Coupling and Analysis of Marine Economy and Marine Environment

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Abstract: This paper uses the entropy weight method to determine the weight of the index, and uses the coupling degree and coupling coordination degree model to study the coupling relationship between the marine economy and the marine environment in the Bohai Rim. The results show that there are regional differences in the coupling and coordination of the marine environment and marine economy in the Bohai Rim, Liaoning and Shandong have good coordination, while Hebei and Tianjin have poor coordination. At the same time, I hope to provide countermeasures and suggestions for marine development in the region.

1. Introduction

Since 1990, China's marine economy (ME) has entered a stage of rapid development. The rapid development of the ME has worsened the marine environment (MC); The main manifestations are intensified eutrophication, severe marine ecological disasters, uncontrolled reclamation, and major damage to marine-related ecological services.

Domestic scholars have used a variety of mathematical methods to study the ME and MC. Weixiang X [1] et al. used position entropy, coupling coordination, and gravity models to study the urban functions and regional innovations. The study found that there are obvious spatial differences in the Yangtze River Delta.Hao Z[2] et al. coupling relationships among cultivated land protection, intensive use of construction land, and urbanization in Shaanxi; Xiu W[3] et al. used SPSS cluster analysis and analysis of variance to analyze the coupling coordination degree and exploratory space analysis of the new urbanization quality and intensive land use efficiency in Heilongjiang, and found significant differences between different cities; Yingbiao S[4] et al. used the DEA model to study the use of carbon dioxide emission efficiency under different land intensities; Zhang W[5] et al. proposed a population-based evaluation index system for industries and built-up areas, and studied the urban spatial coupling degree of Xinjiang on this index system; Haibin C[6] et al. measured the coupling and coordination of industrial development in different cities in China and found that there are obvious differences in spatial distribution; Weixuan S[7] et al. coupled the relationship between urban housing prices in Nanjing from the perspective of price and residential space, and compared the choices and needs of different social groups; Chengli T[8] et al. used big data analysis, GIS spatial analysis, multi-agent system modeling, and cellular automata to analyze the coupling relationship between urban agglomeration-development zones-industrial clusters; Luyao W[9] and others considered the coupling and coordination relationship between urban intelligent development and ecological environment from the perspective of development, consumption development and management development; Liu Y[10] et al. established an index system from people, plant, and urbanization, and analyzed the global and local spatial coupling relationship of people-plant-urbanization in Jilin.

To sum up, the researches of regional ME and MC by Chinese scholars mostly stay at the level of theoretical analysis. And few scholars research both regional ME and MC. Therefore, We will choose coupling model to find the regular between ME and MC in the Bohai Rim region.

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2. Establishment of Index System

2.1. Establishment of indicator system

In this article, three provinces and one city in the Bohai Bay area are taken as the research object, based on research needs and previous studies, the establishment of ME and MC indicator system are as follows:

Table 1. Coordinated development indicator system for marine economy and marine environment in the Bohai Rim.

Target layer	Indicator layer	Feature layer
Marine Economic Development Potential System	Economic scale	Proportion of coastal employment to regional employment P1
		Marine aquaculture area P2
		Cargo throughput of coastal ports P3
		Gross Ocean Product P4
		Proportion of gross domestic product in GDP of coastal areas P5
	Economic structure	Marine secondary industry value proportion P6
		Marine tertiary industry proportion P7
Marine Environmental Carrying Capacity System	Environmental pollution	Industrial wastewater discharge C1
		Comprehensive utilization of industrial solid waste C2
	Environmental protection	Number of pollution treatment completed C3
		Investment in industrial pollution treatment in coastal areas C4
		Protected area C5

2.2. Indicator weight determination

The entropy weight method is a common method to compute weight of indicator. And the ways of calculation are as follows:

(1) Data standardization:

$$\text{Forward pointers: } h'_{mn} = \frac{h_{mn} - h_{\min}}{h_{\max} - h_{\min}} \tag{1}$$

$$\text{Backward pointers: } h'_{mn} = \frac{h_{\max} - h_{mn}}{h_{\max} - h_{\min}} \tag{2}$$

Where h'_{mn} is the processed data, $h_{\max}, h_{\min}$ are the maximum and minimum values in each indicator, h_{mn} is every data.

(2) Comentropy of pointer

From the query, we can know calculation formula of comentropy: $G_j = -\ln(j)^{-1} \sum_{m=1}^{j} t_{mn} \ln t_{mn}$.

Where $t_{mn} = h'_{mn} / \sum_{m=1}^{j} h'_{m_n}$ .If $t_{mn} = 0$,let $\lim_{t_{mn} \to 0} t_{mn} \ln t_{mn} = 0$.

(3) Determine the index weight

compute the weight:

$$Q_m = \frac{1 - G_m}{k - \sum G_m} (m = 1,2,3 \cdots j) \tag{3}$$

2.3. Coupling model

The coupling degree is calculated by the comprehensive index of each system. This article only covers two systems. The comprehensive index formula of each system is as follows:

ME Comprehensive Benefit Function: $f(h)=\sum_{m=1}^{j} Q_m h_m^{'}$ (4)

MC Comprehensive benefit function: $g(h)=\sum_{m=1}^{s} Q_m h_m^{'}$ (5)

Where j,s represent the number of indicators of the ME and MC systems, respectively. The indicator weight of the system is Q_m. h_m is the i-th dimensionless data. The composite index of the ME and MC system are $f(h)$ and $g(h)$.The comprehensive index reflects the development of the system.

The count is in the following:

$$B=\left\{f(h)g(h)/\left[(f(h)+g(h))/2\right]^2\right\}^{v}. \quad (6)$$

The degree of coupling is represented by B. Generally speaking, the coupling degree is from 0 to 1, the closer it is to 1, the stronger the coupling ability between the systems; On the contrary, the worse the coupling ability between the systems. The value of v is generally between 2 and 5, which indicates the adjustment coefficient. For the convenience of calculation, this paper defines the value as 2.

2.4. Coupling degree coordination model

The degree of coupling harmonious is a measure of the harmony between the reaction systems, reflecting the state of coordination, and can indicate whether the functions promote each other at a high level or restrict each other at a low level. The equations are as follows:

$$D=\sqrt{B*L}、\ L=\alpha f(h)+\beta g(h) \quad (7)$$

In the formula, R is the degree of coupling harmonious, B is the degree of coupling, and p is the comprehensive index of ME and MC.α is the weight of ME, β is the weight of MC; This article determines that the environment and the economy are equally important, so this limit α = β = 0.5.

According to the calculation results, the harmonious ME and MC is divided into the following types:

Table 2. Types of Marine Economic Development Potential and Marine Environmental Carrying Capacity.

R	Coordinated Development Type	R	Coordinated Development Type
0~0.09	Extreme disorder	0.50~0.59	Barely coordinate
0.10~0.19	Severe disorder	0.60~0.69	Primary coordination
0.20~0.29	Moderate disorder	0.70~0.79	Intermediate coordination
0.30~0.39	Mild disorder	0.80~0.89	Well coordinated
0.40~0.49	Endangered	0.90~1.00	Quality coordination

3. Empirical Results and Analysis

The data in this paper is from the China Marine Statistical Yearbook. From the above computing, the index weight are as follows：

Table 3. Indicator weight of marine economic development potential.

Index	P1	P2	P3	P4	P5	P6	P7
Weights	0.1088	0.1083	0.0535	0.0855	0.0638	0.0354	0.0345

Table 4. Indicator weight of marine environmental carrying capacity.

Index	C1	C2	C3	C4	C5
Weights	0.0261	0.0929	0.1147	0.1200	0.1566

According to the formulas of the coupling, relevant indicators are calculated, and the type of coordinated development is defined based on the results. The status of coupled and coordinated development is in the following:

Table 5. Coupling and Coordinated Development of Tianjin, 2007-2015.

Year	Composite Index of Marine Economic Development Potential	Marine Environmental Carrying Capacity Comprehensive Index	Coupling	Coupling coordination	Coordinated Development Type
2007	0.1473	0.1473	0.9523	0.3279	Mild disorder
2008	0.1446	0.0860	0.9672	0.3339	Mild disorder
2009	0.1466	0.0749	0.9461	0.3237	Mild disorder
2010	0.1602	0.0640	0.9034	0.3182	Mild disorder
2011	0.1594	0.0764	0.9359	0.3322	Mild disorder
2012	0.1620	0.0775	0.9356	0.3347	Mild disorder
2013	0.1684	0.0753	0.9242	0.3456	Mild disorder
2014	0.2517	0.0723	0.8326	0.3672	Mild disorder
2015	0.1724	0.0737	0.9160	0.3358	Mild disorder

Table 6. Coupling and Coordinated Development of Hebei Province, 2007-2015.

Year	Composite Index of Marine Economic Development Potential	Marine Environmental Carrying Capacity Comprehensive Index	Coupling	Coupling coordination	Coordinated Development Type
2007	0.0674	0.1280	0.9506	0.3048	Mild disorder
2008	0.0697	0.1256	0.9582	0.3059	Mild disorder
2009	0.0605	0.1144	0.9512	0.2884	Moderate disorder
2010	0.0672	0.1012	0.9793	0.2872	Moderate disorder
2011	0.0768	0.1389	0.9577	0.3214	Mild disorder
2012	0.0818	0.1163	0.9847	0.3122	Mild disorder
2013	0.0882	0.1616	0.9559	0.3455	Mild disorder
2014	0.0989	0.1755	0.9603	0.3629	Mild disorder
2015	0.0987	0.1467	0.9807	0.3469	Mild disorder

Table 7. Coupling and Coordinated Development Status of Liaoning Province, 2007-2015.

Year	Composite Index of Marine Economic Development Potential	Marine Environmental Carrying Capacity Comprehensive Index	Coupling	Coupling coordination	Coordinated Development Type
2007	0.1177	0.2420	0.9384	0.4108	Endangered
2008	0.1488	0.0779	0.9498	0.3282	Mild disorder
2009	0.1643	0.1745	0.9995	0.4114	Endangered
2010	0.1906	0.1436	0.9900	0.4067	Endangered
2011	0.2008	0.1346	0.9804	0.4055	Endangered
2012	0.2117	0.1398	0.9789	0.4147	Endangered
2013	0.2327	0.1503	0.9766	0.4324	Endangered
2014	0.2418	0.1618	0.9802	0.4448	Endangered
2015	0.2452	0.1442	0.9657	0.4336	Endangered

Table 8. Coupling and Coordinated Development of Shandong Province, 2007-2015.

Year	Composite Index of Marine Economic Development Potential	Marine Environmental Carrying Capacity Comprehensive Index	Coupling	Coupling coordination	Coordinated Development Type
2007	0.1589	0.2056	0.9918	0.4251	Endangered
2008	0.1721	0.2598	0.9792	0.4598	Endangered
2009	0.1812	0.1936	0.9995	0.4328	Endangered
2010	0.2074	0.2363	0.9979	0.4705	Endangered
2011	0.2198	0.1383	0.9737	0.4175	Endangered
2012	0.2338	0.1914	0.9950	0.4599	Endangered
2013	0.2478	0.2102	0.9966	0.4777	Endangered
2014	0.2701	0.2400	0.9983	0.5046	Endangered
2015	0.2863	0.1924	0.9806	0.4844	Endangered

According to the results in the table, the Bohai Ocean Comprehensive Index increases year by year, which indicates that the ME in the Bay Area is showing a growth trend; The changes in the MC may be related to the government's environmental protection policies, but the marine ecosystem is facing severe challenges. By analyzing the coupling degree, the coupling degree gap between the three provinces and one city in the Bohai Bay Rim is not obvious. At the same time, by analyzing the degree of coupling harmony, Shandong and Liaoning have the best coupling coordination, but there is also the risk of imbalance; However, the coordination between Tianjin and Hebei has been in a state of imbalance. For example, in 2008-2009, Hebei Province reached a state of moderate imbalance. In addition, the ME in this area has achieved rapid development, but the quality of MC is too low, showing it is harmful to the environment of which the speed of development of ME is too fast.

4. Suggestions

(1) While developing ME, the public’s awareness should be paid to the protection of MC. The coupling and harmony exist some discrepancies in the Bohai Rim region, but the gap is not large. Among them, the marine economy and marine environment indexes of Liaoning and Shandong are better, but there is a risk of imbalance between the two systems; Therefore, the government should make marine environmental protection the top priority of the marine system. Tianjin and Hebei's marine economic development is lacking, and the development of ME does not match MC; Therefore, at this stage, the region should encourage the development of ME and pay attention to protect MC, so as to promote the coordinated development between them.

(2) Adjust the marine industry and transform high-addition, low-pollution industries. With the rapid development of ME, MC in some areas has been unable to support the development of ME. Excessive exploitation of ME has caused the phenomenon of retrogression of MC. Therefore, our government needs to adjust the marine industry, and at the same time clarify the red line of MC, and impose severe penalties on acts that pollute the ocean.

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