

Application of D-S Evidence Theory in Marine Environmental Security Posture Assessment

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Abstract. In the past, in geological exploration, marine development and offshore safety management, we have realized that the development and damage to the marine environment are very serious and important. While technology has improved rapidly over the years, the marine environment is changing faster than geological exploration, development and management. We must ensure the safety of hydrographic, meteorological conditions and sea wind weather forecasting. Due to the limitations of geological exploration techniques and methods, many problems are difficult to deal with or unpredictable when analyzing the factors that affect the management of the marine environment. Therefore, we need to solve these problems by some new means.

1. Introduction

Marine resources are the basis for human survival and provide a constant impetus for China's economic development. China also gradually pays attention to the protection of marine resources and fisheries. Still, due to the influence of land-based environmental factors and the characteristics of the sea itself, there are many shortcomings in the current assessment of the maritime security situation. However, the level of science and technology and people's increasing demand for material life is brought about by a series of problems such as environmental pollution, ecological damage and natural disasters [1]. Especially in recent years, the intensification of human activities has led to the emergence of a large number of sea tides and spread around the world, causing global sea level rise, accompanied by a variety of disasters and accidents resulting in the lack of marine resources, and even the deterioration of the marine ecological environment caused by the irrational use of human, which has become one of the hot topics of global international concern [2].

2. Marine Environmental Security Posture Assessment Methodology

Marine environmental security posture assessment is a dynamic process that keeps changing over time and is an important part of the analysis of the security situation of the marine environment. In recent years, with the rapid development of China's economy and the continuous improvement of people's living standards, the human demand for resources has also increased. Therefore, how to effectively assess marine disaster events and their

impacts and prevent and control their spread and damage becomes an urgent problem. How to assess marine disasters and their impacts and provide a scientific basis for the timely formulation of prevention and control measures has become a major issue for China at this stage. Marine environmental security situation assessment is also a problem of uncertainty reasoning. The commonly used methods for the uncertainty inference problem of situation assessment are the Bayesian, expert system, random set theory, neural network, support vector machine, D-S evidence theory, etc. [3].

(1) Bayesian method. The Bayesian method is a qualitative analysis method based on probability theory, mathematical statistics and neural networks. It obtains relevant information by processing a large amount of data and then combining computer technology to make predictions based on these data. It mainly integrates people's experience and reasoning ability through probability theory, mathematical statistics and neural networks to obtain the consequences that may result or have resulted from the occurrence of the event in question. The following points need to be noted in this method: firstly, the raw data are quantified, then input to the sample set and the features of the sample set are used to make an inference. Secondly, the training set is collected, and a model is built for parameter estimation. The parameters are estimated for the model, and the relationship between the relevant data and the sample set is established based on the training set. Finally, the optimal sample size is determined by selecting the appropriate parameter values according to the actual situation. The theoretical basis is the conclusion obtained by combining the prior probability with the experience, and the Bayesian method can further process this information to form the final decision result. Although

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the Bayesian method has a complete theoretical basis and easy-to-understand mathematical properties, the prior and conditional probability are difficult to obtain in practical applications. Therefore, the method has great limitations [4].

(2) Expert system method. In practical evidence work, there is a lot of need to use expert methods. For example, we use people with different experiences and knowledge to research and analyze relevant disciplines or professionals in various fields. Through the analysis of this evidence, we can determine the problems that exist in the practical application of the relevant disciplines in the field to improve the efficiency of decision-makers in assessing the marine environmental safety situation and thus promote the development of marine ecological protection. However, because these problems are difficult or complex to solve, it is necessary to use this method to make a more comprehensive and systematic judgment and interpretation process to solve the problem, which can greatly reduce the workload and improve efficiency, as well as the expert method by using some specialized knowledge and theories to make the assessment, which can use some better methods in the assessment. For example, the expert method is used to study and analyze relevant disciplines and professionals in various fields and to establish a relatively sound and practical evaluation system and model [5].

(3) Random set theory method. Habermas, a famous American scholar, proposed the random set theory, which refers to people grouping and counting an event according to certain probability principles. The theory predicts the future development trend by analyzing and studying certain characteristic items in the data. In practical application, it is found that: according to the principle of randomness, one can judge that an event occurrence may have some connection but uncertain factors, and according to the principle of agnosticism, one needs to classify it and collect relevant data information first, and then establish random set on this basis, to provide other researchers with a certain probability and correlation degree function relationship formula between events, to conduct qualitative analysis.

(4) Neural network method. The neural network method is a thinking model based on simulating neurons in the human brain and uses computers to process and analyze information stored in the brain by imitating the perceptrons of the biological nervous system. It establishes an information processing system based on an artificial way that consists of multiple input nodes, a multi-level parallel structure with memory function, and can calculate the output signal characteristic value, state estimation and prediction in a certain range of processes, and is realized by computational methods. This new technology has the advantages of easy operation and easy understanding. It significantly reduces labor costs in data storage and analysis. It can be used in various complex data modeling processes to quantitatively describe neural network models with large sample sizes. It allows comprehensive evaluation and prediction research work on different types of problems. The method can be used for studying natural language neural networks and their application areas and for other aspects

of intelligent technologies. For example, fast recognition and classification systems for biosensors, real-time processing of artificial intelligence and information fusion and decision support systems [6].

(5) Support vector machine method. The support vector machine method is a new classification method. The basic idea is to analyze and extract the unknown information present in the total according to the data sample characteristics. In this case, the relevant parameters are calculated by building a mathematical model of the original data and statistics to predict the trend of things to come up with the predicted results. These unknown parameters can be analyzed using the vector machine method, which yields some characteristic quantities that are similar to the original data or have the highest probability of correlation. This algorithm is mainly used in problems of determining linear relationships between indicators and synthesizing causal links between variables. At the same time, the support vector machine method combines the classification results with the decision-making process to form a new method, which has the advantage of high accuracy in the classification process, can accurately reflect the causal relationships between things, and can be applied to other methods when the amount of data is large.

(6) D-S evidence theory method. The evidence theory method summarizes the traditional research methods of natural and social sciences. The original data collected through various activities such as observation and analysis are used as information, and the data are analyzed and judged to conclude. It is a logical reasoning method in natural and social science research. This logical reasoning method is mainly based on scientific experiments. It makes assumptions and inferences about the development process of things and the interconnection and relationship between phenomena and internal laws. D-S evidence theory is a specific application of evidence theory in the field of geological survey, which is a method to analyze, synthesize and compare various natural and social phenomena based on objective facts to form conclusions or processes [7].

3. A Study of the D-S Evidence Theory Approach

3.1. Basic Concepts of Evidence Theory

Definition 1.1: Let $X=\{x_1, x_2, \dots, x_n\}$ be a finite and complete set of theoretical domains in which all X elements are independent and affect each other. The elements of X are mutually constrained. The domain is a set of many small problems, each independent and unrelated to the other. In this case, an aggregate model containing several variables, different properties and characteristics is constructed to describe the interactions and regularity of things. These complex and variable (e.g., concepts and properties) factors interact with each other and form a multi-level structure through a matrix, thus constituting a comprehensive analysis method with a certain theoretical system [8].

Definition 1.2: Let X be an identification frame if the function m is a mapping from the set 2^X to $[0,1]$ and A denotes any subset of the identification frame X , denoted as $A \in 2^X$, and satisfies Equation (1).

$$\begin{cases} m\phi = 0 \\ \sum_{A \in 2^X} m(A) = 1 \\ m(A) \geq 0, \forall A \in 2^X \text{ and } A \neq \phi \end{cases} \quad (1)$$

Definition 1.3: Let m be the basic probability assignment function on the recognition frame X . The function $Bel:2^X \rightarrow [0,1]$ satisfies Equation (2):

$$Bel(A) = \sum_{B \subseteq A} m(B), \forall A \subseteq X \quad (2)$$

Definition 1.4: Let m be the basic probability assignment function on the identification frame X . The function $Pl:2^X \rightarrow [0,1]$ satisfies Equation (3):

$$Pl(A) = \sum_{B \cap A \neq \phi} m(B) = 1 - Bel(A), \forall A \subseteq X \quad (3)$$

Figure 1 visualizes the evidence theory's support, unsupported, and uncertainty interval of information.

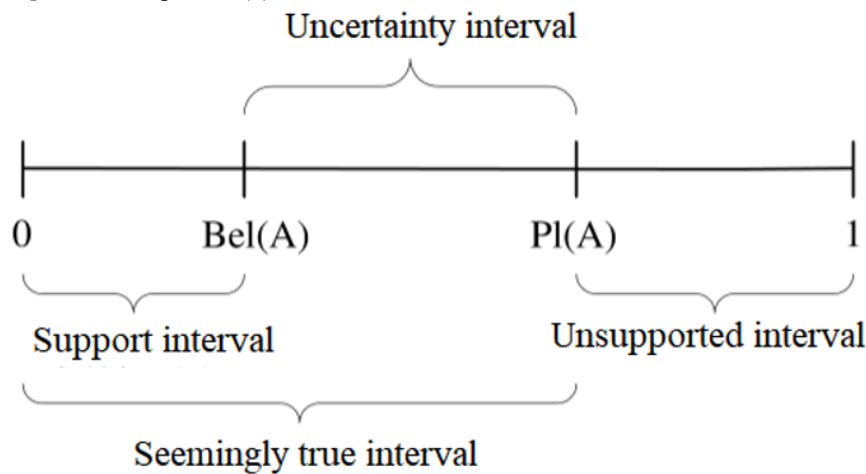


Figure 1. Interval description in D-S evidence theory

3.2. Dempster Fusion Rule

Dempster fusion rule is a new form of marine ecological safety assessment. The method links the natural environment with human activities. It determines environmental change trends through a comprehensive analysis of the ecosystem's internal system structure and function and the influencing factors. Its emergence has led to the rapid and widespread application of the D-S evidence theory. This method can be used for evidence

integration in several fields, such as in exploration and development applied to some mineral resources and the safety status of the marine environment. The D-S algorithm is a promising separation method that divides a whole into several parts and determines the stability of each part based on its interconnectedness and independence. The D-S model of evidence is used to process these relationships and draw conclusions [9]. The decision process of the D-S evidence theory is shown in Figure 2.

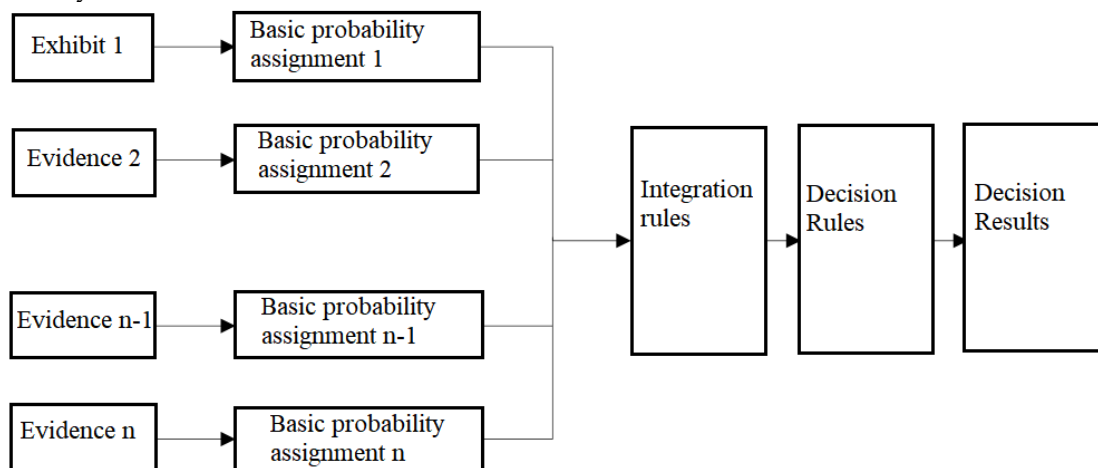


Figure 2. Structure of dynamic evolution of paleoclimate dynamics simulation

Definition 1.5: Let two mutually independent pieces of evidence, E1, and E2, on the same identification frame X with underlying probability assignment functions m_1 and m_2 , respectively, then the Dempster fusion rule for synthesizing $m = m_1 \oplus m_2$ for these two pieces of evidence be defined as shown in Equation (4).

$$m(A) = \begin{cases} 0, & A = \phi \\ \frac{1}{1-k} \sum_{A_i \cap B_j = A, A_i, B_j \subseteq 2^X} m_1(A_i)m_2(B_j), & A \neq \phi \end{cases} \quad (4)$$

The value of k in Equation (4) is calculated as shown in Equation (5).

$$k = \sum_{A_i \cap B_j = \phi} m_1(A_i)m_2(B_j) \quad (5)$$

4. Assessment of the Security Posture of the Marine Environment Based on D-S Evidence Theory

4.1. Determine Assessment Indicators

Assessment indicators are an important basis for evaluation. In practice, there are certain differences in assessment results due to various influencing factors, such as subjective and objective conditions. In the evaluation process, we often need to analyze some specific issues. Therefore, it is very important to establish a complete evaluation system. Firstly, the interrelationship between each element is determined according to the actual situation, and the relationship between each element is identified and quantified to derive various index values. Secondly, considering the factors involved in different levels and the degree of influence, the weight value of each element is determined, and the interrelationship, mutual influence and the corresponding causality matrix are established according to the connection between each indicator. Finally, the strategy is decided by integrating the interests of various parties. According to the degree of interaction between the individual elements, a comprehensive evaluation is made, a corresponding model is established, and finally, a conclusion is drawn [10]. The index system of marine environment security situation assessment is shown in Figure 3.

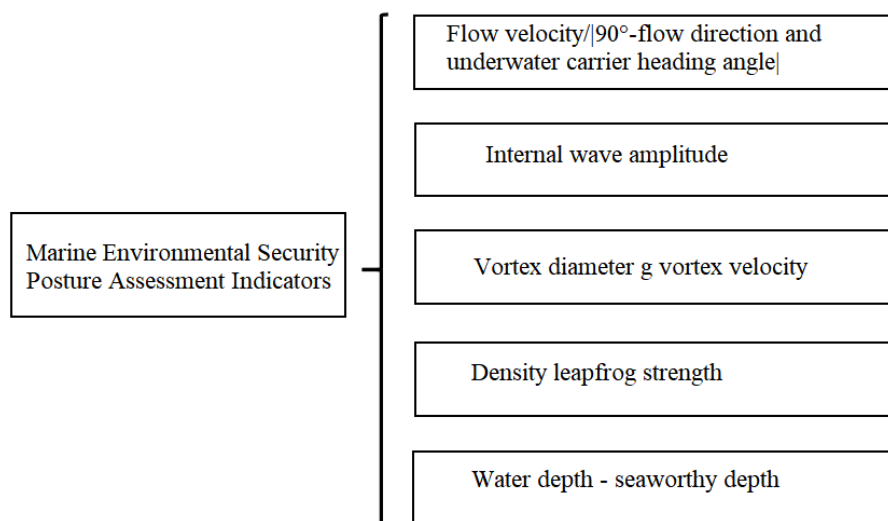


Figure 3. Marine environmental security posture assessment index system

4.2. Determine the Weight of Indicators

Weight refers to the relative importance of the indicators of a project in each field, which reflects the interconnection and interaction between different disciplines and the consistency of the same thing or issue. To better describe the role, value and importance of each assessment index to the assessment results, after the assessment index system is constructed, we should assign weights to each assessment index and determine the weight value better to reflect the influence degree of each assessment index. If different weights are assigned to the same set of index values, will obtain different results and weights will be determined to reflect each assessment index's impact better. There are two main methods for determining indicator weights, namely the

subjective assignment method and the objective assignment method, according to how the weights are generated. The subjective weighting method is based on the subjective experience of decision makers or the expertise of experts to directly determine the weight of each indicator and quantify it by the fuzzy comprehensive evaluation method. The objective assignment method is based on the consistency and difference of each evaluation object and different properties and time points. Its advantage is that it can better reflect the information on the relationship between the attributes of things, the influence factors, and the process of action. Still, it does not necessarily get more accurate results.

4.3. Security Posture Assessment

Safety posture assessment refers to analyzing the geological, hydrological and other natural conditions using some method and establishing a corresponding evaluation index system by combining various relevant information. In the traditional theory, only the seismic wave energy (or time) and spatial distribution patterns are generally considered. However, the earth's surface environment's obvious regional and geophysical characteristics cannot directly apply to production life. Still, it must be verified through many experiments to verify its effectiveness. Because of the crustal and geological tectonic movement and other factors, the exploration method has a lot of errors and may even appear uncertain.

5. Conclusion

To sum up, at this stage, the development of marine exploration in our country is mainly to meet the increasing attention to marine environmental safety and gradually begin to focus on its assessment and control. In this case, we need to establish a new theoretical system of evidence suitable for the current actual situation and has certain feasibility. We constantly research and explore to establish a scientific, reasonable and effective marine environmental safety assessment system. This paper first elaborates on the principle of the D-S method, analyzes the problems and challenges encountered in marine survey work in the new era, then discusses the application method and basic steps, and finally proposes a new assessment model to provide some reference for marine survey work in China.

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