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Spatio-temporal Difference and Influencing Factors of Environmental Adaptability Measurement of Human-sea Economic System in Liaoning Coastal Area

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Abstract: Adaptability theory is an important tool to analyze the degree, mechanism and process of interaction between human and environment, which provides a new perspective for the research of sustainability assessment. Based on the entropy weight-TOPSIS method and the panel Tobit model from the perspective of adaptability, spatio-temporal difference and influencing factors of environmental adaptability assessment of human-sea economic system in Liaoning coastal area was measured by using the city panel data from 2000 to 2014. The results indicate that: 1) The environmental adaptability of human-sea economic system in Liaoning coastal area rose slowly from 2000 to 2014, the developing trend of each city was linearly related, and Dalian was in a leading position. 2) The different adaptability elements and adaptability subsystem show polarization phenomenon and completely different regional evolution characteristics. The adaptability of human-sea environment system and human-sea economic system rose slowly and had the characteristics of linear relationship, and the adaptability of human-sea environment system is the main reason for the difference of environmental adaptability of human-sea economic system. 3) Science and technology, environmental management, marine economic development level, port construction are the driving factors of the healthy development of environmental adaptability of urban human-sea economic system.

Keywords: human-sea economic system; adaptability; human-sea environment system; influencing factors; Liaoning coastal area

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1 Introduction

In recent years, the focus of global environment is changing, especially climate change research and ‘sustainable science’ have shifted to ‘adaptability’ and its related concepts ‘vulnerability, resilience’ and other directions (Gallopín, 2006; Smit and Wandel, 2006; Pelling et al., 2015). Adaptability research has got more and more attention from the 2001 IPCC to the 2013 IPCC fifth assessment presented a new awareness for adaptability definition (Cui et al., 2011). According to the SSCI data retrieval, the literature on adaptation topics showed an annual growth rate of about 350% from 2000 to 2015. At present, this concept which originated in the field of ecology is being applied to the economy, society, environment and other fields, while related disciplines in geography are also involved (Demetrius, 1977). And scholars are not satisfied with the traditional paradigm of adaptability, the research perspective gradually from macro to micro, such as water resources

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(Xia et al., 2015), architecture (Wang, 2014), catastrophe (Birkmann, 2011), Livelihoods (Li, 2016), industrial systems (Qiu et al., 2011), risk management (Liu et al., 2015) and other specific perspective enriched the problem of adaptability research. In terms of the connotation, the analysis frame, index system, research method and countermeasure of adaptability are from the scales of global, regional, local, community (Zhou et al., 2004; Yao et al., 2012; Zhou et al., 2015; Liu et al., 2016a) and the dimensions of economy, society and ecology, coupling system (Liu et al., 2013; Li et al., 2014; Peng et al., 2016). In 2013, the European Union introduced the 'EU Adaptation Climate Change Strategy', which applied adaptive mechanism to national social strategy and risk management. It shows that the application value of adaptability has risen to the height of national strategy (Alfieri et al., 2016).

Since the 21st century, China's marine economy with double-digit annual growth rate of rapid development. With the impact of human development on marine resources and the large-scale development of marine industry, the operation status of marine ecosystems is accelerating deteriorated and the physical, chemical environment and biological ecology of marine are generally changing. With the anthropogenic causes ocean disasters are increasing, the marine natural purifying capability and the balance capacity continue to decline, which shows a certain degree of sensitivity, vulnerability. Initially, adaptability is part of the framework of vulnerability theory, and the study on vulnerability of marine activities has yielded initial results. The study of the vulnerability of marine activities covers coastal states, coastal urban, coastal zones, offshore, marine protected areas, ports and other geographical space areas (Adrianto and Matsuda, 2002; Li, 2014; Button and Harvey, 2015). With the deepening of research, adaptability research is gradually separated from vulnerability framework, and gets more and more attention in the study of human-sea relations. Previously, there have been studies highlighting adaptability to natural systems, such as habitat suitability analysis of marine organism, adaptive management of marine disaster risk, construction of marine environmental adaptability evaluation index, assessment of socioeconomic efficiency marine resources development and utilization, and the adaptability analysis of marine engineering site selection (Birk and Rasmussen, 2014; Holbrook and Johnson, 2014; Mokrech et al., 2015; Chandra and Gaganis, 2016), but adaptability research of economic system is still rare. China's marine oil industry, marine biopharmaceutical industry, seawater chemical industry, marine energy use and marine space utilization and other marine emerging industries developed rapidly over the 21st century, in the realistic background that the risk is difficult to control and the human factors can be adjusted, coastal urban adaptability research should change from the perspective of natural adaptability evaluation to the impact of human economic activities on adaptability.

The human-sea economic system is an important part of the human-sea system. In the past, the study on human-sea economic system was focused on the perspective of vulnerability (Li, 2014), sustainable development (Sun et al., 2015) and coupling coordination (Gai et al., 2013), there were less researches on the adaptability. Based on the above understanding, environmental adaptability of human-sea economic system, namely is based on the status quo of supply and demand, technology, development and management of marine resources, under the premise of considering intergenerational development positioning the current marine economic functions, in order to seek a kind of internal and external elements between structure and function for the relative balance, reduce the sensitivity and maintain the stability, to ensure effective risk response and ultimately promote the sustainable development of the system. Therefore, this paper applies adaptability tools for marine urban, taking Liaoning coastal area as an example to analyze the present situation and influencing factors for environmental adaptability of human-sea economic system under different time and space scales. It is not only an exploration of adaptability microcosmic scale, but a new discussion on the theory and method of 'the mechanism of interaction among human and sea, economy and environment'.

2 Materials and Methods

2.1 Study area

Liaoning coastal area, including Dalian, Dandong, Jinzhou, Yingkou, Panjin, Huludao, which belongs to the Bohai rim region and the Northern Yellow Sea area. Moreover, it is a critical zone in Bohai rim region and Northeast Asia economic circle (Fig. 1). In 2015, the gross regional product of Liaoning coastal area accounted is 23.4% of the three northeastern provinces and became the hub for the opening up and economic development of the Northeast. Since 1980s, 'Marine Liaoning' and 'Development Planning of Liaoning Coastal Economic Belt' have been proposed, making the comprehensive development of marine economy in Liaoning Province. From 2005 to 2014, Liaoning's marine gross product maintained an average annual growth rate of 16%, higher than the national gross ocean product growth over the same period. But the marine ecological health problems have become increasingly prominent, coastal erosion and seawater intrusion are serious, Jinzhou bay marine ecosystems continued to be unhealthy state, land-based pollution into the sea and water pollution in coastal waters seriously, Liaoning coastal area of marine ecological civilization construction is very urgent.

2.2 Index system construction and data sources

To measure the environmental adaptability level of human-sea economic system, it is necessary to examine not only the adaptable development of human-sea economic system, but also the situation of human-sea environment system. The two systems are interrelated and constrained, which form different levels and different contents subsystems. Between them, the human-sea economic system is the main body of adaptation, the human-sea environment system is the object of adaptability, and the interactive stress process within and outside the system is adaptive behavior. The concreted manifestation is under the general goal of environmental adaptability of human-sea economic system, the system will make adaptive adjustment and choice in the process of interaction stress, such as sensitivity, stability and response. Thus, in order to evaluate environmental adaptability of human-sea economic system in an objective, comprehensive and scientific way, the environmental adaptability evaluation index system of human-sea economic system in Liaoning coastal area is constructed from three aspects of sensitivity, stability and response (Table 1). Where the first layer is overall goal: the environmental adaptability of human-sea economic system. The second layer is system layer, including the human-sea economic subsystem and the human-sea environment subsystem. The third layer is criterion layer, which includes three adaptive elements: sensitivity, stability and response. Sensitivity is inversely proportional to adaptability, it is an extent of

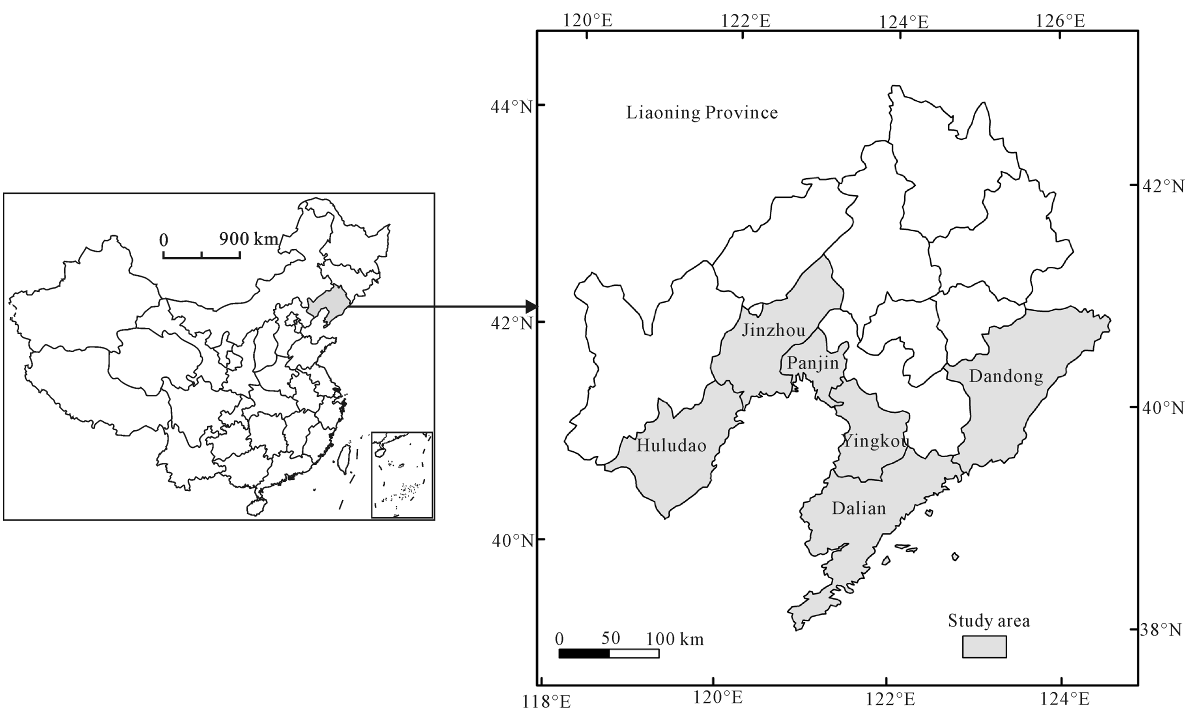

Fig. 1 Location of study area

Table 1 Environmental adaptability indicators of human-sea economic system in Liaoning coastal area

	System layer	Criteria layer (weight)	Index layer	Nature	Weight
Environmental adaptability of human-sea economic system	Human-sea economic system adaptability 0.519	Sensitivity 0.394	Marine industry location entropy X_1	(+)	0.020
			Coastline economic density X_2	(+)	0.019
			Fisheries Output Value X_3	(–)	0.013
			Number of berths at the coastal seaports X_4	(+)	0.043
			Foreign trade dependence degree X_5	(–)	0.025
			Tourism foreign exchange income accounted for the proportion of total tourism revenue X_6	(–)	0.013
			Population density X_7	(+)	0.041
		Stability 0.304	Marine Industrial Structure Conversion Rate X_8	(+)	0.025
			Non-fishing marine industry system structure conversion rate X_9	(+)	0.017
			Financial self-sufficiency rate X_{10}	(+)	0.029
			Market Structure Index X_{11}	(+)	0.025
			Total amount of deposits and loans of national banking system as percentage to GDP X_{12}	(+)	0.028
			Industrial Structure Advanced coefficient X_{13}	(+)	0.024
			tertiary industry industrialization coefficient X_{14}	(+)	0.027
			Port cargo throughput X_{15}	(+)	0.038
			Total investment in per capita fixed assets X_{16}	(+)	0.031
			Number of registered unemployed person in urban areas X_{17}	(–)	0.009
			Science and education investment accounted as percentage to fiscal expenditure X_{18}	(+)	0.023
			Per capita amount of foreign capital actually utilized X_{19}	(+)	0.030
			Students enrollment of regular institutions of higher education per 10000 persons X_{20}	(+)	0.038
			Number of beds of hospitals and health centers X_{21}	(+)	0.026
	Human-sea environment system adaptability 0.481	Sensitivity 0.393	Maricultural area per capita X_{22}	(+)	0.049
			Density of industrial wastewater discharged X_{23}	(–)	0.007
			Density of industrial SO^2 emission X_{24}	(–)	0.014
			Density of industrial solid waste produce X_{25}	(–)	0.011
		Stability 0.299	Environmental Quality Index X_{26}	(+)	0.020
			Per capita coastline length X_{27}	(+)	0.059
			Per capita public green area X_{28}	(+)	0.019
			Per capita mudflat area X_{29}	(+)	0.059
			Per capita sea area X_{30}	(+)	0.055
			Green covered area as percentage to completed area X_{31}	(+)	0.010
		Response 0.308	Environmental governance investment as percentage to GDP X_{32}	(+)	0.019
			Volume of common industrial solid wastes comprehensively utilized X_{33}	(+)	0.023
			Pollution treatment project in coastal regions X_{34}	(+)	0.022
			Number of marine-type nature reserves X_{35}	(+)	0.046
			Marine cities accept capacity for external assistance X_{36}	(+)	0.042

Notes: 1) in the table of the nature of the indicators '+''–'is determined relative to the system layer. 2) The index data of the market structure index, the industrial structure advanced coefficient and the industrial production coefficient of the tertiary industry are the cumulative data of the coastal city industry (the lack of pure marine data)

human-sea systems in coastal area which perceives the external environment changes, including marine industrial agglomeration level, marine economic potential development, fisheries development status, port construction, international exchange, population bearing and other economic indicators, marine biological resources and marine pollution status and other environmental indicators. Stability is the ability to absorb interference and maintain the original state when the environment development of the coastal urban system changes, the stability is closely related to the regional system supply ability, and the stability is positively proportional to the adaptability. Specifically, it includes economic indicators such as marine industry quality, financial support, the marine market, monetary situation and industrial structure, environment indicators such as marine environment status and the space resources status. Response is the adaptation and feedback action formed in the face of internal and external environment changes of the system, it characterizes the processing interference and self-organization update ability of the system, and more emphasis on describing the sustainability of future development, the stronger the responsiveness of the system is, the stronger the adaptability will be (Guo et al., 2016). Meanwhile, it includes economic response indicators such as ports, funds, talents, science and technology education and infrastructure, environmental response indicators such as pollution control, protection, investment and policy control. Specific selection of the 36 indicators involved in the study. Statistical data were predominantly obtained from the China Ocean Statistical Yearbook (State Oceanic Administration, 2001–2015), the China City Statistical Yearbook (National Bureau of Statistics, 2001–2016), the China Statistical Yearbook for Regional Economics (National Bureau of Statistics, 2001–2015), the Liaoning Statistical Yearbook (Liaoning Provincial Bureau of Statistics, 2001–2015) and other statistical bulletin.

Among them, X_1 is the proportion of the each region's gross ocean product in all region's gross ocean product/proportion of the regional GDP in all region's GDP;

$X_8=\sqrt{\sum_{i=1}^{n}\frac{(N_i-G)\times K}{G}}$, N_i and G are the average annual growth rates of Gross Ocean Product and Regional GDP, respectively. K is the Gross Ocean Product/Regional GDP; Similarly, N_i and G in X_9 are the average annual growth rates of marine industry values (except Marine Fishery Industry) and Gross Ocean Product, respectively, K is the marine industry values (except Marine Fishery Industry) /Regional Gross Ocean Product;

X_{11}: Gross Industrial Output Value/Number of Industrial Enterprises;

X_{13}: Total Number of Person Employed in Information Transmission, Computer Services, and Software, Traffic, Transport, storage and Post/Total Number of Person manufacturing and mining ;

X_{14}: Proportion of the Tertiary Industry practitioners × Tertiary Industry as Percentage to GDP;

$X_{26}=\sqrt[2]{D\times R\times E}$ where: D, R, E, respectively, said the Ratio of Industrial Solid Waste Utilized, Ratio of Waste Water and Consumption Wastes Treated;

X_{36} according the state and the province to the each coastal city's attention for qualitative assessment, on the national pilot cities, provincial key cities, general cities, were given 3, 2, 1 score, approximately reflects the marine cities acceptant capacity for external assistance (Qiu et al., 2011).

2.3 Entropy weight-TOPSIS

The Entropy weight-TOPSIS method is a combination of the entropy weight method and 'the technique for order preference by similarity to an ideal solution, TOPSIS'. TOPSIS method is a comprehensive evaluation method which can be used to compare and select according to multiple schemes and indexes. The Entropy weight-TOPSIS is an improvement for the traditional TOPSIS method, traditional TOPSIS weight mainly uses the analytic hierarchy process and the Delphy method with certain subjectivity, Entropy weight-TOPSIS can effectively compensate the defects of subjectivity and arbitrariness, and reflect the indicator information (Du et al., 2014; Liu et al., 2016b; Song et al., 2017). Based on the entropy weight-TOPSIS, the basic steps of environmental adaptability evaluation method of human-sea economic system in Liaoning coastal area are as follows:

(1) Standardization of original data. Using the maximum difference normalization method to deal with the original data, for the nature of the indicators '+' and '–' are calculated as follows:

$$r_{ij}=\frac{v_{ij}-\min(v_{ij})}{\max(v_{ij})-\min(v_{ij})};\quad r_{ij}=\frac{\max(v_{ij})-v_{ij}}{\max(v_{ij})-\min(v_{ij})} \quad (1)$$

where v_{ij} is the initial value of the i-th index in year j; r_{ij} is the i-th index in j-th year normalized value; i = 1, 2,…, m, m is the number of evaluation indexes; j = 1, 2,…, n, n is the number of years evaluated.

(2) Determining of entropy weight.

$$w_i = (1 - H_i) \Big/ \left(m - \sum_{i=1}^{m} H_i \right) \tag{2}$$

where the information entropy $H_i = -1 \Big/ \ln n \sum_{j=1}^{n} f_{ij} \ln f_{ij}$; the specific gravity of the index $f_{ij} = r_{ij} \Big/ \sum_{j=1}^{n} r_{ij}$.

(3) Build the evaluation matrix. Using entropy weight w_i construct the weighting to normalize evaluation matrix Y, the concrete formula is:

$$Y = (y_{ij})_{m \times n} \quad y_{ij} = r_{mn} \times w_n \tag{3}$$

(4) Determine the positive ideal solution Y^+ and negative ideal solution Y^- is shown in the Formula (4). The positive ideal solution is the maximum value of the i-th index in j-years, the negative ideal solution is the minimum value of the i-th index in j-years in the evaluation data.

$$Y^+ = \left\{ \max_{1 \le i \le m} y_{ij} \middle| i = 1, 2, ..., m \right\} = \left\{ y_1^+, y_2^+, ..., y_m^+ \right\};$$

$$Y^- = \left\{ \min_{1 \le i \le m} y_{ij} \middle| i = 1, 2, ..., m \right\} = \left\{ y_1^-, y_2^-, ..., y_m^- \right\} \tag{4}$$

(5) Calculate the distance of positive and negative ideal solution. The calculation method is shown in the formula (5).

$$D_j^+ = \sqrt{\sum_{i=1}^{m} \left(y_i^+ - y_{ij} \right)^2}\ ; \quad D_j^- = \sqrt{\sum_{i=1}^{m} \left(y_j^- - y_{ij} \right)^2} \tag{5}$$

(6) Determining of the ideal proximity. Let T_j be the ideal proximity degree for the j-year adaptability elements, three dimensions of sensitivity, stability and response to determining the ideal proximity. The larger the T_j, the closer the criterion layer index is to the optimal level, calculation method see the Formula (6).

$$T_j = D_j^- \Big/ \left(D_j^+ + D_j^- \right) \tag{6}$$

(7) Calculation of adaptability score. The weight values of the system layer and the criterion layer are weighted by the mean square error (Qiu et al., 2011). The environmental adaptability scores of human-sea economic system and system layer scores are obtained by means of weighted summation method (Table 2).

2.4 Panel Tobit model

The environmental adaptability index of human-sea economic system in Liaoning coastal area is censored data, which as the dependent variable of regression equation is limited to the range from 0 to 1, if the direct use of ordinary least squares, the estimated parameters will prone to bias, while the panel Tobit model is just dealing with cases where the dependent variable of the regression model is limited. Therefore, the panel Tobit model is used to analyze the factors that may affect the environmental adaptability of human-sea economic system (Guo and Wang, 2015; Kong, 2016; Song et al., 2017). Explanatory variables select marine industry location entropy (X_1)to characterize marine economic development level, foreign trade dependence degree (X_2) characterization of marine industry opening up level, science and education investment accounted as percent-

Table 2 Environmental adaptability degree of human-sea economic system in Liaoning coastal area

Region	Sensitivity				stability				response				adaptability				Environmental adaptability of human-sea economic system	
	Human-sea economic system		Human-sea environment system		Human-sea economic system		Human-sea environment system		Human-sea economic system		Human-sea environment system		Human-sea economic system		Human-sea environment system			
	2000	2014	2000	2014	2000	2014	2000	2014	2000	2014	2000	2014	2000	2014	2000	2014	2000	2014
Dalian	0.483	0.668	0.554	0.939	0.479	0.546	0.632	0.632	0.264	0.890	0.771	0.706	0.416	0.698	0.644	0.776	0.525	0.735
Dandong	0.244	0.372	0.383	0.636	0.407	0.539	0.157	0.220	0.163	0.319	0.280	0.480	0.269	0.407	0.284	0.464	0.276	0.434
Jinzhou	0.385	0.389	0.219	0.266	0.478	0.609	0.058	0.157	0.141	0.363	0.269	0.487	0.340	0.448	0.187	0.301	0.266	0.378
Yingkou	0.477	0.559	0.261	0.293	0.483	0.526	0.077	0.172	0.145	0.419	0.454	0.478	0.379	0.506	0.266	0.314	0.324	0.414
Panjin	0.389	0.414	0.260	0.145	0.280	0.498	0.468	0.469	0.150	0.302	0.227	0.548	0.284	0.406	0.312	0.366	0.297	0.387
Huludao	0.357	0.403	0.272	0.269	0.392	0.548	0.154	0.198	0.108	0.243	0.191	0.489	0.292	0.399	0.212	0.315	0.254	0.359
Average	0.389	0.468	0.325	0.425	0.420	0.544	0.258	0.308	0.162	0.423	0.365	0.531	0.330	0.477	0.318	0.423	0.324	0.451

age to fiscal expenditure (X_3) characterization of science and technology factors, port cargo throughput (X_4) to characterize the level of port construction, industrial structure advanced coefficient (X_5) characterization of marine industrial structure, ratio of industrial solid waste utilized (X_6) characterization of environmental management. Set panel data regression model:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon$$

where Y represents the environmental adaptability of human-sea economic system. X represents the vector of environmental adaptability influencing factors of human-sea economic system. $\beta_0, \beta_1, \ldots, \beta_6$ means that each variable regression coefficient. ε refers to the error term.

3 Results and Discussion

3.1 Sensitivity of environmental adaptability of human-sea economic system

On time scales, the sensitivity index of human-sea economic system in Liaoning coastal area is relatively stable (Table 2 and Fig. 2a). As the sensitivity is a negative indicator, the smaller the index is, the more sensitive of the system, the worse the adaptability. Indicating that Liaoning coastal cities remain sensitivity does not rise when response to various economic pressures and risks. On spatial scales, the variation coefficient of sensitivity is 0.251, and the sensitivity index distribution of regional human-sea economic system is relatively concentrated, but insignificant changes. Dalian human-sea economic system sensitivity index is significantly higher than other regions and increase largest, with the construction of Dalian's port area, the influx of floating population and the rapid development of marine economy have stabilized the human-sea economic system. At the same time, it reduces influence on economic change and coercion.

On time scales, sensitivity index of human-sea environment in Liaoning coastal area is a whole and slight upward trend (Table 2 and Fig. 2b), indicating that human-sea environment system is a whole running in good condition, affected by changes in the environment weakened. On spatial scales, the sensitivity index distribution is scattered and its coefficient of variation is 0.581, indicating that the regional difference is large. Dalian, the highest sensitivity index, followed by Dandong, the two gradually developed to a good direction, mainly due to its industrial wastewater, industrial sulfur dioxide and industrial solid waste emissions have been effectively controlled, marine biological resources and marine natural regeneration capacity crescendo. The sensitivity index of the sea environment system for Huludao, Jinzhou, Panjin and Yingkou are obviously low and declining continuously, which indicates that these marine cities are more sensitive to the human-sea environment system, because the extensive economic development led to increased environmental pollution, so that the response to changes in the environment and disturbance capacity deterioration, the lack of ecological risk perception.

3.2 Stability of environmental adaptability of human-sea economic system

On time scales, the stability of human-sea economic system in Liaoning coastal area decreased first and then increased during 15 years, showing 'V' type change characteristics (Table 2 and Fig. 2c). The main reason is that the transformation of economic development model, Liaoning Province has been China's heavy industrial areas, high factor of production inputs, and high consumption of traditional industries exposed more and more problems. After the 2008 global economic crisis and the implementation of various of national revitalization and development strategies in 2009, these contradictions ease, the economic development model tends to green, recycling, low-carbon, financial and other supporting value-added services increased, the development of marine economy was put on the agenda as a new economic growth pole. On spatial scales, the coefficient of variation of stability of human-sea economic system in Liaoning coastal area is 0.145, the regional difference is relatively small, and the stability of human-sea economic system in each coastal city shows certain similarity characteristics.

On time scales, the stability trend of human-sea environment system in Liaoning coastal area is not obvious, and the steady state is maintained (Table 2 and Fig. 2d). On spatial scales, the variation coefficient of stability of human-sea environment is 0.710, and the regional difference is significant. Dalian and Panjin have high stability, and some extent shows that the ecological background conditions of high quality, which can be developed offshore space resources are abundant. Huludao, Jinzhou, Yingkou, Dandong stability is poor, mean stability of Dalian were 3.5 times, 6.5 times, 4.9

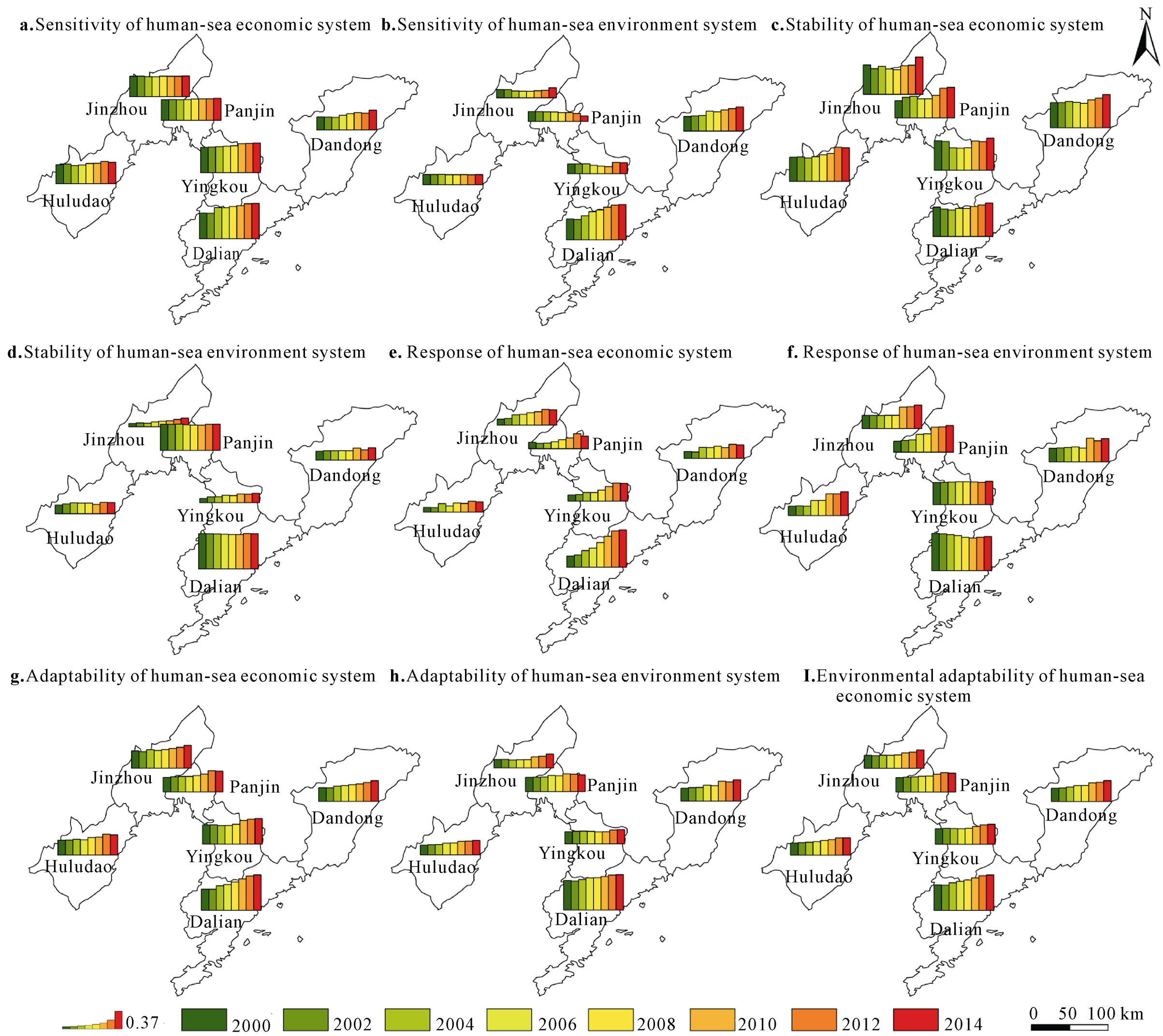

Fig. 2 Spatio-temporal difference of environmental adaptability measurement of human-sea economic system in Liaoning coastal area from 2000 to 2014

times and 3.5 times of these cities. Such urban per capita possession of the coastline and offshore beach and other marine space resources are relatively low, the ecological supply of human-sea environment system is fatigue, and environment quality has yet to be repaired.

3.3 Response of environmental adaptability of human-sea economic system

On time scales, the response of human-sea economic system in Liaoning coastal areas was positively developed, and the response index increased significantly (Table 2 and Fig. 2e). On spatial scales, the regional response is quite different, and the coefficient of variation is 0.574. Dalian's human-sea economic system has the strongest response ability, and its development speed is faster than other regions. It shows that Dalian has a significant effect in the construction of port area, investment pulling, science and technology resource allocation, perfect the basic public service functions and other aspects of the effect is significant. There is no significant difference in the response capacity of other areas except Dalian, so the responsiveness of each region is slow, and the port, capital and talent driving path is the area of its human-sea economic system to enhance the path.

On time scales, the response index of human-sea environment system in Liaoning coastal areas increased at a rate slower than that of human-sea economic system (Table 2 and Fig. 2f). On spatial scales, the variation coefficient of response is 0.377, which indicates that the regional difference of response for human-sea environment system in Liaoning coastal area is relatively moderate. Although the response of Dalian human-sea environment system is the best, its declining trend is obvious. Yingkou human-sea environment system response is medium, and there is no obvious ups and downs. The human-sea environment system response capacity of Panjin, Dandong, Jinzhou, and Huludao is low but shows an upward trend, indicating the marine ecological civilization construction has achieved initial results. The future should keep respond to national policies, strengthen the reform of marine ecological supply side, improve government participation, ban red line, the establishment and delineation of marine nature reserves, to ensure marine ecosystems recuperate, and curb ecological environment of malignant development, improve human-sea environment system to address the current or potential ecological risk adjustment and recovery capacity.

3.4 Adaptability of human-sea economic system and human-sea environment system

From the regional difference, the adaptability coefficient of variation of human-sea economic system in Liaoning coastal area is 0.248, showing a small regional difference and can be obviously divided into two gradients of Dalian and other marine cities (Table 2 and Fig. 2g). The adaptability coefficient of variation of human-sea environment system in Liaoning coastal area is 0.466, and the regional difference is obvious, and presented Dalian as the growth pole polarized growth pattern. The improvement of the adaptability of human-sea environment system plays an even more important role in eliminating the polarization of environmental adaptability of human-sea economic system (Fig. 2h).

On the whole, the adaptability of human-sea economic system and human-sea environment system is increasing slowly, and the two trends are consistent and linearly related. The adaptability of human-sea economic system of Liaoning coastal cities is more coordinated with the adaptability development of the human-sea environment system, and there is no prominent comparative advantage system. In the future, we should proceed from the different adaptability weak elements, classification and then specifically adjust the 'not adaptability' in the working process of human-sea economic system and human-sea environment system.

3.5 Environmental adaptability measurement of human-sea economic system

The environmental adaptability of human-sea economic system in all the city of Liaoning coastal area improve slowly between 2000 and 2014 (Table 2 and Fig. 2i), and the urban development trend of each city is linearly related, which indicating that the coastal urban linkage development. The variation coefficient of adaptability is 0.328, which indicates that the regional difference of environmental adaptability of human-sea economic system in Liaoning coastal area is relatively moderate. The environmental adaptability of human-sea economic system is ranked as follows: Dalian, Yingkou, Dandong, Panjin, Huludao and Jinzhou, the average of its 15 years were 0.622, 0.349, 0.340 0.339, 0.300 and 0.295. The environmental adaptability of human-sea economic system in Dalian is much higher than that of other Liaoning coastal cities, and the gap of adaptability is increasing gradually, and present Dalian polarized growth situation. The environmental adaptability of human-sea economic system in Yingkou, Dandong, Panjin, Huludao and Jinzhou is generally low, and the regional gap is not significant. The future to strengthen the radiation and service functions of Dalian, while the differentiated development and dislocation competition is to improve the Liaoning coastal area human-sea economic system of environmental adaptability drive path.

3.6 Analysis on the influencing factors of environmental adaptability of human-sea economic system

Using the Stata 12.0 software to run the panel Tobit model and analyze the factors may affect the environmental adaptability of human-sea economic system (Table 3).

(1) The model estimates show that the industrial structure has not passed the 1% significance test, and the industrial structure has no obvious correlation with the environmental adaptability of human-sea economic system. In the Liaoning coastal area, the industrial structure is irrational and the effect of transformation and upgrading is not obvious. Under the pressure of overcapacity, economic development still relies on traditional industries, and industry structure there is a certain time lag in the range of marine areas. So the future should do a good job of marine economic development model of the addition and subtraction, give full play to the advantages of marine emerging industries.

Table 3 Influencing factors of environmental adaptability of human-sea economic system in Liaoning coastal area

Explain variables	Coefficient estimate	Standard Error	*Z*-statistics	Probability
X_1	0.0416713	0.0085064	4.90	0.000
X_2	–0.0951197	0.0261482	–3.64	0.000
X_3	0.2950588	0.0703388	4.19	0.000
X_4	0.0403096	0.0039764	10.14	0.000
X_5	0.032412	0.0459004	0.71	0.480
X_6	0.0931697	0.0179728	5.18	0.000
Constant term	0.2004943	0.0497018	4.03	0.000

(2) Science and technology, environmental management, marine economic development level and port construction have a positive effect on environmental adaptability of human-sea economic system in Liaoning coastal area. The role of scientific and technological factors strength up to 0.295, and plays a leading role in the environmental adaptability of human-sea economic system. Liaoning coastal city science and education investment accounted for the proportion of fiscal expenditure increased from 7.576% in 2000 to 12.635% in 2014, the gradual increase of government's investment in marine science and technology is of great significance to cut excessive industrial capacity, adjust the industrial structure, strengthen the marine products. Environment management efforts for each increase of 1 unit, the human-sea economic system to improve the environmental adaptability of 0.093, should continue to adhere to the marine environment management drive path, enhance the system risk resistance, carry out marine economic activities within the threshold of benign development of marine ecosystems. The regression results show that the level of marine economic development for each increase of 1 unit, the human-sea economic system to improve the environmental adaptability of 0.042 units. The degree of specialization of the marine economy and the status and role of the marine economy in the region can obtain more development opportunities and act directly on the environmental adaptability of human-sea economic system. Port construction level of the role of strength 0.403, second only to the level of marine economic development, Liaoning Province has Dalian port and Yingkou port two throughput of over 100 million tons of big port, more than 10 000 t of production berths 197, Liaoning coastal area is optimizing the layout of the port construction, better grasp the port resources to adapt to opportunities.

(3) The level of opening to the outside world of marine industry has a negative effect on the environmental adaptability of human-sea economic system in Liaoning coastal area. Although opening up will increase the coastal city trade port increase and the large inflow of technical funds, but the effect of opening up is not obvious, it brought about the increase in the dependence on foreign investment, foreign trade and tourism foreign exchange, weak foreign exports, as well as shoreline and coastal tide even other pollution and damage, making human-sea economic system exposed to risk and stress, is not conducive for the adaptability's healthy development.

4 Conclusions

Based on the perspective of adaptability, this paper constructed the environmental adaptability system index of human-sea economic system with the human-sea economic system and human-sea environment system in Liaoning coastal area as the object of evaluation. Using the entropy weight TOPSIS method to analyze spatio-temporal difference for environmental adaptability measurement of human-sea economic system in Liaoning coastal area. The panel Tobit model is used to analyze the influencing factors for environmental adaptability of human-sea economic system in Liaoning coastal area. The following conclusions are reached:

(1) The environmental adaptability of human-sea economic system in Liaoning coastal area is slowly increasing, and the adaptability of cities is linearly related. The environmental adaptability ranking of human-sea economic system is Dalian, Yingkou, Dandong, Panjin, Huludao and Jinzhou. Liaoning coastal cities as a whole show the situation of Dalian as a single growth pole.

(2) The different adaptability elements and adaptability subsystem show polarization phenomenon and completely different regional evolution characteristics. From

the point of view of adaptability elements, the spatio-temporal difference of urban sensitivities and stability in the human-sea environment system are significant, and the spatio-temporal difference of urban response in human-sea economic system are significant, it is necessary to improve the adaptability spatial relationship from the weak elements of each system. From the subsystems point of view, the adaptability trend of human-sea economic system and human-sea environment system show a relatively consistent and slowly upward trend, and the regional difference of human-sea environment system is larger than human-sea economic system, which is the main reason for the formation of adaptability difference. The future can be based on adaptability elements and adaptability subsystem to develop adaptability risk planning, from the point and surface to promote the environmental adaptability spiral evolution of human-sea economic system.

(3) From the influencing factors, the effect of industrial structure on the environmental adaptability of human-sea economic system is not significant. The effects of opening to the outside world for marine industry on the environmental adaptability of human-sea economic system are negative. Scientific and technological factors, environmental management, marine economic development level, port construction level from strong to weak have a positive impact on environmental adaptability of urban human-sea economic system. The results can be used as basis of adaptive response measures for the future development.

The panel Tobit model was first applied to adaptability study, which enriched adaptability influencing factors measure method. We tried to introduce adaptability to the study of human-sea economic system, solve economic and environment problems of ocean development, and provide a new research paradigm for the sustainable development of land-sea coordination. However, there are some shortcomings in this paper, with the lack of urban data on municipal level, we use urban statistics instead pure ocean data will give the evaluation results some deviation. Based on the theory of adaptability of human-sea economic system development process and mechanism research is still in the initial stage, there are some difficulties in the study. Thus, the summarize the selection model of environmental adaptability of human-sea economic system, its future scenario summarize of different adaptability goals and optimize the adaptability early warning mechanism should be investigated in future works.

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