Study on Comprehensive Risk Assessment of Marine Environment Safety Based on Public Safety Triangle Theory

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Abstract. With the continuous improvement of marine strategic status, the degree of emphasis on marine environmental security incidents has increased. In order to effectively prevent and manage marine environmental events, we need to work through risk assessments to prevent the occurrence of events or reduce the impact of events. Based on the theory of public safety triangle, this paper studies and analyzes the comprehensive risk assessment of marine environmental safety. Based on the historical disaster situation investigation and the existing disaster risk assessment research results, a comprehensive risk assessment framework was established. According to the development process of the marine environmental safety incident and the influence of the incident, the comprehensive risk evaluation index system is constructed from three aspects: event risk, disaster tolerance and emergency management. According to the expert experience and judgment matrix, considering the acceptable level of risk, the risk assessment grading standard is established, which provides theoretical support for the comprehensive risk assessment of marine environmental safety.

1 Introduction

The issue of environmental safety has become an associated issue that cannot be ignored in the process of industrialization. Comprehensive risk assessment of environmental safety is increasingly becoming an important area of risk assessment research. In recent years, with the introduction of the “One Belt, One Road” policy, the marine development process has been accelerating. China has a vast sea area, and a large number of marine environmental safety incidents have emerged, which seriously affect the sustainability of marine development and utilization, and it is an important aspect of national security.

On January 10, 2017, the "Opinions of the Central Committee and State Council on Promoting Disaster Prevention, Mitigation and Disaster Relief Institutional Mechanism Reform" clearly stated that prevention should be the mainstay and that prevention and rescue should be combined, and efforts should be made to shift from focusing on post-disaster relief to pre-disaster prevention, and from the response to a single disaster to comprehensive disaster reduction. Therefore, taking integrated risk assessment as an entry point, analyzing the distribution and weaknesses of the marine environment security situation, and then realizing the targeted enhancement of marine environmental safety incidents, is of great significance for effective protection of the marine environment.

2 Public safety triangle theory and comprehensive risk assessment

2.1 Public safety triangle theory

The "triangle" framework of public safety science and technology is a theoretical framework widely used in the field of public safety and emergency management. The framework of public safety science and technology can be represented by a triangle. The three sides of the triangle represent emergencies, affected objects and emergency management. The three sides are linked together by disaster elements such as matter, energy, and information[1].

Emergencies are the result of the disastrous effects of disaster factors. Studying the gestation, occurrence, development, and mutation evolution of emergencies can provide effective support for preventing, blocking, and reducing the intensity of emergencies.

The disaster-bearing carrier is the object of unexpected events. The unexpected event acts on the disaster-bearing carrier, which can cause the destruction of its function or ontology, which may lead to the occurrence of secondary and derivative events.

Emergency management is a series of human intervention methods and processes aimed at preventing or reducing emergencies and their impacts. It is an

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important aspect of the "triangular" framework of public safety.

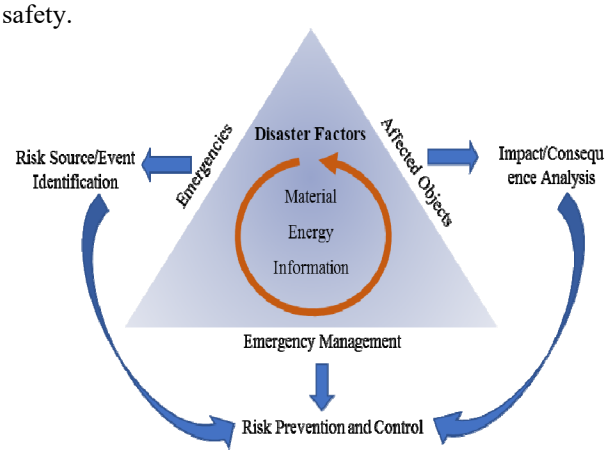

Fig. 1. Triangle theory of public safety

The triangle theory of public safety can be better applied to risk assessment work. Risk assessment includes three important aspects: risk source identification, risk analysis(possibility & impact) and risk prevention and management. The risk analysis includes the possibility of occurrence and impact analysis. The important aspects of the above risk assessment can correspond to emergencies, impacts, and emergency management.

There is a corresponding relationship between emergencies and risk source identification. Risk source identification is an important prerequisite for risk assessment. Mastering the development trend and induced causes of emergencies can provide a basis for future event development trends, which is also an important work content for risk source identification.

There is a corresponding relationship between the emergency affected-objects and the impact analysis in the risk analysis. The analysis and assessment of the possible impacts of risk events is at thecore link of the risk assessment process. In the public safety triangle theory, analyzing the affected objected of emergencies can provide specific analysis targets for the impact analysis in risk assessment.

There is a corresponding relationship between emergency management and risk prevention and control. Emergency management has operational, controllable and adjustable characteristics, which are important factors and important breakthrough points for determining the overall level of public safety. Similar to emergency management, risk prevention and control is also an important purpose and ultimate goal of risk assessment. At the same time, emergency management is also an important measure for risk prevention and control.

2.2 Comprehensive risk assessment

2.2.1 Comprehensive connotation of risk assement

The current research status of the academic community is integrated, and from a different perspective, the definition of risk is different. Among them, the ISO organization defines the risk as "the impact of uncertainty on the incident"[3]. Currently, the risk assessment work involved in various fields focuses on the event itself, ignoring the impact of the incident.

Compared with the above traditional risk assessment, the comprehensiveness of risk assessment is mainly reflected in two dimensions. First, from the point of view and objects involved in risk assessment, comprehensiveness is reflected in both the risk and possible impact of the event itself; second, it is divided according to the coupling degree of events, and comprehensiveness is embodied in the synthesis of multiple disasters.

The comprehensive risk assessment has multi-element characteristics. According to the formation mechanism of risk, comprehensive risk mainly depends on three elements, the risk of the incident, the vulnerability of the disaster-bearing carrier, and the ability to prevent and mitigate disasters. Traditional risk assessments are often limited to considering the dangers of the event itself, and there are fewer considerations for the possible impact of the event.

The comprehensive risk assessment has multi- hazard characteristics. Multi-hazard is a concept that exists in relation to a single disaster, and usually refers to situations in which multiple events coexist or concurrently occur in a specific region and at a specific time. Due to the variety of events involved, the complex relationship between events, and the comprehensive vulnerability characteristics of the disaster-bearing entity for multiple events, the research on multi-event coupled risk is more difficult, but it is also a problem that needs urgent research and solution in the risk field.

Table 2. The relationship between multiple hazard factors.

Perspective	Relationship
Interaction	Independent/Related/Triggered
Time of occurrence	Synchronized/ Successively
Sphere of influence	Overlap/Separate
Impact on the disaster	Aggravate/Mitigate/Non

2.2.2. Integrated risk assessment process

Through the analysis of existing risk assessment projects or research work, the steps of comprehensive risk assessment generally include risk identification, risk analysis, and risk assessment.

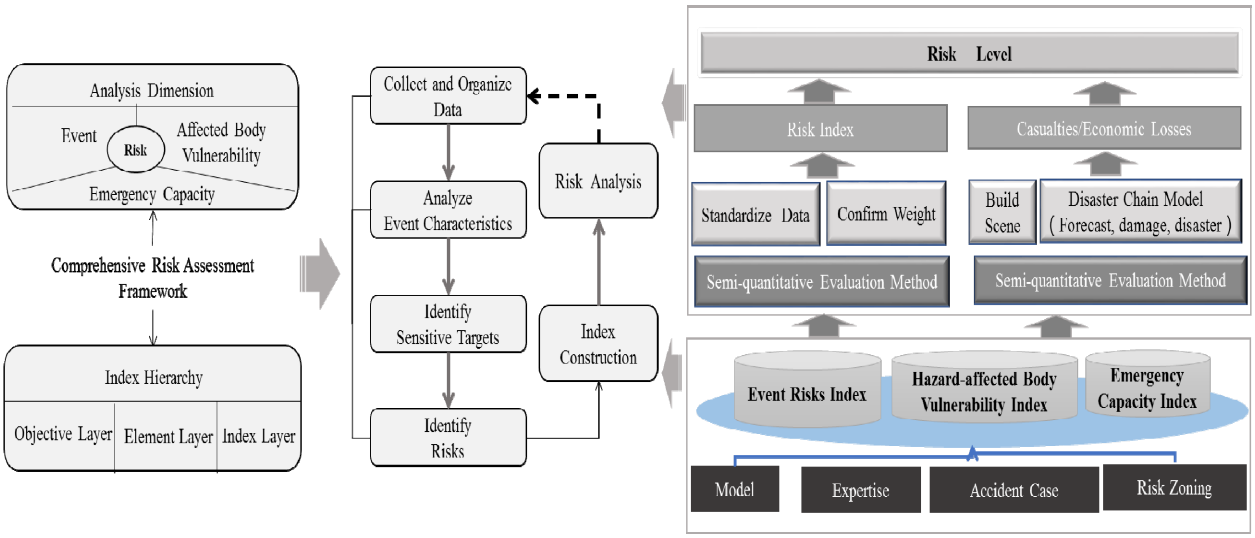

Figure 2. Risk assessment process

The risk identification is based on the accident case base, which generates a comprehensive risk list by identifying the source of the risk, the scope of the impact, the impact objects, their causes and potential consequences. Risk analysis must be carried out in a specific scenario[4]. Potential risk sources that have a large impact on the region (high frequency and great harm) need to be selected to analyze the possibility of its occurrence and possible impacts. Risk assessment is to compare the results of risk analysis with the established risk level criteria, comprehensively consider the acceptable level of risk[5-6], determine the risk level, and provide support for risk prevention and control.

At present, there are many methods for risk assessment at home and abroad. The methods can be divided into qualitative methods, quantitative methods, and semi-quantitative methods. Starting from the driving factors of methods, risk assessment methods can be divided into index driven and pure data driven methods[7]. The index-driven assessment method is flexible and unstable, and the assessment results can only roughly reflect the risk level of the study area, and only provide indications. The pure data-driven risk assessment method is based on historical disaster damage and sample data of the study area. The mathematical model is used to statistically analyze the sample data to obtain the statistical laws of disaster severity and loss, and then implement risk assessment.

3 Comprehensive risk assessment of marine environment security

3.1 Comprehensive risk assessment framework of marine environmental safety

3.1.1 Marine environmental safety incidents

The safety of the marine environment mainly includes the protection of the marine natural environment, the resources development environment, and the safeguarding of the environment. Therefore, in this study, marine environmental safety incidents mainly included marine dynamic disasters,. marine ecological disasters, marine emergencies and marine rights protection incident. Marine dynamic disasters include storm surges, giant waves, and sea ice. Marine ecological disasters inlude brassica and red tides. Marine emergencies include marine oil spills, leakage of hazardous chemicals, and leakage of radioactive substances. Marine rights protection incidents include the invasion of illegal ships and the occupation of islands and reefs[8].

3.1.2 Integrated risk assessment framework for marine environment security

In the risk assessment of marine environmental security incidents, comprehensive assessment should be conducted from the three dimensions of incident risk, vulnerability of disaster-bearing vehicles, and emergency management. In addition, the above-mentioned parts of the marine environment security incidents often appear as associated and secondary derivatives. Therefore, to study the risk assessment of marine environmental safety incidents, we must consider multi-factors and multi-event equivalences to comprehensively assess the degree of damage to marine environmental safety incidents.

Historical case data based on typical marine environmental security incidents such as storm surge, Brassica mosses, red tides, and oil spills, the actual business needs for risk prevention and control, and the development process of the marine environmental safety event chain, from the hazards of the incident, the vulnerability of the disaster-bearing entity and the emergency Three aspects of the distribution of rescue capabilities are used to screen indicators for marine environmental safety risk assessment. Based on the mutual influence and conversion relationship between indicators, a comprehensive risk assessment index system covering the event's own risks and impacts is constructed; a threshold for the classification of risk assessment indicators for marine environmental safety events is established and constructed. The grading standards for marine environmental safety incidents

provide support for the comprehensive risk assessment and risk space-time characteristics research.

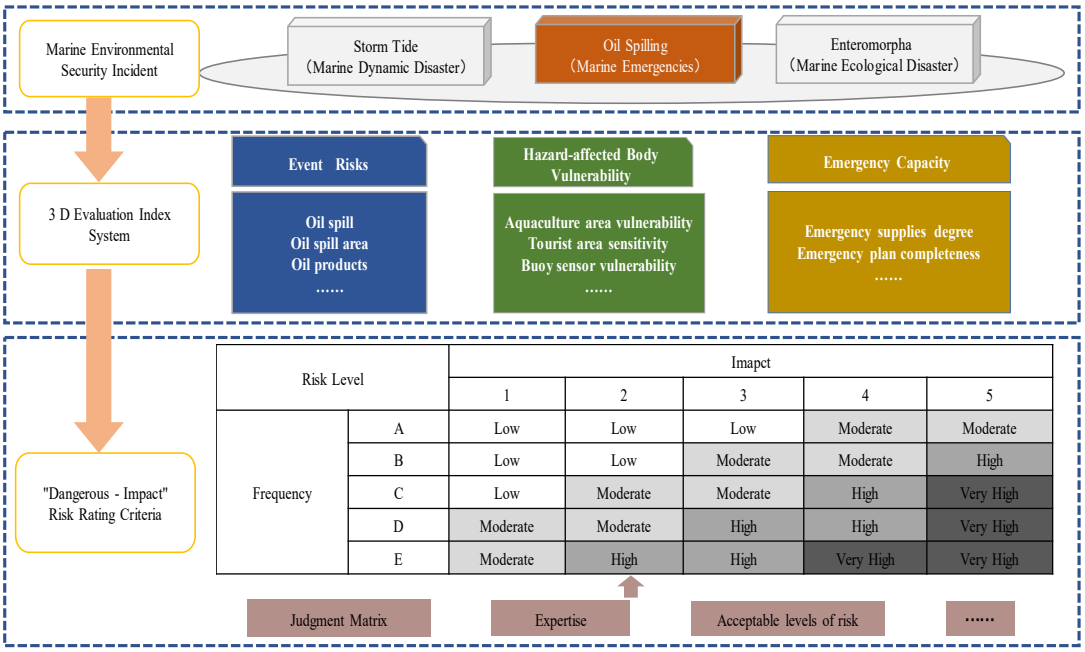

Figure 3. Marine Environment Safety Risk Assessment Framework

3.2 Comprehensive risk assessment index system for marine environment security

The comprehensive risk assessment and assessment system of the marine environment is based on the event itself, the carrier of disaster tolerance and response capacity. Based on the quantitative and qualitative analysis of the relevant index set, based on a certain evaluation model, the risk of marine environment security is assessed.

Marine environmental disasters (red tides), marine dynamic disasters (storm surges), and marine emergencies (oil spills) are represented as the representatives to build a comprehensive risk assessment index system for marine environmental security, as follows.

3.2.1 Oil spill disaster risk assessment index system

Oil spill disaster risk assessment indicators are selected from the following three aspects: event risk, vulnerability of disaster-bearing body, and emergency response capacity. Among them, the risk of the incident is characterized by the amount of oil spilled, the area of oil spilled, the type of oil spilled. The disaster-afflicted targets will be selected from the aspects of aquaculture, tourism, maritime transport, maritime monitoring equipment, offshore industrial facilities, seaside construction, and population and economy that may be affected; emergency capabilities mainly consider emergency plans, emergency supplies, and emergency response Equipment and other indicators[9].

3.2.2 Storm tide disaster risk assessment index system

Storm tide risk assessment indicators are selected from the following three aspects: event risk, vulnerability of disaster-bearing body, and emergency response capacity. Among them, the hazards of the event are characterized by storm surge, tidal range, and sea level change; coastal elevations, seawall standards, coastal gradients, and population and economic impacts may be affected. The emergency response capability mainly considers contingency plans, emergency supplies, emergency drills, public education for people around the sea, etc.[10].

3.2.3 Red tide disaster risk assessment index system

Red tide risk assessment indicators are selected from the following three aspects: event risk, vulnerability of disaster-bearing body, and emergency response capacity. Red tide area, red tide toxicity, and average density are used to characterize the hazards of the event. The aquaculture, tourism, fisheries, industrial and economic that may be affected are selected for the target of the disaster-affected body. The emergency response capability mainly considers indicators such as emergency plans, emergency team disposition capabilities, and propaganda and education[11].

3.3 Index standardization and weight

To solve the problem that there are many different units and different degrees of variation among various indicator data in the evaluation index system, it is necessary to study the standardization method of indicator data applicable to the indicator system of marine environmental safety comprehensive risk assessment based on marine business and literature research. In addition, in order to quantify the contribution of different indicators to the risk assessment

results, it is necessary to study the method for determining the index weights that are applicable to the comprehensive risk assessment of marine environmental security.

3.4 Comprehensive risk rating standard

Based on the risk assessment results of marine environmental security incidents, the risk grading method including expert experience, risk matrix, discriminant function, and index system method was investigated. Based on the analysis of risk acceptable level, the comprehensive risk classification applicable to marine environment security was studied. The standard method is to determine the classification threshold of early-warning indicators and establish a grading standard for comprehensive risk of marine environment security.

4. Conclusion

This article starts with a comprehensive perspective and conducts research and analysis on the comprehensive risk assessment of marine environment security. The basic framework and process for comprehensive risk assessment of marine environmental safety are refined. In the process of comprehensive risk assessment of marine environmental security, the risk factors of events, the vulnerability of the disaster-bearing body, the vulnerability curve, the scenario construction, and the dynamics are the key elements of comprehensive risk assessment.

Risk assessment which is based on vulnerability curves. Prior to the vulnerability analysis of hazard bearing bodies, it is necessary to first clarify the corresponding relationship between the event risk and the hazard entity according to historical accidents; and build a library of hazard vulnerability curves for use in risk assessment under different risk scenarios.

Establish situation-based risk assessments. Risk assessment must have practical guidance for a particular risk scenario. Therefore, on the basis of the identification of risk sources and the analysis of the disaster-bearing body, the possible risk scenarios should be sorted out to provide specific analysis scenarios for risk assessment.

Event-based risk dynamic assessment. The results of the risk assessment should include three elements: "time, space, level values." The traditional probability risk represents the expected loss value of a disaster event in the study area, which lacks the indicators of the time elements and lacks the dynamic representation.

Acknowledgments

The authors appreciate the Project 2017YFC1405303 support by MOST, the project 71373139 supported by NSFC.

References

1. Fan.W C, Bull Natl Nat Sci Found Chin **2**, 71-77(2007)
2. Fan.W C, Liu.Y, Weng.W G, Sci Technol Rev **27**, 3(2009)
3. Huang.C F, Journal of Basic Science and Engineering **16**, 371-381(2008)
4. Xia.F Q, Kang.X W, Wu. S H, Geog Raphical Research **27**, 229-240(2008)
5. Shang.Z H, Liu.X L, Progress in Geography **29**,20-30(2010)
6. Xie.R R, Xiang.Y, Zhang.Q, Environment Science **33**,2244-2250(2012)
7. Yuan.H Y, Huang.Q Y, Su.G F, *Theory and practice of key technologies of emergency platform system*(Tsinghua university press,Beijing,2012)
8. Zou.H P, Mu.L,Dong.J X, Ocean Dev Manag **11**, 23-27(2011)
9. Xiong.S G, *Study on risk assessment and emergency management system of Marine oil spill*(Nankai University,Tianjin,2014)
10. Yin.J, *Study on the risk assessment of Typhoon storm tide in China coastal area*(East China Normal University,Shanghai,2011)
11. Zhang.X X, Xu.Z Z, Cheng. J Y, Fisheries Science **34**, 708-713(2015)