Overview of research on marine resources and economic development

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Abstract

Purpose – With increasing marine resource development, the rapid development of the marine economy, and the continuous decline of the marine natural resource system, the contradiction between marine resources and economic development is becoming increasingly acute. The study of marine resources and economic development has become a hot and challenging issue in marine resource economics research in recent years. The purpose of this study is to analyze the current situation of marine resources and to realize the sustainable use of marine resources.

Design/methodology/approach – This study systematically reviews and analyzes the current status of research on marine resources and economic development issues in four main aspects: marine resource management, marine resources and economic growth, marine resources and economic security, and marine resource accounting in the field of marine resource economics.

Findings – It is found that compared to the current status of research on land-based resources and economic development, there is a significant lag in both theoretical construction and methodological innovation in marine resources and economic development.

Originality/value – The purpose of this study is to systematically grasp the current status of marine resources research, promote the coordinated development of marine resources and economic growth, and then realize the safe and sustainable development and utilization of marine resources.

Keywords Marine resources, Economic development, Economics of marine resources

Paper type Research paper

1. Introduction

In recent years, with the depletion of terrestrial resources, the focus of human resource development and utilization has gradually begun to turn to the ocean (Taelman *et al.*, 2014). Marine resources are vital to human survival and prosperity as an important part of the Earth's life support system, a treasure trove of resources for sustainable social development and a strategic location for future high-quality economic development. However, the intervention and impact of human behavior on marine resources have led to numerous conflicts between marine resources and economic development (Barange *et al.*, 2014; Teh and Sumaila, 2015). With the large scale of marine resource exploitation by man, and marine industry development, the natural purification capacity and balance of the ocean are declining, and the phenomenon of marine water pollution, habitat destruction and resource

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depletion is becoming increasingly severe. In addition, the operation of marine resource systems is becoming increasingly poor (Halpern *et al.*, 2008; Visbeck *et al.*, 2014). Given the acute conflict between economic development and marine resources, in the late 1990s and especially since the beginning of the 21st century, there has been a growing concern about marine resources and economic development. In the "Our Oceans, Our Future" initiative introduced in June 2017, the United Nations called on all stakeholders to conserve and sustainably use oceans and marine resources for sustainable development. In addition, countries and international organizations are actively developing "blue economy" strategies to increase the production and trade of existing consumables related to marine ecosystems (Fenichel *et al.*, 2020) to achieve the goal of a positive interaction between marine resources and economic development.

The linkages between marine resources and economic development are complex and variable. Understanding these linkages and identifying their important drivers and pressure mechanisms is at the forefront of marine resource economics (Fath, 2015). Throughout the existing research on marine resources and economic development, the research objects involve different marine resources such as biodiversity, community management, environmental issues, economic growth and accounting. Most of the studies start with the integrated management of marine resources, focus on the basic contradiction of marine economic demand and marine resources supply and build a model of the relationship between marine resources and economic development and a sustainable development evaluation model based on marine resource accounting. In recent years, marine resource integrated management measures continue to innovate breakthroughs; research results are becoming increasingly fruitful, providing important theoretical support for the actual development and management of the ocean. The results of the study were compiled in the Science Citation Index Expanded (SCI-EXPANDED) and Social Sciences Citation Index (SSCI) databases to capture the research content and clarify the research context, and Figure 1 was drawn.

Summarizing the existing research results: it can be found that the research ideas of marine resources and economic development can be organized as starting point of marine resources management, using marine resources to drive economic growth, taking into

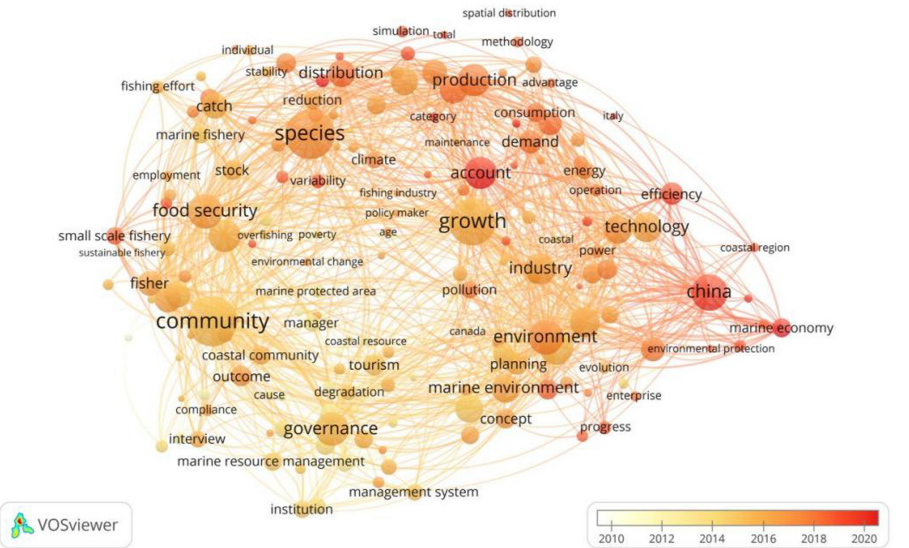

Figure 1.
Temporal trend of research themes

account marine economic security and beginning to try to carry out marine resources accounting. The research methods used cover many fields, including marine economics, environmental economics, resource management, geography, mathematical modeling, ArcGIS and systems analysis. Since the study on marine resources and economic development started relatively late, various aspects of research are still at the crossover stage, and there is no obvious stage character. Therefore, the research results of domestic and foreign studies in this field are reviewed in the following four aspects according to the existing research logic and content; the specific research idea is shown in Figure 2.

2. Marine resource management

Marine resource management is the key to harmonizing the relationship between economic development and marine resources. In the 21st century, countries worldwide are paying increasing attention to marine resource management and gradually integrating the integrated management of marine resources into the daily work of the country. In 2004, the USA established the National Commission on Ocean Policy, making several important ocean policy recommendations. The US management system combines both centralized and decentralized management, with the management of its maritime affairs distributed among the relevant departments of the federal government, whereas maritime law enforcement is managed centrally by the department. The state government is responsible for managing marine resources within three nautical miles of territorial waters, whereas the federal government is responsible for managing marine resources within 3–200 nautical miles. The laws and plans established by the federal government are implemented separately by each federal executive agency according to their functions.

The UK is a typical country with a decentralized system of marine management. Its Maritime Aviation and Environment Unit of the Ministry of Foreign Affairs is responsible for coordinating foreign maritime policies and laws across government ministries and has introduced market mechanisms into the maritime, marine management system and established a maritime licensing system. France is a typical centralized system of marine resource management. In 1981, the Ministry of the Sea was established. Under the Ministry of the Sea, the Marine Fisheries and Aquaculture Administration, the Marine Hydrocarbon and Other Mineral Resources Administration and the Marine Renewable Energy Administration were set up. Meanwhile, Australia has achieved innovation in marine resource management. The Integrated Community Services-based Marine Management Project, or the Coastal Zone Protection Project, was introduced in 1995 to encourage community participation in the

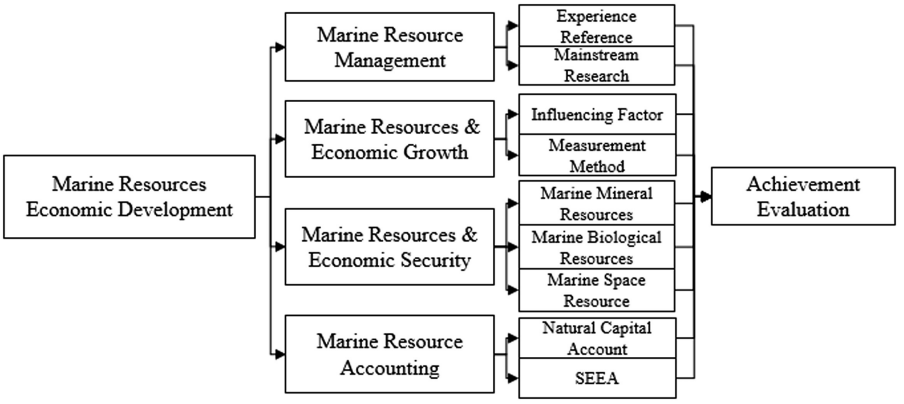

Figure 2.
Research ideas map

protection and management of the coastal zone, with cooperation and co-management between the community and government departments.

The accumulation of practical experience has provided a wealth of information for academic research, leading to an increasing number of research results in this field. Its mainstream research framework is mainly based on community management, government management and other aspects. Day and Dobbs (2013) and Singleton (2000) found that the establishment of community-based or co-managed marine resource management systems can effectively address the complex and interrelated problematic disputes pertaining to oceans, coastal zones and islands and have important practical social value. Stephenson *et al.* (2019) found that compared to single-sector marine resource management models, integrated marine resource management can better overcome the problems of sectoral fragmentation, management disconnection, duplication, unclear responsibilities and poor coordination. Garmendia *et al.* (2010) argue that the traditional top-down bureaucratic management approach is insufficient to address the conflicting issues of sustainable use of marine natural resources. It is proposed that different expertise and values should be integrated, and social multi-criteria evaluation methods should be applied as a decision support tool for integrated coastal zone management to avoid value conflicts and uncertainties in the management process.

In addition to the mainstream research directions, scholars have also conducted more diverse discussions on the management of marine resources from different perspectives. Giglio *et al.* (2019) further explored the assessment of the effectiveness of marine resource management, arguing that the diversity of stakeholders involved in management should be taken into account to bring the results closer to reality. Ban *et al.* (2019) argue that marine protected areas are the cornerstone of marine conservation and are significant for the effective implementation of integrated marine management. Lloret and Riera (2008) further suggest that marine protected areas should be integrated with integrated coastal zone management plans to ensure the sustainability of marine resources and species, based on an analysis of human activities affecting various ecological elements in the Cape Creus region of the Mediterranean coast over the past 50 years. Chang *et al.* (2008) established a system dynamics model for an integrated coastal zone management decision support system through an in-depth study of the coastal zone system, dividing it into four subsystems: socioeconomic, ecological, environmental and management. Based on the coordination of the internal elements of each subsystem, a system dynamics model for an integrated coastal zone management decision support system was developed and applied to analyze the sustainability of the Kenting coral reef ecosystem.

3. Marine resources and economic growth

The survival and development of human society require a certain amount of marine resources as a prerequisite for production and reproduction. Although the growth of total output is often decomposed into capital factor inputs, labor factor inputs and total factor productivity increases, the neoclassical growth model (Solow, 1956) does not include resource factors in the analysis of the production function and economic growth factors, ignoring the role of resources in the economy. However, marine resources are an important component of a country's national wealth, and a great deal of scholarly research and development has found that marine resources are a positive contributor to economic development (González-Val and Pueyo, 2019). Watkins (1963) found that the exploitation and export of marine resources are closely related to economic and industrial development. The positive effect of marine resources such as oil and minerals on per capita income has been demonstrated (Alexeev and Conrad, 2009).

Abundant marine resources can attract international direct investment (Aleksynska and Havrylchyk, 2013; Naz *et al.*, 2019) as an important basis for economic growth (Wu *et al.*, 2018). Wang *et al.* (2019) studied the industrial pathways of marine resource extraction and consumption in China and found that their most important supply chain pathways begin in the marine resource extraction sector and end in the marine construction sector. Different marine resource endowments often influence the industrial structure of a country and can have a significant impact on the manufacturing structure (Li *et al.*, 2019). Simultaneously, the exploitation and use of marine resources is an important influencing factor for technological development (Tsuboi, 2019). As Ahmadov and van der Borg (2019) suggest, the abundance of marine resources facilitates the development of renewable energy technologies within the country.

However, experience has also shown that the economic development of countries or regions with abundant marine resources lags behind that of countries or regions with scarce marine resources, a phenomenon also known as the "resource curse." Papyrakis and Gerlagh (2004) empirically investigated the direct and indirect effects of marine resources on economic growth in the United States. The other explanatory variables incorporated within the model were found to be critical to the ability of marine resources to promote economic growth, but the negative effect of marine resources on the economy remained dominant. Satti *et al.* (2014) and Ahmed *et al.* (2016) further found that even after controlling for other variables, the abundance of marine resources still hindered the regional economic growth. Biresselioglu *et al.* (2019) further constructed a composite index incorporating economic, governmental, social and political aspects by analyzing the factors influencing the resource curse phenomenon to measure the vulnerability to the resource curse in countries with abundant marine resources. Meanwhile, Adams *et al.* (2019) explored the causes and effects of the natural resource endowment curse in oil-rich developing countries.

Many studies on the relationship between the abundance of marine resources and economic growth have yielded varying conclusions (Mirza *et al.*, 2019; Hassan *et al.*, 2019). The main reason for this is that different scholars have inconsistent criteria for defining the abundance of marine resources or have adopted different research methods. Most of the indicators currently used in the literature to measure marine resource endowment are annual per capita rent for marine resource production (Brunnschweiler, 2008; Apergis and Payne, 2014), marine resource rent per unit of the gross domestic product (GDP) (Auty, 2007; Bhattacharyya and Hodler, 2014), total marine resource exports as a share of GDP (Wang *et al.*, 2019; Li *et al.*, 2019; Tsuboi, 2019; Ahmadov and van der Borg, 2019; Papyrakis and Gerlagh, 2004; Satti *et al.*, 2014; Ahmed *et al.*, 2016; Biresselioglu *et al.*, 2019; Adams *et al.*, 2019; Mirza *et al.*, 2019; Hassan *et al.*, 2019; Brunnschweiler, 2008; Apergis and Payne, 2014; Auty, 2007; Bhattacharyya and Hodler, 2014; Neumayer, 2004; Boschini *et al.*, 2013) and marine resources as a share of total exports (Dietz *et al.*, 2007). The measurement methods used to study the relationship between marine resources and economic growth also vary.

The production function is a commonly used method to study the relationship between economic output and factor inputs. Meanwhile, energy as a natural resource is usually included as an input factor in the production function. For example, most studies consider the capital, labor and energy factor inputs in the Cobb–Douglas production function (Moroney, 1992; Dieck -Assad and Peralta, 2013). The elasticity of substitution production function (CES) is also more common. Zha *et al.* (2018) studied energy-biased technological progress by developing a theoretical framework and considered mainly capital, labor and energy among the production input factors. In addition, some studies incorporate energy into an analytical framework beyond logarithmic functions. For example, Pablo-Romero and Sánchez-Braza (2015) analyze the impact of human capital, physical capital and energy use on economic growth in different countries using a transcendental log production function. Lin and Ahmad (2016) considered labor, capital and energy beyond logarithmic production function to

provide ideas for achieving sustainable economic development in Pakistan. Dombi (2018) estimated the capital stock in agriculture, industry and services based on a transcendental log production function, both in physical and monetary terms.

4. Marine resources and economic security

In the past few decades, the study of national security issues has gradually evolved from the traditional political and cultural fields to the economic field (Homolar, 2010). Economic security is an important component of the national security system and is the foundation of national security (Otaki *et al.*, 2018). As national security awareness continues to awaken, the place of economic security in national security is becoming more prominent [A-2]. Economic security is one of the fundamental criteria for the effectiveness of the state as a subject of social relations. In the economic system, economic security creates the necessary material basis for the social and demographic development of the country (Akimova, 2018). Economic security depends on a sustainable supply of marine resources, and this dependence is increasing as the world's population grows and people's living standards improve (Wang *et al.*, 2021a). Therefore, the maintenance of economic security must be based on a certain quantity and quality of marine resources as the material basis.

After the "International Decade of Ocean Exploration" in the 1970s, mankind has further deepened its understanding of marine mineral resources' types, distribution and reserves. The ocean contains polymetallic nodules, cobalt-rich crusts, polymetallic sulfides, rare earth and other mineral resources. In addition to the proven marine minerals, the seafloor also contains many unknown mineral resources. According to Hein and Cherkashov (2017), as a treasure basin of marine mineral resources, the ocean, with its wide variety of mineral resources and abundant reserves, has gradually developed into a prime mover of economic development and an important guarantee of economic security. Meanwhile, Kaluza *et al.* (2018) found that marine mineral resources are transforming from natural capital to financial capital with increasing industrialization and rapid advances in extraction technology. This transformation will directly affect economic security. In summary, it is concluded that the impact of mineral resources on economic security is mainly reflected in three aspects: the ability to access marine mineral resources in a stable manner (Jenkins and Joppa, 2009), the affordable cost of access to marine mineral resources and the ecological protection of the mineral resources extraction process (Kaikkonen *et al.*, 2018).

Marine biological resources are a healthy, green, abundant and renewable new resource. Farcy *et al.* (2019) considered marine biological resources as raw materials for high-quality food, pharmaceuticals, bioproducts and other refined and processed products, which are an important basis for world economic security. Alshubiri *et al.* (2020) found that in the context of economic globalization, marine biology-related industries such as marine capture, mariculture and aquatic product processing industries have developed rapidly and have assumed an important place in the world economy. Marine biological resources are not only the material basis for developing marine economy and building world food security (Shahidi and Ambigaipalan, 2015), but also an important element for expanding the space of marine exploitation and deep ocean strategy (Quaas *et al.*, 2016) and a solid guarantee for safeguarding marine rights and interests and marine economic security (Fu *et al.*, 2018).

Marine spatial resources are the basis and carrier of economic and social development in coastal areas and play an important role in the high-quality economic development of coastal areas. Barale (2018) and Văidianu and Ristea (2018) argue that marine spatial resources such as the coastal zone and the seabed are highly competitive in economic activities such as shipbuilding, tourism and fishing. As an important space for economic development, marine space resources have an important impact on economic security. Other scholars (Wang *et al.*, 2017a; Appiott *et al.*, 2014; Tuya *et al.*, 2014) argue that marine spatial resource management

is facing a critical situation such as the scarcity of high-quality reserve resources and serious damage to the ecological environment on the one hand, and on the other hand, the pressure of seeking development space for high-quality economic development. The pressing responsibility for resource protection and environment and the growing demand for marine resources have become a difficult contradiction to reconcile in marine resource management. In the new period, the core task of marine work is to comprehensively protect marine resources and comprehensively improve marine ecological services.

5. Marine resources accounting

As an important tool for the government to impose behavioral constraints on society, enterprises and individuals, marine resource accounting can help prevent and correct the hollowing out of marine resources, reasonably determine the sustainability of marine resource utilization and predict in advance the potential response of marine resources to stress factors (Allen *et al.*, 2013). Accounting for marine resources can help promote the high-value and habitat utilization of marine resources, thus facilitating the development of the marine economy [A-1]. Early national economic accounting did not focus on accounting for natural resources and was limited to the realm of economic activity. For example, the System of National Accounts (SNA) proposed by Western countries in 1953 ignored natural resources accounting, creating the illusion of economic growth. It was not until the 1970s that Western countries such as France, Norway (Alfsen *et al.*, 1987) and Spain (Laurans *et al.*, 2013) made initial explorations of natural resource accounting.

With the increasing importance of natural resource endowments in recent years, natural resource accounting has gradually gained international significance (Stebbings *et al.*, 2021). In 1992, the World Conference on Environment and Development brought new opportunities for research on natural resource accounting and SNA. In 1993, the United Nations established a framework for systematically accounting for resource stocks and capital flows consistent with the SNA, the System of Environmental-Economic Accounting (SEEA). In 2012, the United Nations and five other major agencies jointly promulgated the "System of Environmental-Economic Accounting-Central Framework (UNSD-2012)," which designed two categories of accounts, physical and value, and set up a framework of flow and stock tables, providing a measurement method and theoretical basis for environmental resource value accounting and becoming an international standard for environmental asset accounting. Among them, the development of SEEA is a milestone in achieving a major advancement in natural resource accounting. Its preparation indicates that the international community is beginning to pay attention to natural resource accounting (Smith, 2007). Accounting for natural resources has now gained momentum, and an increasing number of countries are establishing natural capital accounts based on SEEA (Ruijs *et al.*, 2019).

As an important part of natural resources accounting, marine resource accounting has gained wide attention in recent years; however, at this stage, it is still limited to a single resource area. Accounting for marine renewable energy is the focus of their studies. With growing concerns about environmental pollution and climate change, the search for affordable and environmentally sound marine renewable energy has become an important goal for marine resource researchers. Many scholars have accounted for marine renewable energy resources, mainly including ocean current power resources (Yang *et al.*, 2015; Ching-Piao *et al.*, 2012), ocean wind energy resources (Zheng and Pan, 2014) and ocean thermal energy resources (Devis -Morales *et al.*, 2014). Most of these renewable energy resource accounts are limited to a single sea area, and only a few scholars have conducted global accounts (Zheng and Pan, 2014). As an important component of marine resources, accounting for mineral resources also has great economic value.

Countries such as Australia, Canada, China, India, Kenya, Madagascar, South Africa, Sri Lanka and the USA have explored the field. Notably, accounting studies in this area currently attract a lot of interest due to the huge commercial value of mining marine minerals such as manganese nodules, cobalt-rich ferromanganese crusts, and massive sulfides on the seafloor (Petersen *et al.*, 2016; Ren *et al.*, 2016). In the field of marine living resource accounting, many scholars have now recognized the importance of marine fisheries resource accounting and explored it in (Arreguín-Sánchez *et al.*, 2017; Grüss *et al.*, 2014). However, accounting for the diversity and biomass of plankton, which accounts for 95% of the total living marine resources, is still largely in the exploratory stage (Abida *et al.*, 2013). In addition, progress has been made in accounting for some advanced areas such as marine climate resources (Cole, 1995) and deep-sea genetic resources (Harden-Davies, 2017).

As the technical support for marine resource accounting, all countries have made important progress in technical monitoring and measurement of marine resources in the past decades, laying a solid foundation for accounting marine resources (Pearlman and Zielinski, 2017). The USA has been particularly successful in this area and established the US Ocean Action Plan as early as 2007 to integrate various ocean observation sites and build the Integrated Ocean Observing System (IOOS). Canada has built Ocean Networks by integrating observation facilities from programs such as Neptune and Venus, and developed the Smart Ocean System (SOS) for ocean resource monitoring. The Russian Navy's latest development in 2016 is a system that inter-converts communication information with sound waves, linking active submarines, deep-sea manned submersibles, unmanned submersibles and divers to build an underwater "Internet." The French Copernicus Marine Environment Monitoring Service (CMEMS), part of the EU Earth Observation and Monitoring Project, provides an open platform for ocean data by enabling automated data acquisition through space-based and *in situ* observations. In 2007, the UK launched a major marine research program called "Oceans 2025," which has greatly improved the knowledge and capability of marine resources. Korea's Operational Ocean System (KOOS), which enables the ocean to perform daily monitoring and 72-h forecasting, provides forecasts and warnings for ocean hazards (Park *et al.*, 2015).

The construction of an ocean information system with intelligent ocean information infrastructure as the core is the basis for marine resource accounting (Buonocore *et al.*, 2020). Marine resource accounting is carried out through structured and standardized compilation of relevant data on marine aspects (Gacutan *et al.*, 2022). Countries such as Canada and Portugal have developed physical and value volume accounts for marine resource accounting. Australia has conducted research on marine and coastal ecosystem accounting based on the Great Barrier Reef region. The European Union (EU) is developing an experimental marine ecosystem account for seagrasses. The Netherlands and Finland have also started work on planning marine ecosystem accounts. Although there is still a certain distance to build a perfect global marine resource accounting system, the advanced exploration of some countries has provided the direction for the subsequent research.

6. Evaluation of available research results

Throughout the research on marine resources and economic development, it is evident that scholars worldwide attach great importance to the mutual influence and coordinated development between marine resources and economic development. Marine resources play an important role in boosting the development of the marine economy as an essential element. Promoting economic growth based on the rational development and utilization of marine resources contributes to the goal of sustainable development (Wang *et al.*, 2017b). In recent years, China has attached great importance to the study of the finite supply of marine resources and the unlimited demand for them by economic development. Based on this, this

paper starts from exploring the influence mechanism between the two and deeply grasps the existing contradictions that hinder human sustainable development. Several major topics in the development of management, economy, security and accounting in marine systems are analyzed in the direction of community-based management of marine resources, development of marine economy, biodiversity security and accounting. We have also adopted analytical methods such as correlation of interest and production functions, technical means such as remote sensing and acoustic intercommunication support, and accounting models such as SNA and SEEA to improve and update the content and methods of research on marine resources and economic development research areas continue to expand. However, in general, the research on marine resources and economic development has the following shortcomings.

(1) The research horizon is not broad enough. As an important foundation for the study of marine resources and economic development, the social system is of great importance to the study of marine resources and economic development. However, in the existing studies of marine resources and economic development, no attention has been paid to studying society as an independent system combined with the marine economic system and the marine resource system. The vast majority of current research on marine resources, economy and society has focused on qualitative or quantitative studies of the relationship between marine economies and marine resources. The development of the marine economy is the main focus, with little consideration given to social factors, and is not integrated with the marine resource economy. The findings of research that delve into the coordinated management mechanisms among marine resources, economy and society, and the principles of coordinated governance, are not yet available. The basic issues of the structure, function, interaction and spatial and temporal evolution laws of the composite system of marine resources, economy and society have not been comprehensively covered, making the study on marine resources and economic development lack depth.

(2) Lack of innovation in research methodology. The empirical models and conclusions of many existing studies on land-based resource economics are empirical summaries based on specific conditions and are not fully applicable to the field of marine resource economics (Wang *et al.*, 2021b). Marine resource-economic complex systems have relative independence and integrity, and land-based empirical models and findings may fail when applied to marine systems. Moreover, most of the existing studies on the economic relationship of marine resources are limited to qualitative descriptions and sustainable short-term evaluations. There are relatively few long-term, systematic and quantitative empirical studies on the paths of action of the relationship between the factors of marine resource economy and the state of the composite system of the marine resource economy. In particular, there is a lack of new research concepts, ideas and programs for the current accounting mechanism, management mechanism, coordination mechanism and early warning mechanism of marine resources and economic development. The existing development strategies and countermeasure suggestions based on inductive-deductive methods are generally superficial and formal, with little guidance and concrete efficacy for the practical work of relevant departments.

(3) The theoretical system is not yet sound. Theoretical research results are the subjective reflection of objective practice. Although marine resources and economic development have been supported by a series of theoretical disciplines such as marine economics, resource economics, marine geology, marine biology, etc., a basic consensus has been reached at the level of understanding. However, the existing statistical system of marine economic and resource data are not yet sound due to the

late start of marine resource economics. The contradictions between many social productions and resource productivity such as marine economic growth and marine resource consumption, marine industry development and marine resource protection, coastal population explosion and marine resource-carrying capacity have not yet been fully unfolded on the whole. The essential laws of the interaction between marine resources and the economy have not yet been fully exposed. Therefore, many basic issues in this research field cannot reach a unified consensus, and the research results are scattered, failing to make a more systematic theoretical overview and form a comprehensive research framework system of marine resource economics.

In conclusion, the study of marine resources and economic development involves many intersecting theories and disciplines and is extremely systematic and complex. At present, the academic community's understanding of marine resources and economic development is not yet uniform and comprehensive. The theoretical basis of the research is weak and lacks methodological support in the marine field of expertise. Compared with the research on the economic development of land-based resources, there is an obvious lag in the definition of relevant concepts, theoretical construction and methodological innovation. There is an urgent need to continue in-depth research based on successive collations, generalizations and summaries to open up the existing research horizons, update the research methods, improve the research system and develop a scientific, objective and comprehensive research results to provide strong support for marine resources development, marine economic development and marine resources protection.

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