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Factor decomposition and spatio-temporal difference analysis of China's marine resource consumption intensity

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ABSTRACT

Based on the connotation of the intensity of marine resources consumption, this paper measures the intensity of marine resources consumption in China's coastal provinces from 1996 to 2015, reveals its spatio-temporal evolution characteristics, establishes a factor decomposition model by using the improved logarithmic mean Di exponential decomposition (LMDI), analyzes the factor contribution of changes in the intensity of marine resources consumption in China, and compares the differences. The results show that: (1) from 1996 to 2015, the overall consumption intensity of China's marine resources increased first and then decreased steadily, and the consumption intensity of resources in the primary industry decreased steadily, ranking second. The resource consumption intensity of the tertiary industry is basically synchronized with the change trend of China's marine resource consumption intensity; in the evolution of spatial pattern, the provinces with medium and high intensity of marine resource consumption gradually reduce, while the provinces with low intensity provinces gradually increase, and the regional differences gradually narrow. (2) The contribution rates of technological progress effect, industrial structure effect and regional scale effect to the decline of China's marine resource consumption intensity are 78.224%, 18.334% and 3.442%, respectively; there are significant differences in factor decomposition effects among coastal provinces, among which Fujian is dominated by technological progress effect, Zhejiang, Shandong and Hainan are dominated by technological progress effect and regional scale effect, Tianjin, Hebei and Jiangsu are dominated by technological progress effect and industrial structure effect, while Liaoning, Shanghai, Guangdong and Guangxi are jointly driven by technological progress effect, industrial structure effect and regional scale effect to reduce the intensity of marine resource consumption. (3) From the perspective of the three marine industries, the effect of technological progress is the largest contribution within the secondary industry, accounting for 77.118% in total; the industrial structure effect has the largest contribution within the primary industry, accounting for 314.547% in total. There is no significant difference in regional scale effect among the three industries. Different provinces and regions should pay different attention to the implementation of technologies or measures for the intensive utilization of resources in the three marine industries.

Keywords: Marine Resources; Consumption Intensity; Factor Decomposition; LMDI Model; Effect of Technological Progress; Industrial Structure Effect; Regional Scale Effect; Spatio-temporal Difference; China

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1. Introduction

The ocean is a treasure house of resources for human survival and national development. The rational development and utilization of marine resources has become an important way to solve the problems of lack of land resources, environmental degradation, population expansion and so on. However, with the rapid development of the marine economy in coastal areas and the continuous expansion of the breadth and depth of marine resources development[1], the traditional and extensive

development model has led to the decline of offshore biological resources, the high consumption intensity of marine resources, the deterioration of the marine ecological environment and other problems becoming more and more serious[2], which has restricted the sustainable development of China's marine economy. Therefore, reducing the consumption intensity of marine resources and improving the utilization efficiency of marine resources are the key to the sustainable development of marine economy. Due to the differences in regional marine resource endowments and marine industrial structure, there are significant regional and industrial differences in China's marine resource consumption intensity. Therefore, an in-depth study of the contributing factors to the changes in China's marine tertiary industry resource consumption intensity is of great significance for achieving high-quality development of the marine economy and reducing regional marine economic development differences[3].

In recent years, foreign scholars have mostly taken a single sector or industry as the research object, and carried out research from the perspectives of marine economic efficiency, vulnerability of marine resources system, sea area carrying capacity, the relationship between marine resources development and marine economic growth. For example, Pham et al. used data envelopment analysis (DEA) to explore the economic performance and capacity efficiency of gill net fisheries in Danang[4]; Chen et al. used vulnerability index to analyze the vulnerability of marine fishery system[5]; Ferreira et al. introduced the development and application of a comprehensive framework for determining the sustainable carrying capacity of shellfish farming areas[6]; Barange et al. took climate change and development activities as influencing factors, established a coupling and coordination model to explore the relationship between marine economic activities and the sustainable utilization of marine fishery resources[7]; Managi et al. established the index variable of technological change and studied the impact of technological change on offshore oil and gas exploration[8]. Domestic scholars' research on the development and utilization of marine resources mainly focuses on the following aspects: (1) from

the perspective of resource carrying capacity, focusing on the sustainable utilization of marine resources, through quantitative and qualitative analysis, seek the critical point of dynamic balance between resource utilization and the acceptable threshold of ecosystem, and analyze the comprehensive carrying capacity of specific sea areas for human development activities[9,10]; (2) from the perspective of vulnerability, by establishing an index system and using mathematical analysis methods such as data envelopment analysis (DEA) and set pair analysis to evaluate vulnerability, we explore the response and feedback relationship between human activities and marine economy, resources and environmental systems[11,12]; (3) from the perspective of coordinated development of economy and resources, the level of coordinated development of marine resources and environment and marine economy is analyzed by using variable fuzzy identification model[13]; (4) from the perspective of resource constraints and economic growth, based on the corresponding theoretical basis, the "tail effect" model and Tapio decoupling model are used to explore the impact of marine resource consumption on marine economic growth and the decoupling relationship between the two[3,14]; (5) from the perspective of marine economic efficiency, by selecting input-output indicators, we use DEA model, SBM model and Malmquist productivity index model to measure marine economic efficiency, and use regression model to analyze its influencing factors[15,16].

Resource consumption intensity is an important indicator to measure the quality and efficiency of resource utilization in a country or region[17]. At present, relevant research is mainly focused on energy and water resources. For example, Kong et al. have made an empirical analysis of China's regional industrial energy consumption intensity and its influencing factors by establishing a Regional Panel Data Model[18]; Cornellie et al. decomposed the energy data and determined the main factors affecting the reduction of energy intensity. The results showed that energy prices and the progress of enterprise restructuring were the two most important factors[19]; Zang et al. quantitatively analyzed the convergence characteristics of inter pro-

vincial water resources intensity in Chinese Mainland by using panel data on the basis of defining the concept and connotation of water resources intensity and water resources relative intensity[20].

Summarizing the existing research findings, foreign scholars' research on marine resources and marine economy tends to be phenomenon analysis and framework guidance. Combined with economic models, they take marine ecological economic system, marine resource value and integrated management as the entry point for basic theoretical and empirical research. Domestic scholars mostly start from the perspective of carrying capacity, vulnerability, coordinated development, etc., by building an evaluation index system to measure the coordinated development degree of human-sea relations or the level of regional sustainable development, or by using "tail effect", decoupling, DEA and other models to quantitatively analyze the relationship between marine resource consumption and marine economic growth. There is relatively little research on the differences in resource consumption of marine tertiary industries and the contributing factors of changes in the relationship between marine resource consumption and economic growth. At present, the application of the concept of resource consumption intensity is relatively mature, but it is mostly used in the field of energy and water resources, and few scholars use it to analyze the relationship between marine resources and economic growth.

From the perspective of the intensity of marine resource consumption, this paper measures the intensity of marine resource consumption in China's coastal provinces from 1996 to 2015, and reveals its temporal and spatial evolution trend; using the improved logarithmic mean Di exponential decomposition method (LMDI), a factor decomposition model is established to analyze the factor contribution of the change in the intensity of resource consumption of China's three marine industries and compare the differences, in order to enrich the relevant theories of sustainable development of marine economy and provide a scientific basis for the rational and efficient development and utilization of marine resources.

2. Research methods and data sources

2.1 Connotation and comprehensive characterization method of marine resource consumption intensity

The economic indicators of resource consumption can be expressed in absolute and relative quantities. Absolute quantity refers to the absolute quantity of resource consumption, such as the total amount of resource consumption; relative quantity refers to the resource consumption per unit output, of which resource consumption intensity is the most commonly used indicator[21]. Resource consumption intensity refers to the total amount of resources consumed per unit of GDP. Considering the close relationship between marine resources and energy and water resources, and there are many commonalities (for example, seabed mineral resources, oil and natural gas also belong to energy, and seawater resources also belong to water resources), the concept and connotation of energy consumption intensity[18] and water consumption intensity[20] are used for reference, the consumption intensity of marine resources is defined as the amount of marine resources consumed per unit of gross marine product (GOP), which reflects the utilization efficiency of marine resources. This index is affected by economic scale, industrial structure, technical level, resource endowment, policy factors and other aspects. The consumption intensity of marine resources is a reverse index. The greater its value, the lower the utilization efficiency of marine resources. Its mathematical expression is as follows:

$$I = \sum_i \sum_j \frac{E_{ij}}{Q_{ij}}$$

(1)

Where: I is the consumption intensity of marine resources (unit: 10,000 t/100 million yuan); E_{ij} is the resource consumption of marine industry j in the i-th province (unit: 10,000 t); Q_{ij} is the gross marine product of the j industry in the i-th province (unit: 100 million yuan).

Previous studies have shown that the quantity of marine resources is the direct cause of affecting the development of marine economy, but simply attributing the constraints of marine economic de-

velopment to the stock of marine resources cannot effectively reflect the dynamic role of human activities in the development of marine resources, while marine fishing, mariculture and other marine resource development activities closely related to human dynamic role are the root causes of the rise in the consumption of marine resources[3]. Therefore, on the basis of previous studies[3,22,23], starting from the root causes of the rise in marine resource consumption, combined with data continuity and availability, the marine fishing volume and mariculture volume of the primary marine industry, the marine raw salt production, raw oil production, natural gas production of the secondary marine industry The output of coastal placers, marine chemical products and the marine cargo transportation volume of the marine tertiary industry comprehensively reflect the consumption of marine resources.

2.2 Factor decomposition model of marine resource consumption intensity

The treatment methods of factor decomposition in the evaluation of resource consumption intensity mainly include structural decomposition analysis (SDA) and index decomposition analysis (IDA). Because SDA method needs input-output data as support, China generally produces input-output tables every five years, with a large time span[24], and at present, China has not included marine economy into the statistical scope of input-output tables[25], which is not conducive to in-depth research. IDA method uses the total data of departments and industries, which makes it easier to conduct time series analysis and regional comparison[26]. IDA method includes Laspeyres IDA and Divisia IDA. The residual term in Laspeyres IDA method is large, and there is a large result decomposition error; however, the Divisia IDA method meets the requirements of reversible factors and has the main advantages of "no residual value can be generated, and zero is allowed to be included in the data"[27,28], which avoids the problem of affecting the decomposition results due to the existence of residual terms, improves the reliability of the results[29], and is widely used in the decomposition research of factors such as changes in energy consumption[30], changes in water consumption[31],

changes in grain production[32], changes in human well-being[33].

Referring to the existing research[34], this paper uses the improved LMDI addition model and adds regional factors on the basis of the original LMDI model to investigate the impact of the change of the proportion of the marine GDP of each province in the National Marine GDP on the change of China's marine resource consumption intensity.

The formula of total marine resource consumption intensity is as follows:

$$I = \sum_i \sum_i \frac{E_{ij}}{Q} = \sum_i \sum_j \frac{E_{ij}}{Q_{ij}} \frac{Q_{ij}}{Q_i} \frac{Q_i}{Q} = \sum_i \sum_i I_{ij} S_{ij} R_i$$

(2)

Where: I is the total consumption intensity of marine resources; E_{ij} is the resource consumption of marine industry j in the i-th province; Q_{ij} is the gross domestic product of the marine industry of the i-th province; Q_i is the gross marine product of the i-th province; Q is the gross national marine product; I_{ij} is the resource consumption intensity of marine industry j in the i-th province; S_{ij} is the proportion of the gross domestic product of the marine industry j in the gross domestic product of the i-th province; R_i is the proportion of the marine GDP of the i-th Province in the National Marine GDP.

The formula of the variation of the intensity of marine resource consumption is:

$$\Delta I_{tot} = I_t - I_0 = \Delta I_{tech} + \Delta I_{indu} + \Delta I_{regi}$$

(3)

The contribution degree of each decomposition factor is shown as follows:

$$\Delta I_{tech} = \sum_i \sum_i \frac{E_{ij}^T/Q^T - E_{ij}^0/Q^0}{\ln(E_{ij}^T/Q^T) - \ln(E_{ij}^0/Q^0)} \ln \frac{I_{ij}^T}{I_{ij}^0}$$

(4)

$$\Delta I_{indu} = \sum_i \sum_i \frac{E_{ij}^T/Q^T - E_{ij}^0/Q^0}{\ln(E_{ij}^T/Q^T) - \ln(E_{ij}^0/Q^0)} \ln \frac{S_{ij}^T}{S_{ij}^0}$$

(5)

$$\Delta I_{regi} = \sum_i \sum_i \frac{E_{ij}^T/Q^T - E_{ij}^0/Q^0}{\ln(E_{ij}^T/Q^T) - \ln(E_{ij}^0/Q^0)} \ln \frac{R_{ij}^T}{R_{ij}^0}$$

(6)

Where: ΔI_{tot} is the total effect, indicating the change in the intensity of total marine resource consumption; ΔI_{tech} is the effect of technological progress, which indicates the contribution of changes in the efficiency of marine resources utilization caused by technological progress to changes

in the overall intensity of marine resources consumption; ΔI_{indu} refers to the effect of industrial structure, which indicates the contribution of marine industrial structure adjustment and optimization to the change of marine resource consumption intensity; ΔI_{regi} refers to the regional scale effect, which indicates the contribution of the change in the status of regional marine economic scale in the country to the change in the intensity of marine resource consumption. The contribution rates of the three decomposition effects to the change of China's marine resource consumption intensity are $\Delta I_{tech}/\Delta I_{tot}$, $\Delta I_{indu}/\Delta I_{tot}$ and $\Delta I_{regi}/\Delta I_{tot}$. When the sign of a decomposition factor effect is consistent with the total effect, it means that the factor plays a positive role in the change of the intensity of marine resource consumption, and vice versa.

2.3 Research area and data source

The geographical units studied in this paper mainly involve 11 coastal provinces and regions of China, including Liaoning, Hebei, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi and Hainan. Due to difficulties in obtaining data, Hong Kong, Taiwan and Macao are not included in this study.

The time span is 1996−2015, and the research data are from the China Ocean Statistical Yearbook (1997−2016)[35]. Due to the change of the statistical caliber of the marine GDP indicators in 2006, the marine GDP indicators from 1996 to 2005 are integrated according to the three marine industries for the convenience of research.

3. Results and analysis

3.1 Temporal and spatial evolution of China's marine resource consumption intensity

3.1.1 Time evolution of consumption intensity of marine resources

(1) Time variation of marine economic output value and marine resource consumption. According to the original data, China's marine GDP and marine resource consumption from 1996 to 2015 are calculated, and the change trend is shown in **Figure 1**. From 1996 to 2006, the change trend of Chin's marine GDP and marine resource consumption

was basically synchronized. The resource consumption of first, secondary and tertiary industries of marine all increased with the increase of GDP, of which the growth trend was flat from 1996 to 2000, and the growth rate accelerated from 2000 to 2006. From 2006 to 2015, the GDP and resource consumption of the Marine primary and secondary industries showed a slowing trend, and the gross output value and resource consumption of the marine tertiary industry are generally consistent with the change trend of the national level. Among them, the output value of the marine tertiary industry and the national gross output value are gradually increasing, and the resource consumption of the marine tertiary industry and the national marine resource consumption are slowing down and increasing.

(2) The intensity of marine resource consumption changes over time. The temporal change of China's marine resource consumption intensity is shown in **Figure 2**. From 1996 to 2015, the consumption intensity of China's marine resources generally showed a trend of first rising and then declining steadily, rising from 8.058 ten thousand t/100 million yuan in 1996 to 13.877 ten thousand t/100 million yuan in 1999, and then gradually declining, reaching 3.958 ten thousand t/100 million yuan in 2015. The resource consumption intensity of the primary marine industry showed a steady downward trend. The resource consumption intensity of Marine secondary and tertiary industries is basically synchronized with the change trend of China's marine resource consumption intensity, which generally shows an upward trend and then downward trend.

From 1996 to 1998, China's marine economy grew slowly, most of the marine resources have not been developed and utilized, and the consumption of marine resources is small. At the beginning of the 21st century, China began to vigorously develop the marine economy, but the initial stage was still dominated by the development of traditional marine resources and the production of primary products. The development of the marine economy was heavily dependent on the input of resource factors, and the intensity of marine resource consumption increased slightly.

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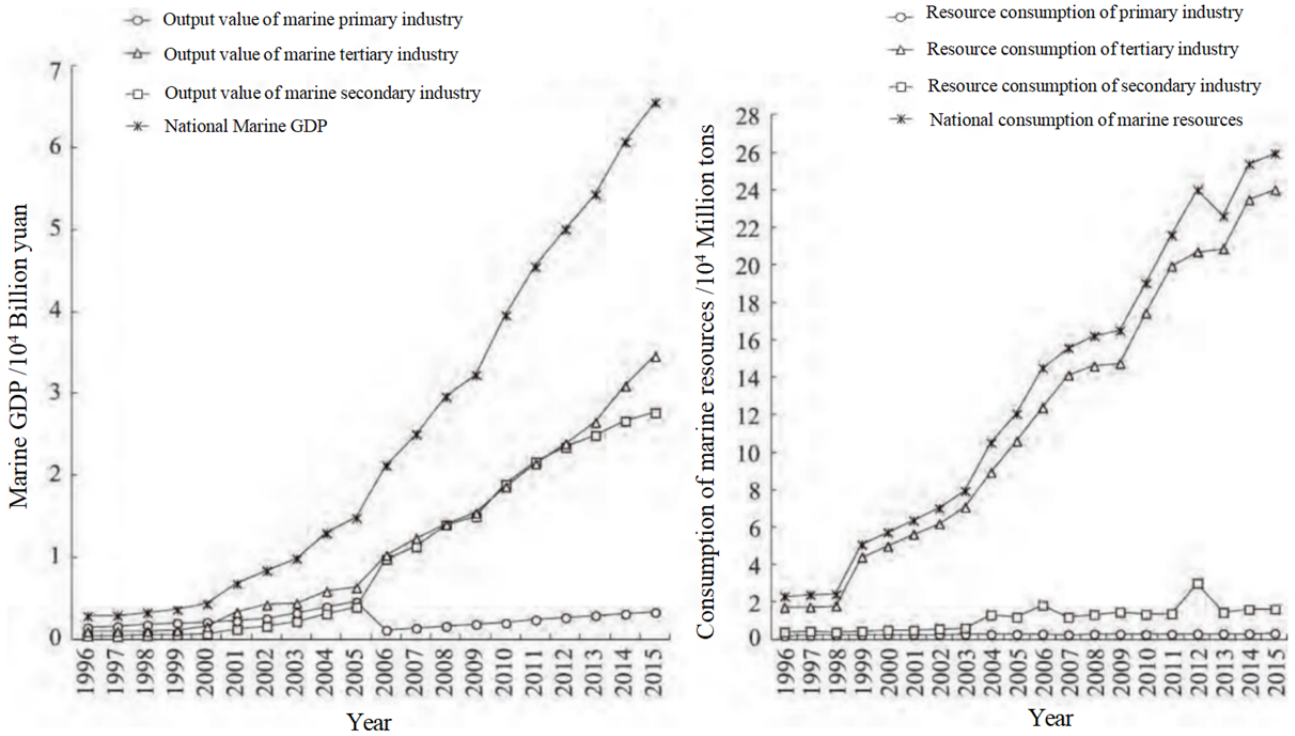
Figure 1. The trends of gross output values of marine economy and the number of marine resources consumed in China from 1996 to 2015.
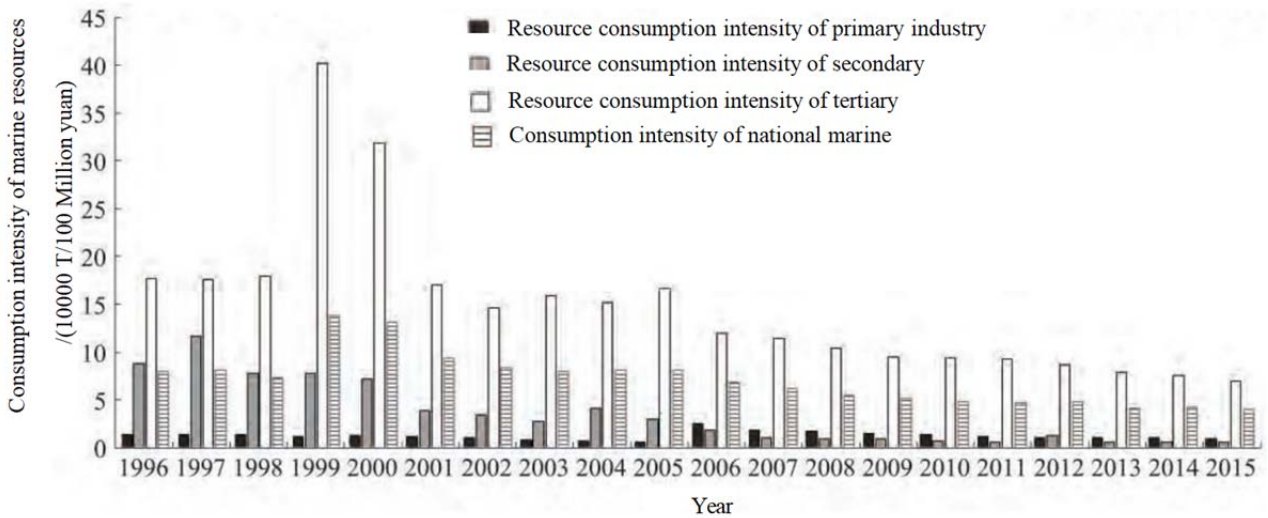
Figure 2. The trends of China's marine resources consumption intensity and the three industries resources consumption intensity from 1996 to 2015.

Since then, the marine economy has developed rapidly, the development mode of marine resource intensive industries has gradually changed from extensive to intensive efficiency, the marine strategic emerging industries with high scientific and technological content and low environmental pollution have gradually risen, the marine industrial structure has been continuously optimized, and the intensity of marine resource consumption has gradually decreased. From 2010 to 2015, the marine economy maintained steady growth, and the marine industry gradually changed to the marine resources deep processing industry and service industry. The growth rate of the pressure of marine resources consumption slowed down, and the intensity of marine resources consumption decreased slightly.3.1.2 Spatial evolution of consumption intensity of marine resources

(1) Evolution characteristics of regional differences. Combined with the calculation formula of

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standard deviation and coefficient of variation, the standard deviation and coefficient of variation of marine resource consumption intensity in 11 coastal provinces are obtained, as shown in **Figure 3**.
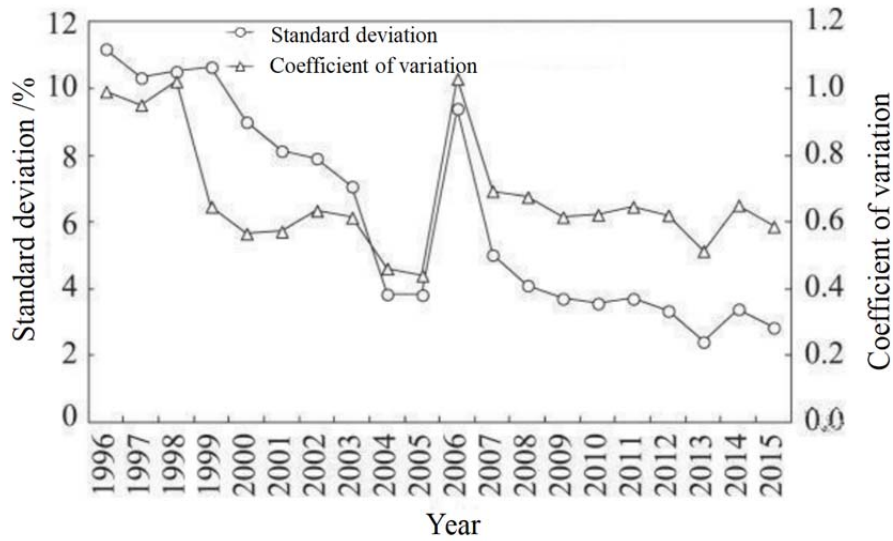
Figure 3. The standard deviation and coefficient of variation line graph of marine resources consumption intensity in China from 1996 to 2015.

The value of standard deviation reflects the change of regional absolute difference. By analyzing the standard deviation of marine resource consumption intensity from 1996 to 2015, it can be seen that the standard deviation has been decreasing from 1996 to 2005 and from 2006 to 2015, of which the maximum standard deviation in 1996 was 11.190 and the minimum value in 2015 was 2.845. The regional absolute difference of marine resource consumption intensity shows a trend of fluctuation and reduction on the whole. The coefficient of variation reflects the change of regional relative difference. Through analysis, it can be seen that the change trend of coefficient of variation is similar to the fluctuation characteristics of standard deviation, and the regional relative difference of marine resource consumption intensity also shows a trend of fluctuation and reduction. Based on the changes of regional relative differences and absolute differences, it shows that the gap of marine resource consumption intensity among coastal provinces shows the characteristics of fluctuation and narrowing during the study period.

(2) Spatial variation and type division of marine resource consumption intensity. Combined with the intensity value of China's marine resources consumption from 1996 to 2015, the ratio f between the intensity of marine resources consumption in each province and the intensity of national marine resources consumption is taken as the division standard[36]. When $F > 1$, it is high intensity, $F < 1$ is low intensity, and $F = 1$ or its value is medium intensity. The calculation results are shown in **Table 1**. From 1996 to 2015, the spatial difference in the intensity of marine resources consumption in 11 coastal provinces and regions in China gradually narrowed, and the number of high-intensity provinces and regions basically remained unchanged, from Hebei, Hainan, Zhejiang and Fujian in 1996 to Hainan, Zhejiang, Shanghai and Guangxi in 2015; the number of medium intensity provinces and regions decreased, from Tianjin and Guangdong in 1996 to Liaoning in 2015, and the proportion of provinces and regions was small; the number of low-intensity provinces and regions has increased, with great regional changes. In 1996, it was mainly distributed in Jiangsu, Shandong, Liaoning, Guangxi and Shanghai, and in 2015, distributed in Fujian, Jiangsu, Guangdong, Tianjin, Hebei and Shandong.

Specifically, the change trend of marine resource consumption intensity in various provinces and regions of China can be divided into the following two types. (1) The consumption intensity of marine resources is gradually decreasing, including Tianjin, Hebei, Fujian, Shandong, Guangdong and Hainan. With the development of marine economy, such provinces and regions accelerate the transformation of marine economic development mode,

Table 1. The ratio of the marine resource consumption intensity in coastal provinces to the national marine resource consumption intensity in China from 1996 to 2015

Year	Tianjin	Hebei	Liaoning	Shanghai	Jiangsu	Zhejiang	Fujian	Shandong	Guangdong	Guangxi	Hainan
1996	0.957	1.922	0.632	0.070	0.823	1.702	1.364	0.663	1.143	0.629	5.494
1997	1.210	1.701	0.600	0.073	0.605	1.728	1.383	0.683	1.042	0.593	5.029
1998	1.456	1.786	0.485	0.051	0.474	1.680	1.396	0.535	1.315	0.607	5.549
1999	3.119	1.210	0.801	1.862	0.943	0.986	0.697	0.452	0.942	0.261	1.774
2000	2.646	1.188	0.843	1.806	0.995	1.151	0.721	0.579	0.902	0.267	2.160
2001	3.082	1.359	0.967	3.029	1.154	1.834	0.910	0.802	0.913	0.403	2.252
2002	3.187	1.562	0.944	3.305	1.108	1.403	0.676	0.757	0.941	0.355	2.159
2003	2.620	1.331	0.938	3.464	0.950	1.556	0.541	0.569	0.827	0.946	2.026
2004	1.813	1.025	0.672	1.714	1.032	1.554	0.490	0.504	0.668	0.550	1.301
2005	1.667	1.237	0.747	1.682	0.911	1.382	0.686	0.521	0.583	0.562	1.786
2006	1.629	0.478	0.775	1.245	0.842	2.181	0.758	0.473	0.576	0.392	5.364
2007	1.761	0.389	0.848	1.439	0.733	2.092	0.742	0.463	0.618	0.636	3.109
2008	0.565	0.193	0.879	1.567	1.005	2.676	0.905	0.385	0.643	1.057	2.363
2009	1.236	0.390	0.889	1.682	0.870	2.037	0.780	0.475	0.557	1.168	2.908
2010	1.056	0.523	0.872	1.740	0.786	2.114	0.838	0.461	0.574	1.193	2.968
2011	0.957	0.494	0.769	1.763	0.816	2.182	0.865	0.432	0.603	1.365	3.068
2012	0.716	0.434	0.813	1.674	0.798	2.072	0.901	0.335	0.613	1.358	2.650
2013	0.624	0.510	0.898	1.433	1.161	2.392	1.019	0.347	0.749	1.572	1.747
2014	0.630	0.577	0.886	1.696	1.036	2.397	0.933	0.323	0.756	1.368	3.127
2015	0.700	0.622	1.013	1.769	0.936	2.408	0.942	0.305	0.716	1.404	2.640

focus on organizing and promoting the high value-added utilization of marine resources, deep processing and the production of low consumption high-tech products, technological progress, industrial structure adjustment and optimization, and regional economic development promote the decline of marine resource consumption intensity, and the pressure on marine resources slows down. (2) The consumption intensity of marine resources is increasing, including Liaoning, Shanghai, Jiangsu, Zhejiang and Guangxi. Such resource consuming industries as marine fisheries and marine mining industries in provinces and regions are still in the development mode of high energy consumption, the proportion of marine emerging industries is still low, the overall level of marine science and technology development in some provinces and regions such as Liaoning and Guangxi is low, the degree of marine intensive production is not high, and the comprehensive advantages and potential of marine resources have not been effectively transformed into economic advantages.

3.2 Analysis on the difference of decomposition effect of changing factors of China's marine resource consumption intensity

3.2.1 Time difference of decomposition factor effect

According to formula (3) to formula (6), the decomposition factor effect and contribution rate of changes in China's marine resource consumption intensity from 1996 to 2015 are calculated (**Table 2**). During the study period, the resource consumption of 100 million yuan of marine GDP decreased by 358,520 tons, of which the effects of technological progress, industrial structure and regional scale reached -280,450 tons, -65,730 tons and -12,340 tons, with the contribution rates of 78.224%, 18.334% and 3.442% respectively, which fully shows that all decomposition factors have a driving effect on the decline of marine resource consumption intensity, and the contribution of technological progress effect is the most significant.

From 1996 to 2015, the effect changes of each decomposition factor have obvious stage characteristics. Before 2006, there were positive and negative alternations. The reason is that China's marine economic development started late. The economic development policy of "emphasizing the land and ignoring the sea" and the industrial structure with too high proportion of traditional industries have a negative effect on the decline of resource consumption intensity, making the utilization efficiency of marine resources relatively low during this period. After 2006, the effect of each decomposition factor tends to be stable, in which the effect of technological progress and the total effect are always negative, and the effect of technological progress contributes the most to the decline of the intensity of marine re-

Table 2. Factor decomposition of marine resources consumption intensity in China from 1996 to 2015 (10,000 t/100 Million yuan)

Time interval	Effect of technological progress $\Delta Itech$		Industrial structure effect $\Delta Iindu$		Regional scale effect $\Delta Iregi$		Total effect $\Delta Itot$
	Effect value	Contribution rate/%	Effect value	Contribution rate/%	Effect value	Contribution rate/%	
1996–1997	0.884	-82.123	-2.878	267.448	0.918	-85.325	-1.076
1997–1998	-1.448	107.715	1.028	-76.470	-0.924	68.756	-1.344
1998–1999	6.491	75.427	2.219	25.789	-0.105	-1.216	8.605
1999–2000	0.820	-39.636	-1.975	95.497	-0.913	44.139	-2.068
2000–2001	-7.618	56.132	3.130	-23.062	-9.083	66.930	-13.571
2001–2002	-5.497	140.694	0.919	-23.515	0.671	-17.179	-3.907
2002–2003	-2.040	112.337	-1.240	68.304	1.464	-80.641	-1.816
2003–2004	-3.524	-114.915	-1.061	-34.613	7.652	249.528	3.066
2004–2005	-3.506	171.268	0.951	-46.454	0.508	-24.814	-2.047
2005–2006	2.577	-52.295	-6.761	137.187	-0.745	15.109	-4.929
2006–2007	-5.044	101.953	0.183	-3.706	-0.087	1.753	-4.947
2007–2008	-1.503	82.678	-0.149	8.181	-0.166	9.142	-1.818
2008–2009	-1.477	95.465	-0.186	12.036	0.116	-7.502	-1.547
2009–2010	-4.537	87.127	-0.588	11.288	-0.083	1.585	-5.207
2010–2011	-0.774	83.070	-0.102	10.939	-0.056	5.991	-0.932
2011–2012	-0.288	72.052	-0.023	5.679	-0.089	22.269	-0.400
2012–2013	-0.638	75.580	-0.173	20.560	-0.033	3.861	-0.844
2013–2014	-0.178	43.086	0.099	-23.934	-0.333	80.848	-0.412
2014–2015	-0.747	113.274	0.035	-5.280	0.053	-7.994	-0.659
1996–2015	-28.045	78.224	-6.573	18.334	-1.234	3.442	-35.852

source consumption; the industrial structure effect and regional scale effect gradually stabilized at negative values in fluctuations, and the industrial structure adjustment is a secondary contributing factor to the decline in the intensity of marine resource consumption. In 2005, the state proposed to build a resource-saving society.

The marine economic development of coastal provinces and regions gradually transformed, and increased investment in energy conservation and consumption reduction, scientific and technological innovation. The efficiency of resource utilization slowly increased with technological progress. However, due to the problems of "path dependence" in industrial development and significant differences in regional marine economic development, China's modern marine industrial system is still not mature. The influence of industrial structure effect and regional scale effect on the decline of marine resource consumption intensity is relatively limited.

3.2.2 Regional differences of decomposition factor effects

(1) Comparison of regional total effects. As shown in **Table 3**, from 1996 to 2015, the consumption intensity of marine resources in 11 coastal provinces and regions decreased to varying degrees, and the standard deviation of the total effect of each province and region was 3.255 ten thousand t/100 million yuan. Among them, the provinces and regions with the largest and smallest decline in the consumption intensity of marine resources were Shanghai and Guangxi, reaching -9.878 ten thousand t/100 million yuan and -0.112 ten thousand t/100 million yuan respectively, with significant regional differences.

(2) Comparison of decomposition effects of regional factors. As shown in **Table 3**, the effect of technological progress in 11 coastal provinces and regions is negative, indicating that the efficiency of marine resources utilization in coastal areas is generally improved, and the effect of technological progress is the main driving factor for the decline in the intensity of marine resources consumption.

The standard deviation of the effect of technological progress is 1.691 ten thousand t/100 million yuan, and the maximum absolute value (Guangdong, -6.048 ten thousand t/100 million yuan) is 205 times that of the minimum value (Guangxi, -0.030 ten thousand t/100 million yuan), indicating that there are great differences in the contribution of the improvement of the utilization efficiency of marine resources in various provinces to the decline of the intensity of marine resources consumption.

The industrial structure effects of Liaoning,

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Table 3. Disposition factor effect of marine resources consumption intensity of each coastal province from 1996 to 2015 (10,000 t/100 million yuan)

Province	Technological progress effect ΔI_{tech}	Industrial structure	Regional scale effect ΔI_{regi}	Total effect ΔI_{tot}
Tianjin	-1.669	-2.669	2.085	-2.253
Hebei	-0.986	-0.302	0.440	-0.848
Liaoning	-1.577	-0.056	-0.557	-2.190
Shanghai	-2.229	-6.642	-1.008	-9.878
Jiangsu	-2.445	-0.036	0.613	-1.868
Zhejiang	-4.593	2.853	-0.541	-2.282
Fujian	-2.791	0.136	0.172	-2.483
Shandong	-3.651	1.011	-0.656	-3.296
Guangdong	-6.048	-1.602	-1.687	-9.337
Guangxi	-0.030	-0.003	-0.080	-0.112
Hainan	-2.026	0.737	-0.015	-1.305

Hebei, Tianjin, Jiangsu, Shanghai, Guangdong and Guangxi are all negative, indicating that each province has the first place in the high consumption of marine resources. The secondary industry has shifted to the marine tertiary industry, which mainly focuses on technical services. The marine strategic emerging industries have begun to develop rapidly, and the modern marine industrial system has been gradually established, which has a significant positive effect on the decline in the intensity of marine resource consumption. Except Tianjin and Shanghai, the absolute value of the industrial structure effect of the other five provinces and regions is less than the effect of technological progress, indicating that technological progress plays a greater role in promoting the reduction of the intensity of marine resource consumption than the adjustment and optimization of marine industrial structure. The industrial structure effect of Zhejiang, Fujian, Shandong and Hainan is positive, indicating that in the process of improving the efficiency of marine resources utilization, the industrial structure that has not yet reached rationalization and upgrading is its constraint and limiting factor. The standard deviation of industrial structure effect is 2.443 ten thousand t/hundred million yuan, and the maximum absolute value (Shanghai, -6.642 ten thousand t/hundred million yuan) is 2.367 times that of the minimum value (Guangxi, -0.003 ten thousand t/hundred million yuan), indicating that there are also significant differences in the contribution of industrial structure adjustment in various provinces to the decline of marine resource consumption intensity.

Regional scale effect is the driving factor for the decline of marine resource consumption intensity in Liaoning, Shandong, Shanghai, Zhejiang, Guangdong, Guangxi and Hainan, and the restrictive factor for the decline of marine resource consumption intensity in Tianjin, Hebei, Jiangsu and Fujian. The standard deviation of regional scale effect is 0.985 ten thousand t/100 million yuan, and the maximum absolute value (Tianjin, 2.085 ten thousand t/100 million yuan) is 139 times the minimum value (Hainan, -0.015 ten thousand t/100 million yuan), indicating that there are great differences in the impact of marine economic growth in various provinces and regions on the decline of resource consumption intensity, and the change of the status of regional marine economic scale in the country affects the change of marine resource consumption intensity.

3.2.3 Industrial differences that decompose factor effects

(1) Comparison of decomposition effects of internal factors in the three marine industries. As shown in **Table 4**, from 1996 to 2015, there were significant differences in the effects of technological progress and industrial structure among the three marine industries, and there was no significant change in the regional scale effect.

The cumulative effect of technological progress in the three marine industries is -1,878 thousand t/hundred million yuan, -21,628 thousand t/hundred million yuan and -4,539 thousand t/hundred million yuan, respectively, accounting for 6.696%, 77.118% and 16.186% of the effect of technological progress respectively. It can be seen that the technological progress effect of the marine secondary industry has the greatest contribution to the decline in the intensity of marine re-

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Table 4. Industrial difference of decomposition factor effect of marine resources consumption intensity in China from 1996 to 2015 (10,000 t/100 million yuan)

Time interval	Effect of technological progress ΔI_{tech}			Industrial structure effect ΔI_{indu}			Regional scale effect ΔI_{regi}		
	Primary industry	The secondary industry	The service sector; the tertiary industry	Primary industry	The secondary industry	The service sector; the tertiary industry	Primary industry	The secondary industry	The service sector; the tertiary industry
1996–1997	0.189	1.158	-0.463	-0.090	-2.804	0.016	0.306	0.306	0.306
1997–1998	-0.319	-1.041	-0.088	0.381	0.893	-0.246	-0.308	-0.308	-0.308
1998–1999	-0.668	-2.622	9.781	0.159	3.657	-1.596	-0.035	-0.035	-0.035
1999–2000	-0.481	2.499	-1.198	-1.203	-1.656	0.883	-0.304	-0.304	-0.304
2000–2001	-1.366	-6.472	0.220	-0.836	4.816	-0.851	-3.028	-3.028	-3.028
2001–2002	0.050	-2.882	-2.665	-1.518	1.041	1.395	0.224	0.224	0.224
2002–2003	-0.843	-0.722	-0.474	-0.688	-0.228	-0.325	0.488	0.488	0.488
2003–2004	-1.647	3.545	-5.422	-2.963	-0.707	2.609	2.551	2.551	2.551
2004–2005	-1.628	-2.277	0.399	0.703	0.500	-0.253	0.169	0.169	0.169
2005–2006	12.041	-7.571	-1.893	-13.875	6.409	0.705	-0.248	-0.248	-0.248
2006–2007	-2.291	-2.415	-0.338	0.254	-0.211	0.141	-0.029	-0.029	-0.029
2007–2008	-0.084	-0.760	-0.660	-0.170	0.218	-0.197	-0.055	-0.055	-0.055
2008–2009	-0.472	-0.581	-0.425	-0.156	-0.113	0.082	0.039	0.039	0.039
2009–2010	-2.859	-1.577	-0.101	-0.604	0.066	-0.050	-0.028	-0.028	-0.028
2010–2011	-0.421	-0.322	-0.031	-0.076	-0.044	0.018	-0.019	-0.019	-0.019
2011–2012	-0.312	0.383	-0.359	-0.004	-0.106	0.087	-0.030	-0.030	-0.030
2012–2013	0.056	-0.289	-0.405	-0.164	-0.100	0.091	-0.011	-0.011	-0.011
2013–2014	-0.419	0.310	-0.069	0.125	-0.231	0.205	-0.111	-0.111	-0.111
2014–2015	-0.404	0.006	-0.349	0.048	-0.125	0.111	0.018	0.018	0.018
1996–2015	-1.878	-21.628	-4.539	-20.676	11.274	2.829	-0.411	-0.411	-0.411

source consumption, followed by the marine tertiary industry and the marine primary industry. Vigorously promoting the technological innovation of the marine secondary industry and improving the scientific and technological level of the marine tertiary industry play a vital role in continuously reducing the intensity of marine resource consumption.

The cumulative effect of industrial structure within the three marine industries is -20.676 ten thousand t/hundred million yuan, 11.274 ten thousand t/hundred million yuan and 2.829 ten thousand t/hundred million yuan, accounting for 314.547%, 171.511% and -43.036% respectively, indicating that the driving effect of industrial structure adjustment on the reduction of marine resource consumption intensity mainly comes from the primary marine industry and the second marine industry The change of tertiary industry structure restricts the decline of marine resource consumption intensity, but the impact is still limited, and the effect of technological progress still plays a major role. We will accelerate the adjustment and optimization of the tertiary industry structure and the construction of a perfect modern marine industry system have a very important positive impact on reducing the in-

tensity of marine resource consumption.

(2) Comparison of factor decomposition effects among the three marine industries in provinces and regions. As shown in **Table 5**, the effects of technological progress and industrial structure are significantly different among the three marine industries in each province, and the regional scale effect has no significant change.

The effect of technological progress in most provinces and regions is negative within the three marine industries, indicating that technological progress in most provinces and regions plays a positive role in reducing the intensity of marine resource consumption, and the resource utilization efficiency of the three marine industries has been improved. However, there are still great differences in the contribution of the technological progress effect among the three marine industries in various provinces and regions to the decline in the intensity of marine resource consumption. Among them, the technological progress effect of Tianjin is positive in the primary and tertiary marine industries, Hebei is positive in the primary marine industry, and Shanghai and Guangxi are positive in the tertiary marine industry, indicating that due to the differences in resource endowment and emphasis on

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Table 5. industrial difference of decomposition factor effect of marine resources consumption intensity of each coastal province from 1996 to 2015 (10,000 t/100 million yuan)

Province	Effect of technological progress ΔI_{tech}			Industrial structure effect ΔI_{indu}			Regional scale effect ΔI_{regi}		
	Primary industry	The secondary industry	The service sector; the tertiary industry	Primary industry	The secondary industry	The service sector; the tertiary industry	Primary industry	The secondary industry	The service sector; the tertiary industry
Tianjin	0.191	-1.984	0.123	-2.701	0.467	-0.435	0.695	0.695	0.695
Hebei	0.109	-0.758	-0.337	-0.580	0.225	0.054	0.147	0.147	0.147
Liaoning	-0.320	-1.032	-0.224	-0.622	0.037	0.530	-0.186	-0.186	-0.186
Shanghai	-0.239	-3.466	1.476	-7.033	0.770	-0.378	-0.336	-0.336	-0.336
Jiangsu	-0.367	-1.940	-0.138	-0.707	0.447	0.224	0.204	0.204	0.204
Zhejiang	0.029	-2.715	-1.907	-3.235	4.480	1.608	-0.180	-0.180	-0.180
Fujian	-0.210	-1.367	-1.214	-1.148	0.715	0.569	0.057	0.057	0.057
Shandong	-0.113	-2.155	-1.384	-1.617	1.468	1.160	-0.219	-0.219	-0.219
Guangdong	-0.651	-4.654	-0.743	-2.718	1.318	-0.202	-0.562	-0.562	-0.562
Guangxi	-0.107	-0.041	0.118	-0.044	0.171	-0.130	-0.027	-0.027	-0.027
Hainan	-0.201	-1.515	-0.310	-0.270	1.177	-0.170	-0.005	-0.005	-0.005

economic development. The effect of technological progress limits the reduction of marine resource consumption in individual industries in these provinces.

The effect of industrial structure is negative within the primary marine industry and positive within the secondary marine industry in all provinces and regions; the industrial structure effect within the marine tertiary industry in Tianjin, Shanghai, Guangdong, Guangxi and Hainan is negative, and the other provinces are positive. It shows that the adjustment and optimization of the marine primary industry structure has significantly greater contribution to the decline in the intensity of marine resources than the marine second industry The decline in the proportion of tertiary industry and marine primary industry has a significant positive effect on the decline in the intensity of marine resource consumption, and marine second The optimization and upgrading of the structure of the tertiary industry is the focus of the future adjustment of the marine industrial structure.

4 Conclusions and suggestions

4.1 Conclusion

Based on the connotation of the intensity of marine resources consumption, this paper measures the intensity of marine resources consumption in China's coastal provinces from 1996 to 2015, and reveals its temporal and spatial evolution trend; using the improved logarithmic mean Di exponential decomposition (LMDI) method, this paper decomposes the factor contributions of the changes in the resource consumption intensity of the three marine industries, and explores the temporal, regional and industrial differences. The main conclusions are as follows: (1) China's marine resource consumption intensity changed from 8.058 ten thousand t/hundred million yuan in 1996 to 3.958 ten thousand t/hundred million yuan in 2015, showing a steady decline after rising on the whole; the resource consumption intensity of the primary marine industry showed a steady downward trend, and the marine industry ranked second The resource consumption intensity of the tertiary industry is basically synchronized with the change trend of China's marine resource consumption intensity. In terms of spatial pattern evolution, the medium and high intensity provinces are gradually decreasing, the low intensity provinces are gradually increasing, and the regional differences are gradually narrowing. Among them, Tianjin, Hebei, Fujian, Shandong, Guangdong and Hainan belong to the gradually decreasing type of marine resource consumption intensity, while Liaoning, Shanghai, Jiangsu, Zhejiang and Guangxi belong to the gradually increasing type of marine resource consumption intensity.

(2) The time difference comparison of factor decomposition effect shows that technological progress effect is the most important factor to promote the decline of marine resource consumption intensity, with a cumulative contribution rate of 78.224%; the industrial structure effect is the secondary influencing factor of the decline in the intensity of

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marine resource consumption, with a contribution rate of 18.334%; regional scale effect plays a weak role, with a contribution rate of 3.442%.

(3) The comparison of regional differences in factor decomposition effects shows that there are significant differences in technological progress effects, industrial structure effects and regional scale effects in coastal provinces. Fujian is dominated by technological progress effects, Zhejiang, Shandong and Hainan are dominated by technological progress effects and regional scale effects, Tianjin, Hebei and Jiangsu are dominated by technological Progress Effects and industrial structure effects, and Liaoning, Shanghai, Guangdong and Guangxi are dominated by technological progress effects Industrial structure effect and regional scale effect jointly promote the decline of marine resource consumption intensity.

(4) The comparison of industrial differences of factor decomposition effect shows that the effect of technological progress makes the largest contribution within the marine secondary industry, accounting for 77.118% in total; the industrial structure effect has the largest contribution within the marine primary industry, accounting for 314.547% in total; there is no significant difference in regional scale effect among the three marine industries. The effects of technological progress and industrial structure of each province and region are significantly different within the three marine industries. In the future, the implementation of technologies or measures for the intensive utilization of resources in the three industries should be different and focused.

The calculation of China's marine resource consumption intensity and the analysis of the contributing factors affecting its change have explored the temporal and spatial evolution characteristics of marine resource consumption intensity and the differences in time, region and industry to a certain extent. However, there are many types of marine industries, which are limited to the issue of statistical caliber. This paper studies the intensity of marine resource consumption from the perspective of three industries. The contributing factors to the change of resource consumption intensity of specific marine industries still need to be further analyzed to make the research more targeted.

4.2 Suggestions

Continuously reducing the consumption intensity of marine resources is the key to the sustainable development of marine economy. Based on the above analysis, the following suggestions are obtained: (1) promote the technological innovation of marine economic development. The primary stage of marine economic growth mainly depends on the input of marine resources. However, when the economic growth exceeds a certain critical value, the dependence of marine economic development on resources gradually decreases, and the advantages of the connotation expansion reproduction mode led by technological progress are prominent. Technology has become the most important factor in reducing the intensity of marine resource consumption and improving the efficiency of marine resource utilization. Therefore, we should rely on scientific and technological innovation to realize the optimal allocation of marine resources, Strengthen the R & D and promotion of resource saving technologies, reduce the intensity of marine resource consumption and alleviate the pressure of marine resources through the improvement of technical efficiency.

(2) Accelerate the adjustment and optimization of the marine industrial structure, and implement the development strategy of differentiated industries. With the transformation of marine economic growth mode, the effect of industrial structure plays an important and positive role in reducing the intensity of marine resource consumption. Provinces and regions such as Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan, which have reduced the intensity of marine resource consumption, should focus on marine biological resources, oil and gas resources, mineral resources, port resources, etc., rely on talents Technology, location and other advantages, accelerate the transformation of industrial structure to the marine secondary industry and tertiary industry, and support the development of marine emerging strategic industries; Guangxi, where the consumption intensity of marine resources is on the rise, should speed up the transformation and upgrading of traditional marine industries to achieve green industrial transformation and upgrading.

(3) Adopt unbalanced development strategies to promote cross regional exchanges and cooperation in marine economy and technology. Regional scale effect has a positive impact on reducing the intensity of marine resource consumption. The government should reasonably regulate the growth rate and development scale of marine economy, encourage the first developing areas of marine economy to radiate and drive the second developing areas, promote the transfer of production factors in coastal provinces through technology spillover effect and industrial relevance spillover effect, promote the overall improvement of the level of marine economic development, and reduce the differences in the intensity of marine resource consumption between regions.

Conflict of interest

The authors declared that they have no conflict of interest.

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