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Study on the Evaluation of the Carrying Capacity of Marine Resources and Environment in Weihai City in China

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Keywords: Marine resources and environment carrying capacity; entropy TOPSIS; marine economy; sustainable development

Abstract: This paper establishes a marine resources and environment carrying capacity evaluation index system from the socio-economic system, marine resources system and marine environment system for the development of marine economy of Weihai in China, adopts the entropy weight TOPSIS model to quantitatively analyze the marine resources and environment carrying capacity of Weihai from 2011 to 2020, and uses the changes in these ten years as an entry point to analyze the problems in the development of marine resources, environmental protection and sustainable economic development in Weihai in a targeted manner. The model is used as a starting point to analyse the problems in the development of marine resources, environmental protection and sustainable economic development in Weihai, and to propose timely countermeasures and suggestions in the areas of laws and regulations, development and construction, and industrial transformation.

1. Introduction

The ocean is the largest ecosystem in the natural ecosystem, and it is also an important spatial carrier for human survival and economic and social development. To achieve the goal of building a strong ocean state, the sustainable development of marine resources based on the rational and effective development of marine resources, the reasonable maintenance of the marine environment and the stable development of the coastal marine economy should be realized.

As a backbone city in the core area of the Shandong Peninsula Blue Economic Zone in China, Weihai has rich marine resources and development value: it has 779 kinds of marine biological resources such as sea cucumber, abalone, shrimp, seaweed and scallop, and is the largest seaweed breeding base in China and the largest breeding base of sea cucumber, abalone, oyster, turbot, puffer fish, scallop, rock flounder, jellyfish and wakame in the province. According to the "Chinese Marine Economy Statistics Bulletin", the latest data of seafood production in Weihai City is 3,071,000 tons, more than 1 ton per capita, accounting for 35.9% of the province, and the production has ranked first in the Chinese prefecture-level cities for more than 30 consecutive years; the construction of intelligent marine pasture is a national leader, with 15 national-level marine pasture demonstration areas, 33 provincial-level marine pasture demonstration projects, and marine pasture exceeding 1.35 million mu; the seaside tourism industry is well developed, with 8 national and The city has 8 national and provincial marine protected areas, more than 200 kilometres of clean beaches, more than 30 public welfare coastal parks, and 7 large coastal tourism resorts. Weihai has been awarded the National Marine Ecological Civilization Construction Demonstration Zone, the National Marine High Technology Industry Base, the National Marine Economy Innovation Development Demonstration City, the National Marine Economic Development Demonstration Zone and the National Aquaculture Green Development Demonstration Zone, and is the only city in China to have received five national marine demonstration pilots[2].

However, with such a good construction foundation, Weihai's marine economy and environmental development are facing the problems of gradual tension of marine resources, acceleration of unit energy consumption and weak sustainable use of marine resources, which have become key factors limiting the development of Weihai's marine economy. Therefore, it is of strategic importance to assess the carrying capacity of marine resources and the environment in Weihai and to analyse and coordinate the relationship between marine resources, the environment and the economy in order to build a sustainable marine economy in Weihai and the Shandong Peninsula.

The carrying capacity of marine resources and environment refers to the ability of human diverse social activities to be carried by the marine resources and environment system within a certain period and regional scope, provided that the marine environment remains in a stable state and the structure of marine resources is in line with the concept of sustainable development[1] (State Oceanic Administration of China, 2015).

With regard to the definition of the carrying capacity of marine resources and environment, scholars have numerous opinions: Miao Lijuan[3] (2006) and others believe that the environmental carrying capacity of marine resources is constrained by factors determined by both the marine ecological and socio-economic systems, and divide the evaluation system of the carrying capacity of marine resources and environment into indicators reflecting the pressure of regional socio-economic development on the marine ecological environment and indicators reflecting the marine ecological environment on regional; STOJANOVIC [15](2013) and others believe that the carrying capacity of marine resources and environment is based on the premise that the marine environment maintains a healthy direction of development and the marine resources meet the ability to support human social development; Guan Daoming (2016), Wang Meng (2016) and others[4] focus more on the environmental carrying rate, ecological condition and environmental development intensity. The assessment of the environmental carrying capacity of marine resources is conducted.

For the research methods of marine resources and environmental carrying capacity, Huang Wei [6](2012) and others used the system dynamics SD model and MOP model to assess the composite system of marine environmental carrying capacity; Guan Daoming[4] (2016) and others used the DPSIR model to make the assessment; Wang Meng[5] (2016) and others introduced the coupling degree and coupling degree coefficient to analyse the coordination degree of marine resources and environmental carrying capacity and marine economic development in the Bohai Sea region; Li Ai[7] (2018) used GIS-based marginal opportunity cost assessment of marine resources and environment and GIS-based marginal opportunity cost assessment of marine resources and environment to assess the carrying capacity of marine resources and environment. opportunity cost assessment and a model for assessing the carrying capacity of marine resources and environment based on marginal effect analysis; Gai Mei[8] (2018) used a grey correlation model to measure the carrying capacity drivers to provide a reference basis for China's sustainable marine development.

For the analysis of the problems and improvement measures of the carrying capacity of marine resources and environment, Huang Wei[6] (2012) proposes countermeasures related to the creation of marine economic demonstration zones; Gai Mei[8] (2018) analyses the composite carrying capacity of the ocean for different provinces, analyses the different industries in each province through the influencing factors of different provinces and gives economic countermeasures for the corresponding industries; Su Zilong[9] (2018) gives corresponding countermeasures for environmental protection and optimization of industrial structure in terms of regulations; Song Zeming[10] (2020) puts forward relevant suggestions for the development of China's marine economy in terms of trade cooperation and coastal zone economic construction.

In the past 10 years, marine resources and environmental carrying capacity have gradually received attention due to the gradual scarcity of land resources and the increase of marine problems. Most scholars have elaborated on the theory of marine resources and environmental carrying capacity, constructed an evaluation system, applied entropy TOPSIS method and hierarchical analysis method to give weights, identified the problems in the sustainable development of marine resources and marine economy, and given countermeasures and suggestions. The system is designed to identify the problems in the sustainable development of marine resources and marine economy, and to give countermeasures and suggestions.

However, there are still some areas for improvement in the existing research. Most of the early scholars in China tended to conduct some research on definitions, theories and temporal evolution, but neglected to conduct statistical analysis through mathematical models and construct a clear evaluation system. In statistical analysis, most scholars in China tend to conduct longitudinal time studies or horizontal comparative studies of the carrying capacity of China's marine resources and environment in general, while the studies on the time changes within the unit areas are relatively weak. In order to develop the overall marine economy, it is necessary to start with each specific urban area and finally aggregate it in the whole Chinese region, so that conclusions can be made in a more refined and targeted manner. The majority of scholars in China have focused on the assessment of the carrying capacity of marine resources and the environment, but lack a holistic analysis of the marine multi-system. In the analysis of the carrying capacity of the ocean, socio-economic and demographic factors are inevitable constraints, and the assessment system of the carrying capacity of marine resources and environment should be established in a more diversified and objective way. Most scholars in China usually make general suggestions for one point, and lack of timely suggestions for a certain bill or a certain government initiative, which should be carried out in a detailed manner for the authorities, so as to produce a point-to-point effect.

In this paper, a combination of statistical and empirical analyses for individual regional cities over time. A combination of the former study to establish a diversified evaluation system, so that the evaluation is more diversified and objective. The countermeasures are presented in a comprehensive manner for several aspects, and suggestions are made for the response to time-sensitive events and the formulation and implementation of time-sensitive policies.

This paper establishes a marine resources and environment carrying capacity evaluation index system from the socio-economic system, marine resources system and marine environment system, and uses the entropy TOPSIS model to quantitatively analyse the marine resources and environment carrying capacity of Weihai City from 2011 to 2020. The analysis will provide theoretical support and practical case studies for the sustainable development of Weihai's marine economy and China's strategic goal of building a strong marine nation.

2. Model Construction

2.1 Construction of indicator system

The establishment of a rich, objective and targeted marine resources and environment carrying capacity evaluation system is of great significance for research and analysis. In this paper, by summarizing the previous research results (Miao Lijuan, 2006; Guan Daoming et al, 2016; Su Zilong et al, 2018; Gai Mei et al, 2018; Zhang Jing et al, 2020), referring to the evaluation ideas and framework of the Food and Agriculture Organization of the United Nations (FAO, 1977), following the principles of scientificity, evaluation, relevance and objectivity, and combining the actual geographical location of Weihai City, the marine economy and the availability of actual data, the former study selected the highest frequency of indicators. In the socio-economic system, there are 3 secondary indicators, namely population index, economic index and sea-related economy; in the marine resource system, there are 3 secondary indicators, namely In the marine resources system, there are four secondary indicators: marine space resources, energy resources, marine resources supply and water resources; in the marine environment system, there are three secondary indicators: atmospheric environment, terrestrial environment and water environment. (See Table 1 and Table 2 for the explanation of the secondary indicators)

Table 1: Marine resources and environment carrying capacity evaluation index system

The first order	The second order	Explanation
Socio-economic system	Population indicators	Selected population data to reflect its population pressure and demographic status
	Economic indicators	Economic development data selected to reflect their level of socio-economic development and the standard of living of their people
	Maritime-related economy	Data selected to reflect the economic development of its marine industry
Marine Resource Systems	Marine space resources	The area of sea and shoreline per unit of population was selected to reflect the level of spatial resource presence and exploitable potential
	Energy resources	Energy consumption data selected to reflect the rate of energy consumption
	Marine resource supply	Selecting regional marine development data to reflect the role of marine aquatic resources, etc., in supporting the marine economy
	Water resource	Reflects per capita water use and utilization
Marine Environmental Systems	Atmospheric environment	The concentrations of selected atmospheric pollutants reflect their atmospheric pollution levels
	Water environment	A water body pollution index was selected to reflect the pollution status of its water environment
	Terrestrial environment	Reflecting land-sea interactions and land-based coastal environmental protection and development

Table 2: Marine resources environmental carrying capacity evaluation index system

The first order	The second order	Specific indicators	Unit	Indicator attributes
Socio-economic system	Population	Population densityA1	Person/km2	*
		Resident populationA2	million people	*
		Natural population growth rateA3	%	*
	Economics	Total imports and exportsA4	billion	+
		GDP per capita A5	yuan	+
		Share of secondary industry output A6	%	+
		Share of tertiary sector output A7	%	+
		Disposable income of rural residents A8	yuan	+
		Disposable income of urban residents A9	yuan	+
	Marine space resources	Gross Marine Product A10	million	+
		Share of marine GDP A11	%	+
Marine Resource Systems	Marine space resources	Sea area per capita B1	M^2/person	+
		Shoreline maintenance per capita B2	m/person	+
	Energy resources	Growth rate of energy consumption per unit of GDP B3	%	-
		Growth rate of electricity consumption per unit of GDP B4	%	-
	Marine resource supply	Port throughput B5	Billion t	+
		Seafood production B6	Billion t	+
		Mariculture area per capita B7	M^2/person	+
	Water resources	Water resources per capita B8	M^3person	+
Marine Environmental Systems	Atmospheric environment	Annual SO2 emissions C1	M^3	-
		Annual NOX emissions C2	M^3	-
	Water Environment	COD emissions C3	t	-
		Industrial wastewater discharge C4	t	-
		Total sewage treatment C5	t	+
	Terrestrial environment	Offshore landscaped areas C6	M^3	+
		Park Green Space C7	M^3	+

Note: "+" indicates positive indicators, which are correlated with the evaluation results in the same direction of change, i.e. the larger the value the better the indicator; "-" indicates negative indicators, which are correlated with the evaluation results in the opposite direction of change, i.e. the smaller the value the better the indicator; "*" indicates moderate indicators, which are closer to the moderate value the better the indicator.

2.2 Research Methodology and Models

2.2.1 Entropy TOPSIS

Entropy TOPSIS is an evaluation model combining the entropy method and TOPSIS method, which firstly standardises the evaluation indicators to obtain objective weights, which are less subjective than methods such as hierarchical analysis and can scientifically and dynamically reflect the changes in the importance of evaluation indicators on a time scale.

This paper uses the entropy-weighted TOPSIS model to evaluate the changes in the carrying capacity of Weihai's marine resources and environment from 2011 to 2020.

2.2.2 Entropy-weighted TOPSIS-based evaluation model of the carrying capacity of marine resources and environment

(1) Standardized evaluation matrix construction

Establish the original evaluation index matrix according to the selected indicators $V = (v_{ij})_{m\times n}$, V is the initial evaluation matrix; v_ij is the i-th indicator, the initial value in year j.

$$V = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix} \tag{1}$$

Based on the direction of action of the different properties of the selected indicators, a standardization process is carried out to obtain a standardized evaluation matrix, with the formula Positive indicators:

$$y_{ij} = \frac{x_{ij} - \min\limits_{1\leqslant i\leqslant n}(x_{ij})}{\max\limits_{1\leqslant i\leqslant n}(x_{ij}) - \min\limits_{1\leqslant i\leqslant n}(x_{ij})} \tag{2}$$

Negative indicators:

$$y_{ij} = \frac{\max\limits_{1\leqslant i\leqslant n}(x_{ij})}{\max\limits_{1\leqslant i\leqslant n}(x_{ij}) - \min\limits_{1\leqslant i\leqslant n}(x_{ij})} \tag{3}$$

Moderate indicators:

$$y_{ij} = \begin{cases} 1 - \dfrac{p - x_{ij}}{\mathrm{m}\left(p - \min\limits_{1\mathrm{sin}}(x_{ij}), \max\limits_{1\mathrm{sin}}(x_{ij}) - p\right)}, x_{ij} < p \\ 1 - \dfrac{x_{ij} - p}{\mathrm{m}\left(p - \min\limits_{1\mathrm{sin}}(x_{ij}), \max\limits_{1\mathrm{sinn}}(x_{ij}) - p\right)}, x_{ij} \geqslant p \end{cases} \tag{4}$$

$\max\limits_{1\leqslant i\leqslant n}(\mathrm{x_{ij}})$, $\min\limits_{1\leqslant i\leqslant n}(\mathrm{x_{ij}})$ represent the maximum and minimum values of the indicators in the evaluation area, respectively; p is the optimal value of the moderate indicator in the evaluation area. The standardisation process yields the standardisation matrix:

$$\boldsymbol{A} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{5}$$

(2) Entropy method to calculate indicator weights

$$w_i = \frac{1 - e_i}{m - \sum_{i=1}^{m} e_i} \tag{6}$$

Where: $w_i$is the weight of the carrying capacity indicator; e_i is the information entropy. The lower the entropy value, the more orderly the system is, while the higher the entropy value, the more chaotic or fragmented the system is.

$$e_i = -\frac{1}{\ln n}\sum_{j=1}^{n} f_{ij} \ln f_{ij} \tag{7}$$

If $f_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}}$, $f_{ij} = 0$, so $\lim_{f_{ij}\to 0} f_{ij} \ln f_{ij} = 0$

(3) Construction of TOPSIS model

$$\boldsymbol{Y} = \left|\gamma_{ij}\right|_{m\times n} = \left|w_i \times x_{ij}\right|_{m\times n} \tag{8}$$

(4) Determine the positive and negative ideal solutions

The positive ideal solution Y+is the optimal solution of the indicators of the carrying capacity analysis, which is the maximum value of the i-th indicator in j years; the negative ideal solution Y- is the worst solution of the indicators of the carrying capacity analysis, which is the minimum value of the i-th indicator in j years. The specific calculation formula is:

$$Y^{+} = \max\{\gamma_{ij}\} \tag{9}$$

$$Y^{-} = \min\{\gamma_{ij}\} \tag{10}$$

(5) Distance calculation

Determine the distance between the indicator and the positive and negative ideals using the TOPSIS method.

Distance to positive ideal:

$$D_j^{+} = \sqrt{\sum_{i=1}^{m} \left(z_i^{+} - z_{ij}\right)^2} \tag{11}$$

Distance to negative ideal:

$$D_j^{-} = \sqrt{\sum_{i=1}^{m} \left(z_i^{-} - z_{ij}\right)^2} \tag{12}$$

where z_i^{+} is the maximum value of the evaluation indicator in year j and is the positive ideal solution.

where, z_i^{-} is the minimum value of the evaluation index in year j, which is a negative ideal solution

(5) Calculate the comprehensive evaluation index

j is the comprehensive evaluation index of the carrying capacity of marine resources and environment in year j. The value is 0-1, the closer to 1 means the highest overall evaluation score and the closer to 0 means the lowest overall evaluation score. The calculation formula is:

$$f_j = \frac{D_j^{-}}{D_j^{+} + D_j^{-}} \tag{13}$$

2.3 Results and Analysis

2.3.1 Evaluation data and acquisition channels

The research data were obtained from Weihai City Statistical Yearbook 2012-2021, Statistical Bulletin, Shandong Province Statistical Yearbook 2012-2021, Weihai Ocean Development Bureau Ocean Bulletin 2021, China Statistical Yearbook and other statistical information.

2.3.2 Empirical calculation

The original evaluation matrix (1) is standardized through the formulas (2)-(4) to obtain the standardization matrix (5), and the standardization results are calculated according to (6)-(7) to obtain the weights, and the results are shown in Table 3 below, and the positive and negative ideal solutions are determined according to the formulas (8)-(10), and the distance between the carrying capacity of marine resources and environment of Weihai City from 2011 to 2020 is obtained through the formulas (11)-(12). The results are shown in Table 4, and then the comprehensive evaluation index is obtained according to formula (13), which is shown in Table 4.

Table 3: Weights of each evaluation indicator for the carrying capacity of marine resources and environment

Indicator	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
weight(%)	5.949	5.312	3.175	5.383	1.569	2.884	3.025	2.117	2.117	2.913	5.355
Indicator	B1	B2	B3	B4	B5	B6	B7	B8			
weight(%)	3.486	3.443	3.854	3.808	2.854	2.758	2.133	4.019			
Indicator	C1	C2	C3	C4	C5	C6	C7				
Weight(%)	4.279	5.235	5.234	4.828	3.165	4.891	5.397				

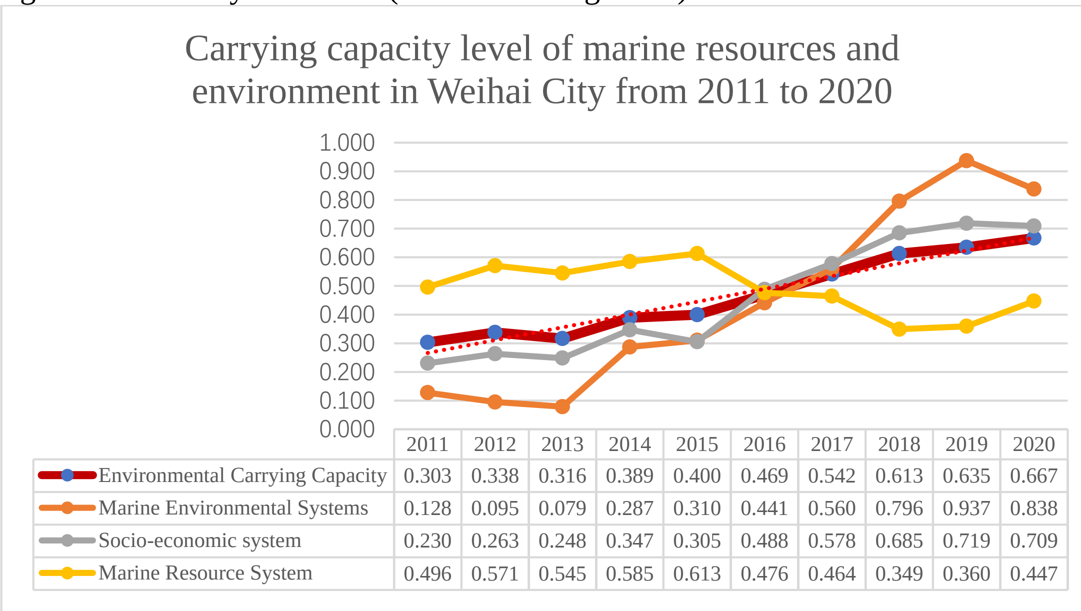
Table 4: Distance of marine resources environmental carrying capacity close to/deviating from positive and negative ideal solutions

Index value	Positive ideal solution distance(D+)	Negative ideal solution distance(D-)	Overall score index ranking	Order
2011.0	0.47887936	0.20827539	0.30309823	10
2012.0	0.445192	0.22699277	0.33769401	8
2013.0	0.44574939	0.2062433	0.31632763	9
2014.0	0.38746739	0.24707524	0.38937531	7
2015.0	0.37999728	0.25318141	0.39985775	6
2016.0	0.32128484	0.28411634	0.46930259	5
2017.0	0.27437125	0.32443686	0.54180439	4
2018.0	0.24577645	0.38929175	0.61299204	3
2019.0	0.25119021	0.43623964	0.63459514	2
2020.0	0.22823428	0.45732835	0.66708471	1

3. Analysis of results

The changes in the marine resources and environmental carrying capacity of Weihai City from 2011 to 2020 are shown in Figure 1. This paper further calculates the marine environmental carrying capacity indices and change trends of the three secondary indicators and compares them with the overall marine environmental carrying capacity trends, as shown in Figures 2.

In a comprehensive manner, the marine resources and environment carrying capacity of Weihai City from 2011 to 2020 showed a slow upward trend, with a small overall change trend, and only a slight decrease from 2012 to 2013, with the index dropping from 0.338 to 0.316. In order to further analyse the relationship between the overall change of the marine resources and environment carrying capacity of Weihai City and the three secondary indicators, as well as the relationship to the marine economy of Weihai City, this paper In order to further analyse the relationship between the overall change in the carrying capacity of marine resources and environment and the three secondary indicators, as well as the relationship to the marine economy of Weihai, this paper analyses the dynamic evolution trend of the marine resources and environment carrying capacity system containing three secondary indicators (as shown in Figures 2).



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Environmental Carrying Capacity	0.303	0.338	0.316	0.389	0.400	0.469	0.542	0.613	0.635	0.667
Marine Environmental Systems	0.128	0.095	0.079	0.287	0.310	0.441	0.560	0.796	0.937	0.838
Socio-economic system	0.230	0.263	0.248	0.347	0.305	0.488	0.578	0.685	0.719	0.709
Marine Resource System	0.496	0.571	0.545	0.585	0.613	0.476	0.464	0.349	0.360	0.447

Figure 1: Carrying capacity level of marine resources and environment in Weihai City from 2011 to 2020

For the socio-economic system, the overall socio-economic development level of Weihai City from 2011 to 2020 showed a fluctuating upward trend, and in 2013, 2015 and 2020, due to the influence of external factors, such as the new coronavirus in 2020, China's macro-economy was in a difficult turning period, and Weihai City's economic development showed a slight downward trend, and the overall and overall marine environmental carrying capacity From 2011 to 2020, Weihai's economy will grow rapidly, with the proportion of secondary and tertiary industries increasing, per capita GDP increasing from RMB 31,106 in 2011 to RMB 102,897 in 2020, and the disposable income of residents doubling. At the same time, Weihai City attaches importance to the high-quality development of the marine economy, following the pace of the country's vigorous development of the marine economy, planning the economic development of the marine industry in the Twelfth Five-Year Plan and Thirteenth Five-Year Plan of Weihai City, releasing the Development Plan for the Blue Economic Zone of Weihai City, the Shandong Weihai Marine Economic Development Demonstration Zone Construction Overall Plan", "Weihai Marine Functional Zone Planning (2013-2020)", "Weihai Marine City Construction Overall Plan" and other policy documents to promote the sustainable development trend of marine economy and socio-economic development, in 2020, the total value of Weihai's marine industry has reached 36.23 billion yuan, accounting for 65.4%, the development of Weihai's marine industry has become an important pillar of Weihai's economic development.

For the marine resource system, from 2011 to 2015, the development level of the marine resource system was high, and the potential for exploitation and sustainable use of marine resources was strong; from 2015 to 2016, there was a significant decline and a downward trend, and from 2019 to 2020, there was a slow rebound; the marine resource system was the opposite of the trend of changes in the marine resource and environmental carrying capacity from 2016 to 2018, and the marine carrying capacity was steadily increasing, indicating that the negative effect of the increase in resource consumption on the marine carrying capacity was smaller than the positive effect brought about by the development of the marine economy in Weihai City at this stage. In turn, this time period Weihai City sacrificed consumption of resources to vigorously develop the economy, which unit electricity consumption GDP from 2016 increased more, the rate of change from -4.03% to 1.42%, the rate of unit energy consumption from -7.65% to -4.33% (as shown in Figure 3), per capita mariculture area fell 10 square meters, resource consumption is faster; after 2019 with the impact of the new crown epidemic port throughput gradually declined (as shown in Figure 4), the marine resource system rebounded more slowly in 2019-2020.

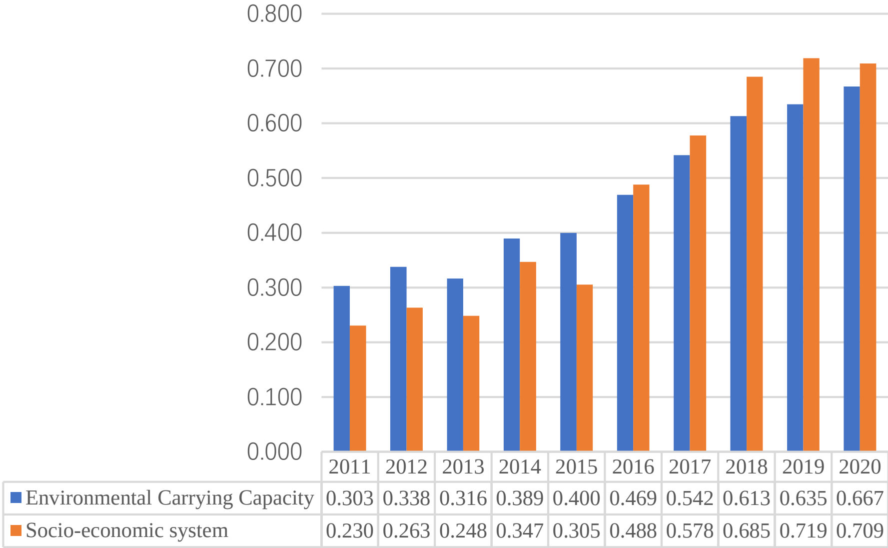


Figure 2: Socio-economic development level of Weihai City, 2011-2020

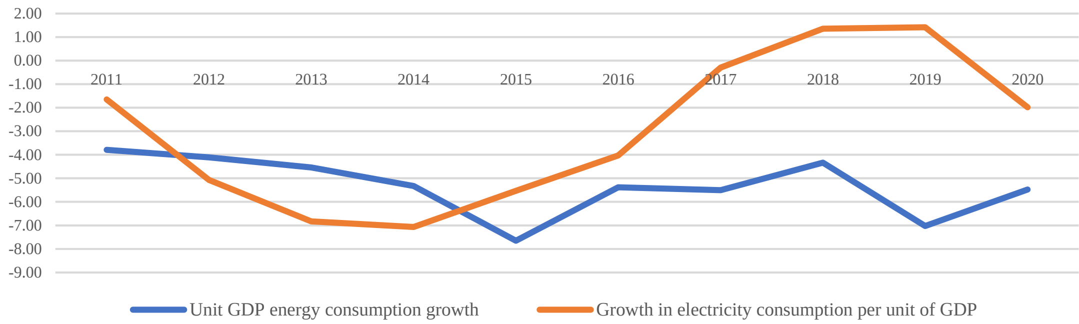


Figure 3: Change in the growth of energy consumption per unit of GDP and growth of electricity consumption per unit of GDP in Weihai City from 2011 to 2020

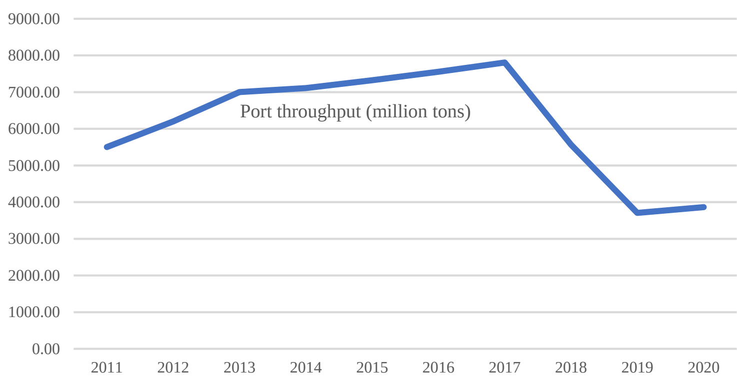


Figure 4: Change in Port Throughput of Weihai City from 2011 to 2020

In 2018, Weihai City began to protect its resources, issuing the implementation plan for the "Blue Sea 2018" special action and the "Implementation Measures for Strengthening Marine Law Enforcement and Supervision" to protect marine space resources and seafood resources, which led to a significant increase in such specific indicators; Weihai City issued the "Key Work Intentions of the Municipal State-owned Assets Committee in 2018" and the "Implementation Opinions on Implementing the Spirit of Lu Zheng Fa [No. 8] Document to Promote the Creation of a Model of Energy and Electricity Conservation in Land and Resources". Work Intentions" and "Implementation Opinions on Implementing the Spirit of Lu Zheng Fa [2018] No. 8 Document to Promote the Creation of Demonstration Work on Saving and Collecting Land and Resources", to clarify and implement various cost expenditure and resource consumption standards, and further reduce energy and electricity consumption, so that the growth rate of energy consumption declined afterwards and fell back to negative growth, which in turn led to a slow rebound in the development level of the marine resources system[14].

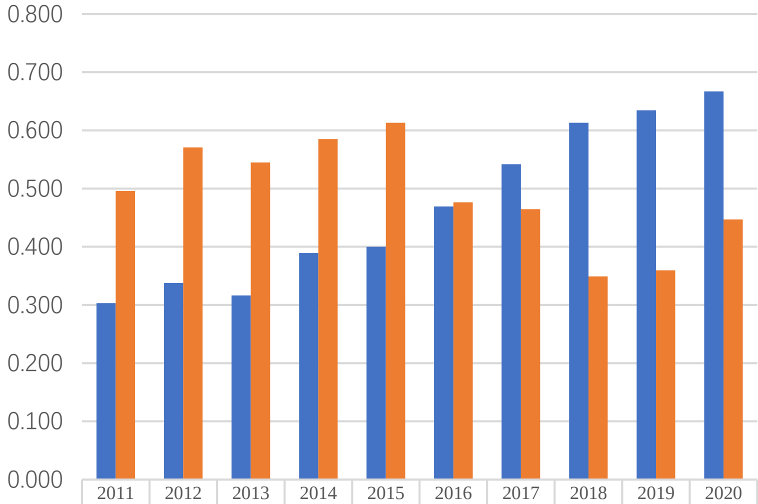


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Figure 5: Level of development of the marine resource system in Weihai City, 2011-2020

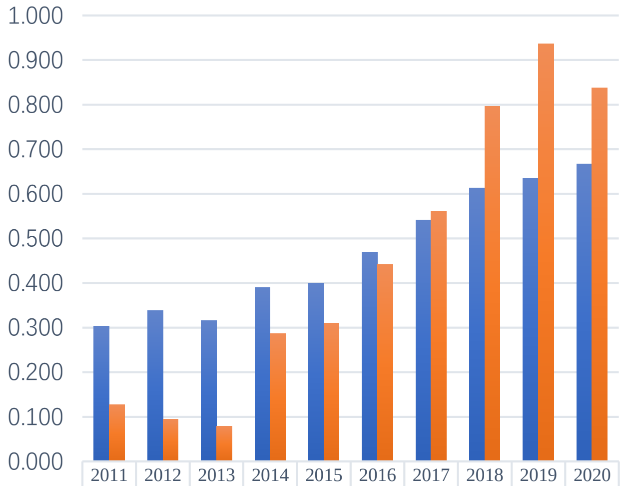

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Figure 6: Level of development of the marine environmental system in Weihai City, 2011-2020

Seen in Figure 5 and Figure 6, for the marine environmental system, the marine environmental system first declined and then rose from 2011 to 2020, and finally fell slightly in 2020, with the lowest marine environmental carrying capacity of 0.095 in 2013 and the highest of 0.937 in 2019. The reason. In 2012 and 2013, the People's Government of Weihai Municipality issued the Notice of the 12th Five-Year Plan for Environmental Protection and the Notice of the 13th Five-Year Plan for Environmental Protection of Weihai Municipality, respectively. Strictly control pollution emissions and attach great importance to environmental protection. For the air environment, sulphur dioxide emissions will be reduced from 51,452.63 cubic metres in 2011 to 5,570 cubic metres in 2020, and nitrogen oxides will be reduced from 51,343 cubic metres in 2011 to 4,409 cubic metres; for the water environment, industrial wastewater emissions will gradually decline, while the total amount of sewage treatment will continue to rise, with a change rate of over 100%; for the land environment, wetlands by the sea will be reduced from 1,590 cubic metres in 2011 to 1,570 cubic metres in 2020. The garden area and park green area rose from 5,940 square metres and 1,465 square metres in 2011 to 14,057 square metres and 4,219 square metres in 2019 respectively[13].

4. Recommendations

This paper will combine the findings and the current status of timeliness to target three secondary indicators with recommendations.

4.1 Socio-economic system

For the socio-economic system: coping with the impact of the New Crown epidemic and optimising the development of the industrial structure of the marine economy

(1) Response measures for the marine economy under the New Crown epidemic.

Optimize the marine digital economy, optimize the operation of the marine industry's e-commerce, adopt a combination of online and offline methods to speed up the operation of marketing fisheries products and seafood, create and optimize a digital operation industry chain for seafood, and enhance the competitiveness of Weihai's marine digital economy.

With the weakening of the Omicron virus, Weihai should comply with the national "Article 20" and "New Article 10" and appropriately liberalise the flow of goods and people in the port, so as to enhance the development of the trade and marine tourism industries while ensuring the safety of life[12].

(2) Industrial optimisation

The proportion of secondary and tertiary industries in Weihai has gradually increased over the past decade, with the marine industry accounting for a larger proportion. In order to further develop the marine economy and social economy, Weihai should further optimise the layout of the marine industry and promote further transformation and upgrading of the marine economy.

First, refine the primary marine industry. The proportion of primary industries in Weihai's marine economy is gradually decreasing, but it does not mean that they can be neglected. For the production of fisheries, fishing products and fishing gear to further improve quality, create a brand effect, promote internally to China and build a Made in China brand externally; build a large-scale procurement centre and trading centre for primary industry products; improve the income of fishermen, accurately help the production and marketing of fishermen in fishing villages, help improve aquatic technology and optimise marketing strategies. Second, strengthen and optimise the secondary and tertiary industries and expand the development of strategic new industries. As the proportion of secondary and tertiary industries gradually increases over the decade, Weihai should optimise and strengthen the industries already in existence, improve the efficiency of new technologies invested in the operation of secondary industries, such as marine ship manufacturing, marine health products industry and new marine energy industry, continue to develop new marine technologies and biological products, and actively develop coastal tourism to create a large-scale tourist destination to attract foreign tourists[11].

4.2 For the marine resource system.

Improve regulations, enhance the degree of implementation of resource protection regulations and strengthen supervision. Although Weihai City has the objectives of the 12th Five-Year Plan and 13th Five-Year Plan, there are no systematic policy documents on marine resource protection and laws and regulations on the control of energy consumption of resources. The requirements for resource protection only exist in other comprehensive resource protection documents such as the "Key Work Intentions of the Municipal State-owned Assets Supervision and Administration Commission in 2018" and the "Implementation Opinions on Implementing the Spirit of Lu Zhengfa [2018] No. 8 Document to Promote the Creation of Demonstration of Land and Resource Conservation and Intensification". The Weihai Municipal Government should formulate reasonable regulations with a system for unit energy and electricity consumption and strictly supervise the implementation efforts to increase resource protection and reduce the negative effects of resource consumption on the carrying capacity of marine resources and the environment.

Governments should balance the relationship between resource consumption and marine economic development, and focus on the protection and rational use of resources while consuming them for economic development. The government should also develop new marine energy resources, increase the proportion of wind energy capacity in Weihai, and support new energy enterprises in Weihai such as the Hua neng power plant.

4.3 For the marine environmental system

The government of Weihai city should be aware of and continuously improve the operational mechanism for marine environmental protection and close the loopholes that exist in the existing marine environment. Although Weihai's ecological environment has improved significantly, there are still some gaps, such as the imbalance of nitrogen and phosphorus nutrient ratios and red tides. Weihai should continue to pay attention to all aspects of the environment, protect the environment and optimise the marine environmental system.

As the carrying capacity of marine resources and environment changes gradually over time, future research should continue to optimise and improve the evaluation system and calculation model, refine the data, and lay a theoretical foundation for the rational development and sustainable development of marine resources and environment in a more scientific and objective manner.

5. Conclusion

This paper follows the principles of scientificity, objectivity and relevance, and uses the entropy TOPSIS model to carry out an empirical study on the carrying capacity of marine resources and environment in Weihai City from 2011 to 2020, and draws the following conclusions.

(1) The overall trend of the environmental resource carrying capacity of Weihai City from 2011 to 2020 is slowly increasing, although there is a slight fluctuation of decrease in 2012, but the overall trend is increasing, the comprehensive value is between 0.303 and 0.667, the marine resource environmental carrying capacity has improved from a lower level to a middle to upper level, and there is still some room for improvement.

(2) The policy documents on marine economy, marine resources and marine environment of Weihai City in various periods have positive effects on the carrying capacity of marine resources and

environment, and the "12th Five-Year Plan" and "13th Five-Year Plan" of Weihai City have positive effects on the development of marine economy, marine resources and marine environment from 2011 to 2020. The 12th Five-Year Plan and the 13th Five-Year Plan of Weihai are of great significance to the development of the marine economy, the sustainable use of marine resources and the development and protection of the marine environment in the period 2011-2020.

(3) From the secondary indicators, Weihai's economy has been fluctuating and rising in the past ten years, with the marine economy developing and the proportion of marine industries gradually increasing; marine resources declined significantly at the beginning and rebounded to a certain extent in the later stage after macroeconomic regulation and control, but the positive effect of using resources for economic development was greater than the negative effect, so that the carrying capacity of marine resources and environment steadily increased; marine environmental protection regulation and control had significant effects.

(4) At present, the factors affecting the carrying capacity of Weihai's marine resources and environment are mainly unit energy consumption, unit electricity consumption and port throughput. This suggests that the key to improving the carrying capacity of Weihai's marine resources and environment is to optimise the marine resource system.

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