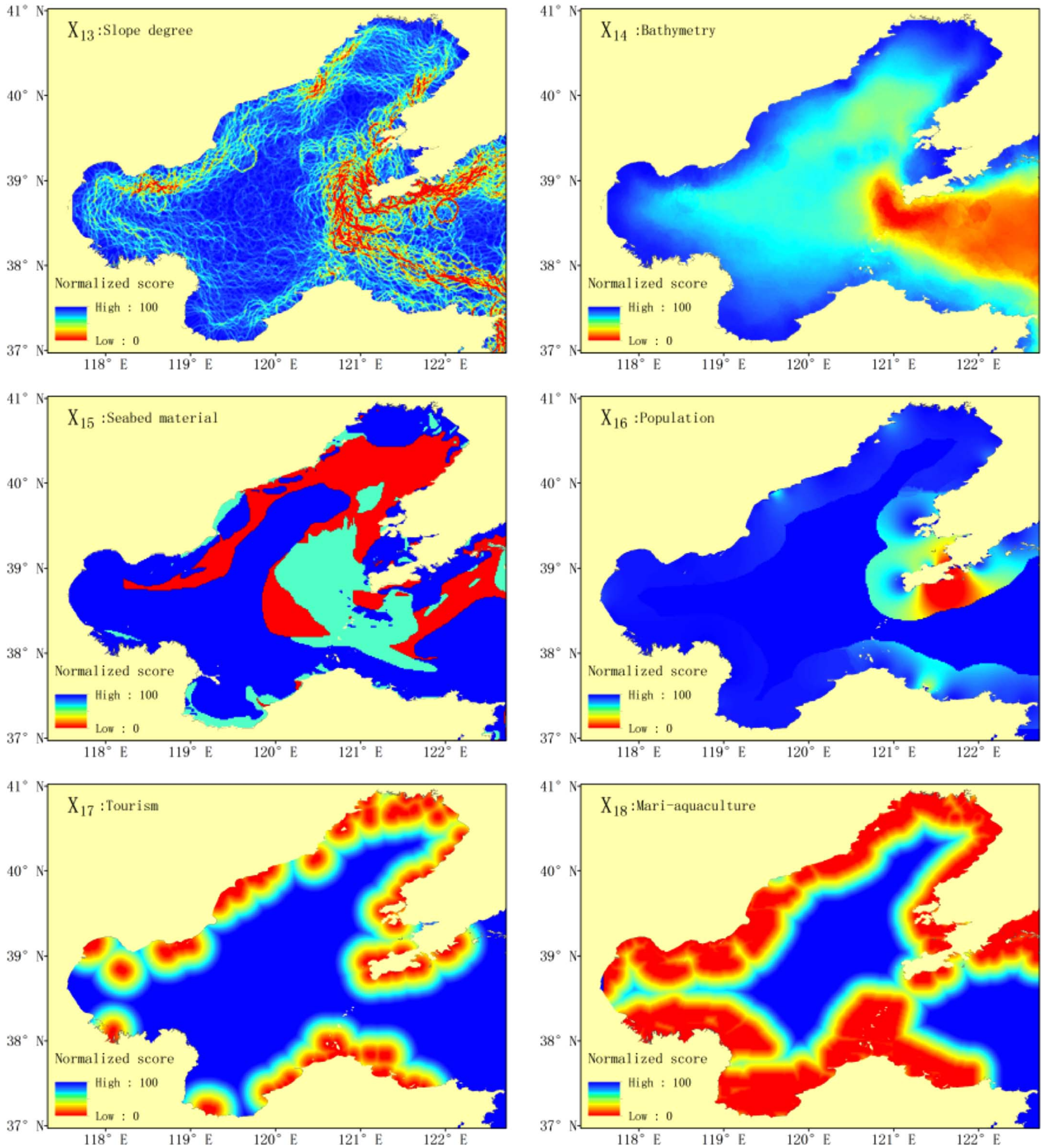

Fig. 3. (*continued*)

and Weihai Harbor were the two most recommended sites to shelter endangered oil tankers followed by Anchorage 43, Anchorage 35, and Anchorage 37.

3.3. Suggestions for PoR

Based on the ranking of individual anchorages and harbors, a list of the five most appropriate and five least appropriate PoR were obtained for each scenario (Tables 4–6). Once oil tankers encounter a dangerous situation, these suggested potential PoRs would be ideal for towing the tanker into shelter immediately on the basis of first identifying which scenario the emergency corresponds to. The same ranking between two PoR means that they share the same score.

4. Discussion

According to the IMO guidelines, the selection of PoR is a complicated research topic in which diverse indicators should be considered.

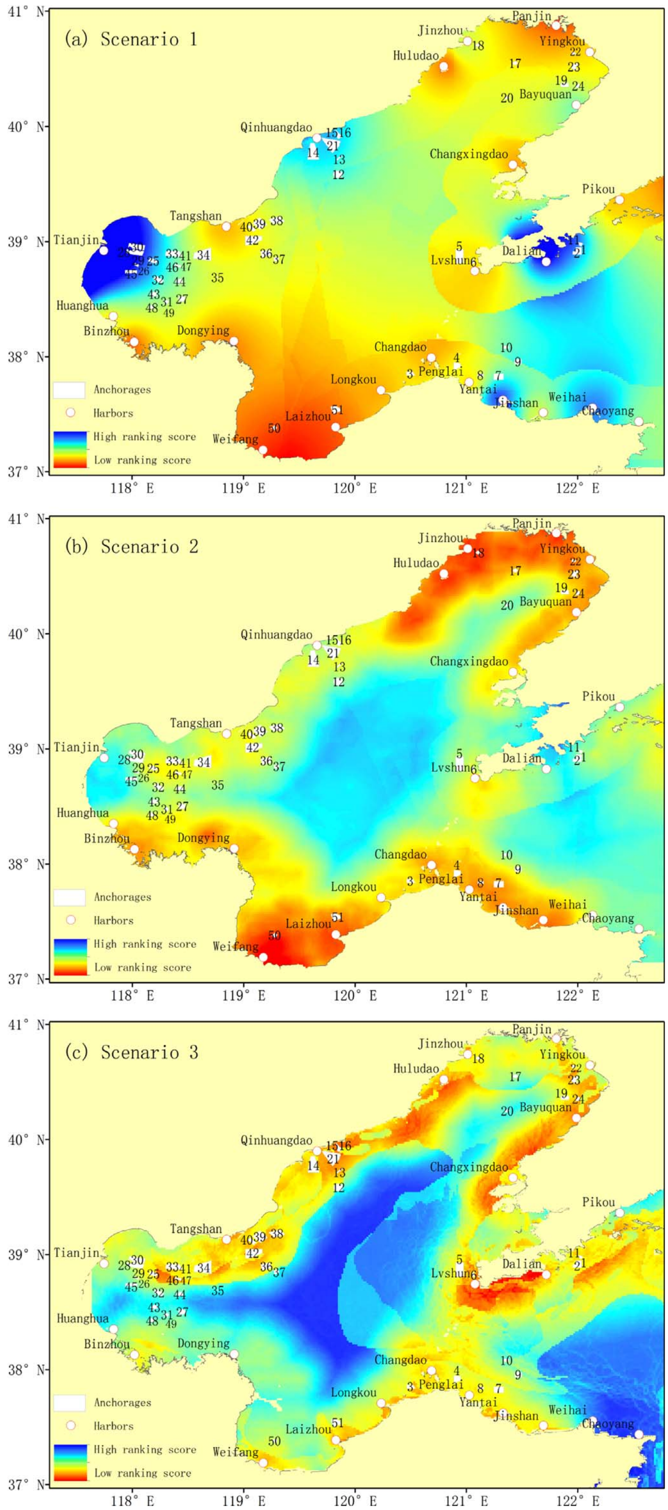

Fig. 4. Maps for determining PoR in (a) Scenario 1: explosion/fire on board; (b) Scenario 2: oil leaking into the sea; and (c) Scenario 3: risk of sinking. The anchorages are represented by white patches with gray outlines and harbors are represented by the white circles with red outlines.

Firstly, GIS is a powerful tool and has widely been used to deal with multiple criteria simultaneously [32,33]. Croatia built a system called the Decision Support System (DSS) for PoR selection based on a GIS module [34]. Furthermore, DSS included some pre-designated scenarios. Different scenarios were also considered in an oil accident response simulation for allocation of potential PoR [35]. Moreover, a researcher in Jamaica attempted to evaluate PoR from some pre-designated sites [36]. All of these previous works were referenced and used to support this Chinese case study. Three major emergency risk scenarios for oil tankers were considered (explosion or fire on board, oil leaking into the sea, and sinking) to demonstrate the application of the proposed evaluation procedures for each individual scenario, although real conditions could be more complex. In cases in which two risk scenarios occur simultaneously (e.g., ship at risk of explosion/fire and leaking oil), it is here suggested that common optimal or sub-optimal options be identified by overlapping the evaluation results (e.g., those in Fig. 4(a) and Fig. 4(b)).

Sometimes there is only a minor difference in consequences between an optimal option and a sub-optimal option. However, there may be a considerable difference between the optimal option and the least optimal option. A reasonable decision-making process is required to ensure that the most appropriate option is selected. Hence, the least appropriate options were listed for each scenario in this study. This helps decision makers to avoid a poor decision when selecting a PoR for oil tankers in emergency conditions.

Preliminary work for the construction of a decision-making system for PoR selection in the Chinese Bohai Sea was here conducted. However, the question of whether oil tankers in emergencies would be allowed to enter a PoR remains controversial, with difficulties in both legal and practical aspects [37]. However, it has been shown that offering refuge for oil tankers in emergencies is better than refusing them [38]. The presence of a decision-making system would be helpful for the selection of PoR, especially for countries such as China that have not yet designated any potential PoR.

However, when it comes to making decisions, the consideration of additional factors such as incident-specific characteristics, real-time exterior factors [39], and the multiple stakeholders [40] are unavoidable in light of the complexity of the topic. Moreover, in this study, all the factors shared the same weights; however, in reality, the weights of the involved factors should depend on the immediate environment in which the accident occurs. Further work should be conducted to support this study incorporating more indicator-related and weight-related factors.

5. Conclusions

The designation of PoR is a major challenge for policy makers across the world. This study put particular emphasis on solving technical problems using a GIS-based method. The first attempt was made to designate potential PoR for oil tankers in the Bohai Sea, China, based on the existing anchorages and harbors. Multiple sources of data including the emergency response capacities indicator, the environmental indicator, and the social indicator were involved in this work. For each individual criterion, a mesh of 1000 m × 1000 m grid cells was generated and scored. In addition, three scenarios to define oil tankers in a state of emergency were pre-defined based on the normalized meshes. A selection map of potential PoR was obtained for each scenario. Subsequently, the score for each anchorage and harbor was calculated and ranked. The most and least recommended five sites for each individual scenario were listed according to the ranking scores.

In conclusion, this study provides a quantitative GIS-based assessment method of selecting PoR for oil tankers in emergencies and applied this approach to the Chinese Bohai Sea. Potential PoR for specific emergency scenarios were suggested and the work was prepared for the development of an appropriate decision-making system in this area. However, some other problems should be further discussed such as incident-specific characteristics, real-time exterior factors and immediate environment-related weight.

Acknowledgments

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Table 4
The most appropriate and least appropriate PoR for Scenario 1: explosion/fire on board.

Most appropriate PoR	Ranking	Coordinates		Least appropriate PoR	Ranking	Coordinates	
Tianjin	1	117°51'52"E	38°54'23"N	Weifang	76	119°11'55"E	37°12'32"N
Anchorage28	2	118°1′04″E	38°55'54″N	Anchorage 50	75	119°18'16″E	37°23'9″N
		117°57'14″E	38°55'49″N			119°16'37″E	37°24'16″N
		117°56'49″E	38°54'21″N			119°15'05″E	37°22'39″N
		118°0′34″E	38°53'14″N			119°17'09″E	37°21'36″N
Anchorage29	3	118°6′23″E	38°54'52″N	Zhuanghe	74	122°59'06"E	39°38'10"N
		118°1′04″E	38°55'54″N				
		118°0′34″E	38°53'14″N				
		118°5′22″E	38°52'46″N				
Dalian	4	121°39'24"E	38°54'45" N	Panjin	73	121°56'52"E	40°48'32" N
Anchorage30	5	118°6′58″E	38°58'06″N	Laizhou	72	119°52'16"E	37°11'45"N
		117°58'25″E	38°59'10″N				
		117°57'47″E	38°57'06″N				
		117°0′02″E	38°56'31″N				
		117°6′23″E	38°55'33″N				

Table 5
The most appropriate and least appropriate PoR for Scenario 2: oil leaking into the sea.

Most appropriate PoR	Ranking	Coordinates		Least appropriate PoR	Ranking	Coordinates	
Tianjin	1	117°51'52"E	38°54'23"N	Weifang	76	119°11'55"E	37°12'32"N
Dalian	2	121°39'24"E	38°54'45"N	Anchorage 50	75	119°18'16″E	37°23'9″N
						119°16'37″E	37°24'16″N
						119°15'05″E	37°22'39″N
						119°17'09″E	37°21'36″N
Anchorage45	3	118°2′38″E	38°45'09″N	Anchorage 18	75	121°7′45"E	40°43'16"N
		117°56'15″E	38°45'09″N			121°5′3"E	40°43'16"N
		117°56'15″E	38°43'32″N			121°5′3"E	40°41'39"N
		118°2′38″E	38°43'32″N			121°7′45"E	40°41'39"N
Anchorage2	4	122°2′18″E	38°54'53″N	Panjin	74	121°56'52"E	40°48'32"N
		121°57'29″E	38°54'53″N				
		121°57'29″E	38°53'16″N				
		122°2′18″E	38°53'16″N				
Chaoyang	5	122°29'12"E	37°22'56" N	Jinzhou	73	121°4′44" E	40°50'08" N

Table 6
The most appropriate and least appropriate PoR for Scenario 3: risk of sinking.

Most appropriate PoR	Ranking	Coordinates		Least appropriate PoR	Ranking	Coordinates	
Chaoyang	1	122°29'12"E	37°22'56"N	Anchorage 16	76	119°53'19″E	39°54'45″N
						119°49'38″E	39°58'24″N
						119°50'39″E	39°53'41″N
Weihai	2	122°7′44"E	37°30'16" N	Anchorage 42	75	119°10'08″E	39°2'57″N
						119°0′54″E	39°2'57″N
						119°0′54″E	39°58'07″N
						119°3′34″E	39°58'07″N
						119°3′34″E	39°0'43″N
Anchorage43	3	118°14'05″E	38°32'15″N	Bayuquan	75	122°4′32"E	40°13'40"N
		118°12'24″E	38°34'15″N				
		119°9′49″E	38°32'46″N				
		118°10'45″E	38°31'05″N				
Anchorage35	4	118°46'26″E	38°41'54″N	Anchorage 21	74	119°51'42″E	39°50'57″N
		118°45'50″E	38°41'54″N			119°42'41″E	39°53'05″N
		118°45'50″E	38°40'46″N			119°47'56″E	39°46'15″N
		118°46'26″E	38°40'46″N			119°51'43″E	39°49'57″N
Anchorage37	4	119°19'17″E	38°50'39″N	Dalian	73	121°39'24"E	38°54'45"N
		119°16'06″E	38°51'39″N				
		119°16'40″E	38°49'31″N				
		119°19'18″E	38°50'28″N				

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