Chin. Geogra. Sci. 2017 Vol. 27 No. 2 pp. 176–187
doi: 10.1007/s11769-017-0857-y

Springer Science Press
www.springerlink.com/content/1002-0063

Symbiotic State of Chinese Land-Marine Economy

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Abstract: The simultaneous development of both the land and marine-based economy is required to achieve the economic development of coastal regions in China. Based on symbiosis theory, this study discusses land and marine-based economic symbiosis mechanisms and uses a logistic symbiotic function to construct a symbiotic evolution model of the land-marine economy. We conduct a division and feature analysis of the interactive model between the land and marine-based economies of 11 provinces (or cities) along the coast of China between 1996 and 2013, and discuss their economic development. The results show that, during the study period, the coordinated development model of the national land-marine economy is a parabiosis model. Fujian Province exhibits mutualism, Jiangsu, Hebei, Shandong, and Guangdong show commensalism, while Tianjin, Zhejiang, and Shanghai display parasitism, Guangxi and Hainan exhibit an antibiosis model, while Liaoning displays a parabiosis model. The land economic development model of Jiangsu and Fujian and the marine economic development model of Guangdong are improving the quality and efficiency of the factors of production. All other provinces' development models improve the productivity of the production factors to expand the scale of production.

Keywords: symbiosis; logistic model; land-marine economic system; coordinated development

Citation: Di Qianbin, Dong Shaoyu, 2017. Symbiotic state of Chinese land-marine economy. *Chinese Geographical Science*, 27(2): 176–187. doi: 10.1007/s11769-017-0857-y

1 Introduction

Weighing, distributing, and coordinating the development of energy between the land and marine are major problems that can not be ignored in the economic and social development of China. The developments of the Chinese land and marine areas are increasingly interrelated, causing significant economic benefits, as well as prominent contradictions. Therefore, there is an urgent need for research to focus on land-marine economic mechanisms and development patterns.

At present, academic research is focusing on the problem of coordinated development in China. Zhao constructed an appropriate index system and used a coupled coordination model and grey relational model to measure the coupling coordination degree of the land-marine economy (Zhao *et al.*, 2016). Zhou used the data envelopment analysis evaluation method and established a quantitative analysis model for the evaluation of the coordinated continuous economic development of the land and marine areas (Zhou, 2015). Zhao constructed an evolution model of the land-marine industrial system self-organization process referencing a Haken Model. He constructed the model using the slaving principle to obtain an evolution model of the land-marine economy (Zhao and Sun, 2009). Yin constructed an evaluation index system to assess harmonious land-marine economic development through four aspects: total output, structure, efficiency, and sustainability. Then, he measured and analyzed the degree of economic development using grey correlation analysis of 11 coastal provinces in China (Yin and Li, 2011). Li and

Received date: 2016-7-10; accepted date: 2016-11-04

Foundation item: Under the auspices of the National Natural Science Foundation of China (No. 41571127), Executed by Scientific and Technical Personnel in Universities of Liaoning Province, the Excellent Technology and Talent Supported Project in Liaoning Provincial Institution of Higher Education (No.WR2014005)

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Xiao calculated the co-evolution coefficient of the land-marine industrial structure to quantitatively analyze the characteristics of the co-evolution of land-marine industrial structure (Li and Xiao, 2012). Constructing an evaluation index system of the land-marine economic system, and solving parameters in the collaborative development model of Liaoning Province, Fan and Sun examined the characteristics in the process of the collaborative evolution of the land-marine economy in Liaoning (Fan and Sun, 2011). Sun constructed an evaluation index system of land-marine integration for resources, industries, technologies, and environments, and evaluated the integration degree of the land-marine economy in the Bohai Rim Region using the competence structure model and analytic hierarchy process (Sun *et al.*, 2012). Zhou and Cao analyzed the relevance of land-marine industries using grey correlation degree in Shandong Province (Zhou and Cao, 2014).

Land-marine economic development is an important issue outside of China as well. Usually, the effects of the marine economy on the regional and national economy in coastal areas are emphasized. For example, Surís-Regueiro set out a specific proposal for the definition and characterization of marine sectors and economic activities within the EU (Surís-Regueiro *et al.*, 2013). Morrissey and O'Donoghue analyzed the economic role of marine industry departments in the national economy of Ireland with an input-output analysis (Morrissey and O'Donoghue, 2013).

The concept of 'coordinated development of land-marine' is not widespread outside of China. Most of the research focuses on the land economy and marine economy separately, ignoring their interactions. Chinese scholars mostly analyze the relationship between the land and marine economy by constructing an evaluation index system. Although we discuss the determinants of the coordinated development of the land-marine economy in our country, we also rely on other analytic methods for reference. However, the construction of a theoretical framework restricted by selected indicators can not reflect the intrinsic relationship between of the land-marine economy, its coordinated development, or the overall situation of the coordinated evolution of the land-marine economy. Therefore, this study analyzed the land-marine economy in China through the biological symbiosis theory and symbiotic model.

The phenomenon of symbiosis, which, in this case, is the interrelation and interdependence between the land and marine economies, exists in biology. Academic research has well studied the theory and methods of symbiosis. German biologist Debarry Anton introduced the symbiosis theory (symbiosis). In 1879, he defined symbiosis as different species living together. At present, the application of symbiosis theory in social science research has been extended to industrial ecology (Teresa and Machael, 2011), urban-rural integration (Liu and Qi, 2009; Luo and Zhu, 2011), regional cooperation (Zhu, 2010; Li *et al.*, 2012), industrial clusters (Cheng, 2003; Rao, 2010), urban development (Zhang, 2004; Chen *et al.*, 2005), and to the establishment of the basic logical framework and analysis method for symbiosis models (Yuan, 1997).

Symbiosis theory studies the land-marine economy as a unique system, integrating the problems of different systems into one system. In the past, studies that analyze the relationship between the land and marine using symbiosis theory were only theoretical, with a lack of application and systematic analysis. This study uses symbiosis theory to establish the macro system of coordinated development of the land-marine economy in China. In addition, it examines the process of dynamic evolution within the land-marine economy by using a logistic model, distinguishing the interactive stage, and analyzing the characteristics and usage of energy. Finally, it examines the symbiotic state of the land-marine economy of 11 coastal provinces in China from 1996 to 2013. The aim of this study is providing a reference for promoting the order of development of the land-marine economy and achieving the strategic target of the coordination of the land-marine economy.

2 Analysis of Land-Marine Economic System Based on Symbiosis Theory

2.1 Symbiosis and its applicability in research on land-marine economic system

Symbiosis theory studies two populations with intrinsic relationships, which form a symbiotic relationship according to symbiotic behaviors and organization patterns. The symbiotic exchange of materials, energy, and information occurs via a symbiotic interface. The symbiotic interface is a set composed of the media of the interaction between the land-marine economic systems. A symbiotic system (S) is a collection of symbiotic relationships formed by symbiotic units (U) according to a symbiotic model (M). Symbiotic units (U), symbiotic environment (E), and symbiotic model (M) are three essential elements of the system (Yuan, 1998). The symbiotic unit refers to the basic units that produce and exchange energy, which from a symbiotic relationship. A symbiosis model (or a symbiosis relationship) relates to a way of interaction, or a form of integration between different symbiotic units. A symbiosis environment refers to the exogenous condition where a symbiosis model exists and develops, and the sum of all the elements besides the symbiotic unit. The essence of symbiosis is that symbiotic units attract and cooperate with each other based on the division of labor, making up for the functional defect of a single symbiotic unit and pursuing symbiotic interests. The concept of cooperation and co-evolution is the essence and core of the symbiosis theory.

The compatibility among symbiotic units is the essential determinant of the symbiotic relationship. The intrinsic relationship between symbiotic units shows their compatibility. One or a set of elements can express the symbiotic units' characteristics. The land-marine economic system is subject to the principle of separability, and the standard used for the division relates to the differences in and utilization of resources. Labor, resources, capital, and technology are the constituents of the land-marine economic system. These economic factors combine in the land-marine economic system due to their compatibility. Therefore, we look at the land-marine economy as one system. The problems of both economies are translated into issues of a unique system, which satisfies the principles of symbiosis theory. From the perspective of symbiosis, the relationship between the land and marine is not only a kind of cooperation, but also a type of healthy competition, and a form of co-evolution. This relationship has the potential to enhance the economic development of coastal areas.

2.2 Symbiotic evolution mechanism of land-marine economy

The development of the symbiotic system of the land-marine economy is affected by various mechanisms, which can be classified into two types: profit-driven and social-ecological equilibrium mechanisms (Wang *et al.*, 2006). The profit-driven mechanism is the internal growth method of the system, and its power depends on the economic system's maximization of individual interests. In the profit-driven mechanism of the land-marine economy, efficiency and scale are the dominant factors in system coupling (Wu, 2004). At the early stage of development, the density of population increases with time, ignoring population evolution (the rate of natural growth), until the symbiotic unit (U) extends and fills the whole symbiotic environment (E). At this point, pushed by the interest-driven mechanism, and pursuing the ultimate individual benefit, the development of the land-marine economic system ranges from the original state, growth period, to maturity (Gai *et al.*, 2013).

In the mid-term stage of development, the land- marine economy performs symbiotically via the network and multiplier effects determined by the recombination of the factors of production and the industry. On the one hand, influenced by the interest-driven mechanism, the land-marine economy recombines the original factors of production. The newly increased bidirectional flow of funds changes the structure of productivity, enhances the efficiency of resource transformation, and optimizes the development of land-marine industries (Zhao and Wang, 2009). On the other hand, the exploitation of marine resources can supplement the lack of land resources due to the social-ecological equilibrium mechanism. The emergence of new marine industries provides more employment opportunities and promotes social development. The land-marine economic system develops from symbiotic growth to symbiotic maturity, and, finally, to the integration stage combining different means, eliminating or reducing the effect of the lack of resources.

The above-mentioned symbiotic role is played inside the land-marine system on the coastal areas. To broaden the symbiotic environment, the interactions within the land-marine economic system will expand to coastal areas, and other areas between the coast and inland. On the one hand, increasing energy input from other regions renews the impetus for the development of the land-marine economic system. On the other hand, the energy output of the coastal areas promotes the development of other areas, and expands the symbiotic unit (U) and symbiotic environment (E) of all regions to achieve coordination of the land and marine economies. However, the excessive pursuit of economic interests, or the imperfection of legal regulation mechanisms, may push the system into overload or a recession (Fig. 1).

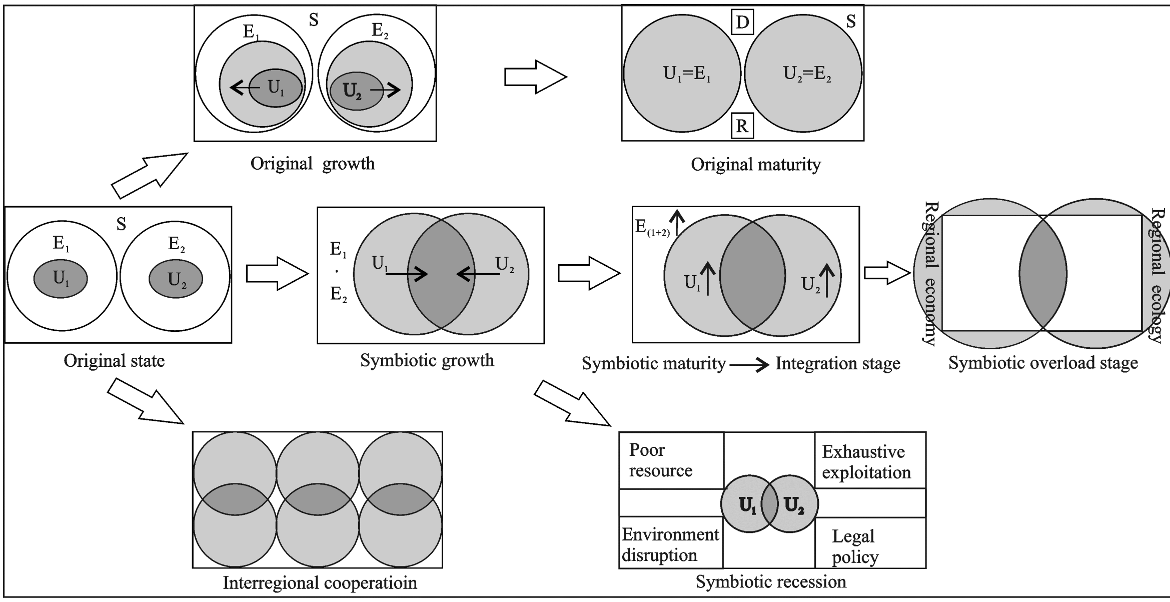

Fig. 1 Symbiotic evolution mechanism of land-marine economy

2.3 Co-evolution model of land-marine economic system

There are many complex and interactive symbiotic relationships inside the land-marine economic system, such as natural symbiosis, in which the land and marine ecological environment interact with material and energy, and social symbiosis, in which the land and marine ecological environment interact with information under the action of human initiative. Given the fundamental role of the land and marine elements in the symbiotic system of land-marine economy, we can take the two as the symbiotic units of the symbiotic system of the land-marine economy.

The symbiotic environment can be divided into direct and indirect environments, depending on their different influences. The direct environment of the land-marine economic symbiotic system consists of the interactive medium between the land and marine economic system. Mutual restriction, promotion between the environment and the economy, and the significant role that cultural factors, the natural symbiont of the land and marine ecological environment, and the cultural background of the land and marine culture are the key elements of the indirect environment of the land-marine economic symbiotic system. Figure 2 shows the symbiotic system of the land-marine economy in coastal areas, which consists of the symbiotic unit and environment in the land-marine economic system.

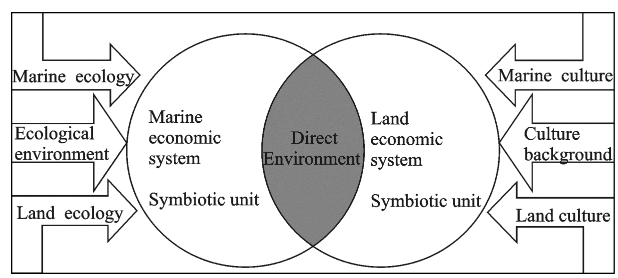

Fig. 2 Symbiotic system of land-marine economy

3 Materials and Methods

3.1 Study area and data sources

To examine whether the superposition of time internal of the logistic co-evolution model is able to accurately describe the co-evolution process of the land-marine economy, this study selects regional GDP and GOP (gross ocean production) of 11 coastal provinces in China as a basis for the empirical analysis. The present analysis can provide references for land-marine coordination in China. The data used in this study are obtained from the China Statistical Yearbook (National Bureau of Statistics of China, 2014) and China Marine Statistical Yearbook (State Oceanic Administration of China, 2014), and the study period ranges from 1996 to 2013.

3.2 Basic logistic symbiotic model

The essence of the land-marine symbiotic system is a process of 'population' increase in the land and marine economy. A logistic symbiosis function is a suitable tool to describe the symbiotic situation of the land-marine economic system. In this study, we build a model of symbiotic evolution by using a logistic symbiosis function and combining economic development with the essential characteristics of the symbiotic evolution of the marine industry economy. We consider 11 coastal provinces separately.

Let us suppose that the population density of the land and marine economy are N_1 and N_2, respectively, and the natural growth rates of the two are r_1 and r_2, respectively. Under the influence of certain external environmental factors, such as material, capital, labor, technology, and the size and policy of the market, the largest environmental capacities are k_1 and k_2, and the logistic symbiotic function model describing the interaction of the two parties can be expressed as:

$$\begin{cases} \dfrac{\mathrm{d}N_1(t)}{\mathrm{d}t} = r_1[1 - \dfrac{N_1(t)}{k_1} + \alpha_{12} \cdot N_2(t)]N_1(t) \\ \dfrac{\mathrm{d}N_2(t)}{\mathrm{d}t} = r_2[1 - \dfrac{N_2(\mathrm{t})}{k_2} + \alpha_{21} \cdot N_1(t)]N_2(t) \end{cases} \quad (1)$$

where $1–N_1(t)/k_1$ and $1–N_2(t)/k_2$ are the respective retardation factors of land and marine economic development, which gradually slow down their development due to the limited resources. In addition, α_{12} and α_{21} are symbiotic interaction coefficients and indicate where the marine economy interacts with the land economy and vice versa. We can assess the symbiotic relationship through the range of α_{12} and α_{21}.

When $\alpha_{12} < 0$, $\alpha_{21} < 0$, there is a negative symbiotic relationship between the land and marine economies.

Additionally, when both symbiotic coefficients are not equal to each other, the land and marine economies are different in the degree of damage; namely, there exists a negative asymmetry symbiosis. When the two symbiotic coefficients are equal to each other but are both degenerate, there exists a negative symmetry symbiosis.

When $\alpha_{12} =0$, $\alpha_{21}=0$, there is no symbiotic relationship between the land and marine economy. They develop independently, following a parabiosis model.

When $\alpha_{12} > 0$, $\alpha_{21} < 0$, or $\alpha_{21} > 0$, $\alpha_{12} < 0$, the economy with the positive value symbiotic coefficient is the beneficiary, and the economy with the negative value is the victim, following a parasitism model.

When $\alpha_{12} > 0$, $\alpha_{21} = 0$, or $\alpha_{21} > 0$, $\alpha_{12} = 0$, the economy with the positive value symbiotic coefficient is the beneficiary, and the economy with 0 is the non-beneficiary, following a positive commensalism model.

When $\alpha_{12} < 0$, $\alpha_{21} = 0$, or $\alpha_{21} < 0$, $\alpha_{12} = 0$, the economy with the negative value symbiotic coefficient is the victim, and the economy with 0 is not a victim, following a negative commensalism model.

When $\alpha_{12} > 0$, $\alpha_{21} > 0$, there exists mutualism between the two economies. In particular, when $\alpha_{12} \neq \alpha_{21}$, the interests are not equal, and the land and marine economy benefit from different shares of development, following a positive non-symmetrical mutualism. When $\alpha_{12} = \alpha_{21}$, the benefits are identical, following a positive symmetrical mutualism.

3.3 Superposition of time interval logistic model

The symbiotic process of the land-marine economy follows the basic rules of the evolution of population ecology. Their characteristics are multi-parameter, time internal, and dynamic, and conform to the law of logistics curve changing. The values of parameter n vary across time in the model; therefore, this study refers to the methods of the superposition of the time interval logistic model proposed by Tang *et al*. (2009). Dividing the evolution of the land-marine economy into periods by year, and between any adjacent two periods $[t_i, t_i+1]$ (interval length is $\Delta t= t_{i+1}–t_i=1$), we hypothesize that the increase of population density of the marine economy is $\Delta N_1(t_{i+1}) = N_1(t_{i+1}) –N_1(t_i)$. Its average is $N_1(t_{i+1}) = [N_1(t_{i+1})+N_1(t_i)]/2$, and the slope is $\Delta N_1(t_{i+1})/\Delta t$. The increase of population density of the land economy is $\Delta N_2(t_{i+1}) = N_2(t_{i+1})–N_2(t_i)$, its average is $N_2(t_{i+1}) = [\Delta N_2(t_{i+1})+N_2(t_i)]/2$, and the slope is $\Delta N_2(t_{i+1})/\Delta t$. Between two adjacent periods, the slope of the straight line can substitute for the approximate curvature that represents the true relationship. As the curvatures vary, the population density curve becomes much less representative of the land-marine economy (Tang *et al.*, 2009). Equation (1) can be transformed into a superposition of the time internal of the logistic co-evolution model:

$$\begin{cases} \dfrac{\Delta N_1(t)}{\Delta t} = r_1[1 - \dfrac{\bar{N}_1(t_{i+1})}{k_1} + \alpha_{12} \cdot \bar{N}_2(t_{i+1})]\bar{N}_1(t_{i+1}) \\ \dfrac{\Delta N_2(t)}{\Delta t} = r_2[1 - \dfrac{\bar{N}_2(t_{i+1})}{k_2} + \alpha_{21} \cdot \bar{N}_1(t_{i+1})]\bar{N}_2(t_{i+1}) \end{cases} \quad (2)$$

3.4 Coefficient of energy selection

In the symbiotic system, the selection of the symbiotic interface determines not only the quantity and quality of the symbiotic units but also the model of production and reproduction of symbiotic energy. In the logistic model, the symbiotic energy is divided into two parts: one part is employed to increase the number of symbiotic units, and the other is used to improve the function of symbiotic units. The former is a complete non-density constraint on the stability that the symbiotic system has on the number and non-binding scale of symbiotic units, performing at the rate of maximum environmental capacity k'; we call this option a. The latter is a complete density constraint on the stability that the symbiotic system has on the number and restricted scale of symbiotic units performing at the rate of natural growth r; we call this option b. The symbiotic system of the land-marine economy is between the two sides whose number and size of symbiotic units can not expand excessively. Density increases with the growth of symbiosis energy and loss. When symbiosis energy is equal to the loss, the system reaches the density equilibrium, and the usage of energy is known as hybrid selection. The coefficient of energy selection is $\beta = r/k' = a/b$. When $\beta > 1$, economic development is expanding the production scale and achieving economic growth by increasing the input of the production factors. When $\beta = 1$ or $\beta < 1$, economic development is achieving economic growth by improving the quality and efficiency of the factors of production.

4 Results and Analysis

This article uses MATLAB 2014a to separate the iterative formula, obtaining the maximum bearing capacity of the environment of the land and marine economy, and the estimation method of the population density of the land and marine economy. Then, it uses the Nelder-Mead simplex algorithm to obtain the natural growth rate of the land and marine economy, r_1 and r_2, and the largest environmental capacities, k_1 and k_2, for the year 2013. Then, it estimates the parameters and tests the superposition of the time interval logistic model. The results are reported in Table 1.

Comparing the simulation value and the actual value through MATLAB, we finally obtain the fitting curve of the symbiotic coefficient of the land and marine economies in 11 coastal provinces in China (Fig. 3).

Figure 3 shows that the symbiotic development of the land and marine economy belongs to the growth stage in coastal regions of China and increases rapidly. Since 2005, the marine economy has been developing rapidly, and the virtual curve fitted by the symbiotic coefficient is similar to the actual development situation both in values and trends. In particular, except from the period between 2001 and 2004, when the economy developed rapidly because of China's entry into the WTO, and from 2009 to 2013, when the economy grew slowly because of the 2008 financial crisis, the land economy completely fits the analog data. To test the fitting effect further, this article uses t-tests on the actual value and

Table 1 Results of logistic model

Region	α_{12}	α_{21}	r_1	r_2	k_1	k_2
Tianjin	0.0001	–0.0004	0.309	0.105	2266.978	–5388.937
Hebei	0.0000	–0.0003	0.471	0.091	1356.450	–66154.712
Liaoning	0.0000	0.0000	0.365	0.090	44170.908	121278.386
Shanghai	–0.0001	0.0001	0.697	0.214	55351.203	13782.403
Jiangsu	0.0000	0.0021	0.445	0.038	6446.079	3599.872
Zhejiang	0.0001	–0.0009	0.185	0.069	2235.935	–6930.915
Fujian	0.0004	0.0120	0.079	0.004	1061.159	190.627
Shandong	0.0000	–0.0003	0.436	0.076	–191363.788	–17619.813
Guangdong	0.0000	–0.0002	0.226	0.127	11521.973	–53989.973
Guangxi	–0.0001	–0.0001	0.267	0.123	–743.821	34602.902
Hainan	–0.0001	–0.0009	0.267	0.074	1357.437	–3868.386
Overall	0.0000	0.0000	0.331	0.073	108250.418	–110280.561

Notes: α means symbiotic relationship rate, r means natural growth rate, k means the largest environmental capacities

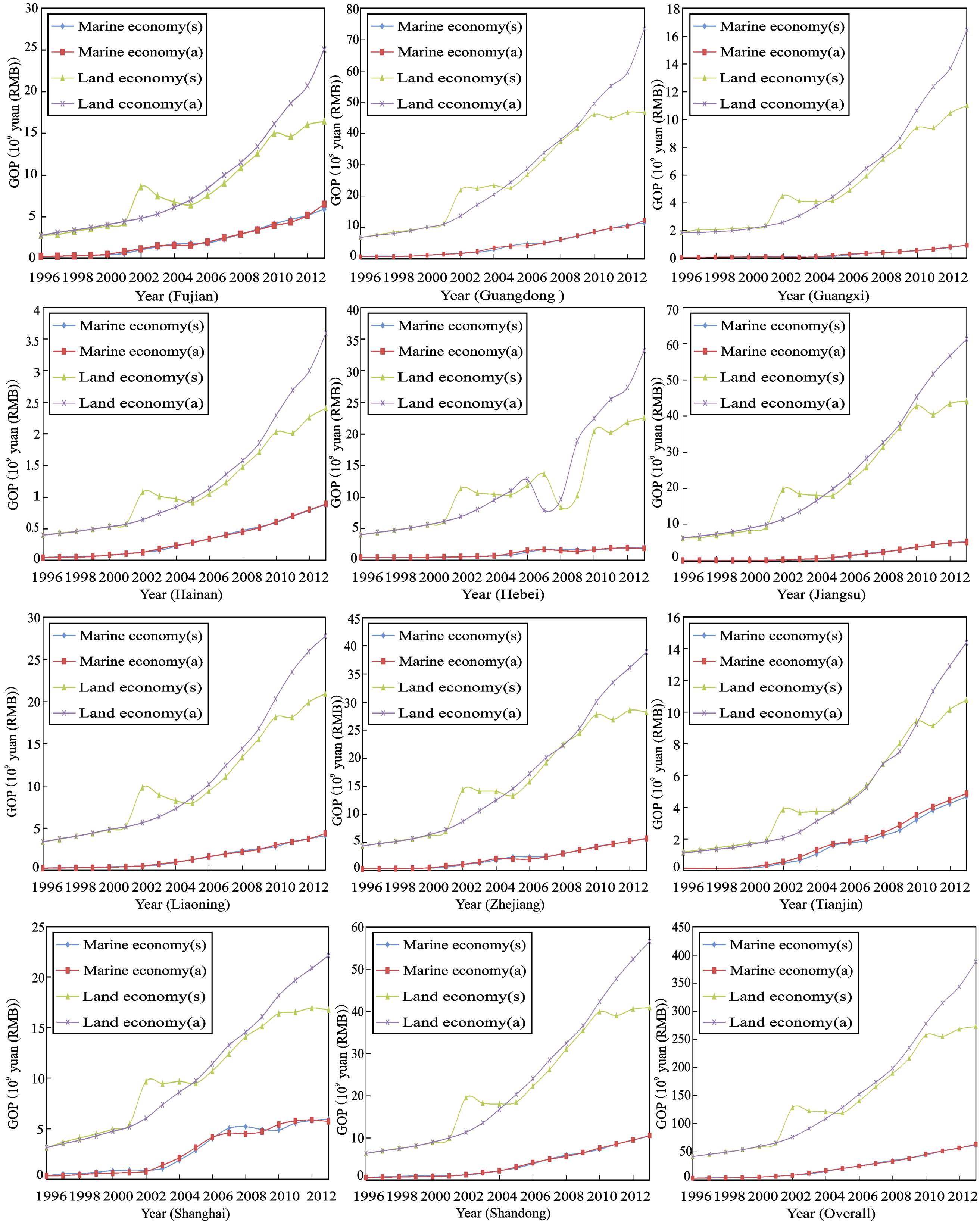

Fig. 3 Symbiotic evolution curve of coastal provinces and cities (GOP: Gross Ocean Product)

simulation value, *n*, of the land and marine economies of 11 coastal provinces (data of 11 coastal provinces during 18 years is a small probability event). The results are shown in Table 2.

As shown in Table 2, the correlation coefficients between the simulation value and the actual values are higher than 92%. From the results of the *t*-test, the values of the test on the land and marine economies are both less than 1.650 in 11 coastal provinces, indicating that the simulation value is very close to the actual value, the fitting effect is good, and the value of the symbiotic coefficient is reasonable. In China's coastal areas, there are various levels of development of the marine economy, and the symbiotic patterns vary.

(1) Positive asymmetrical mutualism. The symbiotic development model of the land-marine economy of Fujian, whose primary industry is a transportation port and secondary industries are coastal tourism and fisheries, entered the positive asymmetry mutualism model first. The symbiotic development stage is moving from the mature stage to the integration stage, as shown in Fig. 2. During the '12th Five-Year Plan' period, the Fujian Province optimized its spatial layout, accelerated the transformation of the production model, promoted the development of marine tourism with special Mazu culture, and initially realized the overall land-marine development.

(2) Partial interest symbiosis. The development of the land-marine symbiotic economy in Hebei, Shandong, and Guangdong provinces follows a negative partial interest symbiosis model. The marine economy is fundamental for these provinces. Guangdong and Shandong, whose marine economic gross values were in the forefront of the nation, did not achieve land-marine coordination because the largest environmental capacity, *k*, of the land-marine economy of the two provinces was sometimes negative, and their model of symbiotic development tended to overload. When the two provinces pursued economic development, the consumption and destruction of the natural resources exceeded the environmental carrying capacity threshold. These provinces have an urgent need to protect the environment, or their economies will soon enter a symbiotic recession period.

In addition to developing the port, salt industry, aquaculture, and tourism, the Jiangsu Province developed and utilized tidal-flat resources, transforming the area into a base for grain, fish, fruit, and vegetables and developing its marine economy. Therefore, its exploitation of marine resources boosts the development of the land economy. The Jiangsu Province exhibits positive partial interest symbiosis, as shown in Fig. 2.

(3) Parasitism. Tianjin, Zhejiang, and Shanghai, which have a smaller land area, supported the development of the land economy mainly relying on the marine transportation, fisheries, coastal tourism, and marine industries. Therefore, Tianjin and Zhejiang both follow

Table 2 *T*-tests of the land-marine symbiosis system

Region	Symbiotic coefficient		Correlation coefficient		Value of *t*-test	
	sea	land	sea	land	sea	land
Tianjin	0.0001	–0.0004	0.997	0.971	0.163	–0.584
Hebei	0.0000	–0.0003	0.978	0.920	0.198	–1.214
Liaoning	0.0000	0.0000	0.998	0.973	–0.139	–1.519
Shanghai	–0.0001	0.0001	0.990	0.969	0.709	–1.086
Jiangsu	0.0000	0.0021	0.999	0.969	0.687	–1.572
Zhejiang	0.0001	–0.0009	0.996	0.966	0.165	–1.304
Fujian	0.0004	0.0120	0.994	0.954	–0.394	–1.484
Shandong	0.0000	–0.0003	0.999	0.969	0.369	–1.417
Guangdong	0.0000	–0.0001	0.996	0.955	–0.399	–1.320
Guangxi	–0.0001	–0.0001	0.994	0.973	–0.660	–1.535
Hainan	–0.0001	–0.0009	0.999	0.968	–0.177	–1.568
Overall	0.0000	0.0000	0.999	0.969	0.137	–1.456

the symbiotic model, where the land economy parasitizes the marine economy. In Shanghai, industrial clusters (such as the High-Tech Zone, Binhai new area, *etc*.) take advantage of scale and the marine economic development needs to rely on infrastructure, science, and technology from the land economy; therefore, the symbiotic model shows the marine economy parasitizing the land economy.

(4) Negative asymmetry symbiosis. Guangxi and Hainan provinces both follow the symbiotic model of competition, due to the struggle for resources caused by their relatively backward economies. A late start in marine economic development means that the marine economy has a weak link with the land economy, and the development model of land-marine economic symbiosis follows an indifferent parabiosis model. The development model of the land-marine economy of the Liaoning Province still lies in the original growth period of symbiosis development. The area has already reached the original maturity period, although the industrial structure of the marine economy has gradually reached the 'three, and two or one' model, in recent years. The analysis of the symbiosis model is shown in Table 3, and specific categories are reported in Fig. 4.

To further define the model of economic development of the coastal provinces, this study uses option *b* to analyze usage of energy, as shown in Table 4.

In Tianjin, Shanghai, Hebei, Liaoning, Guangxi, Hainan, Shandong, and Zhejiang, the model of the land-marine economy is following option *a*, in which the economy develops by increasing industrial factors to expand the scale of production. In Jiangsu and Fujian provinces, the development model of the land economy is the same as the development model of the marine economy of the Guangdong Province, option *b*, where the economy develops by increasing the efficiency and quality of factors of production. In Jiangsu and Fujian provinces, the development model of the marine economy is the same as the development model of the land economy of Guangdong Province, option *a*. Overall, the model of economic growth in China still needs to transform from extensity to intensity. The classification is reported in Fig. 5.

Table 3 Land-marine symbiosis model of coastal provinces and cities in China

Relationship	Regions	Main characteristics
Positive symmetrical mutualism	None	Equal interests, win-win
Positive asymmetrical mutualism	Fujian	Unbalanced resources, unequal interests
Positive partial interest symbiosis	Jiangsu	One part benefits, the other is not affected
Negative partial interest symbiosis	Hebei, Shandong, Guangdong	One part is harmed, the other is not affected
Parabiosis	Overall, Liaoning	Their developments depend on themselves separately and are independent to each other
Parasitism	Tianjin, Zhejiang, Shanghai	One part benefits, the other suffers
Negative symmetry symbiosis	None	All degenerate
Negative asymmetry symbiosis	Guangxi, Hainan	All suffer from competition for resources

Table 4 Coefficient of energy selection

Region	β_1	β_2	Option *a*	Option *b*
Tianjin	0.2369	0.0522	Tianjin, Shanghai Hebei, Liaoning Guangxi, Hainan Shandong, Zhejiang Fujian (marine) Guangdong (land) Jiangsu (marine)	Jiangsu (land) Fujian (land) Guangdong (marine)
Hebei	–0.5256	0.1197		
Liaoning	–0.0341	–0.0404		
Shanghai	0.1491	–1.2870		
Jiangsu	–0.8945	1.4686		
Zhejiang	0.6916	–0.5067		
Fujian	0.9063	1.0390		
Shandong	–0.0162	0.5599		
Guangdong	1.2766	0.1782		
Guangxi	0.1077	–0.0704		
Hainan	–0.6231	0.2446		

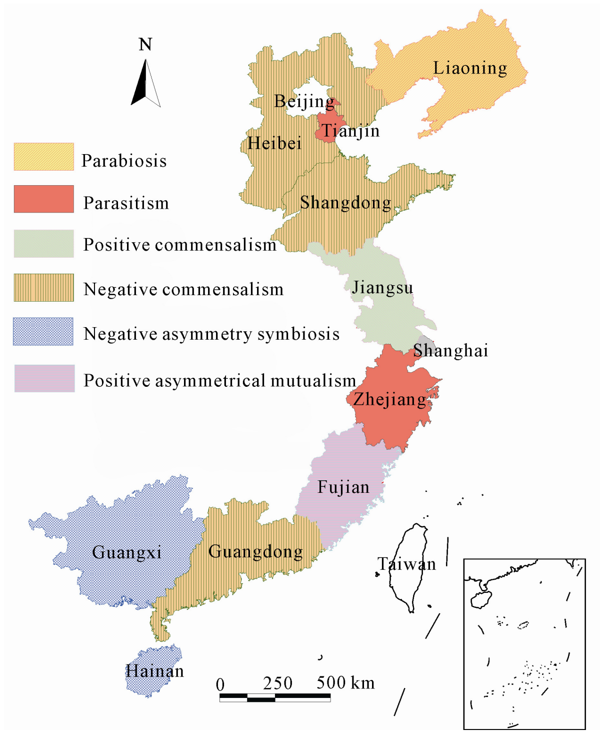

Fig. 4 Coastal provinces of land and marine economic development pattern classifications

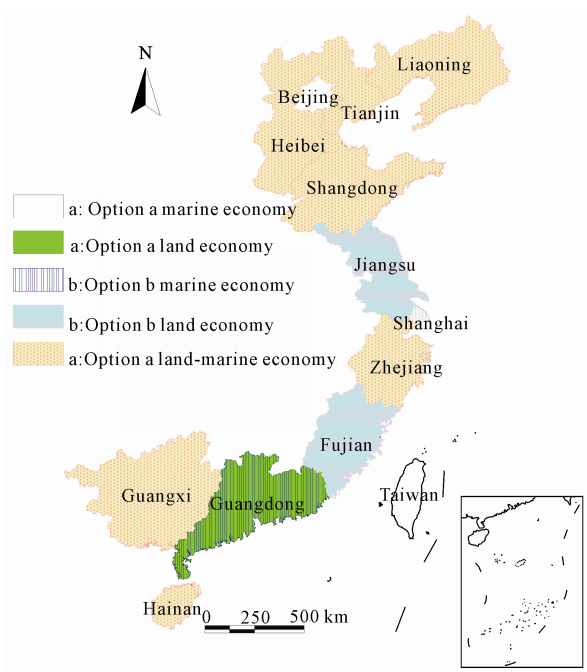

Fig. 5 Coastal provinces and cities' energy use coefficient of choice

5 Conclusions and Prospects

5.1 Conclusions

This study analyzes and explains the land-marine economic interaction and model of energy usage of 11 provinces along the coast of China from the perspective of the ecology population logistic growth equation. The fundamental conclusions are as follows:

(1) From the viewpoint of a symbiosis model, at present, the land-marine economic development of China's Fujian, Jiangsu, Hebei, Shandong, and Guangdong provinces follows symbiosis models. In Tianjin, Zhejiang, and Shanghai, the land-marine economic development follows a parasitism model. In Guangxi and Hainan, the land-marine economic development is a negative symbiosis model. In Liaoning, the land-marine economic development symbiotic coefficient is too small to make conclusions, and the land-marine economic growth is in parabiosis.

(2) From the perspective of the capacity of resources and the environment, the largest environmental capacity, k, of the marine economy in Shandong and Guangxi provinces is negative. The largest environmental capacity, k, of the land economy in Tianjin, Hebei, Zhejiang, Shandong, Guangdong, and Hainan is negative. When these provinces pursue economic development, the consumption and destruction of the natural resources exceeds the environmental carrying capacity threshold.

(3) With regards to the model of land-marine economic growth, the land economic development of Jiangsu and Fujian provinces and the marine economic development of the Guangdong province belong to option b, while the other provinces follow option a. Improving the coefficient of energy selection, β, transforming symbiotic energy option a to b, and raising the transformation rate of science and technology are important guarantees to realize the shift of symbiosis of the land-marine to the mutualism model.

5.2 Prospects

(1) The purpose of the coordination is to transform the symbiosis model of the land-marine economies in coastal areas from a parasitism model to a mutualism model. To achieve this transformation, we should increase the coefficient of energy selection, β, and improve the function of symbiotic units with symbiotic energy. This means transforming the model of economic development from extensity to intensity by improving the quality of production factors and improving its efficiency while reducing the symbiotic retardation. A management system adapting to the coordinated evolu-

tion of the land and marine economy can decrease the use of symbiotic energy, avoid 'system failure,' achieve 'system performance,' and the co-evolution of the land-marine economy orderly and cooperatively. In addition, improving the environmental carrying capacity, *k,* is essential. At present, China has not yet achieved the integrated protection of the marine and terrestrial environment. The coastal land and immediate offshore area are interdependent in the environment, and pollution can simultaneously affect the two. Protecting the marine environment to achieve integrated protection of the marine-terrestrial environment and improving the environmental carrying capacity is required. To improve the symbiotic relationship between the economy and the environment and realize a sustainable development of the economy, an innovative system of land-marine science and technology needs to be realized. The circular economy needs to be developed; the economic system needs to improve its function and form.

(2) As one of the core theories of population ecology, a logistic model can be used to predict the population growth through the behavior pattern "S" of population growth. However, due to the late start and short duration of the development of the marine economy in China, the symbiotic population is still in the initial stage, and the data is deficient, with not enough significance, scientific rigor, and accuracy of prediction. We do not predict the future population in this study.

(3) Provinces in China have different development status and different land-marine symbiosis scenarios; therefore, the processes to achieve the ultimate goal of land-marine symbiosis are different. Further study can build a land-marine symbiosis model with various stages, and perform quantitative research according to the symbiotic status in different provinces. This study examined the coordination of the land and marine economies universally based on the symbiosis theory, and future studies may carry out targeted research according to the specific situations of coastal provinces.

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