

Original Research Articles

Research on the resilience level of fishery economy in coastal areas of China

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Multiple risks such as environmental pollution, market risk, and extreme weather pose severe challenges to fishery production, fishermen's lives and property, and the sustainable development of fishery. Improving the resilience of fishery economy is an inevitable requirement for coping with fishery production risks and achieving high-quality development of fishery economy. Therefore, based on the three dimensions of resistance and recovery ability, adaptation and adjustment ability, innovation and transformation ability, this study constructs a comprehensive index evaluation system of fishery economic resilience, and uses entropy method and Theil index method to measure the level of fishery economic resilience and regional differences in coastal areas of China from 2016 to 2023. The conclusions are as follows: (1) From 2016 to 2023, the level of fishery economic resilience in coastal areas of China showed a fluctuating growth trend of 'first decline and then rise', with an average value of 0.2566. (2) There are significant differences in the level of fishery resilience in different coastal areas. From 2016 to 2023, Shandong Province had the highest level of fishery economic resilience (0.5226), and Hainan Province had the lowest level of fishery economic resilience (0.0751). The eastern marine economic circle has the highest fishery economic resilience (0.2713), followed by the southern marine economic circle (0.2650), and the northern marine economic circle has the lowest fishery economic resilience (0.2371). (4) The regional differences in the level of fishery economic resilience in coastal areas of China mainly come from inter-group differences, with a contribution rate of 68.36 %. The difference in the level of fishery economic resilience between the three major marine economic circles has gradually become the most important factor affecting the difference in the level of fishery economic resilience in China.

INTRODUCTION

The old saying " Hongfan eight politics, food is the head of politics " profoundly reveals the important position of food security in national governance and economic development.¹ Fishery is an important part of the global food supply system. It not only provides a rich source of protein for human beings, but also is a key industry to maintain ecological balance and promote economic growth. However, with the continuous changes in the global environment and economic situation, fishery development is facing multiple risks and severe challenges. First, the pressure on resources and environment is increasing. Excessive inter-

vention of human activities, such as overfishing, environmental pollution and resource development, aggravates the degradation of marine ecology and threatens the long-term stable development of fisheries.² Second, the market risk increases. The increasing competition in the international fishery market and the upgrading of domestic aquatic product consumption demand have put forward new requirements for fishery transformation and industrial chain optimization. Third, frequent natural disasters. Extreme weather such as typhoons and storm surges pose a serious threat to fishery production and the safety of fishermen's lives and property.³ These risk factors are intertwined and pose a serious challenge to the sustainable development of fisheries. In addition, since the outbreak of the COVID-19,

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the global fishery economy has been impacted by supply chain disruptions, declining market demand, and the complexity of the relevant international trade situation, revealing that the current fishery industry has a weak ability to resist sudden risk events.⁴ At the same time, the development of China's fishery economy is also restricted by the problems left over by the urban-rural dual structure. There are significant differences in production mode, technical level and capital investment among different regions, resulting in significant differences in recovery ability and adaptation speed in the face of sudden environmental or market changes.⁵ Therefore, for China, a global fishery power, improving the level of fishery economic resilience is an inevitable requirement to cope with fishery production risks and achieve high-quality development of fishery economy.

The concept of resilience was originally proposed by Holling, an ecologist, to describe the ability of ecosystems to resist and recover from external disturbances.⁶ Martin further enriched the connotation of resilience, emphasizing that resilience is not only reflected in the ability to respond to emergencies, but also covers the process of continuous adaptation and transformation.⁷ In recent years, resilience research has begun to extend from an ecological perspective to an interdisciplinary field, taking into account social, economic, political, technological and other dimensions. In this context, the issue of resilience in economic areas such as agriculture and fisheries has received increasing attention, providing an important reference for addressing global economic uncertainty, ecological challenges and food security issues.⁸ Especially in the field of agriculture, resilience research has become an important practical application of resilience theory. With the continuous development of global climate change and social economy, the issue of agricultural resilience has gradually become the focus of research. Nelson et al. pointed out that climate change has a profound impact on global agriculture, especially in developing countries, where resource shortages and extreme weather events have exacerbated the vulnerability of agriculture. Therefore, improving the level of agricultural resilience has become an important way to ensure food security and promote sustainable agricultural development.⁹

In recent years, scholars have conducted extensive research on the measurement of agricultural resilience, and conducted in-depth discussions on the evaluation framework and index system. First of all, stability and resilience have become the core issues of agricultural resilience research. The theory of ecosystem resilience proposed by Holling provides a theoretical basis for agricultural resilience, emphasizing the importance of resilience after external shocks and maintaining basic functions.⁶ Subsequently, Smit et al. emphasized that resilience is the ability of agriculture to adapt to climate change, and proposed a resilience assessment model based on adaptation strategies.¹⁰ In addition, a multi-dimensional resilience measurement framework has emerged in recent years. Folke et al. proposed a comprehensive model that integrates the resilience indicators of the three dimensions of ecology,

economy and society. This comprehensive model can more fully reflect the resilience performance of agriculture in the face of complex challenges.¹¹ The research on the measurement of agricultural resilience has been deepening, covering many aspects from theoretical basis to practical framework.

When studying the spatial differences in resilience between regions, scholars have found that agricultural resilience is affected by many factors, including natural resource conditions, social economy and policy environment. Some areas can cope with environmental changes more effectively due to their superior natural conditions and rich crop diversity. For example, Schipanski et al. found that due to suitable climatic conditions, subtropical regions can grow diversified crops, and the level of agricultural resilience is generally strong. In contrast, agriculture in some arid or semi-arid regions is often dependent on a single crop or faces a shortage of resources, which leads to a relatively weak level of agricultural resilience.¹² Through the model analysis of global fishery resources, Cheung et al. found that fishery resources in tropical regions are more vulnerable to climate change, while the sensitivity of temperate regions is relatively low.³ As an important part of agriculture, the resilience level of fishery is also affected by factors such as natural resource endowment, market structure and socio-economic environment. Due to the differences in regional natural resource endowments, technological level and policy environment, there are significant differences in the ability of different regions to cope with external shocks.

Applying resilience theory to fishery economic research can not only systematically evaluate the anti-risk ability of fishery, but also provide scientific basis for relevant departments to improve the stability of fishery.⁵ Fishery economy is of great significance to ensure national food security, promote fishermen's income and promote regional economic development. As the world's largest fishery producer and consumer, China's fishery plays an important role in ensuring food security, increasing fishermen's income and promoting economic development. As the core area of China's fishery development, the level of fishery economic resilience in coastal areas has an important impact on the sustainable development of fisheries. Therefore, this study takes the level of fishery economic resilience in coastal areas of China as the research object, and constructs a comprehensive evaluation index system of fishery economic resilience from three dimensions: resistance and recovery ability, adaptation and adjustment ability, innovation and transformation ability, so as to comprehensively evaluate the level of fishery economic resilience and regional differences in coastal areas, and provide scientific basis for improving the adaptability and resilience of fishery in the face of natural disasters, market fluctuations and other shocks. This study not only enriches the application of resilience theory in the field of fishery economy, but also provides decision-making reference for government departments to optimize fishery development policies and enhance industrial anti-risk ability.

RESEARCH METHODS AND DATA SOURCES

RESEARCH METHODS

ENTROPY METHOD

Entropy method is an objective weighting method, which is widely used in index weighting, comprehensive evaluation and multi-factor decision analysis. Based on the principle of information entropy, this method determines the importance weight of each index by analyzing the degree of dispersion within the data, so as to reduce the deviation caused by human subjective judgment.¹³ Because of its scientific calculation method, entropy method can effectively reflect the differences between data, so it is widely used in the comprehensive evaluation of economy, environment, society and other fields.¹⁴ Therefore, in order to comprehensively evaluate the level of fishery economic resilience, this study uses the entropy method to determine the index weight, and uses the obtained index weight to evaluate the level of fishery economic resilience in coastal areas of China.

Since the indicators in the fishery economic resilience system have different dimensions, and the meanings of positive and negative indicators are also different, these indicators must be standardized before analysis to eliminate the impact of units and dimensions on the results. In this paper, we normalize the original index data into the mapping interval [0, 1]. Based on the selected m research provinces and n evaluation indexes, let x_{ij} represent the j -th index value of the i -th province subject (where $i = 1, 2, \dots, m; j = 1, 2, \dots, n$), $y_{\max}$, $y_{\min}$ represent the maximum and minimum values of the required mapping interval, respectively, and x'_{ij} represents the normalized value of the original data after dimensionless processing.

The positive index indicates that the larger the value, the better :

$$x'_{ij} = y_{\min} + \frac{y_{\max} - y_{\min}}{\max(x_{ij}) - \min(x_{ij})} \times (x_{ij} - \min(x_{ij})) \quad (1)$$

The negative index indicates that the smaller the value, the better :

$$x'_{ij} = 1 - \left[y_{\min} + \frac{y_{\max} - y_{\min}}{\max(x_{ij}) - \min(x_{ij})} \times (x_{ij} - \min(x_{ij})) \right] \quad (2)$$

In order to reduce the error caused by the subjective weighting of the index, on the basis of data standardization, the weight P_{ij} of the j -th evaluation index of the i -th research sample is calculated:

$$P_{ij} = \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \quad (3)$$

The information entropy E_{ij} of the j -th index is:

$$E_j = -\frac{1}{\ln m} \sum_{i=1}^m P_{ij} \times \ln P_{ij} \quad (4)$$

The weight W_{ij} of the j -th index is:

$$W_j = \frac{1 - E_j}{n - \sum_{i=1}^n E_j} \quad (5)$$

The comprehensive resilience level evaluation value R_i of the i -th sample is:

$$R_i = \sum_{j=1}^n w_j x'_{ij} \quad (6)$$

THEIL INDEX

The Theil index is a statistical tool widely used to quantify the difference in distribution. It is often used to measure the equilibrium degree of economic income and development level. It is proposed by Theil, an economist, based on the concept of entropy in information theory.¹⁵ By accurately quantifying the degree and source of inequality, the index provides a scientific basis for studying socio-economic disparities. Due to the solid mathematical foundation and strong decomposition ability of the theory, the Theil index has been widely used in many fields such as income distribution, regional economic differences and policy effect evaluation. Therefore, this study uses the Theil index to analyze the regional differences in the level of fishery economic resilience in China's three major marine economic circles. The Theil index of the level of fishery economic resilience can be expressed as :

$$T = \sum_{i=1}^n \frac{v_i}{v} \ln \frac{v_i}{\frac{v}{\mu}} \quad (7)$$

$$T_w = \sum_{j=1}^m \frac{v_j}{v} \sum_{i=1}^n \frac{v_{ij}}{v_j} \ln \frac{v_{ij}}{\frac{v_j}{\mu_j}} \quad (8)$$

$$T_b = \sum_{j=1}^m \left[\frac{v_j}{v} \ln \frac{\frac{v_j}{v}}{\mu_j} \right] \quad (9)$$

In the above formula, T , T_w , T_b represent the total Theil index, the intra-regional Theil index, and the inter-regional Theil index that measure the regional differences in the level of fishery economic resilience in coastal areas of China. v , μ represent the level of fishery economic resilience and the number of fishery population in coastal areas, respectively. m , n represent the total number of regions and the total number of provinces respectively. j , i denote the j -th region and i -th province, respectively.

INDEX SYSTEM CONSTRUCTION

Resilience research mainly focuses on the ability of social economy to recover, adjust and transform when it encounters internal and external shocks. The key is to improve the adaptability and sustainable development level of society to deal with uncertain events.¹¹ In view of the availability of data, according to the relevant literature and the particularity of fishery, this study divides the resilience of fishery economy into three dimensions: resistance and recovery ability, adaptation and adjustment ability, innovation and transformation ability. When constructing the evaluation index system of fishery economic resilience, this study refers to the existing relevant research and constructs the index system of this study. The specific indicators are shown in [Table 1](#).

Resistance and recovery ability refers to the ability of the fishery economy to cope with external shocks and to quickly return to normal operation after shocks. This ability can reflect the stability and resilience of the fishery economy in the face of uncertainty,¹⁶ which is mainly measured

Table 1. Fishery economic resilience evaluation index system and index weight.

First level indicator	Second level indicator	Unit	Indicator attributes	Weight coefficient
Resistance and recovery ability 0.1792	Total output value of fishery economy	Ten thousand yuan	+	0.0730
	Fishermen's per capita income	Yuan	+	0.0212
	Aquaculture area	Hectares	+	0.0734
	Fishery disaster loss degree	%	-	0.0116
Adaptation and adjustment ability 0.2892	Number of fishery employees	Person	+	0.0566
	Mobile fishing vessel ownership at the end of the year	Ship	+	0.0749
	Total output of aquatic products	Tons	+	0.0608
	Total amount of aquatic products processing	Tons	+	0.0969
Innovation and transformation ability 0.5316	Fishermen's technical training	person / time	+	0.1664
	Number of fishery technology achievements	pcs	+	0.0634
	Number of aquatic technology promotion institutions	pcs	+	0.0670
	Fishery technology promotion intensity	%	+	0.1444
	Opening to the outside world	Ten thousand dollars	+	0.0904

by four evaluation indicators. (1) Total output value of fishery economy: This indicator reflects the overall size of the fishery economy. The higher the total output value of the fishery economy, the larger the industrial scale, which can more effectively resist external shocks and reduce losses. (2) Fishermen 's per capita income: higher per capita income means that fishermen have a stronger economic capacity, enhance the ability to withstand shocks, and help fishermen survive and recover better under uncertain conditions. (3) Aquaculture area: This indicator reflects the basis of fishery production capacity. Larger aquaculture area not only means higher production potential, but also shows effective adaptability to market demand. (4) Fishery disaster loss degree: This indicator reflects the degree of economic losses suffered by the fishery in previous disasters. The lower the degree of loss, the stronger the resistance of the fishery economy, which can effectively reduce the damage caused by external shocks. In this study, the ratio of the affected area to the total area of aquaculture was used to represent this indicator.

Adaptation and adjustment ability refer to the flexibility and adjustment ability of fishery economy in the face of external shocks. This ability can reflect the resilience of the fishery in the face of changes in the external environment and the effective allocation of human and material resources,¹⁷ which is mainly measured by four evaluation indicators. (1) Number of fishery employees: This indicator reflects the activity and potential development capacity of the fishery industry, and the adequacy of human resources directly affects the adaptability of fishery production. (2) Mobile fishing vessel ownership at the end of the year: This indicator reflects the fishery production capacity. Large-scale motorized fishing vessels can ensure the stability of

regional fishery production and enhance the adaptability and adjustment ability of the industry. (3) Total output of aquatic products: This indicator reflects the production capacity and market supply capacity of fisheries. The improvement of production capacity helps to meet market demand, thereby enhancing the flexible response capacity of the industry. (4) Total amount of aquatic products processing: This indicator reflects the added value of fishery products and the degree of perfection of the industrial chain. Through processing, aquatic products can better adapt to market demand, improve market competitiveness and economic benefits, thereby enhancing fishery adjustment and adaptability.

Innovation and transformation ability refers to the ability of fishery economy to realize innovation and transformation by updating technology and optimizing mode in the face of challenges and opportunities. This ability can reflect the adaptability and development potential of fisheries in scientific research investment, technological progress and market change,¹¹ which is mainly measured by five evaluation indicators. (1) Fishermen's technical training: This indicator reflects the degree of fishermen 's acceptance of new knowledge and skills. High frequency and wide coverage of technical training can help to improve the professional level of fishermen, enhance their ability to accept and apply modern production technology, so as to promote the optimization of production mode and promote the modernization and transformation of fishery production. (2) Number of fishery technology achievements: This indicator reflects the degree of innovation activity in the fishery field. Technological innovation achievements can promote the industry to improve production efficiency, reduce costs and improve resource utilization, which is very important to

improve the competitiveness of fisheries. (3) Number of aquatic technology promotion institutions: This indicator reflects the intensity and coverage of fishery science and technology dissemination. The greater the number of institutions and the wider the coverage, means that the channels for the dissemination of science and technology are more and wider, which can promote the application of advanced technology in the industry more quickly and contribute to the technological innovation of the industry. (4) Fishery technology promotion intensity: This indicator reflects the breadth and depth of the application of new technologies in fisheries. The greater the promotion of technology, the higher the acceptance of new technologies in fisheries, which is conducive to the adjustment and upgrading of industrial structure. This study uses the ratio of aquatic promotion funds to fishery output value to represent this indicator. (5) Opening to the outside world: The higher the degree of opening to the outside world, the more advanced technologies and ideas can be introduced into fisheries and the international market can be expanded, which will help to improve the innovation ability and transformation speed of the industry, which will enable fisheries to cope with the challenges brought by globalization more comprehensively. This study uses the total import and export of aquatic products to measure this indicator.

DATA SOURCES

This study takes the fishery economic resilience of China's coastal provincial administrative regions as the research object, including Tianjin, Hebei, Liaoning, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi Zhuang Autonomous Region and Hainan Province, a total of 11 provincial administrative regions. In view of the availability of data, this study does not include the Hong Kong Special Administrative Region, the Macao Special Administrative Region and Taiwan Province. The data involved in the study are mainly derived from the 2017-2024 ' China Fisheries Statistics Yearbook '.

RESULTS

MEASUREMENT RESULTS OF FISHERY ECONOMIC RESILIENCE LEVEL IN COASTAL AREAS OF CHINA

HOLISTIC ANALYSIS

From the perspective of the overall level of fishery economic resilience in coastal areas of China, from 2016 to 2023, the level of fishery economic resilience in coastal areas rose from 0.2605 in 2016 to 0.2728 in 2023, with a growth rate of about 4.7 % and an average value of 0.2566, showing a general trend of ' first decline and then rise '. Specifically, (1) From 2016 to 2020, the level of fishery economic resilience in coastal areas generally showed a downward trend, with the average value decreasing from 0.2605 to 0.2416, and the decline rate was about 7.3 %. This change may be related to the impact of the new coronavirus epidemic, which has caused many problems such as disruption of fishery production, decline of market demand for

aquatic products and obstruction of supply chain, resulting in a certain impact on the resilience of fishery economy. (2) From 2020 to 2023, the level of fishery economic resilience in coastal areas has steadily rebounded, with an average increase from 0.2416 to 0.2728, with a growth rate of about 12.9 %. This upward trend may be attributed to the combined effects of multiple factors, including the gradual repair of the economy after the epidemic, the introduction and implementation of support policies, and the recovery of domestic and foreign aquatic product market demand. These factors have significantly enhanced the adaptability and resilience of fisheries, and the level of resilience of China 's fisheries economy has shown a trend of continuous recovery and improvement¹⁸ (Table 2).

From the perspective of the level of fishery economic resilience in various coastal areas of China, there are significant differences in the level of fishery resilience in various regions. From Table 2, it can be seen that the level of fishery economic resilience in Shandong Province in 2016-2023 is ahead of other regions, with an average value of 0.5226, and the fluctuation range is small, reflecting higher anti-risk ability and industrial stability. Followed by Guangdong Province, Fujian Province and Jiangsu Province, the level of fishery economic resilience in these areas is also relatively high, with an average of 3.3975, 0.3797 and 0.3602 respectively. As a traditional fishery province, these areas can effectively cope with various external shocks and show strong resilience and adaptability by virtue of their unique natural resource endowments, perfect fishery infrastructure and high production technology level.¹⁹ In contrast, the level of fishery economic resilience in Hainan Province is the lowest, with an average of only 0.0751. In addition to Hainan Province, the level of fishery economic resilience in Tianjin and Hebei Province is also at a low level, with an average of 0.0766 and 0.0871, respectively. The possible reason is that Hainan Province is located in the tropical region, and its fishery activities are easily affected by meteorological disasters such as typhoons. In addition, the development and utilization efficiency of marine fishery resources in some areas is not high, which restricts the improvement of fishery economic resilience. However, since fishery is not the leading industry in Tianjin 's economic structure, fishery has obvious disadvantages in production scale, market share and trade competitiveness. Hebei Province is subject to the geographical restrictions of short and scattered coastlines. Its fishery production is mainly based on small-scale individual farmers, and the level of industrialization and intensification is low, resulting in a weak ability to resist risks²⁰ (Table 2).

REGIONAL ANALYSIS

According to the 14 th Five-Year Marine Economic Development Plan, China 's 11 coastal areas can be divided into three marine economic circles. The northern marine economic circle mainly includes the sea and land areas of Shandong Province, Liaoning Province, Hebei Province and Tianjin City. The eastern marine economic circle mainly includes the sea area and land area of Zhejiang Province, Shanghai and Jiangsu Province. The southern marine eco-

Table 2. Measurement results of fishery economic resilience level in coastal areas of China from 2016 to 2023.

Year	Tianjin	Hebei	Liaoning	Shandong	Shanghai	Jiangsu	Zhejiang	Fujian	Guangdong	Guangxi	Hainan	Mean
2016	0.0606	0.0899	0.3061	0.5453	0.1407	0.3936	0.3106	0.3575	0.3856	0.1991	0.0769	0.2605
2017	0.0682	0.0857	0.2884	0.5403	0.1442	0.3858	0.2755	0.3525	0.3636	0.1775	0.0765	0.2508
2018	0.0750	0.0821	0.2786	0.5300	0.1718	0.3845	0.2591	0.3681	0.3666	0.2013	0.0822	0.2545
2019	0.0790	0.0808	0.2541	0.5122	0.1879	0.3551	0.2573	0.3733	0.3606	0.2142	0.0750	0.2500
2020	0.0565	0.0843	0.2426	0.4866	0.1898	0.3356	0.2508	0.3678	0.3646	0.2097	0.0695	0.2416
2021	0.0841	0.0858	0.2344	0.4936	0.2089	0.3456	0.2739	0.4033	0.3564	0.2305	0.0723	0.2535
2022	0.1054	0.0939	0.2443	0.5307	0.1793	0.3493	0.2896	0.4141	0.4659	0.2166	0.0722	0.2692
2023	0.0842	0.0939	0.2497	0.5424	0.1743	0.3325	0.3165	0.4012	0.5169	0.2130	0.0764	0.2728
Mean	0.0766	0.0871	0.2623	0.5226	0.1746	0.3602	0.2792	0.3797	0.3975	0.2077	0.0751	0.2566

Table 3. Measurement results of fishery economic resilience level of China's three major marine economic circles from 2016 to 2023.

Year	Northern Marine Economic Circle	Eastern Marine Economic Circle	Southern Marine Economic Circle
2016	0.2505	0.2816	0.2548
2017	0.2457	0.2685	0.2426
2018	0.2414	0.2718	0.2546
2019	0.2315	0.2668	0.2558
2020	0.2175	0.2587	0.2529
2021	0.2245	0.2761	0.2656
2022	0.2436	0.2728	0.2922
2023	0.2425	0.2744	0.3019
Mean	0.2371	0.2713	0.2650

economic circle mainly includes the sea and land areas of Guangxi Zhuang Autonomous Region, Guangdong Province, Hainan Province and Fujian Province. Therefore, this study divides the 11 coastal areas into the northern marine economic circle, the eastern marine economic circle and the southern marine economic circle. From the perspective of the level of fishery economic resilience in China's three major marine economic circles, there are also significant differences in the level of fishery economic resilience in different marine economic circles. The eastern marine economic circle has the highest level of fishery economic resilience, with Jiangsu Province as the core area. The main core area of the southern marine economic circle is Guangdong Province, and the sub-core area is Fujian Province, which drives the development of the surrounding areas through radiation, showing a strong level of resilience. The northern marine economic circle has the lowest level of fishery economic resilience, with Shandong Province as the core area (Table 3).

DIFFERENCE ANALYSIS

In order to further analyze the spatial differences in the level of fishery economic resilience in various regions of China's coastal areas, and to decompose and identify the sources of differences, this study calculated the Theil index of the northern marine economic circle, the eastern marine economic circle and the southern marine economic circle, and analyzed the overall difference, intra-group difference and inter-group difference of the level of fishery economic resilience, and further clarified the contribution rate of each part to the overall difference (Table 4).

From the perspective of the global Theil index, the difference in the level of fishery economic resilience in coastal areas of China generally shows a trend of narrowing first and then expanding. Specifically, the Theil index fell from a fluctuation of 0.0574 in 2016 to 0.0372 in 2021, before recovering slightly to 0.0452 in 2023.

From the perspective of the contribution of intra-group and inter-group differences to the overall differences, (1) In terms of intra-group differences, the differences in the level of fishery economic resilience within the three major

marine economic circles gradually decreased. The Theil index within the group decreased from 0.0249 in 2016 to 0.0143 in 2023, and the contribution rate to the overall differences also decreased from 43.38 % to 31.64 %. This trend shows that the fishery economic development within the three major marine economic circles gradually tends to be balanced, and the coordination within the region has improved. (2) In terms of inter-group differences, the difference in the level of fishery economic resilience among the three major marine economic circles has gradually increased. The Theil index between the groups was 0.0325 in 2016, rebounded after falling to 0.0199 in 2019, and reached 0.0309 in 2023. At the same time, the contribution rate of inter-group differences to overall differences increased from 56.62 % in 2016 to 68.36 % in 2023. This shows that the difference in the level of fishery economic resilience between the northern marine economic circle, the eastern marine economic circle and the southern marine economic circle is widening, reflecting the lack of coordinated development between regions. Overall, the difference in the level of fishery economic resilience between the three major marine economic circles has gradually become the most important factor affecting the difference in China's fishery economic resilience.

Within the three major marine economic circles, the level of fishery economic resilience is obviously different. The results are as follows. (1) Eastern marine economic circle: The Theil index of the eastern marine economic circle is always low. The Theil index in 2023 is only 0.0097, and the fluctuation range of the Theil index in 2016-2023 is not large, indicating that the difference in the level of fishery economic resilience within the eastern economic circle is relatively small, and the development among regions is relatively balanced. (2) Northern marine economic circle: The Theil index of the northern marine economic circle dropped from 0.0217 in 2016 to 0.0132 in 2023, indicating that the difference in the level of fishery economic resilience within the northern marine economic circle has decreased, indicating that the pace of regional coordinated development is gradually accelerating. (3) Southern Ocean Economic Circle: The Theil index of the Southern Ocean Economic Circle has fluctuated from 0.0434 in 2016 to 0.0181 in 2023. Al-

Table 4. Theil index and decomposition of fishery economic resilience level in coastal areas of China from 2016 to 2023.

Year	Global Theil index	Within the group		Between groups		Eastern Marine Economic Circle		Northern Marine Economic Circle		Southern Ocean Economic Circle	
		Theil index	Contribution rate	Theil index	Contribution rate	Theil index	Contribution rate	Theil index	Contribution rate	Theil index	Contribution rate
2016	0.0574	0.0249	43.38%	0.0325	56.62%	0.0038	28.87%	0.0217	32.70%	0.0434	38.43%
2017	0.0580	0.0252	43.45%	0.0328	56.55%	0.0010	30.41%	0.0251	30.76%	0.0443	38.82%
2018	0.0557	0.0283	50.81%	0.0274	49.19%	0.0039	29.34%	0.0251	30.13%	0.0482	40.52%
2019	0.0383	0.0184	48.04%	0.0199	51.96%	0.0007	27.02%	0.0205	29.90%	0.0281	43.08%
2020	0.0404	0.0174	43.07%	0.0230	56.93%	0.0106	28.87%	0.0215	28.64%	0.0192	42.48%
2021	0.0372	0.0163	43.82%	0.0209	56.18%	0.0146	29.07%	0.0100	27.17%	0.0213	43.77%
2022	0.0407	0.0152	37.35%	0.0255	62.65%	0.0142	28.60%	0.0090	28.21%	0.0199	43.19%
2023	0.0452	0.0143	31.64%	0.0309	68.36%	0.0097	28.59%	0.0132	28.66%	0.0181	42.75%

though the Theil index has decreased, it is still higher than the Eastern Ocean Economic Circle and the Northern Ocean Economic Circle. This shows that the internal development imbalance of the Southern Ocean Economic Circle has improved, but the overall internal differences are still large. In addition, its contribution rate fluctuated from 38.43 % in 2016 to 42.75 % in 2023, indicating that the difference in the level of fishery economic resilience within the southern marine economic circle has always had a greater impact on the overall national differences. This situation may be due to the relatively weak fishery economic foundation in some areas within the southern marine economic circle (such as Guangxi Zhuang Autonomous Region and Hainan Province), and the significant gap between Guangdong Province and Fujian Province's fishery developed areas has aggravated the difference in the level of internal fishery economic resilience to a certain extent.

CONCLUSIONS AND DISCUSSION

This study takes the fishery economic resilience of China's coastal areas as the research object, and constructs a comprehensive index evaluation system of fishery economic resilience based on three dimensions: resistance and recovery ability, adaptation and adjustment ability, innovation and transformation ability. The entropy method and Theil index method are used to measure the level of fishery economic resilience and regional differences in coastal areas of China from 2016 to 2023. The conclusions are as follows: (1) From 2016 to 2023, the level of fishery economic resilience in coastal areas of China showed a fluctuating growth trend of 'first decline and then rise', rising from 0.2605 in 2016 to 0.2728 in 2023, with a growth rate of about 4.7 % and an average value of 0.2566. (2) There are significant differences in the level of fishery resilience in different coastal areas. From 2016 to 2023, Shandong Province had the highest level of fishery economic resilience (0.5226), followed by Guangdong Province, Fujian Province and Jiangsu Province, while Hainan Province had the lowest level of fishery economic resilience (0.0751). The level of fishery economic resilience in Tianjin and Hebei Province is also at a low level. The eastern marine economic circle has the highest level of fishery economic resilience (0.2713), followed by the southern marine economic circle (0.2650), and the northern marine economic circle has the lowest level of fishery economic resilience (0.2371). (4) The regional differences in the level of fishery economic resilience in coastal areas of China mainly come from inter-group differences, with a contribution rate of 68.36 %. That is, the differences in the level of fishery economic resilience between the three major marine economic circles have gradually become the most important factor affecting the differences in the level of fishery economic resilience in China. The internal development of the eastern marine economic circle is relatively balanced, with small intra-group differences and contribution rates, while the level of fishery economic resilience in the southern marine economic circle is quite different, which is one of the main driving forces for the difference of fishery economic resilience in China.

Based on the above conclusions, the following suggestions are proposed to improve the level of fishery economic resilience in coastal areas of China: First, promote balanced regional development. In view of the low level of fishery economic resilience (such as Hainan Province, Tianjin City and Hebei Province), targeted differentiated policies should be formulated to improve the level of fishery economic resilience. Among them, Hainan Province can establish a 'typhoon adaptive breeding demonstration area', promote anti-wind and wave deep-water cages, and develop typhoon index insurance products. Tianjin can develop the 'urban leisure fishery complex', use the idle wharf in Binhai New Area to transform the fishing base and the supporting aquatic product processing experience facilities. Hebei Province can guide and support farmers' industrialization and large-scale production. Second, strengthen the linkage development. We should give full play to the radiation and leading role of areas with strong fishery economic foundation (such as Jiangsu Province, Guangdong Province and Shandong Province), promote the comprehensive and coordinated development of the three major marine economic circles through the way of 'point to area', and gradually improve the overall resilience level of fishery economy. Third, strengthen regional collaboration. Establish a cross-regional fishery cooperation mechanism, especially between the northern marine economic circle and the southern marine economic circle, promote resource management, information sharing and technical exchanges, promote coordinated development among regions, and provide support for the overall improvement of China's fishery economic resilience.

This study also has some limitations. First, the coverage of indicators is limited. Due to the availability of data, the index system of fishery economic resilience needs to be further improved. Second, the limitation of regional applicability. The conclusions of the study mainly reflect the characteristics of provincial administrative regions, and are not refined to the city and county scale. Provincial data may cover the differences between cities and counties, so follow-up studies can be carried out when data are available. Third, the conclusion of the promotion of limitations. The index system and analysis conclusions of this study are mainly aimed at coastal fisheries. Inland fishery needs to adjust the index design according to its characteristics in application. Future research can develop a dedicated evaluation model for inland fisheries based on this framework.

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AUTHORS' CONTRIBUTION

Conceptualization: Teng Ma, Shiwei Xu, Yu Zhao; Methodology: Yingjie Chen, Zhikang Deng; Writing - original draft preparation: Yingjie Chen, Teng Ma; Writing - review and editing: Yingjie Chen, Teng Ma, Shiwei Xu, Yu Zhao; Fund-

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COMPETING OF INTEREST – COPE

No competing interests were disclosed.

ETHICAL CONDUCT APPROVAL – IACUC

This study did not involve any experimental research on animals or plants.

INFORMED CONSENT STATEMENT

All authors and institutions have confirmed this manuscript for publication.

DATA AVAILABILITY STATEMENT

All are available upon reasonable request.

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