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Research Article

Performance Analysis of Marine Ecological Environment Governance Based on DPSIR and Entropy Weight TOPSIS Model

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In order to solve the global marine ecological environment problems and ensure their own marine strategic interests, we should participate in the global marine ecological environment governance in an all-round way. There are still some problems in the evaluation system, supervision mechanism, and performance evaluation of the marine ecological environment. Considering the impact and analysis on the ecological environment in the effect of marine governance, this paper puts forward the performance analysis of marine ecological environment governance based on DPSIR (Drive Pressure State Impact Response) and entropy weight TOPSIS model and constructs the performance index evaluation system of marine ecological environment governance combined with the current situation of marine ecological environment governance. Using entropy TOPSIS (technique for order performance by similarity to ideal solution) model and geographic detector, this paper explores the influencing factors of governance performance. From the perspective of marine ecological environment governance effect, the governance effect is good. The influence of pressure factors such as ecological environment, population, and economy is generally large. The main causes of marine environmental pressure are the massive amount of industrial wastewater, the utilization of water resources in coastal areas, and the employees involved in the sea. Through the factor detection method of geographic detector, the strength calculation of the three criteria of pressure-state-response which affect the performance level of marine environmental governance is carried out, and the pressure layer index, state layer index, and response layer index have good response. In marine science and technology innovation ability, government investment in marine construction has a significant impact on environmental governance performance.

1. Introduction

In recent years, marine ecological environment problems appear more and more frequently, and MEEG (Marine Ecological Environment Governance) is one of the important directions in environmental governance. How to solve the problem of marine economic development and protect the marine ecological environment to achieve sustainable development is an urgent problem to be solved in current marine governance. Literature [1] points out that marine ecological environment and marine economy have become strategic issues related to the survival and development of coastal countries. With the economic development of these areas, we should strengthen the protection of marine environment and marine ecosystem at the same time to ensure the sustainable development of marine economy. Literature [2] shows that the transformation from marine environmental management to marine ecological environment management is decisive for the sustainable development of marine economy. It is pointed out that the ecological compensation mechanism has significant advantages in the management of marine ecological environment, and the management of marine ecological environment should be based on this mechanism Literature [3] points out that the government pays more and more attention to marine ecological environment monitoring, which promotes the rapid development of marine ecological environment and marine economy, and the marine monitoring ability is constantly improving. The accumulated basic data can provide decision support for marine ecological environment management. Literature [4] analyzes the economic relationship between the protection behavior of marine environmental managers and whether chemical enterprises adopt "protection" policies and concludes that the number of fines and the implementation cost of the government are the key factors for enterprises to adopt protection behaviors. It is pointed out that constructing ecological compensation mechanism to study environmental risks is an effective way to improve the management level of sea areas. Literature [5] points out that the marine ecological environment in Guangxi coastal areas has been greatly affected because of overexploitation, and pollution, overfishing, aquaculture expansion, lack of management, and other factors have destroyed the marine ecological environment and hindered the sustainable development of the marine ecological environment. A series of countermeasures were put forward to improve and protect the marine ecological environment in Guangxi Beibu Gulf. Literature [6] first puts forward the management plan based on marine ecosystem, which is increasingly favored by managers. Literature [7] proposes that, in order to understand the complexity of marine ecosystems and manage marine ecosystems sustainably, DPSIR method is very valuable. Finally, ocean management countermeasures are put forward through risk assessment and management process, bow method conforming to ISO standards, and so forth. Reference [8] analyzes the factors affecting the change of marine environment in Prydz Bay and its surrounding waters by using the methods of model simulation and remote sensing inversion and concludes that topography, solar radiation, extreme pressure intensity, SST, upwelling, distribution control of sea ice and meltwater, and water stability all have influences on wind field, regional sea ice, and marine environment. The distribution characteristics of organic matter and particle size in Prydz Bay and the influence of marine environmental factors on sedimentation effect were analyzed. Literature [9] analyzes several stages of adaptive governance of marine environment. Through two case studies in Kenya, it is found that knowledge sharing and coping process of adaptive governance are not easy. Literature [10] discusses the processes, factors, and tools that produce two kinds of flows that affect the governance results from the perspective of fisheries. These factors are related to the restrictive relationship and factors of interest community. Literature [11] proposes that the function of effective MEEG is conducive to stimulating better political will to promote the sustainability of marine governance. The questions "what factors contribute to better management?" and "how can international institutions contribute to better management?" focus on analysis and research on marine eco-environmental management and identify some best practices for improved management. Literature [12] identifies the impact of public concern, nongovernmental organizations, national leaders, international institutions, and transnational scientific networks on the establishment of regional environmental governance. These factors are prominent factors affecting the effective protection of the regional environment and indicate the need to develop a deeper long-term effective governance strategy to increase pressure on the government, create and strengthen public attention, and promote cooperation between international institutions and civil society. Literature [13] divides the factors affecting marine environmental governance into relational factors, institutionalized factors, and participant factors for empirical analysis. The analysis results show that the institutional participation group shows a tendency of more positive consciousness in the participant factors. The capacity of local communities plays a key role in determining the level of governance. The final conclusion is that perceptions vary greatly among participants, so it is necessary to institutionalize governance and strengthen the ability of local communities to activate governance. Literature [14] enhances the understanding of stakeholder participation in comanagement by focusing on research and shows that comanagement can be one of the tools for sustainable marine resource management. Through a comparative analysis of the success of marine eco-environmental governance in several sites, some factors affecting the degree of stakeholders were identified. Literature [15] further studies and understands the role of government and other stakeholders in MEEG (marine ecological environment management) by analyzing the formation and influencing factors of marine governance in Busan. The results show that the level of marine governance in Busan is not high in participation, cooperation, and collective decision-making. In addition, by investigating the current situation of marine governance in Busan, this paper puts forward the alternative scheme of applying appropriate marine governance structure in Busan maritime administration department.

2. Research Status and Data Sources of Marine Environment

Rich marine environmental resources, high productivity level in sea areas, the shortage of land resources, and other reasons lead to the increasing intensity of human development and utilization of the ocean. The frequent activities of human beings in the marine field have caused a sharp increase in pollutants such as land-based sources and sea areas, which makes the marine ecosystem face great pressure and even be destroyed, and the marine biodiversity has dropped sharply, making it more difficult to protect the marine ecological environment. In recent years, scholars have made more and more research on marine ecological civilization. As shown in Figure 1, the number of papers on environmental governance published on CNKI has been on the rise in the past 10 years, and, since 2013, the increase rate has been getting faster and faster. By 2020, the number of papers has reached 5152, which shows the importance attached to environmental governance. For the research on environmental governance performance, as shown in Figure 2, the literature on marine governance performance has basically been on the rise from 2012 to 2020, which is undoubtedly of great help for us to put forward better governance schemes. It can be said that we are making greater progress on the road of marine ecological environment management. Therefore, this paper mainly analyzes the

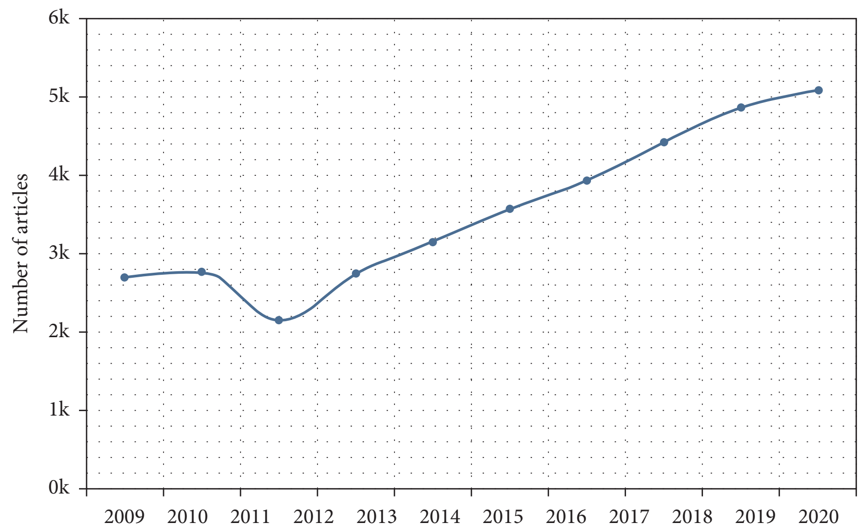

FIGURE 1: Publication of papers related to environmental governance in recent ten years.

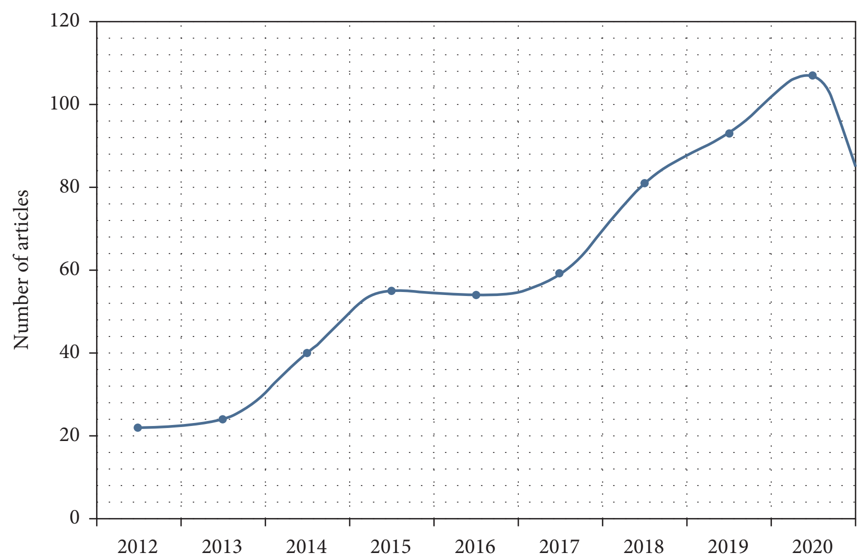

FIGURE 2: The number of papers published on marine governance performance in recent ten years.

performance of marine governance and the influencing factors of performance governance and finally provides feasible suggestions.

In Figures 1 and 2, the number of papers published on environmental governance and marine governance is analyzed, which shows that the marine environment is the current research hotspot, and scholars have many problems in marine environmental governance. In the aspect of ecology, governance and marine environment research play an important role in the important strategic significance of the country and ecological protection.

3. Selection of Research Methods and Reasons

3.1. Construction of Governance Performance Evaluation System. The DPSIR model [16] has the following main meanings:

D (driving force): This index reflects the promotion of human survival and environmental system to the development of the whole society.

P (pressure): This index directly acts on the social system and is a direct influencing factor that reflects human beings' social development after the driving force, including resource pressure, environmental pressure, and ecological pressure.

S (state): The state index measures the living standard and environmental quality in a specific time in the system, which is the starting point for analyzing the impact and corresponding.

I (influence): State change indicators mainly affect human life and social and economic development.

R (corresponding): This index reflects the ability and system of self-regulation produced by human beings

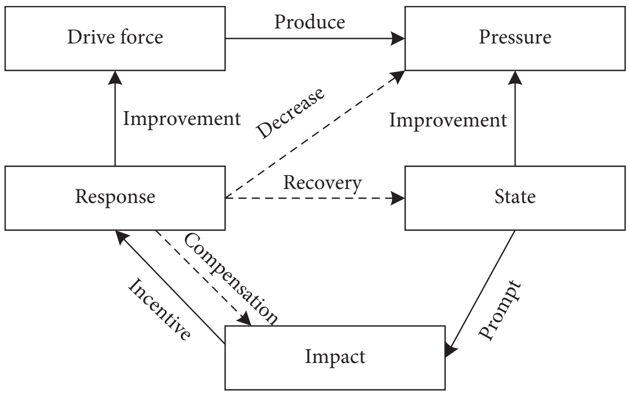

FIGURE 3: Relationship diagram of five indexes of DPSIR model.

adapting to the social system and can adapt to the changes of the social system.

According to the above meaning, the relationship between various indicators can be obtained, as shown in Figure 3.

This paper refers to the "Green Development Index System" and "Ecological Civilization Construction Assessment Target System" formulated by the National Development and Reform Commission to ensure the rationality, integrity, and practicability of the selected indicators. Combined with the current situation of MEEG, the performance index evaluation system of MEEG is constructed based on DPSIR conceptual model. Combined with the research direction of this paper, focusing on the three key questions of "what happened," "why it happened," and "how should we do it," this paper chooses to build a governance performance evaluation system based on P-S-R. This model is flexible and easy to adjust and can effectively reflect the clear causal relationship between environmental and resource indicators. See Table 1 for details.

The evaluation index system proposed in Table 1 is to evaluate the marine ecological performance, and the criterion layer is divided into secondary indicators of pressure layer, state layer, and response layer. The index layer is divided into 30 indicators, which is a complete system structure for the performance evaluation of marine ecological environment governance. The analysis of these indicators can reflect the needs of all levels of marine ecological environment management.

3.2. Impact Factor Detection

3.2.1. TOPSIS Model Based on Entropy Weight. TOPSIS model based on entropy weight method is a commonly used comprehensive evaluation method, which is obtained by improving the traditional TOPSIS evaluation method. Its advantages are as follows:

(1) It can effectively serve subjective factors and avoid difficulties in evaluating the final results due to some factors, such as small differences between some obtained data and difficult choices.

(2) It can make full use of the information of the original data and objectively assign weights, and the results can objectively reflect the gap between various influencing factors.

Firstly, the weight of 20 indexes affecting the performance of MEEG is determined by entropy weight method, and then the comprehensive score is calculated and analyzed by TOPSIS method. The basic process includes the following:

(1) Initial data collation: Assuming that there are m evaluation objects and n performance evaluation indicators of MEEG, the performance judgment matrix of MEEG is

$$X = \left(X_{ij}\right)_{m^*n}, \quad (i = 1, 2, 3, \ldots, m;\ j = 1, 2, 3, \ldots, n), \tag{1}$$

where X_{ij} represents the initial data of the i-th object in the j-th index.

(2) Assume that the ideal value of evaluation index j is X_j^*, define the positive indicator as $X_{j\max}^*$, and define the reverse indicator as $X_{j\min}^*$.

Then the same chemotactic formula of positive index is

$$X'_{ij} = \frac{X_{ij}}{X_{j\min}^*}. \tag{2}$$

The same chemotactic formula of reverse index is

$$X'_{ij} = \frac{X_{j\min}^*}{X_{ij}}. \tag{3}$$

(3) Entropy is as follows:

$$H_j = -K \sum_{i=1}^{m} P_{ij} In P_{ij}, \quad P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{m} X_{ij}}; K = \frac{1}{Inm}. \tag{4}$$

(4) Index weight is as follows:

$$W_j = \frac{1 - H_j}{\sum_{i=1}^{n} \left(1 - H_J\right)}. \tag{5}$$

In the above formula, $W_j \in [0, 1]$, and $\sum_{i=1}^{m} W_j = 1$.

(5) Construct weighted standardization matrix: Firstly, standardize the initial performance evaluation data matrix of MEEG, and obtain the following formula:

$$A = \left(X_{ij}\right)_{m\times n}. \tag{6}$$

The normalized matrix is

$$B = \left(b_{ij}\right)_{m\times n}. \tag{7}$$

Table 1: Performance evaluation index system of MEEG.

Target layer	Criterion layer	Indicator layer	Indicator type	X
Evaluation system of performance indicators for MEEG	Pressure layer	Industrial wastewater enters a large amount (10,000 tons)	−	X1
		Discarded industrial waste gas in coastal areas (10,000 tons)	−	X2
		Utilization of water resources in coastal areas (square meters/person)	+	X3
		Per capita marine catch along the coast (tons/person)	−	X4
	State layer	Employed persons involved in the sea (10,000 people)	−	X5
		Coastal population density (10,000 people/km2)	−	X6
		Per capita marine GDP (10,000 yuan/person)	+	X7
		Level of marine industrial structure	+	X8
		Economic losses from natural disasters (100 million yuan)	−	X9
		Proportion of marine GDP in coastal areas (%)	+	X10
		Output per unit mariculture area (tons/1000 hectares)	+	X11
		Proportion of seawater above Class II water quality (%)	+	X12
		Annual decline rate of marine biodiversity (%)	−	X13
	Response layer	Marine science and technology innovation ability (pieces)	+	X14
		Government investment in marine construction (10,000 yuan)	+	X15
		Coastal industrial wastewater treatment capacity (10,000 tons)	+	X16
		Utilization amount of coastal industrial waste (10,000 tons)	+	X17
		Marine scientific research staff (person)	+	X18
		Area of marine ecological protection area (square kilometers)	+	X19
		Proportion of marine education service industry (%)	+	X20

Write the normalization matrix as the normalization formula:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}}. \tag{8}$$

By weighting the standardization matrix B, a weighted standardization matrix can be obtained:

$$R = \left(r_{ij}\right)_{m\times n}. \tag{9}$$

In the above formula, $r_{ij} = W_j b_{ij}$.

(6) Determine positive and negative ideal sets: R^+ is the positive ideal solution set composed of the maximum value of positive index and the minimum value of reverse index, and R^- is the negative ideal solution set composed of the minimum value of reverse index and the maximum value of positive index. The formula is as follows:

$$R^+ = \left(r_1^+, r_2^+, r_3^+, \ldots, r_n^+\right). \tag{10}$$

From the above formula, $r_j^+ = (\max r_{ij}^+, \min r_{ij}^-)$.

$$R^- = \left(r_1^-, r_2^-, r_3^-, \ldots, r_n^-\right). \tag{11}$$

From the above formula, $r_j^- = (\min r_{ij}^+, \max r_{ij}^-)$.

(7) Calculate the Euclidean distance from the evaluation value of high-quality development of urban tourism to the positive and negative ideal solutions:

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(r_{ij} - r_j^-\right)^2}, \quad d_i^- = \sqrt{\sum_{j=1}^{n}\left(r_{ij} - r_j^+\right)^2}. \tag{12}$$

(8) Calculate the comprehensive value of environmental governance performance, and its formula is as follows:

$$C_i = \frac{d_i^-}{\left(d_i^+ + d_i^-\right)}. \tag{13}$$

The comprehensive value of marine environmental governance performance is between 0 and 1. The larger the value is, the closer the marine ecological environmental governance performance level is to the positive ideal solution; that is to say, the larger the value, the higher the marine ecological environmental governance performance level.

3.2.2. Geographic Detector. Geodetector is a set of statistical methods which explores spatial differentiation and reveals the driving force behind the research object. It mainly analyzes the relationship between the variance of each factor and the total variance. This method can be divided into factor detection, interaction detection, ecological detection, and risk area detection. This article mainly uses the first detection method to study the impact of each factor on the performance of MEEG.

Factor Detection. Generally expressed by the q value, what is obtained is the detection of the spatial differentiation of the dependent variable Y and the interpretation strength of the influencing factors on the dependent variable. The calculation formula is

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{\mathrm{SSW}}{\mathrm{SST}},$$
$$\mathrm{SSW} = \sum_{h=1}^{L} N_h \sigma_h^2;\ \mathrm{SST} = N\sigma^2, \tag{14}$$

where L is the stratification of variable Y or impact factor X, that is, classification or partition; N_h is the number of units in layer h, where $h = 1,2,3, \ldots$; N is the number of units in the study area as a whole; σ^2 is the variance of the MEEG performance indicators; σ_h^2 is the variance of the Y value of layer h; SSW represents the sum of variance within the layer, and SST represents the total variance of the entire region, where the q value represents the degree of influence of the impact factor on the performance of MEEG, and its value range is 0-1; the greater the value of q, the greater the interpretation of the selected indicators for the performance level of MEEG.

4. Analysis of Research Results

4.1. Performance Analysis of MEEG. In this paper, the weight values of the pressure-state-response layer, which is based on DPSIR conceptual model, are calculated by using entropy weight method in the recent ten years. Then the weight values of each subindex under each quasi-side layer are calculated, such as the amount of industrial wastewater entering, the amount of industrial waste gas discarded in coastal areas, and the amount of water resources utilization in coastal areas [10–12], as detailed in Table 1. Combined with entropy weight TOPSIS method, the data calculated include the overall closeness degree of MEEG performance and the fit degree of three criteria layers, as detailed in Figures 1 to 4.

As can be seen from Table 2, on the model based on the three-layer criteria of pressure-state-response, the weight of response layer is the highest, which shows that the key work of MEEG at present is to put forward corresponding solutions around “what should we do,” and to implement a series of solutions will be more conducive to improving governance performance.

As can be seen from Figure 4, generally speaking, the performance of MEEG is on the rise year by year, and the rising speed is getting faster and faster. The trend in previous years tended to rise steadily. In the past two years, it has accelerated, which is related to the increasing attention paid by national leaders to marine environmental ecological protection to a certain extent, and the prevention and control of marine pollution have gradually entered a crucial stage, protecting marine ecology and improving the water quality in coastal waters, all of which have promoted the obvious growth of MEEG performance. Moreover, the development of marine economy is getting faster and faster, and the economy promotes development, so the level of natural governance will increase accordingly.

From Figure 5, we can know that the influence of pressure factors such as ecological environment, population, and economy is generally large, which is closely related to global economic development, scientific and technological development, and population growth. Although the “Twelfth Five-Year Plan” and “Thirteenth Five-Year Plan” have formulated a series of strategies for the development of marine economy and balanced some pressures for the governance of marine ecological environment, the factors of pressure layer are still a very thorny problem.

From the line chart of the state layer of marine environment in Figure 6, it can be seen that the state of marine environment is improving continuously because of the attention and governance of the state and the control of the factors of marine ecological pressure layer, but it is still affected by the development of economy, science and technology, and industry, and some places show oscillation phenomenon.

From Figure 7, marine environmental response layer clearly reflects that people pay more and more attention to marine environmental governance and at the same time shows that our efforts and strategies for marine environmental governance at present are correct and effective. The dynamic change of response layer data and the overall change of MEEG performance are corresponding, so the data used to study the change of marine ecological governance performance has effective guiding significance.

In Figures 4–6, the comprehensive level of marine environmental governance performance, marine environmental pressure layer, state layer, and response layer are analyzed. Each index and analytic hierarchy process showed an increasing trend with the increase of time. It shows that the effect in the direction of marine governance is better, and the effect of annual governance is outstanding.

4.2. Governance Performance Impact Factor Detection. The strength calculation of the three criteria of pressure-state-response, which affect the performance level of marine environmental governance, is carried out by the factor detection method in geographic detectors, andthe resultsshown

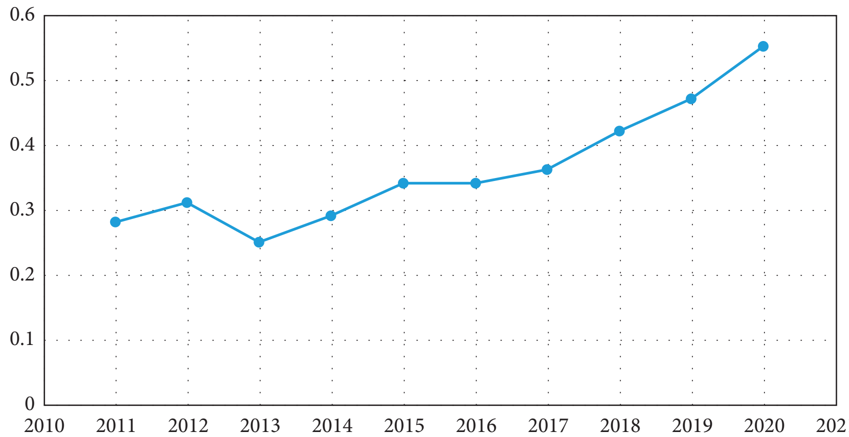

Figure 4: Comprehensive level of marine environmental governance performance.

Table 2: Weight value of performance indicators of MEEG.

Target layer	Value	Indicator layer	Value
Pressure layer	0.332	$X1$	0.2
		$X2$	0.18
		$X3$	0.18
		$X4$	0.15
		$X5$	0.17
		$X6$	0.12
State layer	0.299	$X7$	0.17
		$X8$	0.12
		$X9$	0.13
		$X10$	0.14
		$X11$	0.15
		$X12$	0.16
		$X13$	0.13
Response layer	0.369	$X14$	0.17
		$X15$	0.14
		$X16$	0.16
		$X17$	0.13
		$X18$	0.13
		$X19$	0.14
		$X20$	0.13

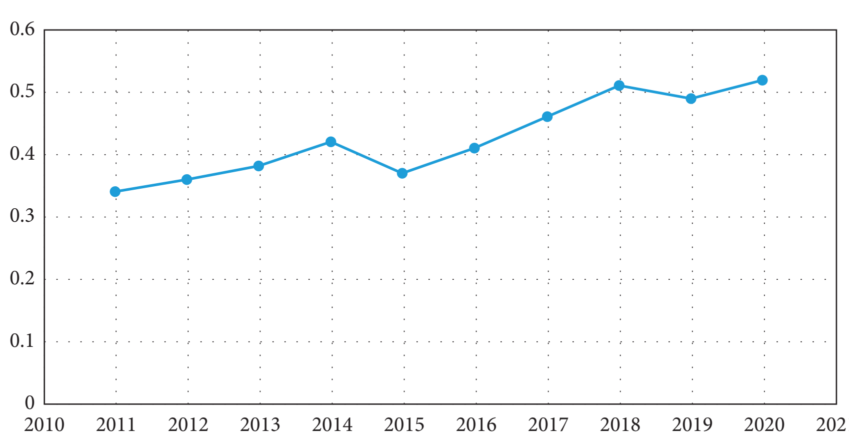

Figure 5: Status of marine environmental pressure layer.

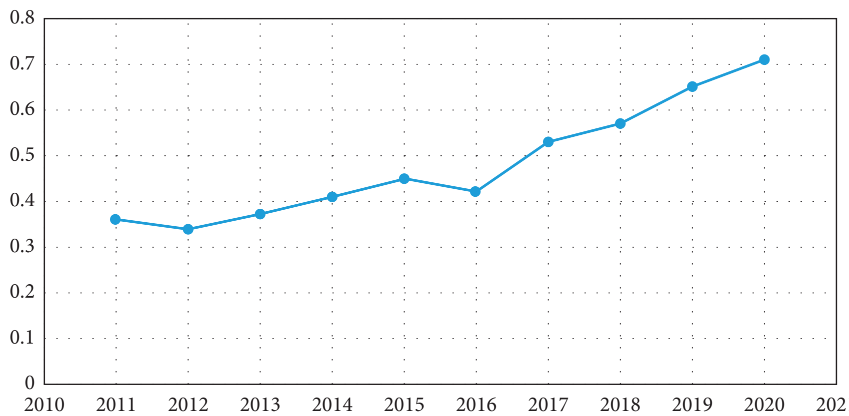

Figure 6: Status of marine environmental state layer.

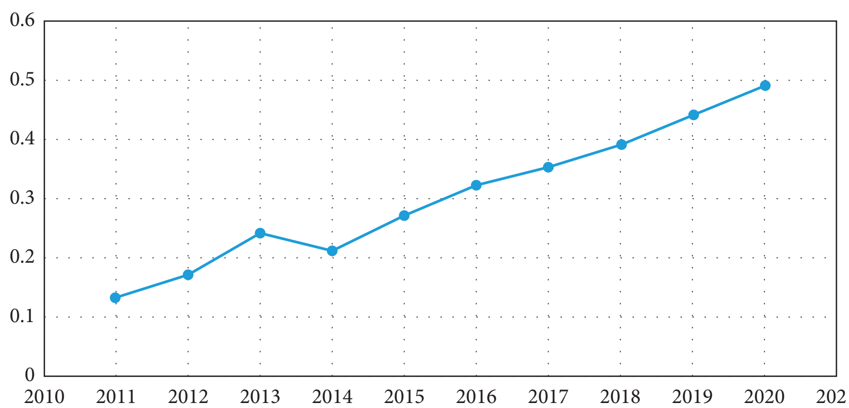

Figure 7: Status of marine environmental response layer.

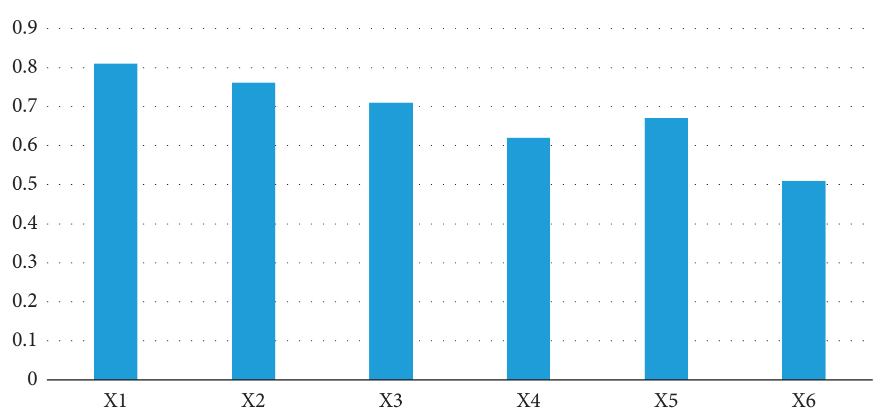

Figure 8: Explanation intensity of pressure layer index to governance performance level.

in Figures 8–10 are obtained. After analysis, we could get the following conclusions.

In the explanation intensity of pressure layer index to governance performance level, we can see that the interpretation intensity of this influence factor, index X_1 (massive amount of industrial wastewater), has reached 0.81, That is to say, it has a great influence on the ecological environment pressure, which can be used as a key reason and direction for further study. In addition, X_2 (industrial waste gas discarded in coastal areas), X_3 (water resources utilization in coastal areas), and X_5 (sea-related employees) have relatively strong explanation intensity, which can be used as key factors for study. Through the analysis of pressure layer index, we can draw the conclusion that the performance of MEEG is closely related to the pressure-related factors facing the marine ecological environment at present. In order to maintain the sustainable and long-term stable development of marine ecosystem, we must seek a balance between the increasing

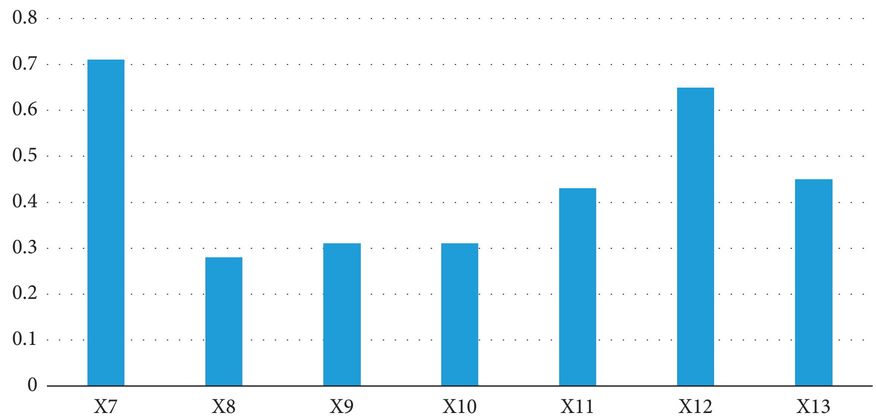

Figure 9: Explanation strength of state level indicators to governance performance level.

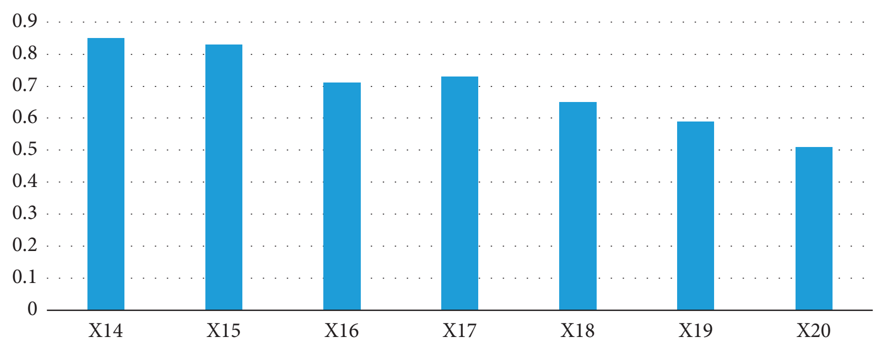

Figure 10: Explanation intensity of response layer indicators to governance performance level.

environmental pressure caused by social development and how to effectively protect the environment [13, 14].

In the explanation intensity of state level indicators to governance performance level, the strongest explanation is that the index is X_7 (per capita marine GDP), which shows that the performance level of marine ecological governance is closely related to the economic development of coastal cities. Therefore, while thinking about how to improve the performance of MEEG, we should take into account how to improve the economic income of marine workers and the development of coastal cities. X_8 (level of marine industrial structure), X_{11} (output per unit mariculture area), and X_{12} (proportion of seawater above Class II water quality) shall play an important and even vital role in the restoration of marine ecological environment in the future. Therefore, we should not only consider various means to control and reduce the continued damage of human beings to the marine ecological environment but also make full use of the self-repair ability of the marine ecological environment.

In the explanation intensity of response layer indicators to governance performance level, we can clearly see that the interpretation intensity of each index is relatively large. The average strength is the largest in the three criteria of pressure-state-response. Among them, X_{14} (marine science and technology innovation ability) has the greatest interpretation intensity. Moreover, it is also the largest among all the indicators of the three standards, so strengthening the construction of marine science and technology is a very critical factor. In the governance of marine ecological environment, government managers, scientific researchers, and other groups play an important role in investment in capital, technology, education, and system construction. What deserves special attention here is X_{15} (government investment in marine construction) [15]; MEEG is a long process, so the economic support of the state in this project will also be a very huge expense. Therefore, in marine environment governance, our scheme must be efficient to avoid the waste of manpower and financial resources.

5. Conclusion

At present, the research and analysis on environmental governance and the influencing factors of governance performance have made many remarkable achievements, but the related research on environmental governance performance in the marine field is still relatively vacant. By constructing the performance index evaluation system of MEEG and exploring the current situation of MEEG and its influencing factors of governance performance, this paper draws the following conclusions:

(1) Generally speaking, the performance of MEEG is on the rise year by year, and the rising speed is getting faster and faster. The trend in previous years tended to rise steadily, and it has accelerated in the recent two years, which is related to the increasing attention

of national leaders to marine environmental ecological protection to a certain extent.

(2) The influence of pressure factors such as ecological environment, population, and economy is generally large, which is closely related to global economic development, scientific and technological development, and population growth, and the pressure layer factor is still a very thorny problem. The state of the marine environment is also improving continuously because of the attention and governance of the state and the control of marine ecological pressure layer factors. The status of marine environmental response layer clearly reflects that people pay more and more attention to marine environmental governance. At the same time, it shows that our efforts and strategies for marine environmental governance at present are correct and effective, and the dynamic changes of data in response layer are corresponding to the overall changes of MEEG performance.

(3) The main reasons for the long-term high pressure of marine environment are the influx of industrial wastewater, the utilization of water resources in coastal areas, and the employees involved in the sea. Per capita marine GDP, the level of marine industrial structure, and the yield per unit area of mariculture play an important role in the future restoration of marine ecological environment; marine science and technology innovation ability and government investment in marine construction have a significant impact on environmental governance performance in the response layer.

Marine ecological environment governance is a long-term research work, which needs continuous investment and institutional support. Future research will focus on the analysis of more comprehensive indicators. With the development of economy, the structure of the index system will change constantly, and it is necessary to adjust the index system dynamically to adapt to the new environmental construction and marine construction.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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