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Policy suggestions for tapping the potential of ocean carbon sinks in the context of “double carbon” goals in China

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China is rich in marine resources and has excellent potential for the development of oceanic carbon sinks. Ocean carbon sinks have shown broad application prospects, but the technical system for trading has not yet been perfected, the relevant legislation has not yet been established, etc. China should actively promote scientific research on ocean carbon sinks, improve the technical system of ocean carbon sinks, establish an ocean carbon sink trading system, and develop the eco-economy of ocean carbon sinks. It should also establish a sound system of laws and regulations to explore the potential of oceanic carbon sinks and contribute to the realization of China’s dual-carbon goal.

KEYWORDS

dual carbon targets, marine resources, ocean carbon sinks, technology systems, policy recommendations

1 Introduction

In September 2020, President Xi Jinping announced at the general debate of the seventy-fifth session of the United Nations General Assembly that China would increase its nationally owned contribution, adopt more robust policies and measures, strive to peak carbon dioxide emissions by 2030, and endeavor to achieve carbon neutrality by 2060. Carbon peaking refers to the situation where at a certain moment, the emissions of carbon dioxide and other greenhouse gases reach their peak and no longer continue to increase, beginning to enter a declining phase. Carbon neutrality refers to the process of reducing carbon dioxide and other greenhouse gases emitted into the atmosphere to near zero through various technologies and measures. This is China’s “dual-carbon” goal (Xi, 2021). The “dual-carbon” goal demonstrates China’s new efforts and contributions to addressing global climate change, reflects its firm support for multilateralism, and injects strong impetus into the international community for the full and effective implementation of the Paris Agreement (Gallo et al., 2017).

The realization of “double carbon” is a broad economic and social systemic change; reducing carbon emissions and increasing carbon sinks are essential factors for the

realization of the “double carbon” goal, and the function of carbon sinks is an important and necessary measure for the realization of the double carbon goal in China. The marine carbon sink function is an integral part of the carbon sink function. The so-called carbon sink function mainly refers to the process and ability to store carbon dioxide in ecosystems such as forests, grasslands, crops, soils, and oceans through natural processes or anthropogenic measures. A marine carbon sink is the carbon dioxide (CO₂) absorption and storage by marine ecosystems (including seawater, seafloor sediments, algae, plankton, coral reefs, etc.), which is an integral part of the global carbon cycle (National Research Council, 2015; Bellenger et al., 2023). The oceanic carbon sink has a huge carbon reservoir, and the biological, biogeochemical, and physical processes of the oceans combine to participate in the cycling of carbon through the oceans, contributing to the productive and energetic transformation of marine ecosystems (Bindoff et al., 2019). The ocean carbon sink is stored in the deep ocean, and its capacity occupies an important place in the Earth's carbon cycle (Devries et al., 2023). In the process of realizing the goal of carbon neutrality, it is necessary to accurately assess and manage the stock and distribution of ocean carbon sinks, so the progress of research on ocean carbon sinks plays a very important role in helping to realize the goal of carbon neutrality. Internationally, the management of ocean carbon sinks is being actively integrated into climate change-related actions, such as nationally owned contributions and greenhouse gas inventories, while recognizing the positive role that the protection and restoration of blue-carbon ecosystems can play in addressing global climate issues.

At present, the theoretical research on ocean carbon sinks focuses on the following aspects: Firstly, understand the scope of ocean carbon sinks. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) defined “sink” as any process, activity, or mechanism that removes greenhouse gases, aerosols, or greenhouse gas precursors from the atmosphere (UNFCCC, 1992). There is currently no official definition of ocean carbon sink internationally, but the term “ocean carbon sink” is commonly used in various government documents. In 2009, the United Nations proposed the concept of “blue carbon” in its assessment report on the role of healthy ocean carbon sequestration and recognized the important role of important coastal ecosystems such as mangroves and salt marshes in global carbon cycling and addressing climate change (Wu et al., 2020). The concept of blue carbon emphasizes more the characteristics driven by biology and its easy-to-manage properties (Mcleod et al., 2011). It is an important field of ocean carbon sinks (Howard et al., 2023; Li et al., 2024). China's “Accounting Method for Marine Carbon Sink,” released in 2023, expands on the definition of marine carbon sink. It specifies that mangroves, salt marshes, seagrass beds, phytoplankton, large algae, and shellfish absorb and store carbon dioxide from the air or seawater.

Secondly, research on the principle of carbon sequestration by ocean carbon sinks. Scholars from different disciplines have studied the principle of ocean carbon sequestration, which can be broadly classified into three types: chemical processes, namely dissolved carbon fixation (Hartmann et al., 2013). Carbon dioxide in the ocean reacts with water to form hydrogen carbonate ions (HCO₃⁻)

and carbonate ions (CO₃²⁻). These dissolved carbons circulate in the ocean and slow down the accumulation rate of carbon dioxide in the atmosphere (Zhang et al., 2023; Zondervan et al., 2023). The second is biological processes, namely carbon sequestration by marine organisms. Planktonic plants in the ocean convert carbon dioxide into biomass through photosynthesis and then deposit it in the deep sea. These biomasses will eventually deposit on the seabed, forming sediments that store carbon dioxide in the ocean. In addition, other organisms in the ocean, such as corals and shellfish, also participate in this process (Gruber et al., 2023; Huang et al., 2023). The third is the physical process, namely the ocean carbon pumping effect (Macovei et al., 2020). The upwelling and downwelling in the ocean can cause the mixing and circulation of seawater, promoting the vertical transport of carbon dioxide. Upwelling will cause seawater with higher concentrations of carbon dioxide to rise to the surface of the sea and release it into the atmosphere. The descending flow mixes water depths containing lower concentrations of carbon dioxide together, dynamically regulating the concentration of carbon dioxide in the entire ocean system. However, some studies have also focused on the influencing factors of ocean carbon sequestration, such as marine ecology, tidal currents, marine biodiversity, and changes in ocean water temperature (McKinley et al., 2023).

Thirdly, research is needed for the measurement of ocean carbon sink efficiency and the accounting of ocean carbon sink value. The effective measurement of ocean carbon sequestration capacity is the foundation and prerequisite for building the ocean carbon sequestration market and developing the carbon sequestration industry (Wang et al., 2023). Due to limitations in detectability, manageability, and data availability, there are currently no authoritative carbon sink statistics for coastal ecosystems, mainly composed of mangroves, seagrass beds, and salt marshes (Rosan et al., 2024). This hampers research on the value accounting of marine carbon sinks. At present, there are options for pricing methods for studying the value accounting of ocean carbon sinks, cost-benefit pricing models, etc.

Fourthly, research is needed on the effects of ocean carbon sinks. Currently, research is focused on the environmental and economic effects of ocean carbon sinks. Scholars found that shellfish, mangroves, and plankton are strong carbon sinks with ecological and environmental functions of increasing carbon sinks and reducing carbon sources (World Ocean Review, 2010; Reithmaier et al., 2023). They also researched nearshore aquaculture's carbon sequestration process and mechanism (Camp et al., 2016). This revealed how fishery production shifts from negative externalities to positive internalities through carbon sequestration (Cheung et al., 2016; Windham-Myers et al., 2019).

This has improved people's understanding of the role of fishery carbon sequestration in marine environmental restoration. Scholars from different perspectives have demonstrated that aquaculture of shellfish and algae in seawater enhances the ability of shallow marine ecosystems to absorb carbon dioxide. This lays a theoretical foundation for establishing a carbon sink fisheries assessment model (Kirwan et al., 2023; Rosentreter et al., 2023). The ocean plays a fundamental role in global climate change and carbon cycling processes (Duarte et al., 2013, 2017). Regarding the

economic effects of ocean carbon sinks, some scholars suggest that combining ocean carbon sinks and carbon sink trading could accelerate China's emission reduction goals and explore new economic growth models while balancing economic and social benefits (Mao et al., 2023). Additionally, the development of marine carbon sink fisheries has promoted the growth of the marine fishery economy and the adjustment of industrial structure, while also promoting the development of the primary industry and related industries of the marine fishery economy. Research has shown that ocean carbon sinks can promote economic growth and enhance the decoupling ability between economic development and carbon emissions. It is important to fully recognize the significance of ocean carbon sinks and utilize their potential to promote the development of marine economy-related industries. This can be achieved by forming a carbon reduction system and sinking industry chains and low-carbon new business models, making ocean carbon sinks a booster for sustained and stable economic development. The sustainable and healthy development of ocean carbon sinks has immeasurable value for the marine economy.

Fifthly, research on the theoretical basis of the ocean carbon sink market and the mechanism of ocean carbon sink trading (Wei et al., 2023) Research has shown that to achieve the capitalization process of marine carbon sink resources, four processes must be gone through. One is the process of association, which converts marine carbon sink resources into marine carbon sink assets through property rights confirmation. The second is the productization process, which achieves the transformation of marine carbon sink assets into marine carbon sink products or services through the research and application of ecological technologies. The third is the process of transforming products or services into capital through value accounting and trading to achieve the transformation of marine carbon sink products or services into marine carbon sink capital. The fourth is the operational process, through ecological investment, to achieve the feedback of marine carbon sink capital on marine carbon sink resources. Research on the mechanism of ocean carbon sink trading. Most scholars have examined the ocean carbon sink trading mechanism based on current carbon emission trading mechanisms in various countries, but there are still many issues worth exploring.

Studies have been conducted on the relationship between marine carbon sinks and marine ecosystems (European Marine Board, 2023). The low-carbon transformation of marine ports (Li J. et al., 2023; Xu et al., 2024a), the risk of oil spills at sea (Chen et al., 2022), and pollution issues related to the passage of marine vessels (Chen et al., 2022; Xu et al., 2024b). The correlation between marine carbon sinks and marine ecological restoration, cost-benefit assessments of marine negative emission technologies (NASEM, 2019; Gattuso et al., 2021), and the impact of marine engineering (GESAMP, 2019; He et al., 2023). Key action issues of blue carbon as a climate solution (McKinley et al., 2016). Distribution and quantification of marine carbon sinks, carbon capture and storage technologies, benefits and risks of national marine strategies

(International Maritime Organization, 2023), ocean carbon sinks and carbon finance (Macreadie et al., 2022), the necessity of interdisciplinary research on ocean carbon sinks, and the effectiveness of national blue carbon strategies (NASEM, 2022). It is important to maintain objectivity and avoid biased language when discussing these topics.

Of course, under the background of climate change, the study of marine carbon sequestration has become a hot topic for scholars all over the world. If using scientometrics methods, social network analysis, and Stochastic Actor-oriented Model (SAOM), based on multivariate databases such as Web of Science, CNKI, and others by visualizing and analyzing the source journals, hotspot co-occurrence networks, and national cooperative networks, the current status and characteristics of marine carbon sequestration research can be comprehensively understood (Xiao et al., 2023).

In practice, cities in China's coastal areas have actively explored the development and trading of marine carbon sink projects and have accumulated a lot of experience in the areas of trading mechanisms, methodology research and development, and financial support. First, establish a marine carbon trading platform and promote the development and trading of marine carbon projects. In 2021, Xiamen Property Rights Trading Center will set up a marine carbon trading service platform and explore the trading of the mangrove ecological restoration project of the Luoyang River in Quanzhou and the trading of marine aquaculture and fishery carbon projects in Lianjiang County. Second, it is about exploring the accounting of ocean carbon sinks and methodology research and development. In terms of accounting, in June 2021, Shenzhen Dapeng New Area released the "Marine Carbon Sink Accounting Guidelines," which constructed an accounting system for the total carbon sinks of marine organisms and coastal wetlands. Third, the innovation of carbon financial instruments to support marine carbon sink projects. Since 2021, several financial institutions have emerged in China's coastal areas to grant credit for marine carbon sink projects. Such as the Industrial Bank of Qingdao Branch, which has issued loans of nearly 40 million yuan to relevant enterprises with the Jiaozhou Bay wetland carbon sinks and the Tangdao Bay wetland carbon sinks as pledges (Cao and Wu, 2022).

Although China's ocean carbon sinks have shown a broad application prospect, the potential of domestic oceanic carbon sinks has yet to be further explored due to factors such as the fact that the accounting standards for carbon sinks and the technical system for trading have not yet been perfected, and the relevant legislation is not yet sound.

2 China's ocean carbon sinks have massive potential for development

China has introduced a series of policies and measures in recent years to promote the development of ocean carbon sinks, strengthen research on ocean carbon sink technologies, and encourage localities to actively explore ocean carbon sink practices.

2.1 Policy deployment: actively promote the development of ocean carbon sinks

China attaches great importance to marine work, and in recent years, with strong policy support, it has accelerated the pace of the development of ocean carbon sinks and promoted the high-quality development of the marine economy. The Central Committee of the Communist Party of China and the State Council formulated the plan for ecological civilization system reform in 2015. They emphasized the importance of marine carbon sinks. In 2017, China proposed the ‘Belt and Road’ construction cooperation to strengthen international collaboration on blue carbon. The proposal for the 2020 ‘dual carbon’ goal presents new opportunities for the development of marine carbon sinks. In 2021, the Central Committee of the Communist Party of China and the State Council jointly issued the ‘Opinions on Fully and Accurately Implementing the New Development Concept and Doing a Good Job in Carbon Peaking and Carbon Neutrality’. The document emphasizes the need to continuously consolidate and improve marine carbon sequestration capacity. The 2022 report of the 20th National Congress of the CPC also emphasized the need to enhance the ecosystem’s carbon sink capacity and actively and steadily promote the ‘double carbon’ goal. In addition, the State Council and its various departments have also issued relevant carbon sequestration policy documents, as shown in [Table 1](#).

2.2 Scientific research support and development of research methods for marine carbon sinks

Basic research on ocean carbon sinks mainly focuses on two aspects. One is to consolidate and enhance the increase in ocean carbon sinks. Research has emphasized the role of land-based pollution prevention and control, as well as marine ecological protection and restoration, in promoting the construction of marine carbon sinks and proposed a coordinated approach between land and sea to reduce pollution and carbon emissions and enhance efficiency. Some studies suggest that we should explore the establishment of a comprehensive governance system that integrates watershed, coastal, and marine areas, effectively leveraging the carbon sequestration role of the ocean and enhancing the carbon sink increment of the marine ecosystem. Some studies suggest that blue-carbon ecosystems should have clear priority protection and restoration areas, corresponding management measures, and improved ecological compensation mechanisms. The second is to explore emerging carbon sinks beyond traditional ocean carbon sinks. Some scholars believe that it is necessary to identify the potential and dynamic mechanisms of carbon sequestration in China’s marine fisheries, continuously explore new ways to expand fishery carbon sequestration, and implement the construction of fishery carbon sequestration expansion projects. Scholars suggest implementing large-scale algae, land, and sea-integrated ecological agriculture projects. Scholars suggest establishing a mixed culture of non-feeding

organisms, like shellfish, algae, and benthic species. They recommend choosing organisms that the environment can support. Then, they propose creating an artificial upwelling ecological sink enhancement project powered by clean energy. Scholars suggest establishing a seaweed field based on live oyster reefs to expand the blue carbon enrichment zone. Some scholars believe that the geological storage of carbon dioxide in the seabed has great potential for carbon sequestration and storage.

After the official proposal of the “Blue Carbon Plan” at the 16th United Nations Climate Change Conference in 2010, China has launched multiple scientific research projects related to blue carbon, focusing on promoting research on marine carbon sinks. Since 2012, the “Collaborative Innovation Center for Marine Carbon Sink and Future Earth” and the “National Marine Carbon Sink Alliance” have been established successively, bringing together outstanding research forces in marine carbon sinks at home and abroad. In 2014, the “China Future Ocean Alliance” was officially unveiled, and the “China Blue Carbon Plan” was launched, promoting the vigorous development of marine carbon sink research in China. The launch of the 2019 International Major Scientific Program on Marine Negative Emissions marked the fact that China’s research on marine carbon sinks is at the forefront of the international community. Through years of scientific research efforts, China’s marine carbon sink research has made significant progress and achievements.

2.3 Practical exploration to promote the exploration of the potential of ocean carbon sinks

Carbon sink trading has expanded globally from forest carbon sinks to include ocean and wetland carbon sinks, promoting the protection and restoration of natural resources—for instance, Madagascar’s marine carbon sequestration project and the United States’ wetland carbon sequestration project. In 2018, Madagascar launched the ‘Protect Mangrove Forests’ plan, which can sequester more than 1300 tons of carbon annually. Similarly, in 2015, the Wakuit Bay Research and Conservation Program in the United States launched the ‘Bringing Wetlands to the Market’ initiative. It was estimated that the reduction in emissions from the Wakuit Bay wetland restoration project would reach 8.5×10^4 tons, and the carbon trading price is 10 USD/t ([Liu et al., 2022](#)).

With the proposal of China’s “dual carbon” goals, coastal regions have begun to practice and continue to make efforts to explore the potential of ocean carbon sinks and promote ocean carbon sink trading. In December 2016, Weihai Nanhai New Area launched the construction of a national marine carbon sink research and development base, promoting the accounting of marine carbon sink transactions and the development of carbon sink fisheries. In May 2021, the Ecological Environment Bureau of Dapeng District, Shenzhen, completed the country’s first “Guidelines for Marine Carbon Sink Accounting” and constructed a method for marine carbon sink accounting in coastal areas, but it was not publicly released. In June 2021, Zhanjiang completed China’s first mangrove carbon sink trading project, with a carbon dioxide reduction of 5880

TABLE 1 Relevant marine carbon sequestration policy documents issued by the State Council and its departments.

NO.	Issuing subject	Name of policy	Release time	Main content
1	The Central Committee of the Communist Party of China and the State Council	Opinions on Fully Implementing the New Development Concept and Achieving Carbon Peak and Carbon Neutrality	October 24, 2021	Continuously consolidating and improving carbon sequestration capacity and increasing ecosystem carbon sequestration increments.
2	The State Council	Action plan for peaking carbon emissions before 2030	October 26, 2021	Consolidate the role of ecosystem carbon sequestration and strengthen the basic support for ecosystem carbon sequestration.
3	The State Council	Opinions of the General Office of the State Council on Encouraging and Supporting Social Capital to Participate in Ecological Protection and Restoration	November 10, 2021	Comprehensively enhance the carbon sequestration capacity of ecosystems and encourage the development of carbon sequestration projects.
4	Ministry of Ecology and Environment	Implementation Plan for Collaborative Efficiency Enhancement of Pollution Reduction and Carbon Reduction	June 17, 2022	Research on the carbon sequestration effects of soil and water conservation measures.
5	Ministry of Natural Resources	Accounting methods for the economic value of marine carbon sinks	February 21, 2022	Accounting methods for the economic value of marine carbon sinks.
6	The State Administration for Market Regulation and the National Standardization Administration	Guidelines for the approval and certification of forestry carbon sequestration projects	December 31, 2021	Guidelines for the approval and certification of forestry carbon sequestration projects.
7	The State Administration for Market Regulation	Implementation of the Action Plan for the National Standardization Development Outline	July 9, 2022	Research and develop standards for ecological carbon sequestration, carbon capture, utilization, and storage.
8	Supreme People's Court (SPC)	Opinions of the Supreme People's Court on Providing Judicial Services and Guarantees for Accelerating the Construction of a National Unified Market	July 25, 2022	Research alternative compensation methods, such as carbon sink subscriptions.
9	Ministry of Agriculture and Rural Affairs, National Rural Revitalization Bureau, National Development Bank, Agricultural Development Bank	Notice on Promoting Policy-Based Development Financial Support for Agricultural and Rural Infrastructure Construction	July 18, 2022	Exploring the mechanism for realizing the value of carbon sequestration products.
10	State Forest and Grassland Administration	Opinions on Accelerating the Innovative Development of the Bamboo Industry	December 6, 2021	Encourage local governments to build forest and bamboo carbon sink trading platforms.
11	Ministry of Science and Technology	Implementation Plan for Science and Technology Cooperation between the East and West during the 14th Five-Year Plan Period	March 4, 2022	Implement demonstrations of forest carbon sink integration in the Greater Khingan Mountains.
12	Ministry of Ecology and Environment	Notice on Doing a Good Job in the Management of Greenhouse Gas Emission Reports for Enterprises in the Power Generation Industry from 2023 to 2025	February 7, 2023	Organize the management of greenhouse gas emission reports for enterprises in the power generation industry.
13	The National Standardization Administration and the National Development and Reform Commission	Guidelines for the construction of carbon peak carbon neutralization standard system	April 22, 2023	It is proposed that the standard system of carbon peaking and carbon neutralization will be built around the basic general standards as well as the development needs of carbon emission reduction, carbon removal, and the carbon market.
14	The State Administration for Market Regulation	Implementing Opinions on the overall use of quality certification services for carbon peaking and carbon neutralization	October 12, 2023	By 2025, it is proposed to establish a carbon peak and carbon neutrality certification system that combines direct and indirect carbon-related activities and combines national unified promotion with institutional independent implementation.

(Continued)

TABLE 1 Continued

NO.	Issuing subject	Name of policy	Release time	Main content
15	National Development and Reform Commission	National Carbon Peak Pilot Construction Plan	October 20, 2023	It is explicitly stated that by 2025, pilot cities and parks will make positive progress in achieving carbon peak and carbon neutrality.
16	National Development and Reform Commission, Ministry of Industry and Information Technology, State Administration for Market Regulation, Ministry of Housing and Urban-Rural Development, Ministry of Transport	Opinions on Accelerating the Establishment of a Product Carbon Footprint Management System	November 13, 2023	Propose to introduce around 50 carbon footprint accounting rules and standards for key products at the national level by 2025.

tons traded. In July 2021, Xiamen established the country's first ocean carbon sink trading platform and completed the first carbon sink transaction, with a carbon dioxide emission reduction of 2000t. In January 2022, Lianjiang County relied on the first marine carbon sink trading platform in China, Xiamen Property Rights Trading Center (Xiamen Carbon and Emission Rights Trading Center), to complete a 15000-t marine carbon sink trading project for aquaculture and fisheries. This project is also the first marine fishery carbon sink trading project in the pilot trial of local carbon sink construction (Li et al., 2022).

3 The dilemma of China's ocean carbon sink development

Despite the great potential of China's ocean carbon sink, there are still some dilemmas in both its theoretical research and practical exploration.

3.1 Research related to ocean carbon sinks is not yet mature

Compared with terrestrial carbon sinks, there are fewer studies on ocean carbon sinks, especially those of marine ecosystems, including algae, marine shellfish, phytoplankton, etc. Many studies are still inconclusive. They need further scientific research to clarify (Dalton, 2002; Heinze et al., 2015). China's research on the accounting and assessment of ocean carbon sinks is still in its initial stages. It must still build a monitoring and accounting system for oceanic carbon sinks per international standards. There is no unified standard for accounting for the value of oceanic carbon sinks at home and abroad, so it is difficult to establish a scientific monitoring and assessment system for oceanic carbon sinks (Hauck et al., 2020).

3.2 Ocean carbon sink trading system is still not perfect

At the theoretical level, the marine carbon sink trading system mainly focuses on the infrastructure construction and implementation path of the marine carbon sink trading market.

Some scholars believe that a legal system for ocean carbon sink trading should be established, clarifying the trading subject and object, trading mode, price, and contract rules, as well as external protection mechanisms (Liu et al., 2022). Some scholars believe that it is necessary to explore the establishment of accounting standards for marine carbon sinks and a value evaluation system for trading projects and to establish a marine carbon sink trading market (Sterner et al., 2019). Some scholars believe that social capital should be encouraged to enter the protection and restoration of mangroves and marine carbon sequestration projects should be included in the design of coastal wetland ecosystem restoration while developing methodologies for marine carbon sequestration projects (Jiang, 2019; Beloto et al., 2023). Some scholars believe that a systematic monitoring and evaluation system for ocean carbon sinks should be established, and ocean carbon sink trading should be promoted in stages to explore the path of market-oriented governance for ocean carbon sinks (Zhao et al., 2021). Scholars have proposed the strategic decision and overall idea of establishing a blue carbon market as soon as possible and promoting the inclusion of blue carbon in the carbon trading system (Yu et al., 2023).

In practice, some places have also begun to actively explore the ocean carbon sink trading system. With the gradual exploration of the development and utilization value of marine carbon sinks, in recent years, major marine provinces such as Guangdong, Fujian, Zhejiang, Hainan, and Shandong have launched practical activities. For example, Lianjiang in Fujian completed the first national fishery carbon sink transaction last year, and Ningbo in Zhejiang also conducted the first national blue carbon auction transaction. These practical actions indicate that China's marine carbon sinks have entered the stage of market trading. However, the lack of sound basic research on marine carbon sinks, the lack of unified carbon accounting standards, and the imperfect setting of related trading mechanisms make it difficult to carry out market-oriented and large-scale carbon sink trading. Marine carbon sinks face many challenges in the trading process (Karstensen et al., 2021).

3.3 The ocean carbon sink legislation system is not yet sound

China needs a mature legal system in the field of ocean carbon sinks. On the one hand, although China has introduced several

policies and regulations at the national and industry levels, most of them focus on blue carbon development and utilization, restoration, and other aspects and lack adequate legal support for the right to benefit from blue carbon, the property rights of the underlying assets, and the standardization of blue carbon trading. On the other hand, the number of local regulatory documents about ocean carbon sinks is relatively small. At the local level, so far, only a few regions have issued policy documents, such as the Action Plan for the Development of the Blue Carbon Economy in Weihai City, Shandong Province, and the number of related records is small, and the legislative system has not yet been improved.

4 Proposals for tapping the potential of ocean carbon sinks and creating a blue carbon demonstration base

In response to the current dilemma of China's ocean carbon sink development, China needs to actively take policy measures to tap the potential of ocean carbon sinks and help achieve the dual carbon goal.

4.1 Promote scientific research on ocean carbon sinks and improve the technical system of oceanic carbon sinks

4.1.1 Strengthen scientific and technological research on ocean carbon sinks

Technical support is crucial for unlocking the potential of ocean carbon sinks. Further research is needed to explore the mechanisms related to ocean carbon sinks. It is also needed to clarify their activity, storage, and carbon increment theories. Finally, we need to determine the carbon sink effect of blue carbon ecosystems (Sheehy et al., 2024). Additionally, there is still controversy over the carbon source and carbon sink attributes of certain fishery activities. It is necessary to deepen research on the scientific mechanisms and accounting methods of marine carbon sinks. A network for monitoring coastal wetland carbon flux will be constructed for typical mangrove, salt marsh, and seagrass ecosystems (Williamson and Gattuso, 2022). The network will identify carbon flux, spatiotemporal evolution, and control mechanisms in natural cycles. In-depth research will be conducted on the carbon sequestration effects of exotic species, such as *Oryza sativa variegata*. Carbon sequestration mechanisms in marine aquaculture, such as shellfish and algae, will be systematically promoted. Carbon footprints in each link will be identified, and effective carbon measurement methods will be established (Mignot et al., 2022; Nguyen et al., 2022). Research and promote core technologies for marine carbon sequestration, develop technologies for carbon sequestration and enhancement, reduce negative emissions (Anderson and Peters, 2016), and observe carbon sequestration networks in the ocean. Conduct special research on ocean carbon sinks and study their development potential.

4.1.2 Establish a monitoring system and evaluation standards for ocean carbon sinks

In the context of technological breakthroughs, we use remote sensing monitoring, mobile monitoring, and other means to monitor the marine carbon sink ecosystem in all aspects and grasp the actual state of the ocean's carbon sink ecosystem and the trend of change to take countermeasures in advance. We will strengthen scientific research and field testing of ocean carbon sinks. This will lead to a set of universal standard systems for measuring, testing, and evaluating oceanic carbon sinks. These standards will lead to the construction of blue-carbon demonstration bases (Cao and Wu, 2022).

China has already explored these areas and has accumulated some preliminary experience. In 2018, the monitoring, investigation, evaluation, and standardization system construction of marine carbon sinks were respectively included in the functional scope of the Ministry of Ecology and Environment and the Ministry of Natural Resources. The Ministry of Ecology and Environment has organized technical teams to explore the distribution of carbon dioxide sources and sinks in China's offshore areas. Greenhouse gases have been included in the '14th Five Year Plan' marine ecological environment quality monitoring network deployment plan, as well as in the '14th Five Year Plan' marine special monitoring tasks. The 'Pilot Work Plan for Carbon Monitoring and Assessment' implemented in 2021 specifies the pilot implementation of carbon sink monitoring in salt marshes, mangroves, seagrass beds, and seaweed aquaculture in four cities: Panjin, Nantong, Shenzhen, and Zhanjiang. The Ministry of Natural Resources has formulated and released the "Carbon Storage Method for Measuring Carbon Sink in the Cultivation of Large Algae and Bivalves" (HY/T 0305-2021), which has been implemented since June 2021. The Notice on Establishing and Improving a Marine Ecological Monitoring and Early Warning System, released in September 2021, specifies the implementation of carbon storage investigation and assessment in typical blue carbon ecosystems such as seagrass beds, mangroves, and salt marshes. It requires including these ecosystems in baseline surveys. The Guangxi Mangrove Research Center compiled and released the Technical Regulations for Carbon Sequestration Capacity Assessment of Mangrove Wetland Ecosystems (DB 45/T 1230-2015). These regulations are currently the most direct technical basis for monitoring and assessing mangroves' carbon sequestration and storage.

4.2 Building a marine carbon sink trading system and developing the marine carbon sink ecological economy

4.2.1 Establish a unified ocean carbon sink trading market

Marine carbon sequestration is an important way for coastal cities to develop sustainably. It can turn regional strengths into economic advantages. This economic value is likely to make marine carbon sequestration more recognized by the nation. Feng et al. (2023) suggest that China's marine carbon sequestration platform is still in its early stages and has significant growth potential. It is

recommended to pilot the development of marine carbon sink projects such as mangroves, seagrass beds, and salt marshes in regions with high biodiversity, such as Jiangsu, Zhejiang, Fujian, Guangdong, and Guangxi. We should research project methodology and marine carbon sink accounting standards based on fully absorbing the experience of Zhanjiang and Xiamen. This will provide experience and data for establishing a unified marine carbon sink accounting and trading system and connecting with a unified carbon sink trading market.

4.2.2 Actively cultivating new forms of marine carbon sequestration economy

Financial empowerment, actively promoting the industry, and scale-up of marine carbon sinks. China is developing marine carbon sequestration economic development zones in coastal areas like Xiamen, Qingdao, and Shanghai. The goal is to create a new form of marine carbon sequestration ecological economy with ‘increasing carbon sequestration and reducing emissions’ as the core. This will support diverse economies such as marine tourism, food processing, and carbon finance, forming an orderly blue carbon economic industrial chain and promoting the formation of a marine carbon sequestration trading system (Zhao et al., 2021).

Establish a carbon sink consolidation and comprehensive development and utilization system for marine clean energy, accelerate the development of marine ecological industries, and form diverse new forms of marine economy. By promoting the development of marine carbon sequestration, we aim to drive related industries, promote the development of marine clean energy, carbon sequestration aquaculture, environmental improvement, and other industries, and form a comprehensive carbon sequestration-related industry chain layout. Incorporate marine carbon sinks into the value-creation system of marine ecological products. Establish a protector benefits, destroyer pays” marine carbon sink ecological compensation mechanism (Li M. et al., 2023).

4.3 Strengthen strategic policy planning and management; establish and improve legal and regulatory systems.

4.3.1 Strengthening top-level strategic design

From the perspective of ecological civilization, consider ocean carbon sinks in the overall context of ecological nation-building. Introduce policies and plans for tapping the potential of ocean carbon sinks in terms of sustainable development and incentive subsidies. Connect them with national development strategies.

4.3.2 Improve legislation related to ocean carbon sinks

China has issued multiple maritime regulations, forming a preliminary legal framework for ocean carbon sequestration, but has not yet organically linked ocean governance with addressing climate change. There are legislative gaps in the fields of climate governance, carbon sequestration market establishment and management, and carbon sequestration trading. The Civil Code does not specify the

attributes of state-owned assets related to environmental resources, and the nature of carbon emission rights is also unclear. For instance, the Law on the Administration of the Use of Marine Areas has been in place for a long time but has not yet made provisions for marine carbon sinks. This lack of clarity hinders the orderly construction of marine carbon sinks (Jiang, 2019). China should actively improve legislation related to ocean carbon sinks. On the one hand, it is recommended to improve legislation in the fields of marine carbon sequestration technology, transaction accounting, and ecological protection at the national and industry levels, starting with early regulation, prevention, and later legal responsibilities, to ensure the sustainable development of marine carbon sequestration. On the other hand, local governments should also closely follow policy development, do a good job in local legislation, and thus establish a sound legal and regulatory system for marine carbon sequestration from top to bottom.

4.4 Carry out typical projects in coastal areas and focus on building blue-carbon demonstration bases

4.4.1 Conducting blue carbon feature demonstration projects

The development of blue carbon demonstration projects is conducive to creating demonstration bases, which is one of the concrete ways to implement China’s carbon-neutral strategy. Priority layout of Shandong coastal seaweed, sea grass, Jiangsu salt marsh, Guangdong and Guangxi coastal mangroves, critical eastern coastal wetlands, and another pilot blue carbon demonstration base and project. The focus is on building mangroves, sea grass beds, tamarisk, alkali ponies, and other unique ecosystem blue carbon demonstration projects and grounds.

4.4.2 Develop a blue-carbon demonstration base program in line with regional development positioning

A scientific and reasonable top-level design should be made, with the central state authorities and local governments working together to develop an excellent corresponding management mechanism and cooperation model. According to the geopolitical characteristics of different regions, we should collaborate to create a blue carbon demonstration base program that best suits the development positioning of the area and actively explore the construction path of the blue carbon demonstration base on this basis.

5 Conclusion

Ocean carbon sinks will help to share and relieve the pressure of carbon emissions, another feasible path outside of “emission reduction.” The development of ocean carbon sinks can significantly enhance the carbon sink capacity of ecosystems, which is an essential path to achieving the double carbon goal. Compared with the carbon sink’s role in terrestrial ecosystems, the solid power of marine ecosystems is excellent, and ocean carbon sinks have the advantages of high carbon sequestration, a long carbon cycle, and a long-lasting

carbon sequestration effect. China has about 3 million square kilometers of jurisdictional sea area, 18,000 kilometers of mainland coastline, and 6.7 million hectares of coastal wetlands, providing a vast space for developing ocean carbon sinks. In addition to adjusting the energy structure and strengthening carbon emission reduction measures, China should actively explore the potential of carbon sinks, especially ocean carbon sinks, to promote the timely achievement of China's dual carbon goals.

Author contributions

XW: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. QW: Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition, Formal analysis, Conceptualization.

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Conflict of interest

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