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The Research on the Value Realization Mechanism of Marine Ecological Products in China

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Abstract: Realization of the value of marine ecological products serves as an important approach to meet the growing needs of the general public for an ecologically sound environment. Through analysis of global research and practice on the value of marine ecological products, this study explores the types, accounting methods, and value realization approaches of marine ecological products in China. The results show that China's marine ecological products are facing a number of problems, namely decreasing product quantity, lack of a unified authoritative accounting standard, absence of a complete trading market, and imperfect legal and institutional systems. Marine ecological products fall into two categories: public products and operational products. They consist of four types: coastal island-based human settlements, marine ecological security-related products, marine ecological materials, and marine cultural services. At present, there are six accountable products: clean seawater, climate regulation, marine ecological resources, fishing products, aquaculture products, and marine ecotourism and leisure products. To realize the value of marine ecological products, it is necessary to establish the following four systems for marine ecological products: (1) a government-led, enterprise-based, diverse product-supply system with wide participation of social organizations and the general public; (2) a unified authoritative value accounting system; (3) a land-sea integrated market trading system; and (4) a legal and institutional system.

Keywords: Marine ecological products; Value realization mechanism; Ecosystem services; Natural resources

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1. Introduction

In recent years, China's central government has attached great importance to the construction of an ecological civilization, requiring the establishment of a sound mechanism for realizing ecological product values. Zhejiang and other provinces were selected for pilot implementation of a mechanism for realizing ecological product values

and exploration of the definition, type, accounting, and value realization methods of ecological products. Great progress has been achieved, but most of the existing pilot work is focused on terrestrial environments with little exploration conducted in marine environments. This study seeks to fill this gap by exploring the types, accounting methods, and value realization methods of China's marine ecological products. The goal is to provide a theoretical basis and decision-making reference for forming a national unified value realization system of ecological products.

2. Global forms and performance of value realization of marine ecological products

2.1. Non-China-based research and practice on the value of marine ecological products

Foreign research on marine ecological products focuses mainly on marine ecosystem services and assessment. In the 1970s, the United Nations Economic and Social Council proposed that coastal resources are "a valuable national wealth" [1]. Subsequently, accounting for marine resource value has gradually become a research focus. To date, more than 20 countries and organizations, including the United States, Japan, France, the United Nations Environment Programme, the United Nations Statistics Division, and the World Resources Institute, have conducted research on the theory and implementation of natural resource accounting [2–4]. In particular, Constanta et al. were the first to complete a global estimation of coastal ecosystem service value, which represents the beginning of quantitative research on marine ecological products [5]. Since the beginning of the 21st century, more extensive research on marine ecosystem services has been conducted in foreign countries, including assessments of marine ecosystem services of different scales and types. Some research results have been applied to the practice of ecological compensation, providing a reference for realizing the value of marine ecological products [6–14].

2.2. China-based research and practice on the value of marine ecological products

In recent years, China has gradually conducted research on the value of marine ecological products, mainly focusing on the connotative definition of marine ecological products and the evaluation of their value.

2.2.1. Definition of marine ecological products

It has been proposed that marine ecological products are a subset of marine resources that provide ecological services, including tangible resources such as marine biological resources, marine mineral resources, marine energy resources, and marine chemical resources, as well as intangible resource assets such as natural heritage [15–17]. Others have proposed that marine ecological products are the services that marine ecosystems provide, such as the provision, regulation, and support of products and cultural services [18–19]. Still others believe that marine ecological products are a subset of marine resources and marine ecosystem services, proposing the concept of marine ecological capital whose value is composed of the stock of marine ecological resources and the service value of marine ecosystems [20].

2.2.2. Valuation of marine ecological products

Xu et al. have explored the classification of marine ecological products [21]. Cheng et al. propose that the value of marine ecological products can be calculated using the evaluation methods of ecosystem service value [22–24]. The quantity of marine physical resources and the value of ecosystem services are considered accounting objects of natural resource assets in Shenzhen Dapeng Peninsula and Huizhou City, Guangdong Province, China [25–26]. At the end of 2018, China began performing an ecological assessment of the consequences of early sea reclamation projects, calculating the loss of fishery resources and the loss of the value of marine ecological services [27]. The goal is to provide a reference for determining the appropriate amount of funding for marine ecological protection and

restoration. In addition, evaluations of marine ecological products have been applied to the compensation of marine ecological damage, setting sea-use fee standards, and performance assessments of marine ecological restoration [28–30].

In summary, progress has been achieved in recent years on researching the value of marine ecological products across the globe, but the mechanisms for quantifying their value and implementing the results of that quantification still fail to meet actual needs for value realization.

3. Existing problems in the value realization of marine ecological products

3.1. Marine ecological products at risk of shrinking

The ocean is the cradle of human life, with more than 50% of the world's population living within about 60 km of the coast. Statistics show that due to the rapid economic and social development of coastal areas, China has lost more than 50% of its coastal wetlands since 1949. By the end of 2017, less than 40% of China's total coastline was in a natural condition, with some areas severely eroded, threatening marine ecological security [31]. According to the Bulletin of Marine Ecology and Environment Status of China in 2018, China's water bodies with Grade-4 water quality had reached 47,310 km^2 by the summer of 2017. More than 90% of the sea areas adjacent to wastewater discharge outlets failed to meet the environmental protection requirements for marine functional zones, with bay ecosystems mostly in a sub-healthy status [32]. Marine ecological products are at risk of shrinking.

3.2. Lack of a unified authoritative standard for the value accounting of marine ecological products

China's domestic practices show that the value of the marine ecosystems of Xiamen City in 2015 was about 1.87 million RMB per hectare [33]. Calculations show that the annual value of Quanzhou Bay, Guangdong provincial mangroves, Hangzhou Bay wetlands, Zhejiang provincial wetlands, Yancheng coastal beach, Minjiang River Estuary wetlands, and reclaimed land in Bohai Sea and Caofeidian district ranges from less than 10,000 RMB per hectare to 1 million RMB per hectare [34–39]. Various national or industry standards and empirical formulas are applied to various assessments, such as marine ecological damage assessment, fishery pollution damage assessment, and marine ecological capital assessment. As a result, there are large differences in the value accounting results of marine ecological products, and an authoritative unified accounting standard is still missing.

3.3. Lack of a trading market for marine ecological products

At present, the market-oriented transactions of ecological products rarely involve marine ecological products, focusing mainly on forests, water rights, and carbon emissions instead. The government usually provides vertical compensation to support local ecological protection and restoration, while horizontal payments between regions or between different social sectors are relatively sporadic. Thus, a market for marine ecological products is missing.

3.4. Urgent need to strengthen legal and institutional systems

An effective legal system is a "catalyst" and a "protector" to effectively promote the realization of the value of marine ecological products. However, China still lacks policies on financial support systems, horizontal fiscal compensation systems, modern market systems, social participation systems, and legal support systems to support ecological products. The need to strengthen the legal system involved in the value realization of marine ecological products is especially urgent.

4. Value realization mechanism of marine ecological products in China

To accelerate the value realization of marine ecological products, it is necessary to take a problem-oriented approach. On the basis of ensuring coastal ecological security, economic instruments should be used to maximize the value realization of marine ecological products. To this end, the following main approaches should be taken.

4.1. Establish a diverse supply system for marine ecological products

4.1.1. Determination of marine ecological product types

In terms of economic attributes, ecological products have four characteristics: (1) positive externalities making social benefits greater than private benefits; (2) characteristics of public goods or quasi-public goods; (3) indivisibility and passive consumption as a whole; and (4) use-value and exchange-value with the dual character of commodities [40].

Marine ecological products are derived from marine ecological resources. Marine ecological resources include marine organisms and their habitats, as well as the entire marine ecosystem. Considering their economic attributes, degrees of biological production, human participation, and types of services that marine ecological products can provide, ecological products can be divided into public marine ecological products and operational marine ecological products.

Public marine ecological products are products directly provided by marine ecosystems to humans, such as clean seawater, climate regulation, species conservation, and coastal protection. Operational marine ecological products are the products that are generated by the intentional alteration of marine habitats by humans, including marine physical products and marine cultural service products. Marine physical products include marine biological resources such as marine organisms, sea areas, and islands, as well as the products that humans can obtain through labor, such as fishing, aquaculture, eco-industry and eco-agriculture, and biomass energy production. Marine cultural service products include marine ecotourism, leisure and entertainment, marine cultural products, and marine scientific research achievements (**Table 1**).

Table 1. Classification of marine ecological products

Category	Biological production	Degree of human participation	Trait		Ecosystem service types	Product types
Public marine ecological products	Direct production from marine ecosystems	Low, for necessary conservation and restoration	Intangible	Coastal island-based human settlement products	Regulation services	Clean seawater
				Ecological security products		Climate regulation Species conservation Coast protection Ecosystem disaster reduction
Operational marine ecological products	Direct production of the marine ecosystem + human production or management	High, for conservation, restoration, and management	Tangible	Physical products	Marine ecological resources	Sea area Island Marine organisms (including rare and endangered species)
					Supply services	Fishing products Aquaculture products Ecological industrial and agricultural marine products (e.g., chemical raw materials, feed, pharmaceutical raw materials, decorative and ornamental materials) Biomass energy products
			Intangible	Marine cultural service products	Cultural services	Marine ecotourism and leisure products Marine cultural products Marine scientific research outcomes

4.1.2. Diversification of the supplies of marine ecological products

It is necessary to explore the establishment of a government-led, enterprise-based supply system with wide participation by social organizations and the general public. This may be achieved through the following three levels of activities: (1) with respect to government supply, it is necessary to optimize the existing marine nature reserves and 71 marine special reserves in China to establish national parks and marine nature reserves; (2) with respect to enterprise-level activities, it is desirable to implement ecological restoration projects to improve sub-regional and local ecological environment; and (3) with respect to social sectors such as NGOs, it is recommended to conduct training, outreach, and public welfare projects to raise awareness of marine ecological product supply and innovate marine-product supply technology to diversify the supply of marine ecological products.

4.2. Establishing a unified authoritative value accounting system for marine ecological products

4.2.1. Value composition of marine ecological products

To promote an ecological civilization, the value of marine ecological products should be composed of the stock of marine ecological resources and the use-value of marine ecological products. When consumers acquire marine ecological resources as a whole, they have to pay for the stock of marine ecological resources and the use-value of marine ecological products produced by the marine ecological resources; when they only acquire marine ecological products, they only have to pay for the use-value of the products.

4.2.2. Accounting principles

Accounting should be conducted in accordance with the following principles: (1) the principle of human benefit, that is, human beings should be the ultimate beneficiaries; (2) the principle of actuality, that is, processes that are necessary for maintaining the survival and development of ecosystems such as atmospheric purification and water cycle are not subjected to accounting; (3) the principle of physical measurability, that is, products should have clear physical quantities with feasible accounting methods, while products such as marine aesthetics that are difficult to quantify are not subjected to accounting for the time being; and (4) the principle of data availability, that is, there must be practically available data sources and parameters, while products with too long a data acquisition cycle or too difficult a data acquisition path are not subjected to accounting for the time being.

According to the above principles, six types of marine ecological products with accountable value are identified, including clean seawater, climate regulation, marine ecological resources (sea areas, islands, marine organisms), fishing products, aquaculture products, marine ecotourism, and leisure and entertainment products. Marine ecological products other than these currently do not have well-developed value accounting methods, or the methods lack the necessary data support [26].

4.3. Accounting methods

4.3.1. Clean seawater

When human development activities such as land reclamation or wastewater discharge cause declines in seawater quality and water exchange capacity, the value of the seawater also declines. Value accounting can be realized by using a shadow engineering method to convert the remaining environmental capacity of clean seawater into the amount of accommodatable domestic wastewater and then using the cost of artificially treating the wastewater as equivalent to the value.

4.3.2. Climate regulation

A key process in climate regulation is the absorption of CO_2 and release of O_2 by phytoplankton through photosynthesis, which balances the global carbon cycle and regulates air temperature. Using the photosynthesis equation with the net primary productivity of marine ecosystems, the amount of carbon sequestration and oxygen production can be calculated. The value is the sum of the benefits of carbon sequestration and oxygen production.

4.3.3. Marine ecological resources

Marine ecological resources include marine biological resources and their habitat resources (sea areas, islands), as well as the marine ecosystem that they constitute. Compared with marine biological resources, the ecological value of the stock of habitat resources is difficult to quantify, but can be roughly estimated using sea-use fee standards or uninhabited island-use fee standards issued by the government. The stock value of marine biological resources can be obtained by conducting surveys to obtain the density of biological resources, multiplying the density by the accounted sea area to obtain the resource stock, and then calculating the stock value according to the average market price.

4.3.4. Fishing products

Fishing presents a product flow generated from the stock of marine biological resources. At present, fishery resources constitute the main component of fishing products. Value accounting of fishery resources can be performed using the market valuation method. According to the *Fishery Statistical Yearbook (Report)* of the administrative division adjacent to the accounted sea area, the fishing production and total production value are determined, and then the accounted cost is subtracted from the total production value to give the value of fishing products.

4.3.5. Aquaculture products

At present, only tidal flats and shallow sea resources that are suitable for aquaculture are accounted for. The accounting can be performed using the market valuation method. Aquaculture production is determined using the *Fishery Statistical Yearbook (Report)* of the administrative division adjacent to the accounted sea area and then multiplied by the average market price of the aquaculture products to give aquaculture income. Next, the accounted aquaculture cost is subtracted from the income to give the value of aquaculture products.

4.3.6. Marine ecotourism and leisure products

This type of product has a tourism function and a leisure function, with the latter especially relevant to the local residents (**Table 2**). The tourism value is accounted for using the travel cost method, which treats the value of tourism as consisting of travel costs, travel time value, and other expenses. The ocean provides a leisure function to the local residents in the coastal area, whose value can be accounted for using the contingent valuation method (i.e., willingness to pay).

Table 2. Value accounting methods of marine ecological products

Marine ecological products			Value accounting methods
Public marine ecological products	Clean seawater		Replacement cost method: $V_{Sw}= Q_{SwT} \times P_w$ V_{Sw}-Clean seawater value; Q_{SwT}-wastewater treatment amount converted from the environmental capacity of clean seawater of the accounted sea area; P_w-Cost of artificial wastewater treatment
	Climate regulation		Replacement price method: $V_{O_2+CO_2} = (1.63C_{CO_2} + 1.19C_{O_2}) \times X \times S$ $V_{O_2+CO_2}$-Total value of carbon fixation and oxygen production; C_{CO_2}-Carbon fixation cost; C_{O_2}-Oxygen production cost; X-Annual dry matter production of phytoplankton; S-Accounted sea area
Operational marine ecological products	Marine ecological resources	Marine biological resources	Market valuation method: $V_L= \sum(Q_{Li} \times P_{Li})$ V_L-Stock value of marine biological resources; Q_{Li}-Stock of marine organism resource i; P_{Li}-Average market price of marine organism i
		Marine habitat resources (sea areas, islands)	Sea-use fee standards or uninhabited island-use fee standards
	Fishing products		Market valuation method:$V_{SC}= \sum(Q_{SCi} \times P_C)–\sum W_i$ V_{SC}-Fishing production value; Q_{SCi}-Production of fishing aquatic product i; P_{Ci}-Price of fishing product i; W_i-Fishing cost of aquatic product i
	Aquaculture products		Market valuation method:$V_{BR}= \sum(Q_{BRi} \times P_C)–\sum W_i$ V_{BR}-Value of aquaculture products; Q_{BRi}-Production of aquaculture product i; P_{Ci}-Price of aquaculture product i; W_i-aquaculture cost of aquatic product i
	Marine ecotourism and leisure products		Travel cost method: $V_{ST} = (\overline{TC} + CS) \times P$ V_{ST}-Travel value; $\overline{TC}$-Average travel cost of individual tourists; CS-Consumer surplus of individual tourists; P-Total number of tourists at tourist attractions Contingent valuation method: Questionnaire survey to investigate people's willingness to pay (WTP) or willingness to accept (WTA) compensation

4.4. Realization of the value of ecological products

Operational marine ecological products can be capitalized through proprietary trades, which transfer management rights from the government to micro-operational entities such as enterprises and individuals, so as to achieve separation of ownership and management. It is ultimately up to the managers to develop and utilize natural resources to generate benefits and realize the value of ecological products. For public marine ecological products, their management rights cannot be transferred, so it is difficult to capitalize on this type of product. However, the government can indirectly realize its value through various forms of fees and taxes, such as pollution discharge fees, franchise fees, and special taxes [41].

4.5. Establishing a land-sea integrated trading market of marine ecological products

An integrated trading market of marine ecological products has three characteristics: market type diversity, trading market standardization, and land-sea integration.

4.5.1. Establishing off-site pollution rights trading markets

Assuming that total pollution load control (TPLC) is in place, off-site pollution may be allowed in some areas. The trading modes of carbon emission rights, water rights, and energy rights should be used as examples for bringing

clean seawater to the market, establishing marine ecological products with equivalent value for marine pollution rights, and implementing a proprietary trading system. Trading of marine pollution rights can be realized through inter-regional competition and negotiation. The government is tasked with strengthening regulatory management and law enforcement during and after the trading so as to ensure legal compliance with the pollution [42–49].

4.5.2. Establishing a national blue carbon sink trading market

Under the leadership of the government, it is necessary to conduct a pre-systematic design of an institutional framework, market element, and external support mechanism for blue carbon sink trading. A market mechanism suitable for blue carbon sink trading should be created so that the emission rights of carbon dioxide absorbed, fixed, and stored in the ocean can be treated as a commodity, which will gradually lead to blue carbon sink trading [50].

4.5.3. Standardizing the market trading

Scientific and reasonable valuation of marine ecological products is a prerequisite for ensuring fair trading. Regular supervision is a necessary means to ensure fair, transparent, safe, and legal trading. It is necessary to design a reasonable trading process and regulatory regime so as to ensure that the trading is fair, standardized, safe, and legal.

4.5.4. Establishing and improving the legal system for marine ecological products

At present, the methods for realizing the value of marine ecological products include ecological compensation, ecological ownership trading, business development and utilization, green financial support, stimulating economic development, and policy and institutional incentives [40]. There is an urgent need for legal systems to provide support and guarantees so as to ensure a smooth value realization of marine ecological products.

5. Conclusion and suggestion

Value realization of marine ecological products is a systematic engineering process and cannot be achieved overnight. This study refers to the experiences of Xiamen City, Huizhou City, and Shenzhen Dapeng Peninsula, but fails to conduct field verification due to time constraints. In the future, typical regions will be selected for empirical research to further optimize the product index system and select suitable accounting methods. This research will provide support for exploring the value realization mechanism of marine ecological products in coastal areas and thereby meet the growing needs of the general public for an ecologically sound environment.

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Authors' contribution

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