Analysis on the coordinated development of marine economy and ecological environment coupling in Guangdong province

Jianhua Xiao¹, Shihui Guo²

¹School of Economics and Management, Wuyi University, China
²School of Economics and Management, Wuyi University, China

Abstract. When constructing the evaluation index system of the coupling development of marine economy and ecological environment, the coupling coordination relationship between marine resources and environment system and marine economic system in Guangdong Province is revealed by using the coupling coordination degree model. The results show that: the ecological environment system of Guangdong province lags behind the marine economic system, while the marine economic development process is facing the dual pressure of resources and environment. According to the empirical results, some suggestions are put forward: optimizing the allocation of marine resources; cultivating marine innovative talents; establishing a scientific development system.

1. Introduction
At present, scholars at home and abroad have made a lot of achievements in the research on the coordinated development of marine economy and ecological environment. For example, Gao Weiming et al. [1] and Wang Yantao [2] studied the coupling and coordination relationship between land economy, marine ecological environment system and marine industrial structure in Zhejiang and Shandong, which provided an important basis for promoting the high-quality development of regional marine economy; Gao Qiang et al. [3] and Xiao canfu et al. [4] respectively constructed marine ecological economic system and marine economic sustainable development system, and analyzed their coordinated development Xu Ziyi et al. [5] and Li Xianxian [6] established the coupling development evaluation model of marine industry and marine science and technology, and put forward countermeasures for coordinated development.

Guangdong Province has a superior geographical position and abundant marine resources. The overall strength of marine economy is in the forefront of China's coastal cities. With the development of science and technology and the support of policy, the marine economy of Guangdong Province has been developing rapidly, and the ecological environment has been seriously damaged and polluted. However, there are few researches on this area in Guangdong Province, especially in marine science and technology. Based on the method of coupling coordination degree, this paper explores the ecological environment and marine economy of Guangdong Province, and puts forward various measures for the effective utilization of marine ecological environment and resources, so as to further promote the construction of a strong marine province in Guangdong Province.

2. Coupling analysis of marine economy and ecological environment in Guangdong province
Marine environment is the foundation of marine economy. Only with good marine environment can marine economy be developed sustainably. First of all, the direct and indirect utilization of marine resources by marine industry can promote the rapid development of marine economy. In addition, marine resources can also affect other marine industries, for example, good marine environment will drive the development of coastal tourism.

The marine economy will react on the ecological environment. First of all, the rapid development of the marine economy has destroyed the ecological environment of some parts of the ocean. Secondly, the financial and technical support obtained from the development of marine economy can make the marine environment be optimized. However, most of the marine resources in the marine environment are non-renewable and cannot be retrieved once they are seriously damaged. Therefore, we should pay attention to the coordinated development of marine economy and ecological environment.

3. Evaluation index and method
According to the actual situation and following the principles of systematic, scientific and hierarchical index design, the index system of coordination level between marine economy and ecological environment is constructed. Firstly, the index data is standardized, and then the weight of each index is determined by entropy method. Finally, the level index of marine economic subsystem and ecological environment subsystem is further determined.

3.1. Index system construction
This paper takes the marine economic system and ecological environment system as subsystems, constructs the coupling coordination index system of marine economy and ecological environment in Guangdong Province, tries to reflect the marine economic growth and ecological environment quality from different levels, and provides reference for the realization of high-quality and high-level development of marine economy in Guangdong Province. Marine economic subsystem includes marine economic level, marine science and technology level index system; ecological environment subsystem includes marine resources utilization, environmental pollution and governance index system. Under the four secondary index system, there are 19 specific index elements, and the specific parameters are shown in Table 1.

3.2. Data source and processing
The data in this paper are from Guangdong statistical yearbook, China Marine Statistical Yearbook, statistical bulletin, etc. Due to the different distribution intervals and characteristics of the original data, it is impossible to compare them horizontally and vertically. Therefore, different indexes need to be standardized to eliminate the influence of dimension. Where m is the year, n is the index, and $X_{ij}$ is the measurement value of J index in the i year.

Positive effect index: $X'_{ij} = \frac{x_{ij} - \min(x_{1j}, x_{2j}, \ldots, x_{nj})}{\max(x_{1j}, x_{2j}, \ldots, x_{nj}) - \min(x_{1j}, x_{2j}, \ldots, x_{nj})}$ (1)

Negative effect index: $X'_{ij} = \frac{\max(x_{1j}, x_{2j}, \ldots, x_{nj}) - x_{ij}}{\max(x_{1j}, x_{2j}, \ldots, x_{nj}) - \min(x_{1j}, x_{2j}, \ldots, x_{nj})}$ (2)

3.3. Index weight calculation
In this paper, the above-mentioned index system is adopted to determine the function degree and importance of each index of marine economy and ecological environment subsystem in Guangdong Province by using entropy method, and the index weight value is determined from a comprehensive perspective.

The first step is to calculate the contribution of year i under the j index: $P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$ (3)

The second step is to calculate the entropy of the j index: $e_{j} = -\frac{1}{lnm} \sum_{i=1}^{m} P_{ij} \ln P_{ij}$ (4)

The third step is to use entropy method to determine the index weight: $W_{j} = \frac{1 - e_{j}}{\sum_{j=1}^{n} e_{j}}$ (5)
Table 1. Coupling development index system of marine economy and ecological environment in Guangdong province.

| System layer | Target layer | Index element layer | Company nature | weight |
|--------------|--------------|---------------------|----------------|--------|
| Marine economic system | Gross marine product | RMB100mn | just | 0.043 20 |
| Marine economic system | Per capita gross marine product | element | just | 0.043 01 |
| Marine economic system | Total revenue of marine Finance | RMB100mn | just | 0.046 70 |
| Marine economic system | Contribution rate of marine GDP | % | just | 0.037 64 |
| Marine economic system | Proportion of tertiary industry in marine GDP | % | just | 0.039 76 |
| Marine economic system | Growth rate of marine GDP | % | just | 0.050 24 |
| Marine economic system | Number of marine research institutions | individual | just | 0.038 95 |
| Marine economic system | Number of papers on Marine Science and technology | piece | just | 0.047 72 |
| Marine economic system | Investment in marine scientific research | Ten thousand yuan | just | 0.069 79 |
| Marine economic system | Proportion of high-quality talents | % | just | 0.045 53 |
| Ecological environment system | Seafood production | 10000 tons | just | 0.053 67 |
| Ecological environment system | Marine fisheries catch | 10000 tons | just | 0.090 96 |
| Ecological environment system | Marine crude oil production | 10000 tons | just | 0.060 94 |
| Ecological environment system | Marine gas production | Ten thousand cubic meters | just | 0.073 73 |
| Ecological environment system | Output of marine salt field | 10000 tons | just | 0.067 33 |
| Environmental pollution and control | Industrial wastewater discharge (per unit area) | 10000 tons | negative | 0.048 45 |
| Environmental pollution and control | Industrial solid waste consumption (per unit area) | 10000 tons | negative | 0.068 73 |
| Environmental pollution and control | Production and domestic wastewater treatment project | individual | just | 0.040 76 |
| Environmental pollution and control | Marine Nature Reserve | individual | just | 0.042 89 |

3.4. Calculation of evaluation index
The calculation formulas of horizontal index of marine economic subsystem $f(x)$ and ecological environment subsystem $f(y)$ are as follows:

$$f(x) = \sum_{i=1}^{m} f(x_i) W_i$$  \hspace{1cm} (6)

In the above formula, $f(x)$ is the marine economic subsystem index; $f(x_i)$ is the standardized value of i index; $w_i$ is the weight value of i index.
In the above formula, \( f(y) \) is the ecological environment subsystem index; \( f(y_i) \) is the standardized value of \( i \) index; \( w_i \) is the weight value of \( i \) index.

4. **Construction of mathematical model**

Coupling is a measure of interaction between systems, also known as linkage effect. Coupling co-scheduling can not only reflect the level of coordinated development, but also reflect the overall system. The calculation model of coupling coordination degree is as follows:

\[
H = \sqrt{L\cdot T} \\
L = 2\sqrt{f(x)\cdot f(y) / (f(x) + f(y))} \\
T = \alpha_1 f(x) + \alpha_2 f(y)
\]

Among them, \( H \) is the coupling coordination between marine economic system and ecological environment system; \( L \) is coupling degree; \( T \) is development measure (comprehensive evaluation index); \( f(x) \) is marine economic subsystem index; \( f(y) \) is ecological environment subsystem index; \( \alpha_1, \alpha_2 \) are weight of marine economic subsystem and ecological environment subsystem. In this paper, we put the marine economy and ecological environment resources in the same position, take \( \alpha_1 = \alpha_2 = 0.5 \). The specific division standard of coupling coordination degree is shown in Table 2.

**Table 2. Division standard of coupling coordination degree between marine economy and ecological environment.**

| Coupling compatibility value | Coordination type                      |
|-----------------------------|----------------------------------------|
| \( 0.0 < H \leq 0.2 \)     | Disorder disorder type                 |
| \( 0.2 < H \leq 0.4 \)     | Severe maladjustment recession         |
| \( 0.4 < H \leq 0.5 \)     | Moderate maladjustment decline         |
| \( 0.5 < H \leq 0.6 \)     | Mild maladjustment decline             |
| \( 0.6 < H \leq 0.7 \)     | Primary coordinated development        |
| \( 0.7 < H \leq 0.8 \)     | Intermediate coordinated development    |
| \( 0.8 < H \leq 0.9 \)     | Advanced coordinated development       |
| \( 0.9 < H \leq 1.0 \)     | High quality and coordinated development|

5. **Empirical analysis and conclusion**

Based on the original data and weights of marine economy and ecological environment indicators in Guangdong Province from 2008 to 2017, the comprehensive evaluation index of marine economic status \( f(x) \) and marine ecological environment status \( f(y) \) of Guangdong Province is calculated. On this basis, the coupling degree and coupling coordination degree of marine economic system and ecological environment system in Guangdong Province are obtained (see Table 3).
Table 3. Coupling degree and coupling coordination of marine economy and ecological environment in Guangdong province from 2008 to 2017.

| Year | f(x)  | f(y)  | Coupling degree | Coupled cooperative scheduling | Type description          |
|------|-------|-------|-----------------|---------------------------------|---------------------------|
| 2008 | 0.1105| 0.3284| 0.8680          | 0.4364                          | Moderate maladjustment decline |
| 2009 | 0.1504| 0.1887| 0.9936          | 0.4105                          | Moderate maladjustment decline |
| 2010 | 0.2446| 0.2566| 0.9997          | 0.5006                          | Mild maladjustment decline   |
| 2011 | 0.2456| 0.2360| 0.9986          | 0.5022                          | Mild maladjustment decline   |
| 2012 | 0.2529| 0.2255| 0.9984          | 0.5027                          | Mild maladjustment decline   |
| 2013 | 0.2726| 0.2355| 0.9973          | 0.5034                          | Mild maladjustment decline   |
| 2014 | 0.4521| 0.3482| 0.9915          | 0.6299                          | Primary coordinated development |
| 2015 | 0.6844| 0.4181| 0.7863          | 0.6584                          | Primary coordinated development |
| 2016 | 0.7197| 0.3972| 0.7059          | 0.6279                          | Primary coordinated development |
| 2017 | 0.8363| 0.4124| 0.9459          | 0.7685                          | Intermediate coordinated development |

From the coupling degree value, the coupling degree of marine economic system and marine ecological environment system from 2008 to 2017 basically conforms to the inverted "U" Economic Environment Kuznets curve. In 2008, the marine economic development of Guangdong Province was in the exploratory stage, and there was little effect due to the impact of the financial crisis; from 2009 to 2011, the coupling degree initially remained stable, and the two were in the stage of coordinated development. From 2012 to 2016, the coupling degree began to decline, mainly due to the unreasonable use of marine economic resources and the destruction of ecological environment. In 2017, due to the formulation and implementation of policies, the coupling degree increased, which made the marine economy develop and the ecological environment is effectively managed.

From the perspective of coupling and coordination, the overall level of coordination between marine economic system and ecological environment system in Guangdong Province has increased significantly, and the level of coordinated development has been continuously improved. Among them, the coupling coordination degree value in 2010, 2014 and 2017 increased the most from 0.4364 in 2008 to 0.7685 in 2017. Guangdong province suffered from financial crisis in 2008 and was hit by marine natural disasters in 2009, which had a great impact on the two systems, with poor stability and coordination. In 2010, Guangdong Province issued the "comprehensive marine development plan", focusing on the goal of promoting the construction of Marine Economic Zone, implemented the strategy of revitalizing the sea through science and technology, and strengthened the construction of marine disaster prevention and mitigation system and marine environmental protection In 2010-2013, Guangdong Province stepped into the track of mild coordinated development; in 2014, Guangdong province implemented the strategy of strengthening marine province, expanding the scale of marine economy and protecting marine ecological environment at the same time, which made the two systems coordinated development. In 2017, Guangdong province implemented a comprehensive development plan in the coastal economic belt, which once again promoted the coordinated development of the two major systems. From 2014 to 2017, the two systems first transited from mild coordination stage to primary coordinated development stage, and then to intermediate coordinated development stage, achieving a leap in coupling coordination level.

Based on the empirical analysis results of the above marine economic subsystem and ecological environment subsystem, combined with the current situation of marine economic development in Guangdong Province, we can draw the following conclusions:

From the comprehensive development evaluation index, the marine economic index of Guangdong Province grew slowly from 2008 to 2010, and began to develop rapidly since 2011. In 2009 and 2015, the marine environment was in a very unstable state. With the improvement of marine science and technology, the quality of ecological environment has been greatly affected, and the uncoordinated factors between the two systems have gradually emerged.
From the coupling degree value, there is a significant coupling development relationship between the two systems, and the coupling degree changes slightly. The two systems basically conform to the inverted "U" Economic Environment Kuznets curve.

From the coupling coordination degree value, the coupling coordination degree of the two systems has changed greatly, from 0.4364 in 2008 to 0.7685 in 2018. From 2008 to 2009, it is in the moderate maladjustment stage, from 2011 to 2011, it is in the primary coordination stage, from 2014 to 2016, it is in the moderate coupling coordination stage, and the coupling coordination effect between the two systems is gradually showing.

6. Countermeasures and suggestions
It can be seen from the above conclusions that the development of marine economy and ecological environment in Guangdong Province is gradually getting better, and has entered the stage of intermediate coordinated development from the primary coordinated development stage, with broad development space. We put forward some targeted countermeasures to change the backward status of ecological environment system and promote the harmonious development of the two systems.

6.1. Optimize the allocation of marine resources and formulate a reasonable long-term plan
Due to the limited quantity of marine resources, it is necessary to make scientific planning and rational utilization to maximize the allocation of marine resources. We should strengthen the construction of marine ecological civilization system, establish and improve the green market access system and paid use system for the development and utilization of marine resources. In the aspect of marine environmental protection, Guangdong Province should take the road of marine ecological protection, implement the marine ecological protection system, and take the road of marine environmental protection.

6.2. Adjusting marine industrial structure and training marine innovative talents
We should strengthen marine innovation, extend the industrial chain, and realize the transformation of marine economic development mode from extensive to high-quality development. We should integrate marine education resources, attach importance to personnel training, improve the mode of industry university research cooperation, and constantly improve the innovation system of marine industry. We should also deepen the reform of higher learning and talent cultivation among marine institutions, and strengthen the construction of marine talents.

6.3. Establishing scientific development system and maintaining ecosystem balance
We should establish a scientific and complete development system, improve the use capacity of marine resources, optimize the marine ecological environment, and keep the bottom line of marine ecological environmental protection. We should adhere to the "ecological use of the sea", simultaneously developing the use and protection of the sea, maintaining the circulation of the marine ecosystem, promoting the transformation of marine economic growth from resource dependence to innovation driven, and realize the coordinated adjustment of the two systems.

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