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Original Article

A SEA OF OPPORTUNITIES: INVESTIGATING CHINA'S MARINE FISHERY GROWTH AND EFFECTIVENESS

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Abstract: China's marine catch and seawater mariculture generated an impressive output value of 603.3 billion yuan in 2020. However, amid the challenges of over-exploitation of marine resources and worsening marine ecology, the current development model for China's marine fishery economy remains extensive, single-structured, and short-sighted.

Marine fisheries constitute a crucial component of both the marine and national economies. Achieving high-quality development in this sector is not merely essential for addressing rural issues; it is also pivotal in attaining the "dual carbon" strategic objective. In an era marked by new challenges and risks, including the pandemic and century-defining changes, ensuring macroeconomic stability, safeguarding the foundations of agriculture, ensuring national food security, and securing a stable supply of aquatic products have taken center stage in the modern fishery development agenda.

Under the "dual carbon" goal, the role of marine fishery carbon sinks in mitigating global warming has gained unanimous recognition. As a major player in marine fishery, China is poised to leverage its abundant marine resources by establishing high-level marine ranches, expanding the scope of marine carbon sink fisheries, and fortifying marine ecosystem resilience. This green development approach necessitates innovation in marine carbon sink mariculture technology to enhance carbon storage per unit seawater mariculture area, thereby augmenting both ecological and economic values.

Accurate assessments of the current state of marine fisheries enable the timely identification of limiting factors and the formulation of development strategies, facilitating the optimization of marine fisheries production structures.

Keywords: Marine Fisheries, High-Quality Development, Carbon Sink, Green Development, Marine Ecology

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1. Introduction

In 2020, the total output value of China's marine catch and seawater mariculture reached 603.3 billion yuan. However, in the new development stage of the new normal economy, under the influence of multiple factors such as over-exploitation of marine fishery resources and the increasingly deteriorating marine ecology, the development mode of China's marine fishery economy is still extensive, singlestructured, and not long-term[1].

Marine fisheries are an important part of the marine economy and national economy. The high-quality development of marine fisheries is not only related to the "three rural" issues but also a key link in the "dual carbon" strategic goal. After socialism entered a new era, we faced the dual risks and challenges of the epidemic test and the changes of the century. Stabilizing macroeconomic development, stabilizing the basic board of "three agriculture", ensuring national food security, and ensuring aquatic product supply as the first task of modern fishery development in the new era is a new requirement for fisheries in the new era. Under the "dual carbon" strategic goal, the important role of marine fishery carbon sink in carbon sink and carbon sink in response to global warming has gradually become a consensus. China is a major marine fishery country. It is necessary to give full play to the rich advantages of China's marine fishery resources, base on marine carbon sink fisheries, build high-level marine ranches, expand the scale of marine carbon sink fisheries, enhance the carrying capacity of marine ecosystems, and promote the green development of marine fisheries; It is necessary to promote the innovation of marine carbon sink mariculture technology, improve the carbon storage capacity per unit seawater mariculture area, and enhance the ecological value and economic value of marine carbon sink. The correct grasp of the current comprehensive level of marine fisheries can timely discover the factors that restrict the development level in the marine fisheries system, can timely formulate development strategies, and adjust and optimize the production structure of marine fisheries[2].

At present, scholars have carried out a lot of research work from the aspects of the influencing factors of marine fishery development, the sustainable use of marine fishery resources, and marine fishery carbon sink, but few scholars only start from the internal marine fishery system and build a comprehensive and objective perspective of the marine fishery comprehensive evaluation system. Therefore, this article is 13

based on an objective perspective, and builds a comprehensive evaluation index

2. Materials and Methods

2.1. Evaluation Indicator System Construction

Considering the important role that marine fisheries and marine mariculture play in the "three rural issues" and the "dual carbon" strategic objectives, and their basic and dominant position in the marine fisheries economy, this paper's comprehensive evaluation indicator system for marine fisheries mainly focuses on the relevant output, value, and production factors of marine fishing and marine mariculture. The data collection range is set from 2006 to 2020, i.e., during the "Eleventh Five-Year Plan", "Twelfth Five-Year Plan", and "Thirteenth Five-Year Plan". Due to the small scale of marine fisheries in Shanghai and Tianjin, this paper excludes these cities from the research, and the relevant index data does not include data from Tianjin and Shanghai.

Marine Fisheries Comprehensive Evaluation Index System: Following the principles of scientific, systematic, and operable index system construction, considering the easy availability of data, and based on the research objectives of this paper, a comprehensive evaluation index system for China's marine fisheries is constructed from three criterion layers: economic benefits, production efficiency, and carbon sink capacity (Table 1).

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Table 1: China's Marine Fisheries Comprehensive Evaluation Index System.

System layer	Guideline layer	Indicator layer	Explanation of indicators
Integrated Marine Fisheries Evaluation System A	Economic benefits B_1	Mariculture production value C_1	-
		Marine fishing production value C_2	-
	Productivity B_2	Mariculture production per unit area C_3	Mariculture production/mariculture area
		Marine fishing production per unit power C_4	Marine fishing production / marine fishing vessel power
		Production of seawater products per unit of employees C_5	Production of marine products / marine fisheries workers
	Carbon Sink Performance B_3	Marine fisheries carbon sink capacity C_6	Mariculture shellfish production * Carbon sink factor
		Carbon Sink Contribution C_7	0.9165*Proportion of shellfish production + 0.0835*Proportion of algae production

From the perspective of economic benefits, we choose the output value of marine mariculture and marine fisheries as the index layer, which reflects the output capacity of marine mariculture and marine fisheries; from the perspective of production efficiency, we choose the unit area marine mariculture output, unit power marine fisheries output, and unit marine employee marine products output as the index layer, which reflects the production efficiency after eliminating the impact of production factors; from the perspective of carbon sink capacity, we choose marine fisheries carbon sink capacity and carbon sink contribution as the index layer, which assesses the carbon sink efficiency of marine mariculture from the perspective of carbon sink capacity and the factors affecting carbon sink capacity.

2.2. Data Processing

The indices of marine mariculture output value, marine fisheries output value, unit area marine mariculture output, unit power marine fisheries output, and unit employee marine products output selected in this paper are obtained directly or through simple conversion from the "China Fisheries Statistical Yearbook". The carbon sink contribution[3] and marine fisheries carbon sink capacity indices need to be measured through the carbon sink capacity estimation method[4].

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2.2.1. Marine Fisheries Carbon Sink Capacity

China's marine mariculture scale ranks first in the world, and China's marine mariculture is mainly based on shellfish and algae cultivation. Studies on marine carbon sink show that shellfish and algae cultivation can transfer a large amount of carbon from the ocean. The impact of China's large-scale shellfish and algae cultivation on shallow sea carbon cycles is significant and is a veritable "mobile carbon sink". In 2020, China's marine mariculture of shellfish and algae was able to remove at least

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1.3756 million tons of carbon, equivalent to reducing carbon dioxide emissions in the atmosphere by 5.0439 million tons. Under the "dual carbon" strategic goals, it is urgently needed to consider the marine mariculture carbon sink capacity in the marine fisheries comprehensive evaluation indicator system to achieve the "dual carbon" goals of marine fisheries. Referring to relevant research results, the calculation method of carbon sink capacity of marine mariculture shellfish and algae is as follows[5-6]:

$CC_{ii} = PP_{ii} + EE_{ii}$ (1)

Where, CC_{ii} represents the carbon sink of variety i, PP_{ii} represents the yield of variety i, and EE_{ii} represents the carbon sink coefficient of variety i.

The carbon sink coefficients(Table 2) for shellfish and algae are calculated with reference to the data on carbon content in shellfish and algae by scholars such as Zhang Jihong and Yue Dongdong et al.. Taking 2020 as an example, the carbon sink capacity of marine mariculture shellfish and algae (represented by the amount of reduced carbon dioxide in the atmosphere) was calculated, and the results are shown in Table 3.

Table 2: Carbon sink coefficients for mariculture shellfish and algae.

Category	Clams	Scallops	Oyster	Mussel	Other shellfish
Carbon Sink Factor	0.0640	0.1017	0.0959	0.1093	0.0972
Category	Kelp	Skunk cabbage	Nori	Gracilaria	Other algae
Carbon Sink Factor	0.062	0.053	0.055	0.041	0.056

Table 3: Carbon sink capacity of mariculture shellfish and algae in China in 2020

Category	Carbon sink capacity (million tons)								
	Fujian	Guangdong	Guangxi	Hainan	Hebei	Jiangsu	Liaoning	Shandong	Zhejiang
Clams	72.75	39.56	23.28	0.04	0.07	1.32	10.96	34.17	8.58
Scallops	4.51	2.97	0.55	0	0	1.72	1.14	15.4	9.28
Oyster	0.37	4.14	0.11	0.04	11.92	0	12.76	35.75	0.04
Mussel	10.96	6.31	6.56	0.07	1.14	9.13	31.75	30.84	2.2
Other shellfish	18.96	5.5	2.09	0.48	0.51	5.76	3.96	7.08	17.12
Kelp	18.81	0.07	0	0	0	0	6.6	11.59	0.48
Skunk cabbage	0	0	0	0	0	0	3.48	0.88	0

Nori	1.47	0.29	0	0	0	0.95	0	0.26	1.5
Gracilaria	4.18	0.7	0	0	0	0	0	0.7	0
Other algae	0.15	0	0	0.07	0	0	0	0	0.4
Total	132.15	59.58	32.6	0.7	13.68	18.88	70.58	136.62	39.6

2.2.2. Carbon Sink Contribution

In 2015, Chinese scholars Ji Jianyue, Wang Pingping, and others [3] used a modified Laspeyres index decomposition method to analyze the influencing factors of China's marine mariculture carbon sink capacity. The results showed that the yield factor was the main contributor to the changes in the carbon sink capacity of marine mariculture, with its contribution exceeding 90%. Marine shellfish farming played a dominant role in the carbon sink capacity of marine mariculture, with the lowest contribution rate of 83.6%. The contribution of marine algae farming was relatively low. Based on these findings, a comprehensive evaluation of the carbon sink capacities of shellfish and algae should be conducted based on their respective contribution to carbon sink when scientifically and accurately evaluating the carbon sink capacity of the marine fisheries industry.

Among the influence of marine mariculture production factors and structure factors on the carbon sink capacity of marine mariculture, the contribution of production factors accounts for more than 90%, and the influence of structural factors is less than 10%, and even less than 5% in most cases. Therefore, when evaluating, the impact of structural factors is ignored, and only the impact of mariculture production factors is considered. Among the production factors, the contribution of shellfish yield is still 91.45% of the production factors at its lowest, with an average share of 91.65%. Therefore, the weight of shellfish carbon sink contribution is set at 0.9165, and the weight of algae carbon sink contribution is 0.0835, that is:

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$$CC_{SS} = 0.9165 \times RR_{aa} + 0.0835 \times RR_{ss} \qquad (2)$$

where CC_{SS} represents the carbon sink contribution, RR_{aa} represents the proportion of shellfish production, and RR_{ss} represents the proportion of algae production.

2.3. Research Methods

The main research methods and models used in this paper include the entropy method and comprehensive evaluation model.

2.3.1. Entropy Method

When conducting multi-indicator evaluations, weights of each indicator are usually determined through objective weighting methods and subjective weighting methods. The subjective weighting method primarily determines weights based on the evaluator's subjective assessment of each indicator, typically using the Delphi method. The advantages of the subjective weighting method are its simplicity, practicality, ease of promotion, collective wisdom, and flexibility to adjust according to current policies. However, this also means the subjective weighting method has certain time sensitivity and may require multiple rounds of weighting to achieve consensus among experts. Therefore, this paper adopts the objective weighting method.

The entropy method is a common method in objective weighting, which can maximally utilize the information entropy of indicator data, overcoming information overlap and errors caused by subjective factors. This paper's comprehensive evaluation of marine fisheries is mainly based on comparisons between provinces, i.e., using the data from all provinces within the same year, to evaluate the benefits, efficiency, and effectiveness of marine fisheries. This approach allows us to understand the gaps between them and the comprehensive level of marine fisheries benefits, efficiency, and effectiveness, and if data allows, this evaluation system can be extended to coastal cities within the province.

Since the dimensions of each indicator are different, it is impossible to compare them directly using raw data. Therefore, this paper uses the range entropy method to solve this problem[7-8]. Suppose there are m evaluation schemes and n evaluation indicators, the specific steps are as follows:

(1)Transform the index value of the i-th plan under the j-th index in the original data by using the standardization method:

$$x'_{ij} = \frac{(x_{ij} - m_j)}{M_j - m_j} \quad (3)$$

where xx_{iiii}' is the index value of the i-th plan under the j-th index, mm_{ii} is the minimum value of the j-th index, and MM_{ii} is the standard deviation of the j-th index.

(2)To avoid negative values after standardization, we use the utility coefficient method, let:

$Z_{ij} = x'_{ij} \times 0.99 + 0.01$ (4) (3) We calculate the proportion pp_{iiii} of the index value of scheme i under the j-th index:

$$p_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{m} Z_{ij}} \quad (5)$$

(4) The entropy value ee_{ii} of the j-th index calculated using the equation given below:

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \ln p_{ij} \quad (6)$$

(5) The coefficient of variance (gg_{ii}) was calculated using the equation given below:

$$gg_{ii} = 1 - ee_{ii} \quad (7)$$

(6) The specific gravity of index was calculated using the equation given below:

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$$a_j = \frac{g_j}{\sum_{j=1}^{n} g_j} \quad (8)$$

2.3.2. Comprehensive Evaluation Model

This study uses the linear weighting method to calculate the evaluation values of economic benefit, production efficiency, and carbon sink effectiveness, and then synthesize the comprehensive evaluation value of marine fisheries. The calculation formula is:

$$ff(xx) = \sum_{ii=1}^{2} ww_{ii} \times ZZ_{ii} \quad (9)$$

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$$ff(yy) = \sum_{ii=1}^{3} ww_{ii} \times ZZ_{ii} \qquad (10)$$

$$ff(zz) = \sum_{kk=1}^{2} ww_{kk} \times ZZ_{kk} \qquad (11)$$

$$(uu) = ff(xx) + ff(yy) + ff(zz) \qquad (12)$$

In these equations, $ff(uu)$, $ff(xx)$, $ff(yy)$, and $ff(zz)$ respectively represent the comprehensive evaluation of marine fisheries, economic benefits, production efficiency, and carbon sink effectiveness; ww_{ii}, ww_{ii}, and ww_{kk} are the weights of the evaluation indicators for economic benefits, production efficiency, and carbon sink effectiveness respectively; ZZ_{ii}, ZZ_{ii}, and ZZ_{kk} are the values of economic benefits, production efficiency, and carbon sink effectiveness evaluation indicators after standardization and shift.

3. Results

3.1. Analysis of Comprehensive Evaluation Results of Marine Fisheries

According to Equation (19), the comprehensive evaluation indices of marine fisheries from 2006 to 2020 for each coastal province are calculated. The results are shown in Table 4.

Table 4: Comprehensive Evaluation Index of Marine Fisheries in Coastal Provinces from 2006 to 2020

Year/ Province	Fujian	Guangdong	Guangxi	Hainan	Hebei	Jiangsu	Liaoning	Shandong	Zhejiang	Average value
2006	1.4	0.84	0.82	0.56	0.45	0.47	0.98	1.59	0.78	0.88
2007	1.37	0.88	0.73	0.55	0.42	0.48	0.84	1.53	0.81	0.85
2008	1.38	0.87	0.69	0.35	0.3	0.52	0.79	1.52	0.69	0.79
2009	1.39	0.89	0.72	0.35	0.3	0.55	0.79	1.6	0.7	0.81
2010	1.48	0.95	0.75	0.39	0.34	0.56	0.93	1.61	0.8	0.87
2011	1.44	0.94	0.71	0.39	0.31	0.53	0.88	1.56	0.79	0.84
2012	1.64	1.06	0.8	0.47	0.39	0.6	1.03	1.87	0.78	0.96
2013	1.7	1.09	0.84	0.51	0.39	0.71	1.12	1.94	0.98	1.03
2014	1.77	1.14	0.87	0.56	0.41	0.71	1.19	2.07	1.04	1.08
2015	1.85	1.19	0.91	0.58	0.44	0.7	1.16	2.15	1.11	1.12
2016	2	1.24	0.95	0.64	0.51	0.71	1.25	2.18	1.07	1.17
2017	2.07	1.32	1.05	0.49	0.51	0.7	1.05	2.08	1.27	1.17
2018	2.2	1.35	1.07	0.52	0.49	0.76	1.01	2.12	1.35	1.21
2019	2.34	1.39	1.09	0.52	0.42	0.66	1.04	2.03	1.37	1.21
2020	2.43	1.39	1.07	0.55	0.48	0.79	1.11	2.2	1.49	1.28
Average value	1.76	1.1	0.87	0.5	0.41	0.63	1.01	1.87	1	1.02

The data from Table 4 was used to plot the comprehensive evaluation index of marine fisheries from 2006 to 2020 for each coastal province, as shown in Figure 1.

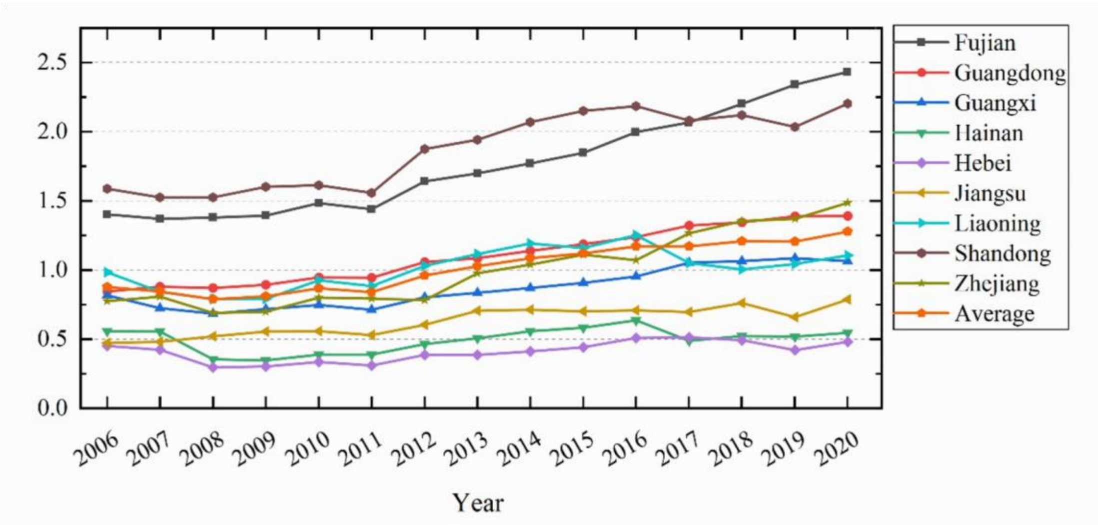

Figure 1: Schematic Diagram of Comprehensive Evaluation Index of Marine Fisheries in Coastal Provinces from 2006 to 2020.

Overall, the average value of the comprehensive evaluation index of marine fisheries from 2006 to 2020 shows a trend of first decreasing and then increasing. The average value of the comprehensive evaluation index of marine fisheries in 2006 was 0.88, which dropped to 0.79 in 2008, and then began to rise. Especially from 2012 to 2016, the comprehensive evaluation index of marine fisheries increased rapidly, with a growth of 39.29% in five years. After 2016, the comprehensive evaluation index of marine fisheries remained generally stable.

Between 2006 and 2008, the index fell to its lowest in 2008 due to severe natural disasters and the global economic crisis. In these three years, the average annual direct economic loss caused by national fishery disasters reached 2,350,284 million yuan, while in 2009 it was only 1,522,716 million yuan. From 2011 to 2016, the annual average value of mariculture production increased by 19.2%, the value of marine catch production increased by 12.6% on average, and the average value of the comprehensive evaluation index of marine fisheries also increased from 0.84 to 1.17.

Looking at the comprehensive evaluation index of marine fisheries in each coastal province, the annual average indices of Fujian, Guangdong, and Shandong are higher than the national average. These provinces have a good foundation in the marine fisheries industry, large scale of the primary industry of marine fisheries, and a high level of development of marine fisheries. Shandong and Fujian are almost in a league of their own in terms of economic benefits and carbon sink efficiency levels, significantly leading other provinces, while Guangdong has balanced evaluation indices in terms of economic benefits, production efficiency, and carbon sink efficiency.

The comprehensive evaluation indices of marine fisheries in Guangxi, Jiangsu, Liaoning, and Zhejiang are 0.87, 0.63, 1.01, and 1, respectively, lower than the average value of China's comprehensive evaluation index of marine fisheries, and are in a middle position among coastal provinces. The comprehensive evaluation indices of marine fisheries in Hebei and Hainan are 0.41 and 0.5, respectively, ranking the last two. The economic development level of marine fisheries in these two provinces is low. From the three-dimensional perspective of benefits, efficiency, and effectiveness, the economic benefit indices of marine fisheries in Guangxi and Hainan are relatively low, the production efficiency of marine fisheries is at a medium level, and the carbon sink efficiency index of Hainan province is the lowest among coastal provinces.

3.2. Temporal Evolution Analysis of Marine Fisheries Comprehensive Index

According to the results of China's marine fisheries comprehensive evaluation index, data from 2006 to 2020 was selected and divided according to the five-year plans, namely the "11th Five-Year Plan", the "12th Five-Year Plan", and the "13th Five-Year Plan". The kernel density estimates of the comprehensive evaluation index of marine fisheries in China during the three five-year plan periods were calculated using Matlab 2020b software, and the kernel density curves were plotted as shown in the Figure 2 below.

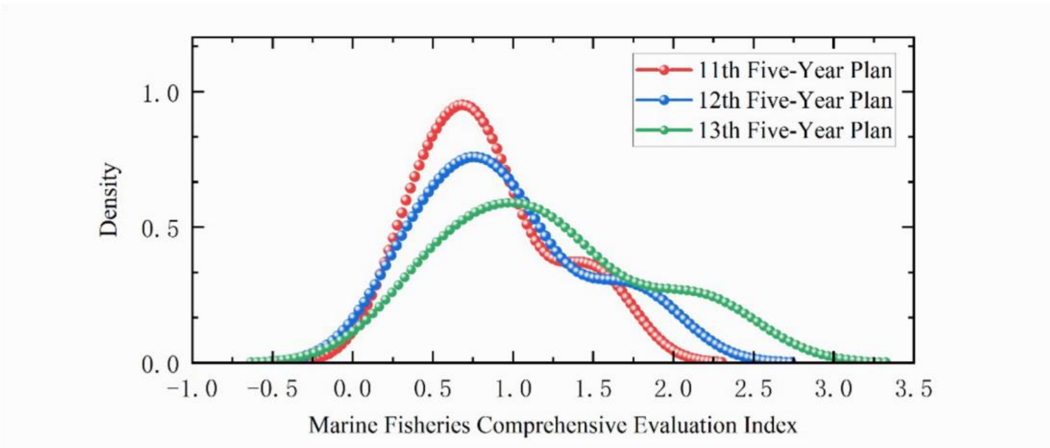

Figure 2: Kernel Density Curve of China's Marine Fisheries Comprehensive Evaluation Index

From the kernel density curve, the dynamic changes in the comprehensive evaluation index of China's marine fisheries during the three five-year plans can be observed as follows: ① From the positions of the three curves, the kernel density distribution curves of the three five-year plans show a trend of moving to the right, which indicates that the overall level of the comprehensive evaluation index of marine fisheries in China's coastal provinces is improving. The coordinates of the highest peaks in the three periods are 0.689, 0.82, and 0.999, respectively. Obviously, during the "13th Five-Year Plan", the comprehensive index of marine fisheries in China increased the most. ② From the shape of the kernel density curves, from the "11th Five-Year Plan" to the "13th Five-Year Plan", the kernel density curve of the marine fisheries comprehensive evaluation index gradually flattens, and the curve has stronger extensibility, indicating that the differences in the comprehensive evaluation index of marine fisheries among provinces are gradually increasing. ③ In terms of the kurtosis of the kernel density curves, during the "11th Five-Year Plan", the kernel density curve was bimodal, indicating that there was a bipolarization phenomenon in the comprehensive evaluation index of marine fisheries in each province. It then gradually transitioned to a unimodal shape, indicating that the bipolarization phenomenon of the comprehensive evaluation index of marine fisheries was weakening.

4. Conclusion and Suggestions

4.1. Conclusion

This paper constructs a comprehensive evaluation index system for China's marine fisheries, considering three key perspectives: economic benefits of marine fisheries, production efficiency, and carbon sink efficiency. By integrating the entropy method with a comprehensive evaluation model, we calculated the comprehensive evaluation index for marine fisheries across all coastal provinces from 2006 to 2020. Upon analyzing the results, we arrived at the following conclusions:

(1) The comprehensive evaluation of marine fisheries in China's coastal provinces from 2006 to 2020 revealed a trend of initial decrease and subsequent increase. The most significant upsurge was noted between 2012 to 2016 with an impressive growth of 39.29% over these five years.

(2) Provinces like Fujian, Guangdong, and Shandong stood out, with their annual average indices surpassing the national average, underlining their strong foundation in the marine fisheries industry. They demonstrated a well-rounded development and robust primary industry of marine fisheries. Guangxi, Jiangsu, Liaoning, and Zhejiang, while still below the national average, are in a mid-level position among coastal provinces. However, Hebei and Hainan, with the lowest economic development levels of marine fisheries, require targeted improvements to enhance their comprehensive evaluation indices.

(3) Temporal evolution analysis reveals a rightward shift in the kernel density distribution curves across the three Five-Year Plans, indicating an overall improvement in marine fisheries' comprehensive evaluation index. However, a widening disparity among provinces is discernible from the flattening kernel density curves. The bipolarization observed during the "11th Five-Year Plan" seems to be diminishing, as suggested by the unimodal shape of the curve during the "13th Five-Year Plan".

4.2. Suggestions

Based on these findings, we suggest that a multi-pronged approach is needed to enhance marine fisheries' comprehensive evaluation indices across provinces:

(1) Enhancing Resilience: To safeguard against the detrimental effects of economic crises and natural disasters, strategies to bolster resilience and disaster preparedness should be implemented. This includes investments in infrastructure, technology, and capacity-building at the local level.

(2) Capacity Building: For provinces with mid-level or low comprehensive evaluation indices, there is a need for capacity building and up-skilling of local communities. This could involve technical training programs, knowledge transfer initiatives, and enhancing access to capital for small and medium enterprises in the marine fisheries industry.

(3) Balanced Development: Efforts should focus on a balanced development across provinces to reduce the disparities in the comprehensive evaluation index. This might involve tailored strategies to leverage the unique strengths of each province and address its specific challenges.

(4) Sustainable Practices: To sustain the upward trend in the comprehensive evaluation index, provinces should also invest in sustainable fishing practices, mariculture technologies, and blue carbon initiatives. This not only benefits the marine environment but can also provide a long-term economic boost.

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