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Evaluation of the development intensity of China's coastal area

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ABSTRACT

An objective and comprehensive understanding of the development intensity of China's coastal area is of great significance to China's planning and marine management. On the basis of specifying the impact factors and characteristic indexes of the development intensity of China's coastal area, this paper constructs a model for ocean development intensity evaluation, comprehensively evaluates the development intensity of China's coastal area and summarizes the distribution features and patterns of ocean development intensities of different areas by fully using the relative data of sea area use and management, providing reference for future ocean development and protection policies.

1. Introduction

China is one of the regions with the greatest ocean development intensity in the world. According to the 2005–2015 Sea Area Use and Management Bulletin issued by the State Oceanic Administration of China, the newly added sea area of China with authentic right covers 25,687.22 km^2, including 14,520.72 km^2 from 2011 to 2015. With its fast growth, it grew by 52.4% in 2012, and in 2014, the newly added sea areas with authentic rights reached 3741.48 km^2, which was much better than the average standard. Sea use in general has been increasing over the years, the environment of the coastal area is worsening year after year. As a result, it is imperative that positive protection of the ecological space of the sea and strict control of the ocean's development intensity should be carried out.

In order to realize sustainable sea development, the State coordinates management of environmental resources and development activities, and so on through policies, planning, zoning, legislation, law enforcement, and administrative supervision. The Chinese government has enacted various plans and policies, including *The National Marine Main Functional Area Planning* (The State Council of the People's Republic of China, 2015), *General Planning of Ecological Civilization System Reform* (The Central Committee of the Communist Party of China et al., 2015), *Guiding Opinion on the Enhancement of Control and Management of Resource Environment and Ecology Red Lines* (National Development and Reform Commission et al., 2016) *and Management Methods of Coastal Line Protection and Utilization* (State Ocean Administration, 2017), and others. The basis and core of the breakdown and implementation of the above-mentioned policies is the mastering of the status quo and change tendency of the development intensity of China's coastal area, which thus realizes the effective protection, scientific management and sustainable utilization of marine resources.

In the last decade, various studies in sea development intensity have been conducted at home and abroad. Some studies in foreign countries focused on the cumulative impacts of human activities on global marine ecosystems. Halpern et al. developed a multi-scale space model based on the ecosystem (Halpern et al., 2008), conducted spatio-temporal change analysis of the cumulative impacts of human activities on the global ocean, and calculated and plotted an impact evaluation diagram of human activities on global marine ecosystems (Halpern et al., 2015, 2017). Stock introduced the software EcoImpacMapper, which was used for mapping thematic maps of human impacts on marine ecosystems (Stock, 2016), based on the cumulative model (Halpern et al., 2008). In addition, Andersen, and Brooks et al. performed analysis and research on the relationship between regional marine ecological conditions and human activities (Andersen et al., 2015; Brooks et al., 2016). Willsteed et al. evaluated the cumulative environmental impacts of marine renewable energy development (Willsteed et al., 2017). Furthermore, Maxwell et al. and Selkoe et al. respectively conducted studied the cumulative impacts that human beings brought upon marine animals and the pristine coral reef ecosystem (Maxwell et al., 2013; Selkoe et al., 2009). Domestic studies mainly concentrate on the evaluation of the development intensity of China's coastal area. They evaluated the coastal zone development intensities of Wenzhou, coastal cities of Shandong, the south bank of the Hangzhou Bay, and eastern Guangdong, respectively (Shu-xi et al., 2015; Meng et al., 2015; Teng et al., 2015; Xiao-yu, 2008). Moreover, Dan-dan et al. (2009) conducted a comprehensive evaluation on the development and utilization of Daya Bay (Dan-dan et al., 2009).

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It can be seen that China and foreign countries use different research scales for the evaluation of ocean development intensity, with foreign studies focusing on the impacts of human activities on the global marine ecosystems while domestic ones emphasize small-scale coastal regions of China. These studies comprehensively evaluated the ocean health in different regions, analyzed the factors driving ocean health change, assessed how and why ocean health has changed, and gave useful suggestions, which played a positive role in protecting the ocean environment. As a result, related research of inshore areas in China is limited although its sea development intensity is very high in the world. Taking China's coastal area as the study area, through a comprehensive use of the detailed data of ocean development activities and functional zoning, we performed statistical estimation of all exclusive sea use activities (excluding temporary sea use activities such as sailing, fisheries, etc.) lasting continuously for more than three months in China's inland and territorial waters. We also categorized the comprehensive evaluation results of ocean development intensities as well as map, and created a thematic diagram.

2. Data and methods

According to the distribution, development and protection characteristics of China's marine resources, this paper deeply analyzed the key factors and characteristic indexes affecting the development intensity of China's coastal area. Based on this, we specified the data source and evaluation methods, screened the evaluation indexes, determined the weights of evaluation indexes, and constructed the evaluation model.

2.1. Data source

A reliable data source is the basis for evaluating ocean development intensity. The data used in this paper mainly came from the *China Marine Statistical Yearbook* (State Ocean Administration, 2001–2015), books of marine functional zoning (Dao-ming et al., 2013; Deng-wen et al., 2013), *the Sea Area Use Management Bulletin* (State Ocean Administration, 2002–2015), investigation information through field survey, etc.

2.2. Evaluation methods

The multi-index comprehensive evaluation method used in this paper was subjected to the multi-scale space model, and was based on the ecosystem proposed by Halpern et al. (2008, 2015), the status quo data of China's coastal area development. The formula of the multi-index comprehensive evaluation model was:

$$I_C = \sum_{i=1}^{n} \sum_{j=1}^{m} P_i * E_j * \mu_{ij}, \quad (1)$$

Where I_C refers to the comprehensive evaluation score; P_i refers to the standardized value (between 0 and 1) of the i^{th} evaluation index; E_j refers to whether the j^{th} evaluation factor has influence (0 or 1); and μ_{ij} refers to the weight value of the i^{th} evaluation index in the j^{th} evaluation factor.

We constructed an evaluation index system consisting of five elements (sea area resources, eco-environment, social economy, policy impact and public's feelings) and fifteen indicators. Based on this, we researched the status quo of China's offshore sea area development and utilization. During the selection period, we consulted experts, this system removed those indexes that are hard to obtain and have little influence on the ranking of the evaluation results (such as fisheries, which are highly intensified in China's coastal sea area but have little influence on the ranking). Thus, seven key indexes that are representative of and have high contribution to the evaluation objectives were selected. These were then coupled with the Delphi method, which was employed to determine the weights of the evaluation indexes. We constructed an ocean development intensity evaluation indicator system that is suitable for China's offshore sea area and is highly operative (Table 1).

Table 1
Evaluation indexes of ocean development intensity.

Evaluation objective	Evaluation factors	Evaluation indexes	Index weight
Ocean development intensity	Utilization degree of ocean space	Utilization ratio of sea area	0.2703
		Reclamation intensity	0.2915
	Utilization degree of ocean functions	Sea area utilization type index	0.1480
		Intensity index of sea use mode	0.1875
	Degree of policy influence	Proportion of marine protected area	0.0257
		Proportion of reserved area	0.0257
		Proportion of industrial and urban construction areas	0.0513

(1) Indexes that reflect the utilization degree of ocean space

Indexes that reflect the utilization degree of ocean space include the utilization ratio of sea area, and the reclamation intensity. Within each sea area unit under administrative management, the size of the sea area with authentic rights is proportional to the development and utilization degree of the sea area space. As indicated by the sea area use classification system(HY/T 123-2009), sea reclamation has the greatest influence on the natural quality of the sea area. Therefore, the greater the reclamation area, the larger the impact on the coastal environment and the higher the ocean development intensity.

The utilization ratio of sea area reflects the development and utilization degree of the sea area space, which is measured with indexes such as sea area with authentic rights. The formula of this is as follows:

$$r_s = S_q / S_g, \quad (2)$$

where r_s represents the utilization ratio of the sea area space; S_q represents the sea area with authentic rights; and S_g represents the managed sea area, which is based on the marine functional zoning area in coastal provinces (district and city) of China.

The reclamation intensity reflects the pressure intensity posed to the marine ecological environment by reclamation, the formula of which is as follows:

$$r_w = S_w / S_g, \quad (3)$$

where r_w represents the sea reclamation intensity; S_w represents the area of sea reclamation; and S_g represents the managed sea area.

(2) Indexes that reflect the utilization degree of ocean functions

Indexes reflecting the utilization degree of ocean functions include the sea area utilization type index and the intensity index of sea use mode. The sea area utilization type index and the intensity index of sea use mode are proportional to the sea area development and utilization activities' impact on the marine resource environment and ocean development intensity.

The sea area utilization type index reflects the proportion of the sea area utilization types[14] with greater influence on the natural qualities of the sea area (equation (4)).

$$r_{lx} = (S_{gy} + S_{jt} + S_{hd} + S_{zd}) / S_{qq}, \quad (4)$$

Here, r_{lx} represents the sea area utilization type index; S_{gy} represents