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Spatiotemporal coupling coordination measurement on islands' economy-environment-tourism system

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ABSTRACT

Regional economy-environment-tourism is an open system with complex structure and coupling characteristics. Tourism is the key link among the three subsystems for coordinating the regional economy and ecological environment. The analysis of the coupling coordination relationship among the three subsystems in islands is of great significance for promoting the sustainable development of the regional island tourism. This paper proposes a conceptual index system using entropy weight method and coupling coordination degree model for analysis of the coupling coordination relationship among the regional economy, ecological environment and island tourism. After that, the paper introduces an obstacle degree model to identify the obstacle factors of coordinated development in each island district. This framework is applied to eleven island districts in eastern China's Zhejiang Province during 2008–2018. The results show that the temporal changes of the coupling coordination relationship among economy, environment and tourism in eleven island districts are quite satisfactory, while the regional differences are large. Although the obstacle factors of coordinated development in each district are distinct, most of them tend to be environmental subsystem. Based on the results of analysis, this paper finally puts forward several policy recommendations to provide a referential path for the sustainable development of island tourism.

1. Introduction

It is widely recognized that coastal zones are one of the regions with the fastest-growing speed in tourism around the world (Hall, 2001; Orams and Michael, 2014; Papageorgiou, 2016). In particular, island tourism which is one important part develops rapidly and even becomes a pillar industry in many island regions (Dodds and Graci, 2010). According to the *World Island Tourism Development Report (2019)*, about 40% of the world's island tourism destinations contributed more than 20% of tourism income to their GDP, and the world's island tourism export reached USD 61 billion. Tourism will be gradually more beneficial to the economics of island regions. Some negative effects however will also be posed to the local ecological environment (Momir, 2017; Khalil et al., 2012). Due to the fragility of the island ecosystem, tourism exploitation may cause irreparable harm to the natural environment, especially to coastlines, soils (Pagán et al., 2017), water and atmosphere (Nitivattananon and Srinonil, 2019; Norgaard, 1990). This will further influence the biodiversity of islands. If the environmental degradation exceeds the threshold, the cost of economic and environmental sustainability will significantly increase (Asongu et al., 2020). In such a case, the goal of long-term development of tourism in island regions may be restricted. It is thus essential to coordinate the relationship among the regional economic development, ecological environment protection and tourism resources exploitation for promoting the sustainable development of tourism in island regions (Zhang and Li, 2020).

Regional economy-environment-tourism is an open giant system with broad connotation, complex structures, and coupling characteristics (Liu and Yang, 2011; Zhou et al., 2016). Various theories and models are employed by researches to analyze the relationship between economy and ecology, such as environmental Kuznets curve (EKC) (Dinda, 2004; Stern, 2004), coordinated development theory (Norgaard, 1990), economic-energy-environmental impact model (Oliveira and Antunes, 2011) and coupling model (Jia et al., 2008). With the increasing popularity of tourism, the relationship between tourism and economic development has been extensively studied (Oh, 2005; Tang and Tan, 2015; Antonakakis et al., 2017), and for the relationship with the eco-environment (Buckley, 2011; Ying, 2015; Ahmad et al., 2019), as well as the interactive relationship among the economy, environment

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and tourism (Petrosillo et al., 2006; Wei et al., 2013; Lu et al., 2018).

By considering the heterogeneous country effect, Wall and Wright (1997) first discussed the concept of tourism impact on the environment and analyzed their relationship. After that, they further investigate the mechanism behind the interaction between tourism activities and environmental factors. Lacitignola et al. (2007) took the tourist resorts as socio-ecological systems and constructed a model to analyze the relationship between their environmental quality and economic society. Lee and Chang (2008) confirmed that there is a cointegrated relationship between GDP and tourism development on the global scale. Wu et al. (2018) explored the causal relationship between the income from international tourism and economic growth in 11 eastern provinces of China. Gssling and Peeters (2015) assessed the global environmental impact by tourism during 1900–2050, which indicates that the global tourism system is becoming increasingly vulnerable to disruptions of resource flows. Overall, the economy, eco-environment and tourism are interdependent (Tao et al., 2017). Due to the strong economic driving force in tourism (Qian et al., 2012; Pons et al., 2014) and slight direct pollution (Tang, 2015), it works as a key link among these three elements for coordinating the regional economy and ecological environment.

The definition of coupling originated in physics and was applied to social economics afterwards (Song et al., 2012), which is used to describe the intensity of interactions between two or multiple systems. The coupling coordination degree model (CCDM) is a tool based on the coupling degree to reflect the intensity of cooperative development and has been widely used in empirical applications (Zhang and Mo, 2014; Sun and Cui, 2018; Lou et al., 2021). Considering the coupling relationship among the regional economy, ecological environment and tourism industry, the coordination of these three subsystems was investigated in recent years. Zhou et al. (2016) analyzed the coordinated development of the economy, eco-environment and tourism industry for 11 provinces in the Yangtze River Economic Belt during 2002–2013. Lai et al. (2020) measured the coupling degree and coordination degree of these three subsystems of 31 provinces in China during 2003–2017. These studies demonstrate the importance of the coupling and coordinated development of the economy, eco-environment and tourism industry, but very few of them have focused on the islands' sustainability. Moreover, most of the studies only showed the temporal or spatial variation of coupling coordination degree while lacking of obstacle factors finding in the coordination of the three subsystems, resulting in practical advices absent in decision making level.

Based on the previous studies and the characteristics of islands, this paper proposes a conceptual index system of the regional economy, ecological environment and island tourism. The entropy weight method (EWM) and the coupling coordination degree model (CCDM) are employed to analyze the coupling coordination relationship among the three subsystems in eleven island districts of Zhejiang, China. Then the obstacle degree model (ODM) is introduced to identify the obstacle factors of coordinated development. After that, appropriate management recommendations are put forward to facilitate the sustainable development of island tourism in Zhejiang Province.

2. Materials and methods

2.1. Study area

Zhejiang Province is located on the southeastern coast of China, and the southern part of the Yangtze River Delta, as well as the edge of the East China Sea. The sea area of Zhejiang Province reaches 260,000 km^2. In its local sea, 4350 islands accounting for 40% numbers of China are distributed with various sizes across the offshore lines of Zhoushan, Ningbo, Taizhou and Wenzhou. On account of the abundant island natural resources, island tourism including natural sightseeing, recreational fishery, historical and cultural education are well developed in Zhejiang Province. From the official tourism data, the Zhejiang island region received nearly 100 million tourists in 2018, and the total income of island tourism exceeded 150 billion yuan.

In August 2019 , *Construction Planning of Island Garden in Zhejiang Province (2019–2025)* issued five major tasks: "ecological island", "tourism island", "green island", "facilities island" and "innovative island". In particular, the "tourism island" action is focused on the construction of international island tourist regions. Presently, as given in Fig. 1, twelve major planned island parks are distributed in eleven districts including Putuo, Dinghai, Daishan, Shengsi, Xiangshan, Sanmen, Linghai, Jiaojiang, Yuhuan, Dongtou and Pingyang. The "ecological island" and "green island" are committed to enhancing the protection level of island resources and providing a healthy ecological environment for the island parks. The "facilities island" and "innovative island" concentrate on the connection of island facilities and the mechanism of innovation, that provide a strong support for the construction of island parks in the province. Overall, "tourism island" is the key object of planning in the five major actions, and the remaining four actions are all conductive to the development "tourism island".

2.2. Index system and data source

Following the principles of data availability, index representativeness, system correlation, and referring to relevant research results ((Lai et al., 2020; Zhou et al., 2016), we set up a conceptual index system for the coupling coordination analysis of three subsystems including economy, environment and tourism (Table 1). From the six dimensions of economic development scale, social and economic construction, environmental pollution status, environmental management effectiveness, tourism market scale and tourism structure elements, a total of twenty-four indicators are selected. Among them, the total amount of industrial wastewater discharge, total industrial waste gas emission and industrial solid waste production are negative indicators.

The data used mainly comes from statistical bulletins for national economy and social development (2008–2018) of the eleven districts and the local statistical yearbook, Zhoushan Statistical Yearbook, Ningbo Statistical Yearbook, Taizhou Statistical Yearbook, Wenzhou Statistical Yearbook and Zhejiang tourism Yearbook, etc. Additionally, we consult the relevant departments through telephone for data which cannot be accessed from yearbooks or communiques. The average method to interpolate is also used to calculate the missing data.

2.3. Standardization and weighting

The EWM is used to determine the weight of each indicator through information entropy, and provides a basis for the comprehensive evaluation of multiple indicators (Mon, 1995; Chen, 2010). The indicators' weights and the three subsystem indices (i.e., economy index, environment index and tourism index) are calculated as follows.

Step1 Establish an evaluation initial matrix based on entropy method $(x_{ij})_{m\times n}$.

Due to the different dimensions of each index, the initial matrix need to be standardized.

For positive indicators: $$y_{ij}=\frac{x_{ij}-x_{jmin}}{x_{jmax}-x_{jmin}} \quad (1)$$

For negative indicators: $$y_{ij}=\frac{x_{jmax}-x_{ij}}{x_{jmax}-x_{jmin}} \quad (2)$$

Step2 Get the normalization matrix $(Y_{ij})_{m\times n}$.

Define the standardized formula: $$Y_{ij}=\frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}} \quad (3)$$

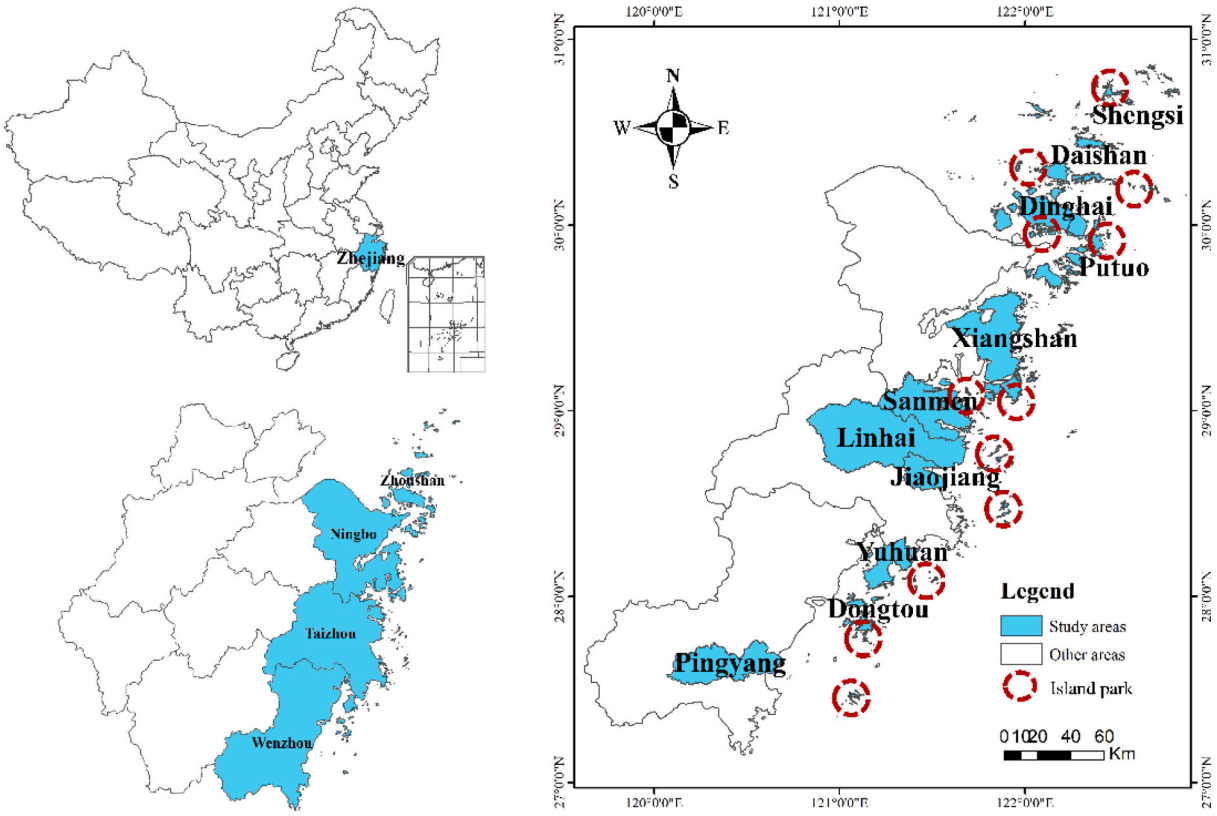

Fig. 1. Distribution map of eleven island districts in Zhejiang Province.

Step3 Calculate the information entropy of item j:

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m} Y_{ij} \ln Y_{ij} \tag{4}$$

and information utility value:$d_j = 1 - e_j$. (5).

Step4 Calculate the weights of item j:

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j}. \tag{6}$$

Finally, calculate the indices of three subsystems in 2008–2018 years:

$$S_i = \sum W_j y_{ij}, (S_i = Ec_i,\ En_i,\ Tm_i) \tag{7}$$

where Ec_i means the economy index; En_i means the environment index; Tm_i means the tourism index.

2.4. Coupling coordination degree model

The CCDM is used to analyze the coupling coordination relationship among the three subsystems and the formulas are given as follows.

$$D_i = \sqrt{C_i \times T_i} \tag{8}$$

$$C_i = \left\{ \frac{Ec_i \times En_i \times Tm_i}{[(Ec_i + En_i + Tm_i)/3]^3} \right\}^{1/3} \tag{9}$$

$$T_i = \alpha Ec_i + \beta En_i + \gamma Tm_i \tag{10}$$

where D_i represents the coupling coordination degree, $D_i \in [0,1]$; C_i denotes the coupling degree, $C_i \in [0,1]$; T_i represents the integrated development index of the three subsystems of economy, environment and tourism; Ec_i、En_i、Tm_i denote the economy, environment and tourism index respectively, while α、β、γ represent their contribution. In this study, it is assumed that $\alpha = 0.4, \beta = 0.4, \gamma = 0.2$ considering that tourism industry is an important component of regional economic activities (Zhong and Liu, 2012; Dang et al., 2015).

According to the distribution function (Liao, 1996), the criteria for classifying the coupling coordination level are determined as given in Table 2.

2.5. Obstacle factors identification

In order to comprehensively enhance the sustainable development of island tourism in Zhejiang, we make a detailed analysis of obstacle factors of coordination among the three subsystems in each district. The obstacle degree model (ODM) proposed by Lei et al. (2016) is introduced to analyze and identify the main obstacle factors in the process of coupling and coordinated development of regional economy, ecological environment and island tourism.

The symbols of obstacle degree is defined as follows: the factor contribution degreeF_j is used to represent the contribution degree of a single index to the overall goal (coordinated development of regional economy, ecological environment and island tourism) and it is expressed by the index weight W_j; The index deviation degree I_j denotes the disparity between the actual value and the optimal value of each index, and it is expressed by the difference between 1 and the standardized value X_{ij}; Obstacle degree Q_j denotes the influence degree of subsystems or indicators on the coupling and coordinated development of regional economy, ecological environment and island tourism.

$$Q_i = I_i W_i \Big/ \left(\sum_{i=1}^{m} I_i W_i \right) \times 100\% \tag{11}$$

where $I_i = 1 - X_{ij}$ (12)

Table 1
The indicators of three subsystem and weights.

Subsystem	First level indicators (F)	Basic level indicators (X)	Unit	Weight
Economy (Ec)	Economic development scale (F1)	Per capita GDP (X1)	Yuan/capita	0.1332
		Growth rate of GDP (X2)	%	0.0196
		Total retail sales of consumer goods (X3)	Yuan	0.1454
		Proportion of tertiary industry (X4)	%	0.0871
		Urban per capita disposable income (X5)	Yuan/capita	0.1018
	Social economy construction (F2)	Built-up area at the end of the year (X6)	km^2	0.1840
		Real urban road area (X7)	m^2	0.2471
		Per capita housing area of urban residents (X8)	m^2/capita	0.0819
Environment (En)	Environmental pollution status (F3)	Total amount of industrial wastewater discharge (X9)	t	0.3291
		Total emissions of industrial waste gas (X10)	m^3	0.0373
		Industrial solid waste production (X11)	t	0.0234
	Environmental management effectiveness (F4)	Comprehensive utilization rate of solid waste (X12)	%	0.0256
		Air quality excellent rate (X13)	%	0.0393
		Sea water quality compliance rate (X14)	%	0.0756
		Green coverage rate in built-up area (X15)	%	0.2454
		Public ecological environment satisfaction (X16)	%	0.2244
Tourism (Tm)	Tourism market scale (F5)	Total tourism revenue (X17)	Yuan	0.1648
		Growth rate of total tourism revenue (X18)	%	0.0607
		Total number of visitors received (X19)	#	0.1394
		Growth rate of visitors received (X20)	%	0.0458
	Tourism element structure (F6)	Total number of coastal tourist Islands (X21)	#	0.1717
		Number of tourist scenic spots above 3A level (X22)	#	0.1781
		Total number of travel agents (X23)	#	0.1300
		Total number of star-rated hotels (X24)	#	0.1095

3. Results and discussions

3.1. Changes of three subsystem indices

Fig. 2 shows the development trend of the three systematic indices of the regional economy, ecological environment and tourism in the island regions of Zhejiang. The economy indices in eleven island districts increase year by year during 2008–2018. The top three are Jiaojiang, Dinghai and Linhai, followed by Xiangshan, Putuo and Yuhuan. The five districts at a low level of economy indices are Pingyang, Sanmen, Dongtou, Daishan and Shengsi. Among them, Dongtou, Daishan and Shengsi, that rank the last three, are all far away from the mainland with a small population. The inconvenience of transportation facilities hinders the development of their economy.

The environmental indices in eleven island districts during 2008–2014 are generally low. All of them are less than 0.5, and the fluctuating frequency is generally high, indicating that the development of environment in these six years is unstable. While during 2014–2018, the environment indices in eleven districts show a linear increasing trend, especially in Pingyang and Xiangshan, and the other nine districts also have relatively stable growth rates. Compared with other regions, the top three of the environment indices are Xiangshan, Pingyang and Jiaojiang, followed by Linhai, Shengsi and Dinghai. The five districts with low environment indices are Dongtou, Putuo, Daishan, Sanmen and Yuhuan.

The tourism indices of the eleven island districts show a steady upward trend while they are largely different among regions. The tourism index of Putuo ranks first, far ahead of the other ten districts, followed by Xiangshan, Dinghai, Linghai, Yuhuan and Shengsi. Their annual average indices of tourism subsystem are all between 0.2 and 0.3. The tourism indices of Jiaojiang, Pingyang, Daishan, Dongtou and Sanmen are lower, with an annual average value of less than 0.2.

According to the indices and development trends of the three subsystems during 2008–2018, the eleven island districts can be divided into four types. (1) Type one is Putuo, whose tourism index is much higher than its economy index and environment index. While the development speeds of its three subsystems are relatively balanced. (2) Type two is Xiangshan, who has the highest initial level of environment indices. In the early stage, it mainly accelerates economy, in the mid-term it focuses on the development of tourism, and in the later period both tourism and environment are promoted. (3) Type three includs Dinghai, Jiaojiang, Linhai and Yuhuan. Among the four districts of type three, although the initial development level of the three subsystems varies a lot, they all experience a same change in development trend. Before 2014, they mainly rely on economic development while after 2014, tourism begins to advance rapidly. (4) Type four includs Daishan, Shengsi, Sanmen, Dongtou and Pingyang. Their initial development level of the three subsystems are relatively low. And the development speed order of each subsystem is that tourism > environment > economy.

Although the beginning point of development is uneven, the growth rate of tourism development of these eleven island districts has basically remained stable after 2014. This is closely related to the *Development, utilization and protection plan of Zhejiang Province' s important islands* issued by the People's Government of Zhejiang Province in 2011. The plan clearly stipulates that coastal tourism should be taken as one of the main directions for the development and utilization of important islands. Among the eleven island districts, Putuo mainly relies on the Buddhist cultural of Putuo Mountain and the resource advantages of Zhujiajian National Scenic Area. Thus it's beginning point of tourism development is the highest and the development speed is fast. The remaining ten regions are limited to varying degrees by tourism resource endowments, ecological environment quality, tourism development strategies, economic support and other factors, resulting in a relatively slow progress of island tourism construction. For example, islands such as Daishan, Shengsi, Dongtou, and Pingyang are far away from the cities. The backward economic development in these regions, coupled with inconvenient transportation, makes the tourism infrastructure more lagging.

3.2. Coupling and coordinated development

The changes of the coupling coordination level are shown in Fig. 3

Table 2
Classification table of coupling coordination degree.

Serial number	Range of coupling coordination	Coordination level	Serial number	Range of coupling coordination	Coordination level
1	0–0.09	Extreme imbalance	6	0.50–0.59	Barely coordination
2	0.10–0.19	Serious imbalance	7	0.60–0.69	Primary coordination
3	0.20–0.29	Moderate imbalance	8	0.70–0.79	Intermediate coordination
4	0.30–0.39	Mild imbalance	9	0.80–0.89	Good coordination
5	0.40–0.49	Imminent imbalance	10	0.90–1	Quality coordination

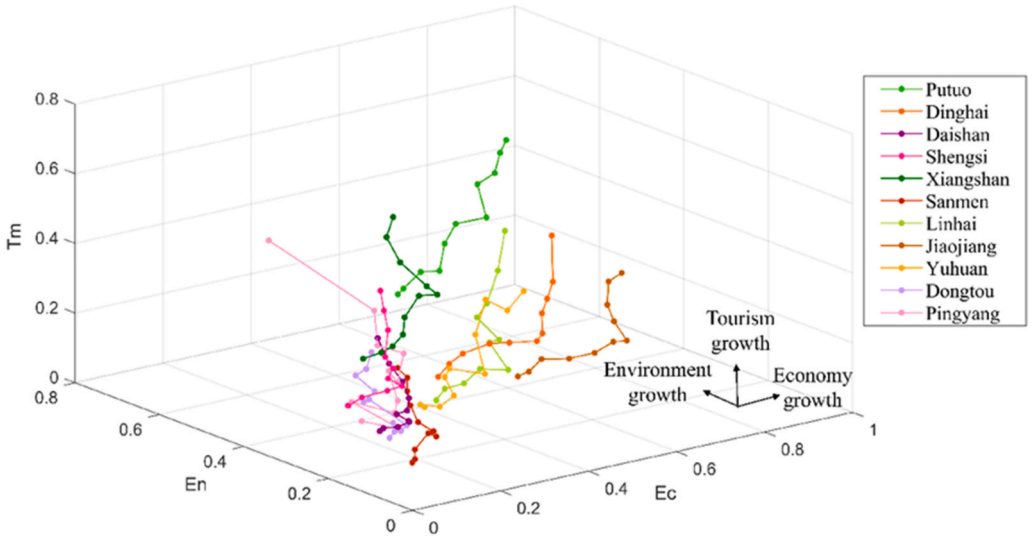

Fig. 2. The indices of the three subsystems in eleven island districts during 2008–2018.

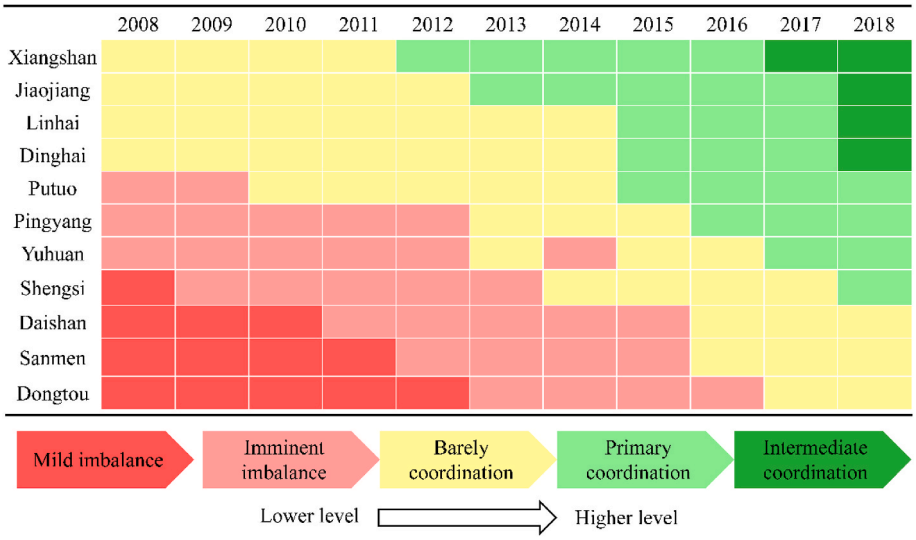

Fig. 3. Coupling coordination level of eleven island districts during 2008–2018.

based on the classification table of coupling coordination degree (Table 2). The coupling coordination level in eleven island districts elevate steadily during 2008–2018 and the overall growth gradient is greater than or equal to three grades. Up to 2018, most regions reach the level of barely coordinated above, and the rising trend is pleasant. It is indicated that the regional economic, ecological environment and tourism industry development in Zhejiang island regions tend to be more and more coordinated.

According to the initial value of coupling coordination level in 2008, the eleven island districts can be divided into three grades. (1) The first grade includs Xiangshan, Jiaojiang, Linhai and Dinghai, which initially reach the level of barely coordination. These four island districts are characterized by high levels of economic development and eco-environment index, which are favorable conditions for the development of island tourism. (2) The second grade includs Putuo, Pingyang and Yuhuan, whose growth speed reduce progressively and reach primary coordination in 2018. Different form Pingyang and Yuhuan, whose subsystem indices are all not high, Putuo's tourism index is much higher than its economic index and eco-environmental index. Yet it still leads to the relatively low level of coordinated development. (3) The third grade includs Shengsi, Daishan, Sanmen and Dongtou, of which the coordinated development level is the lowest and they are in a mild state of

maladjustment in 2008. In these four island districts, the three subsystem indices are all low, especially the economic index, which greatly hinders the eco-environment protection and island tourism development. To sum up, the coupling coordination level of economy-environment-tourism system of eleven island districts in Zhejiang shows an enjoyable trend, but the coordinated development of three subsystems among regions is biased.

The reasons for the unbalanced development in eleven island districts are not only the differences in the level of economic development, the quality of the ecological environment, and the endowment of tourism resources in each region, but also the bottleneck in management policies, particularly the lack of overall planning for the construction of island scenic spots. Each island scenic spot only pays attention to its own development and neglects the interconnectivity between them. Besides, the current island tourism development model in Zhejiang is excessively single, and the product types are similar. Most of them belong to coastal baths, leisure farming and fishery, lacking the in-depth exploitation of unique resources such as natural and cultural landscapes, historical and cultural heritages. Although Putuo's economic index and environmental index are not prominent among the eleven island districts, it has fully explored the unique local Buddhist culture and pinpointed the tourism brand. Therefore, its island tourism development is at the forefront of Zhejiang and even the whole China.

Most of the previous studies focus on the pair-wise analysis of the coupling coordination between economy and tourism (Sheng and Zhong, 2009; Wang and Xia, 2013), or environment and tourism (Tang, 2015; Han et al., 2016), and there are few studies on the coupling coordination of the three subsystems. According to the analysis of Cheng Zhou's research about the coupling coordination relationship of provinces and cities along the Yangtze River Economic Belt in China (Zhou et al., 2016), the coupling coordination degree of the three subsystems in Zhejiang is 0.685 in 2013. And in our study the average coupling coordination degree of eleven districts in 2013 is 0.527. The main reason for the divergence between the two results is the different scales. In comparison, the former involves a wider range of areas and tourism, while the scale of this study is smaller and the accuracy is higher.

3.3. Obstacle factors of coordinated development

Fig. 4 shows the obstacle degree of each subsystem affecting the coordinated development of the regional economy, eco-environment and tourism in eleven island districts, and six years during 2008–2018 are selected as representatives for analysis.

From the perspective of obstacle degree in time series, the economic

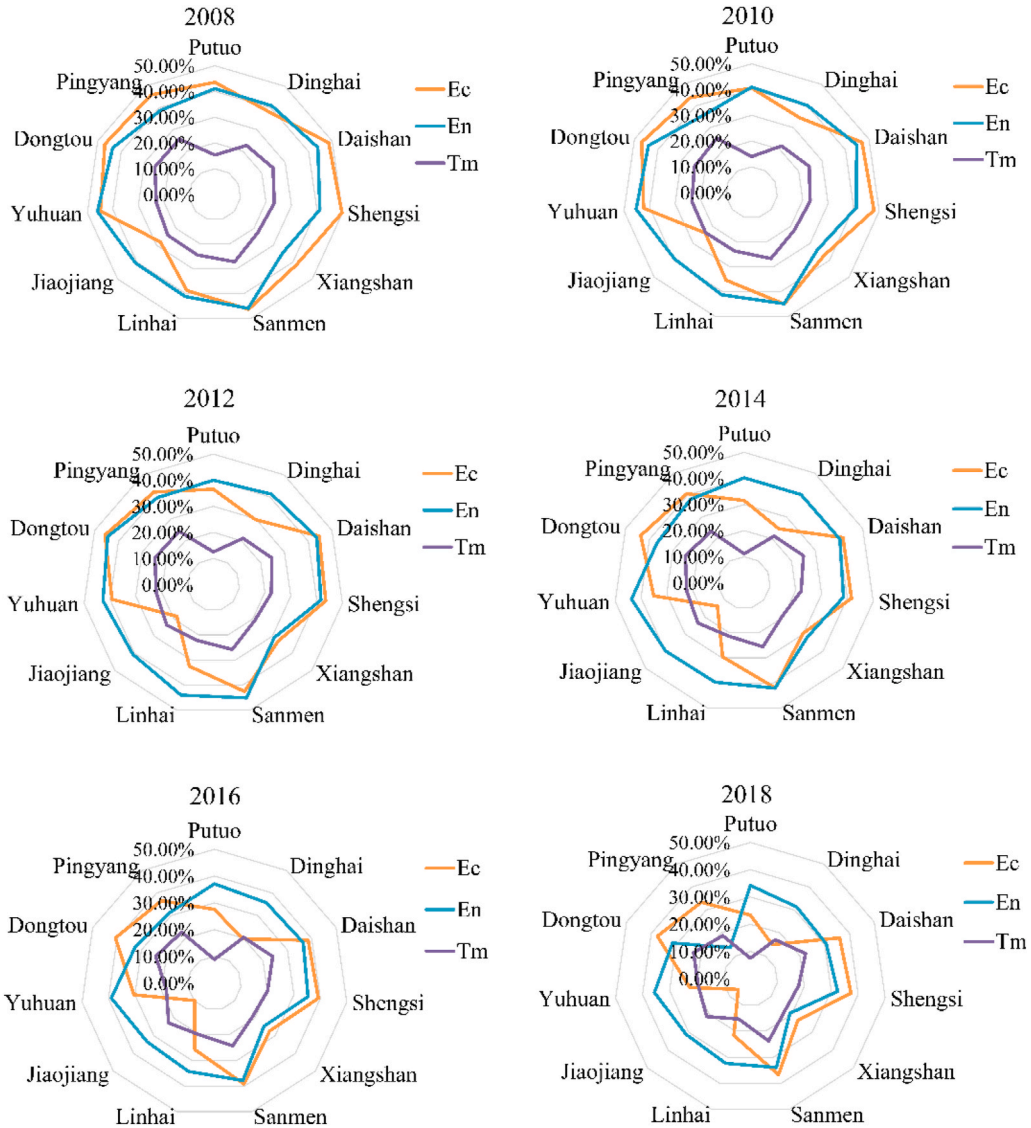

Fig. 4. The degree of obstacles affecting the coordinated development of economy, environment and tourism in eleven island districts.

subsystem has the most significant influence on the coordinated development of island tourism in Zhejiang Province. In 2008, the average economic obstacle degree of eleven island districts is 42.98%, which is the highest among the three subsystems. After that, the average obstacle degree decreases yearly and reduces to 26.59% in 2018. This shows that the economic development of Zhejiang island regions in the past 11 years is swift and violent, and the momentum is pretty good. In comparison, the obstacle degree of the environment subsystem changes in a small range and unstable trend. It's average obstacle degree gradually decreases from 41.64% to 29.64% during 2008–2018. The obstacle degree of the tourism subsystem is pretty low compared with the economic subsystem and the environmental subsystem, and it decreases from 23.46% to 18.48% during 2008–2018.

By comparing the obstacle degree of three subsystems in eleven island districts during 2008–2018, the obstacle factors of each district can be identified. According to the change of different obstacle factors, the eleven island districts can be divided into four categories. (1) The first category includes Dinghai, Linhai and Jiaojiang, whose obstacle factor affecting the coordinated development of regional economy, ecological environment and island tourism is always the environmental subsystem. (2) The second category is composed of Xiangshan, Daishan, Shengsi and Sanmen, of which the obstacle factors include the economy and the environment for both of them have a great impact on the coordinated development. (3) The third category includes Putuo and Yuhuan. At first, the economic subsystem and the environmental subsystem jointly affect their coordinated development. After 2012, the obstacle degree of environmental subsystem has exceeded the economic subsystem and gradually increased yearly. (4) Dongtou and Pingyang belong to the fourth category. The obstacle degree of economic subsystem and environmental subsystem are similar in the early stage, while the influence of economic subsystem on coordinated development is enhancing in the late stage.

According to the overall change of obstacle factors in different regions, it can be inferred that the obstacle factors of most islands will change to environmental subsystem in the later stage. It can be found in Fig. 2 that the environment indices of the eleven island districts during 2008–2018 fluctuated occasionally in the early period. It is due to the extensive economic development in the early stage. Once the ecological environment is damaged, its restoration and protection is a time-consuming process (Li et al., 2010). That's why the growth of environmental quality does not keep up with the increase of economy and tourism, leading to the growth of environmental benefits is relatively slow. With the popularization of the concept of marine ecological civilization in recent years (Zhang et al., 2019; Jiang et al., 2020), island eco-tourism is gradually recognized as an efficient approach to coordinating the regional economy and ecological environment in island regions and further stimulating the sustainable development of island tourism (Jaafar and Maideen, 2012; D'Hauteserre and Funck, 2016).

4. Conclusion and policy implications

Our case study of island districts in Zhejiang Province have clearly proved the effectiveness of the proposed CCDM and we could draw the policy implications based on the main evaluation results.

From the perspective of the development status of the subsystems, the tourism development level of the remaining ten island districts is relatively low with the exception of Putuo. Since most islands are far away from the cities, their development is relatively backward. Furthermore, due to the late beginning of island tourism in Zhejiang Province and insufficient economic and policy support, the island's infrastructure is relatively lagging. The coupling and coordination relationship of the three subsystems in Zhejiang's eleven islands is developed well during 2008–2018, but the development level in different regions is distinct. The construction of island scenic spots lacks overall planning of all the islands based on mutual connectivity. Besides, the current island tourism development model in Zhejiang is too single, lacking tourism products with local characteristics. The obstacles affecting the coordinated development of the regional economy, ecological environment and tourism industry in most island regions tend to be the environmental subsystem. Due to the extensive economic development model in the early stage, environmental protection was neglected in tourism development activities. That makes some islands face varying degrees of environmental pollution risks, and the fragile ecological environment of the islands is also threatened.

Methodologically, the conceptual index system proposed in this paper has been proven as an effective tool to analyze the coupling coordination relationship among the regional economy, ecological environment and island tourism. Moreover, the analysis of obstacle factors for each region helps us gain a deeper understanding of the sustainability of tourism in Zhejiang's island regions. Nevertheless, due to the limited availability of data, the conceptual index system fails to fully reflect the development of the three subsystems in each island region, which may have a certain impact on the research results.

In view of the above conclusions, the paper put forward the following policy recommendations to provide a referential path for the sustainable development of island tourism. 1) Carry out overall planning for island tourism projects based on the resource advantages of each island. In a complete overall planning, it is essential to determine the main tourism functions and themes of each island in accordance with the characteristics of the natural environment, resource advantages, historical and cultural connotations of each island. Besides, it is necessary to comply with the principle of complementary advantages, so that the various islands could form a cohesive whole. 2) Perfect the supervision system of island tourism and boost financial support for island tourism infrastructure construction. Only by establishing a unified management and supervision mechanism for island tourism, can we better promote the sustainable development of island tourism. Furthermore, there is a demand to increase capital investment for the supporting infrastructure of islands, rise the quality of tourism personnel and improve the level of tourism services. 3) Encourage the development of a variety of tourism products, and build regional tourism brands based on local conditions. The functional positioning of island tourism should not be limited to sightseeing, but should make full use of the regional environmental resources and geographical uniqueness to provide a variety of entertainment facilities and enhance the quality of island tourism. For example, the development of holiday tourism products such as luxury cruises and yachts, ecological tourism products such as the underwater world and ocean parks, rehabilitation tourism products such as water sports and sea golf, cultural tourism products such as island folklore, ruins, museums, and academics, and exciting tourism products such as submarine expeditions and extreme sports. 4) Focus on the development of island eco-tourism, and pay attention to the sustainability of island resources and ecological environment. The foundation and core link of island eco-tourism is to create high-level ecological scenic spots. Based on the requirements of ecology, uniqueness and quality, it is a must to build boutique scenic spots that allows tourists to enjoy a unique experience. As the island ecosystem is relatively fragile, corresponding protection and restoration measures must be taken in the process of island tourism development according to the regional environmental capacities of each island to maintain the island's local characteristics and beautiful scenery.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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