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Institutional Obstacles and Countermeasures to Improve the Chinese Ocean Carbon Sink Trading Market

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Abstract: Global climate change is a great challenge shared by human society today. All countries are actively carrying out carbon emissions trading to cope with increasingly serious environmental problems. Ocean carbon sink trading is an important part of the carbon emissions trading market and has become a new academic hot spot. It is urgent to construct an ocean carbon sink trading mechanism that meets China's national conditions. The goal of this study is to determine how to improve China's ocean carbon sink trading market using research methods such as normative analysis, comparative analysis, and case studies. The study shows that there are outstanding problems, such as unclear property rights and imperfect relevant laws and regulations, in the Chinese ocean carbon sink trading market. In order to solve these problems, the property rights of ocean carbon sinks should be clarified, relevant laws related to ocean carbon sinks and the trading market should be improved, and construction of a financial system for ocean carbon sinks should be further developed. At the same time, it is necessary to strengthen the supervision of ocean carbon sink trading and encourage the public to actively participate. According to the results of the study, there is a long way to go towards improving China's ocean carbon sink trading market, requiring the joint efforts of the government, market, society, and public in making greater contributions in the response to global climate change.

Keywords: blue carbon; ocean carbon sink trading; carbon inclusion; climate change; China

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1. Introduction

1.1. Research Background

Global warming is considered one of the most serious challenges facing the world today. In the mid-twentieth century, along with the postwar economic recovery, modern industry developed rapidly. The rate of fossil energy consumption is increasing, and the levels of greenhouse gases in the atmosphere are rising. The exchange of "environmental destruction" for "economic development" has become a uniform practice in many countries [1]. The sources and sinks of greenhouse gases, which had been relatively balanced, have been profoundly altered by human activities as a result of massive deforestation and destruction of vegetation. The greenhouse gases emitted into the atmosphere by human beings have greatly exceeded the Earth's own purification capacity. In recent decades, global carbon dioxide emissions have exhibited a steep upward trend. If the concentration of greenhouse gases continues to increase, global warming will lead to the melting of glaciers at the poles, inundation of coastal areas, and frequent occurrence of extreme weather, posing fatal threats to the survival and development of human society [2]. In the face of the "sword of Damocles" hanging over the heads of mankind, the international community has gradually recognised the importance of carbon emissions reduction. In 1992, the United Nations Conference on Environment and Development (UNCED) adopted the United Nations Framework Convention on Climate Change (UNFCCC), which reached a consensus on the "common but differentiated responsibilities" of all countries in combating climate change. This signalled that the negative impacts of greenhouse gases on climate

change have been incorporated into the regulatory framework of international law. The Kyoto Protocol was subsequently adopted in Kyoto, Japan, in 1997. It provides detailed implementation mechanisms to limit countries' carbon emissions.

Carbon sources mainly include "black carbon" and "brown carbon", while carbon sinks primarily consist of "green carbon" and "blue carbon". The significance of green carbon has been widely acknowledged as an essential component of the global carbon cycle, offering a crucial approach to tackling the global sustainability crisis [3]. Furthermore, blue carbon, or the ocean carbon sink, has gained increasing prominence [4]. Plant growth in the ocean, such as phytoplankton, mangroves, salt marshes, and seagrasses [5], as well as the carbon used by living resource species, such as fish, cephalopods, crustaceans, and echinoderms, which feed on zooplankton and shellfish, algae, and other species of living organisms, through the mechanism of the food web and through their growth activities, constitutes the Earth's ocean carbon sinks (Figure 1). Currently, it is understood that 45 percent of the Earth's carbon sink is stored in terrestrial ecosystems, with the remaining 55 percent stored in marine ecosystems, specifically the ocean carbon sink discussed in this paper [6]. Despite their pivotal role in mitigating low-carbon emissions, ocean carbon sinks are facing significant threats due to insufficient attention from human society. Marine ecosystems, in particular, are experiencing extensive damage, disappearing at a rate faster than any other ecosystem on the planet.

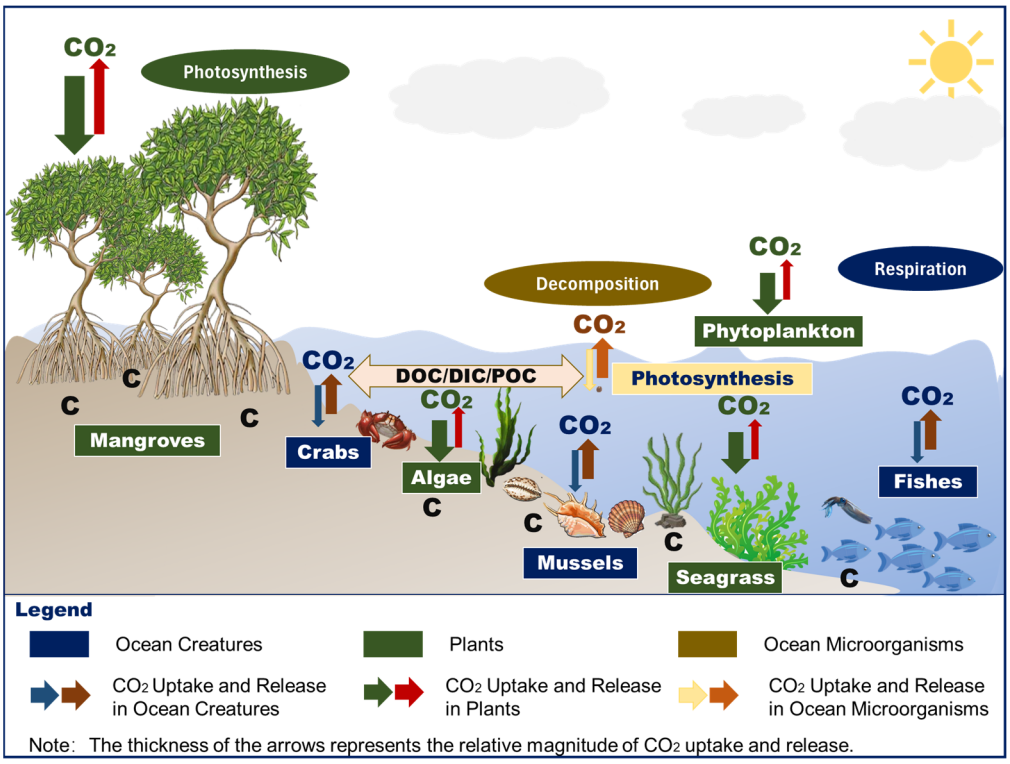


Figure 1. Flow diagram of carbon dioxide absorption and storage in ocean carbon sinks.

The international community's attention towards "ocean carbon sinks" and "blue carbon" has steadily increased year by year. As depicted in Figure 2, the number of papers focusing on "ocean carbon sinks" or "blue carbon" has seen a dramatic rise in recent years. With growing advocacy for the protection and enhancement of ocean carbon sinks, the United Nations Intergovernmental Panel on Climate Change (IPCC) released the 2013 Supplement to the 2006 National Greenhouse Gas Emissions Inventory: Wetlands. This supplement specifically highlights "coastal wetlands" as a type of wetland, formally integrating ocean carbon sinks into the global climate regulatory system. At present, the research on ocean carbon sinks is primarily focused on their development and conservation, and a significant gap exists in the research on trading. Considering the urgency of the

current global climate change situation, insufficient research on ocean carbon sink trading could significantly impede global carbon emissions reduction efforts, thereby hindering the sustainable development of the global ecological environment. Therefore, it is imperative to provide comprehensive theoretical and policy supports for ocean carbon sink trading. This study contributes by identifying barriers in the Chinese ocean carbon sink trading market related to the legal system, market structure, and social perceptions through a detailed examination of the current situation. It also proposes corresponding countermeasures for each obstacle, thereby furnishing a crucial practical foundation for governmental policy actions at each stage.

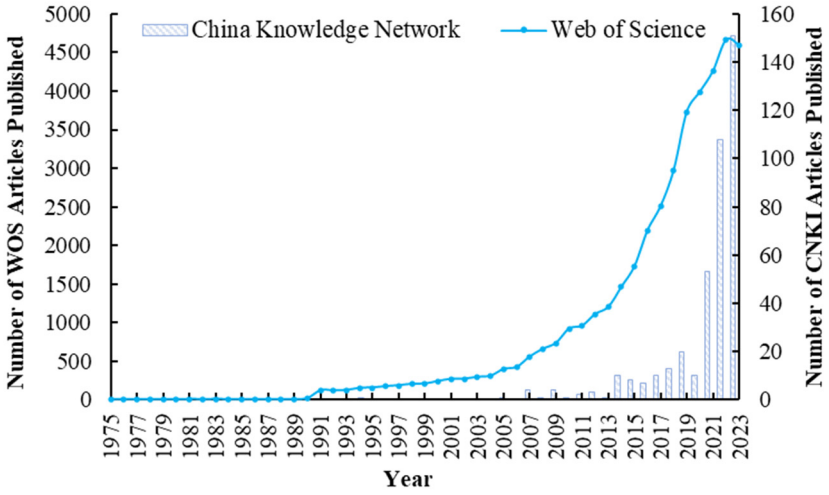


Figure 2. Trends in the numbers of articles published in CNKI and WOS on the topics of "ocean carbon sinks" and "blue carbon".

1.2. Research Framework

This article is guided by the theory of sustainable development and the theory of capitalisation of ecological resources. This study deconstructs the Chinese ocean carbon sink trading market, with a problem-solving mindset and a view to achieving the research goal of improving the current status of the Chinese ocean carbon sink trading market. On the basis of the existing literature, this study classifies the topics related to ocean carbon sinks. Combining the existing laws and regulations, as well as practical cases, in China, the study analyses the deficiencies in the current Chinese ocean carbon sink market, such as unclear resource property rights, lack of relevant laws and regulations, insufficient innovation of financial products in the market, and weak public participation. On the basis of a comparison of domestic and international situations, analysis of relevant cases, and interpretation of policies and regulations, this study suggests that improving the Chinese ocean carbon sink trading market requires the joint efforts of the government, market, and public. Specifically, the government should strengthen legislation related to ocean carbon sink trading, the market should deepen the degree of financialisation, and the public should actively participate in the ocean carbon sink trading business so as to jointly promote the prosperous development of ocean carbon sink trading.

This study systematically collected all existing practical cases of ocean carbon sink trading in China to ensure comprehensive coverage of the relevant studies. In addition, this study compiled and organised policy regulations on ocean carbon sink trading at all levels of government, from the central to the local levels, in order to assess the extent to which they have been effective in improving the ocean carbon sink trading market. Using the foundation laid by these trading practice cases and policy texts, this study conducted a comprehensive and detailed analysis. In the process, the study employed a range of analytical strategies, including literature analysis, case studies, and comparative analyses, among others.

The literature analysis included the meticulous review, interpretation, and assessment of academic publications, international treaties, and government policy documents. This study cites and analyses many examples of ocean carbon sink trading practices as evidence for the case studies, from which the current problems in Chinese ocean carbon sink trading are extracted. Comparative analyses are conducted to derive lessons that are useful for the construction of the Chinese ocean carbon sink trading market by comparing China with other foreign countries so as to take advantage of their strengths and complement their weaknesses to improve the Chinese ocean carbon sink trading market. These analytical strategies were developed to identify the barriers to the development of the Chinese ocean carbon sink market, explore the causes of these barriers, and propose reform options.

The next sections in this paper are as follows: Section 2 provides a literature review of ocean carbon sinks; Section 3 discusses the current situation related to the development of Chinese ocean carbon sinks; Section 4 presents the challenges that exist in the Chinese ocean carbon sink trading market; Section 5 discusses the countermeasures and suggestions for improving the Chinese ocean carbon sinks trading market; and the final part, Section 6, concludes the paper. The research framework is shown in Figure 3.

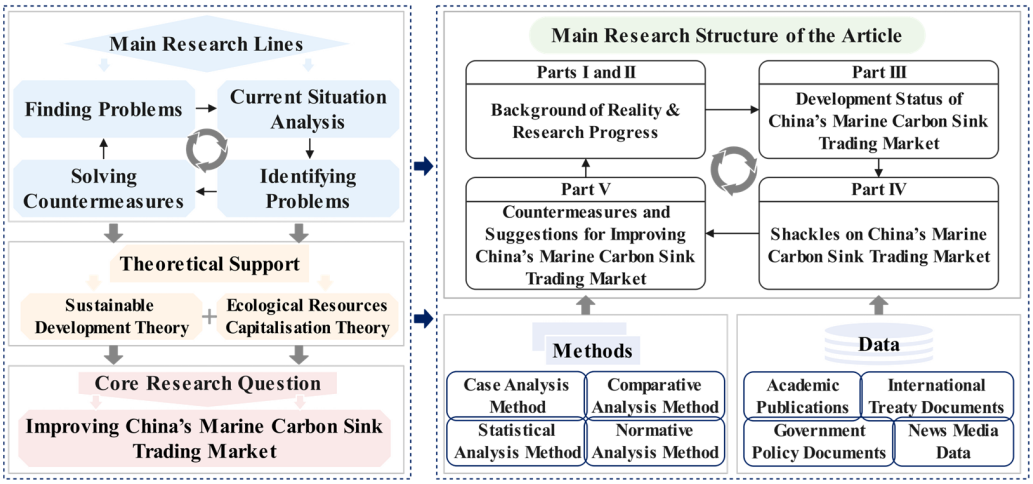


Figure 3. Research framework.

2. Literature Review

At present, academic studies on ocean carbon sinks are mainly divided into four aspects, namely, conceptual analysis of ocean carbon sinks, research on carbon-sequestration technologies for ocean carbon sinks, protection of ocean carbon sinks, and exploration of ocean carbon sink trading.

2.1. Meaning and Concept of Marine Carbon Sinks

Numerous scientific studies have demonstrated the valuable role of ocean carbon sinks in absorbing greenhouse gases [7]. The ocean carbon sink system comprises mangroves, seagrasses, fish, shellfish, macroalgae cultures, and microbial carbon pumps [8], and, in particular, marine plants account for more than half of the total CO_2 absorbed by the oceans while occupying only 0.2 percent of the oceans' surface [9]. It is important to note that the concept of an ocean carbon sink usually excludes dissolved CO_2 from seawater [10]. Compared to land-based carbon sinks, which store for only a few decades, ocean carbon sinks store for much longer periods of time, sometimes up to thousands of years [11]. In addition to the carbon storage function, ocean carbon sinks have some synergistic benefits for biodiversity, water filtration, and coastal protection [12], greatly helping to mitigate climate change risks [13]. The richness of the concept of ocean carbon sinks has led scientists, natural resource conservationists, and policy makers to collaborate for the advancement of carbon reduction [14].

2.2. Carbon Sequestration Capacity of Ocean Carbon Sinks

Effective measurement of ocean carbon sink capacity is a prerequisite for the development of the carbon sink industry and the construction of an ocean carbon sink trading market [15]. Plants in the ocean convert carbon dioxide into organic matter and store it via photosynthesis, and other organisms in the ocean, such as corals, shellfish, and fish, also store carbon in their bodies through the food chain or certain pathways [16]. Influences such as the marine environment and tidal current seawater temperature changes also have an impact on the efficiency of CO_2 uptake by ocean carbon sinks [17]. Scientists have also conducted research on the factors affecting sequestration in ocean carbon sink systems and the extent to which greenhouse gases are released when ocean carbon sink systems are disturbed [18]. They are actively exploring the development of remote sensing methods for monitoring and validating ocean carbon sinks and predicting methane and nitrous oxide fluxes and sequestration pools through biogeochemical modelling [19]. They have assessed information on changes in sedimentary organic carbon stocks and accumulation rates in Australian seagrass habitats and the factors driving such changes to improve global estimates of blue carbon stocks in seagrasses [20], revealing that the carbon storage and sequestration potential of coastal ecosystems has been underestimated in ocean carbon sinks [21]. Chinese scholars have also conducted a large amount of research on the application of new technologies in the measurement of ocean carbon sinks. They used satellite remote sensing to map changes along China's coastline for over more than a decade, from 1991 to 2015, showing the impact of rapid economic development on coastal ecosystems [22]. They also used 10 m resolution Sentinel imaging, spectral/backscatter–time change metrics (magnitudes) from Sentinel-1 SAR (synthetic aperture radar) and/or Sentinel-2 MSI (multispectral instrument) (ICEYE US, Irvine, CA, USA) time-series imagery as input features for random forests to generate accurate high-resolution mangrove maps via Google Earth Engine (GEE). This provides important information for conservation managers, scientists, and other stakeholders to monitor mangrove dynamics [23].

2.3. Conservation of Ocean Carbon Sinks

Nearly one-third of the global ocean carbon sink system has disappeared within a few decades, largely due to human activities such as coastal development and pollution [24]. Forty to eighty percent of coastal wetlands have been lost due to anthropogenic drivers [25]. Incorporating the protection of ocean carbon sinks into climate change policies has become an important strategy for ecosystem protection [26]. Despite the growing attention to ocean carbon sinks, there are barriers to the interface between specific ocean carbon sink science and policy, making policy implementation less effective due to the fact that the ocean carbon sink industry is interdisciplinary and integrated [27]. Institutional difficulties in the protection of ocean carbon sinks include a lack of climate financing mechanisms, unclear property rights for ocean carbon sink resources, and challenges related to payments for ecosystem services [28].

Restoring and regulating ocean carbon sink resources to provide optimal ecosystem services, carbon inventories, and ocean carbon sink policies are recommended priorities [29]. In the process of ocean carbon sink governance, scholars have proposed strengthening theoretical research and technological innovation, accelerating collaborative governance, and deepening market-based mechanisms [30]. On the basis of the analysis and overview of the latest research on ocean carbon sinks, the cooperative game, Weber's law, and regret theories are introduced to establish an international cooperation model for ocean carbon sinks, which proves the feasibility of international cooperation on ocean carbon sinks and the ocean carbon sink economy [31]. Therefore, governments should strengthen their support for ocean carbon sink projects instead of relying on financing from NGOs or private investors [32], while setting up corresponding incentive and penalty mechanisms [33]. Protecting, restoring, and utilising ocean carbon sink ecosystems should meet future societal needs [34]. Governments should also focus on shifting policy priorities from protecting ocean carbon sink ecosystems to increasing ocean carbon sink stocks, from a

single policy actor to an increasing diversity of policy actors, and from simple conservation to fully integrated land–ocean system management [35].

In the study of Chinese ocean carbon sinks, scholars have evaluated the characteristics of blue carbon policy in China using the qualitative literature analysis method of policy instrument theory, putting forward suggestions for the improvement of ocean carbon sink policy, such as via legislation on the protection of ocean carbon sinks, optimising the marine ecological compensation system, stabilising investment in ocean carbon sink projects, establishing a system of verification for ocean carbon sinks, and integrating ocean carbon sinks into the regulated carbon trading market [36]. Other scholars believe that China should actively promote scientific research, improve the technical system, establish a trading system, develop the ecological economy, establish a complete system of laws and regulations, and explore the potential related to ocean carbon sinks to contribute to the realisation of China's "carbon peaking" and "carbon neutrality" goals [37] (hereinafter referred to as the "dual-carbon target"). Other scholars further believe that a clear timetable and roadmap should be formulated to promote research and development of ocean carbon sink technologies, actively cultivate the ocean carbon sink trading market, tap the intrinsic potential of ocean carbon sinks, and strengthen international cooperation to jointly build a carbon-neutral international community [38].

2.4. Ocean Carbon Sink Trading

Similar to forest carbon sinks, ocean carbon sinks can likewise be incorporated into carbon trading markets [39]. Incorporating ocean carbon sinks into market-based climate policy mechanisms may lead to significant financial flows towards the protection and restoration of coastal ecosystems [40]. That is, by significantly increasing the capital value of blue carbon resources, the private sector will be attracted to invest in ecological restoration, which will ultimately generate more socio-economic benefits [7]. The process of achieving the capitalisation of ocean carbon sink resources is divided into the following four steps: joint process, productisation process, conversion of products or services into capital through value accounting and trading process, and operational process [41]. The construction of an ocean carbon sink trading model is conducive to achieving emissions reduction targets and can also be used as a market mechanism for value discovery to create a new economic growth point and promote the protection and restoration of marine ecosystems [42]. Some scholars believe that the most effective blue carbon market mechanism is a government-regulated "total control and trading" system [40]. It is recommended to implement established methodologies and certification standards for ocean carbon sinks, and actively explore financial innovations in the field of ocean carbon sinks [43]. Pilot projects should be created to attract investors' interest and accumulate practical experience [44]. It has also been suggested that combining ocean carbon sinks with carbon trading can accelerate the achievement of the Chinese emission reduction targets, thereby exploring a new economic growth model while balancing economic and social benefits [38]. In China, the establishment of an ocean carbon sink trading market is both feasible and necessary [45]. It is important to incorporate ocean carbon sinks into the trading system centred on Chinese Certified Voluntary Emission Reductions (CCERs) to improve the trading process, broaden the trading methodology, diversify the trading entities, and carry out targeted practices [46]. There is also a demand for the development of specialised methodologies for blue carbon projects and the delineation of new national ocean functional zones for the development of blue carbon projects [47]. China should authorise the right to use sea areas to ensure the legal right to develop blue carbon projects and add appropriate additional requirements, such as extending the project duration and credit period as needed [48]. This will lead to the balanced development of the ocean carbon sink trading model among ocean carbon sink producers, demand enterprises, trading platforms, and local governments [49].

In summary, it is not difficult to see that many aspects still need to be explored in the study of ocean carbon sinks. At present, most studies focus on the development and protection of ocean carbon sinks, and there are fewer studies on ocean carbon sink trading

markets, especially the Chinese ocean carbon sink trading market. This is not only reflected in the lack of relevant literature but also in the lack of detailed and specific information on its current status and problems with ocean carbon sink trading in China. For example, some countermeasures proposed are too general and do not target specific legal provisions, policies, or norms, which results in conclusions that are insufficient. In view of this, this paper discusses in detail existing problems in China's ocean carbon sink trading market and puts forward corresponding countermeasures for each problem, one by one, to improve the ocean carbon sink trading market and promote the achievement of China's energy-saving and emissions reduction goals.

3. Status of the Development of Ocean Carbon Sinks in China

3.1. Chinese Ocean Carbon Sink Policy and Practice

Since the concept of ocean carbon sinks was put forward in 2009, international organisations and various countries have conducted further discussions on the topic, releasing many influential reports [50]. As shown in Figure 4, the progress in China on ocean carbon sinks has been relatively slow compared with that of foreign countries. However, China is deeply aware of the significance of ocean carbon sinks in addressing climate change and has put forward opinions on improving organisational leadership, systems construction, and public awareness in the field of ocean carbon sinks to address climate change, laying a solid foundation for their development. The current progress in China related to ocean carbon sinks in terms of policy and practice is described below.

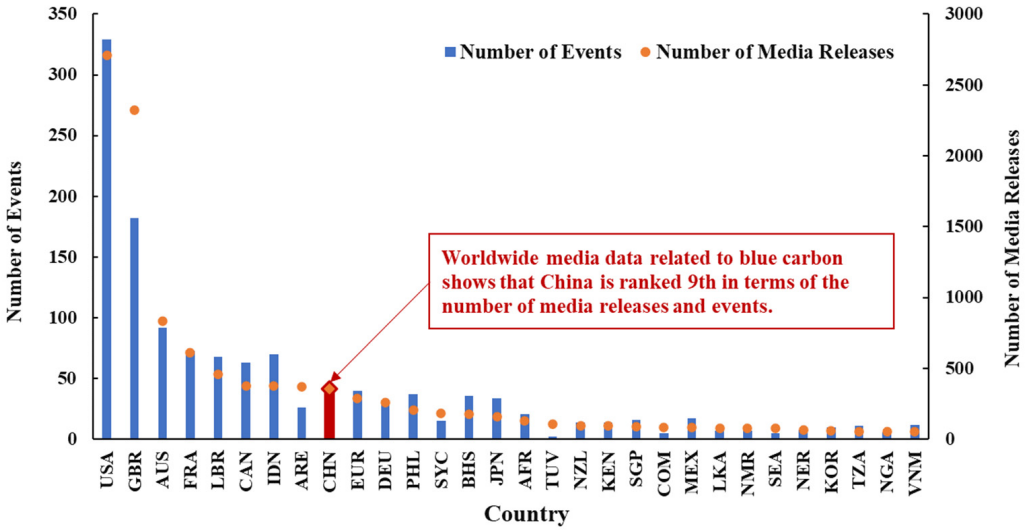


Figure 4. Top 30 countries in terms of global media interest in blue carbon-related topics. The data come from the GDELT project and was processed with SQL on the Google Cloud Bigquery platform. Filtering was performed by requiring that the "sourceurl" field to contain blue carbon phrases, grouped by country.

First, in terms of policy, the Chinese government has actively been promoting the development of ocean carbon sinks. Chinese policy making on ocean carbon sinks has undergone a process from the central to local levels, from overall construction to detailed localisation. In terms of the layout of the central government's overall framework, the State Oceanic Administration (SOA) released its 12th Five-Year Plan for the Development of the National Ocean Programme in 2013, which proposes the protection and restoration of important marine ecosystems such as mangrove forests, coastal wetlands, salt marshes, and other important marine ecosystems. Although there is no explicit reference to ocean carbon sinks, there is already a prototype for their protection. In 2015, the Central Committee of the Communist Party of China and the State Council issued the Opinions on Accelerating the Construction of Ecological Civilisation, pointing out the need to increase

ocean carbon sinks and other means to address global climate change. This marked the formal inclusion of ocean carbon sink protection into China's national strategy, laying down the overall framework for the cause of ocean carbon sinks. In terms of specific details on implementation, the Hainan Implementation Plan for the National Ecological Civilisation Pilot Area, issued by the General Office of the CPC Central Committee and the General Office of the State Council in 2019, explicitly proposes to carry out a pilot project on marine ecosystem carbon sinks, conduct a study on the standard system and trading mechanism for oceanic carbon sinks, and explore the establishment of an international trading venue for carbon emission rights in accordance with the law and compliance. In 2023 and 2024, the Ministry of Natural Resources issued the "Ocean Carbon Sink Accounting Method" and the "Blue Carbon Ecosystem Protection and Restoration Project Sink Effectiveness Assessment Technical Procedures (for trial implementation)" to guide the project scale of the national ocean carbon sinks ecosystem restoration and sink effectiveness assessment, and to quantitatively evaluate the contributions of marine ecosystem protection and restoration projects to consolidating and enhancing the capacity of the ocean carbon sinks. At the local level, coastal provinces have also issued provincial and municipal regulations, such as the "14th Five-Year Plan for the Development of the Marine Economy of Guangdong Province", the "Early and Pilot Work Programme for Blue Carbon in Guangxi", and the "Pilot Work Programme for Marine Ecosystem Carbon Sinks in Hainan Province (2022–2024)". For more details on Chinese ocean carbon sink policies and norms, see Appendix A, Table A1.

Secondly, in terms of practice, provinces such as Jiangsu, Guangdong, Zhejiang, and Fujian have taken advantage of their coastal geography to actively explore the field of the ocean carbon sink trading. The development of Chinese ocean carbon sink trading practices reflects a trend of gradual development from south to north, with the momentum of ocean carbon sinks in Shandong Province being the most rapid in the north. In 2021, the signing ceremony of the Carbon Emission Reduction Transfer Agreement for the Zhanjiang Mangrove Afforestation Project in Guangdong marked the official completion of Chinese first "blue carbon" project transaction. In the same year, the Xiamen Property Rights Trading Centre (Xiamen Carbon and Sewage Rights Trading Centre) set up the first ocean carbon sink trading service platform in China, innovatively conducting "blue carbon" trading. In 2023, the first auction of ocean carbon sinks in China, located in the city of Xiangyashan, Zhejiang Province, was concluded to explore the trading of ocean carbon sinks so that the fishery carbon sink trading of the "Chinese programme" could find a way forward. As an important coastal economic province in the north, Shandong Province has made great efforts to support the development of ocean carbon sinks and has actively carried out pilot of ocean carbon sink transactions, such as via the "Ocean Carbon Sink Loan", ocean carbon sink index insurance, and other innovative ocean carbon sink financial products. The above work reflects the emphasis China has placed on the construction of ocean carbon sinks and lays the foundation for the development of the Chinese ocean carbon sink trading market. For more examples of ocean carbon sink trading practices in China, see Table A2 in Appendix B.

Figure 5 presents distribution maps of Chinese policies and practical cases related to ocean carbon sink trading in recent years (policies at the central level are classified as Beijing). Overall, China has made great progress in the conservation and trading of ocean carbon sinks. At the same time, however, the gap between China and the rest of the world should recognised and more efforts and contributions made toward the development of ocean carbon sinks and the fight against global climate change.

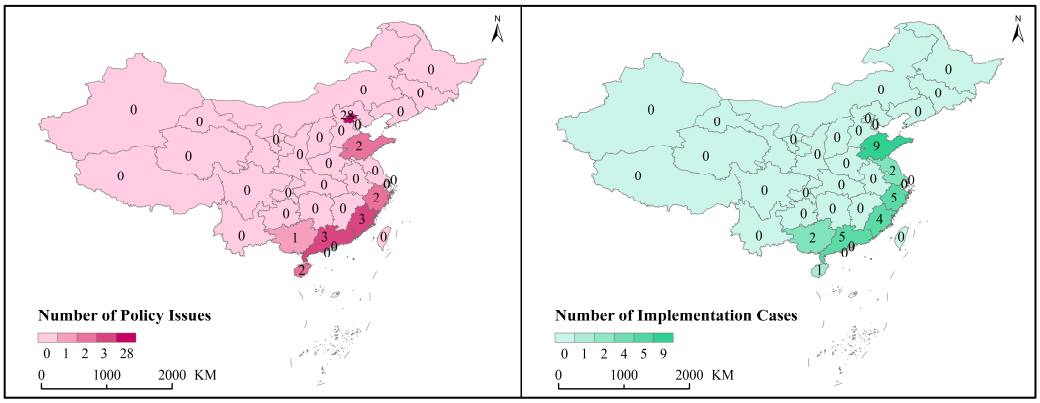


Figure 5. Distribution of Chinese policies and practical cases related to ocean carbon sink trading in recent years.

3.2. Characteristics of the Chinese Ocean Carbon Sink Trading Market

China's ocean carbon sink trading market has some unique features compared to the blue carbon trading markets in other countries, which are mainly reflected in the following aspects:

Firstly, in terms of the scale and potential, it is understood that China has 18,000 kilometres of mainland coastline and nearly 3 million square kilometres of jurisdictional sea area. Mangrove forests, salt marshes, seagrass beds, and other ocean carbon sink ecosystems are widely distributed along the country's coastline. It is very rich in carbon sink resources, and there is huge potential for their development. China is one of the world's largest fishery-based countries, and it has a huge ocean ecosystem; thus, great potential exists for ocean carbon sinks. Compared with other countries, China's ocean carbon sink projects are much larger in scale and have even greater potential.

Secondly, in terms of government support and policies, the Chinese government attaches great importance to the development of ocean carbon sink projects and has introduced a series of support and incentive policies, including financial subsidies, tax incentives, and green financial support, in order to promote the development and operation of ocean carbon sink projects. These kinds of government supports and policies related to ocean carbon sink trading markets are not common in other countries.

Thirdly, in terms of technological innovation and practical experience, China has made great progress in the field of marine science and technology and has accumulated a wealth of data on monitoring marine ecosystems and practical experience in blue carbon sink projects. China has certain advantages in marine scientific research and technological innovation, which makes it unique in the development and management of ocean carbon sink projects.

Fourth, in terms of market demand and investment potential, as one of the world's largest carbon emitters, China is facing severe pressure to reduce carbon emissions, and the carbon market demand is huge. As an emerging means of carbon emissions reduction, ocean carbon sinks have huge market demand and investment potential. China's ocean carbon sink project market demand and investment potential far exceed that of other countries, which is also one of its unique features.

Fifth, in terms of the cultural and social contexts, China has a long tradition of maritime culture and a deep maritime awareness. Chinese ocean carbon sink projects will be influenced by these unique cultural and social contexts over the course of their implementation, which gives China's ocean carbon sink trading market a unique character.

In summary, China's ocean carbon sink trading market is unique compared to those in other countries in that it is larger in scale and potential, receives more active government support and enabling policies, is richer in technological innovations and practical experience, and has greater market demand and investment potential, as well as being more unique in terms of its cultural and social backgrounds. These unique features will provide favourable conditions for the development of the Chinese ocean carbon sink market and, at

the same time, will inject new vitality and provide an impetus for the development of the ocean blue carbon sink market.

4. Obstacles in Chinese Ocean Carbon Sink Trading Market

China has made many efforts to develop ocean carbon sink trading, making great contributions towards mitigating climate change and protecting the ecological environment worldwide. However, as a relatively new issue, ocean carbon sink trading faces many challenges and obstacles in its development. These barriers not only come from the legal and policy level, but also involve technical, economic and social awareness. An in-depth understanding of these barriers is essential to promoting the healthy and sustainable development of ocean carbon sink trading in China.

4.1. Unclear Property Rights over Ocean Carbon Sinks

The core of market transactions is the trading and transfer of property rights, so the prerequisite for trading ocean carbon sinks is the establishment of clear property rights [51].

As an emerging marine resource, ocean carbon sinks are typical public resources. If their property rights are not defined, this will easily lead to a phenomenon similar to the "tragedy of the commons". The trading of ocean carbon sinks and the trading of carbon emission rights are complementary, and the purchase of ocean carbon sinks can offset part of the carbon emission credits. Both are endorsed by the public, but in the trading market they are also of a private nature. This mixing of public and private has led to controversy in the academic community over the properties of ocean carbon sinks as an environmental resource, resulting in the creation of public property rights, private property rights, communal property rights and mixed property rights. As a socialist state, Chinese marine resources are, of course, owned by the state, which enjoys absolute ownership and domination of marine resources. The ownership and use rights of marine resources are elaborated in detail in the Constitution, the Civil Code and the Law on the Administration of Maritime Domain Use, particularly in the Guiding Opinions on the Reform of the Property Rights System for Natural Resource Assets, which was issued in 2020 and explicitly proposes the exploration of a three-dimensional and hierarchical establishment of the right of use of maritime domains. In order to meet the ever-increasing demand for the use of the sea, the law has divorced the ownership and use rights of sea areas, allowing civil entities to obtain the right to use specific sea areas through administrative approval and licensing. However, the current production and business activities permitted by the right to use these sea areas mainly include marine aquaculture, ship-breaking, tourism and entertainment, salt industry, mining, public welfare, construction projects, etc., and there is no clear definition of the ownership of such emerging concepts as ocean carbon sinks. Ocean carbon sinks that rely on specific marine areas under the jurisdiction of public law embody the carbon sequestration capacity of ocean carbon sink ecosystems and are not tangible objects. If the property rights of such special areas are not clarified in private law related to the trading market, this will easily lead to a collision between public and private sectors. This will seriously affect the smooth operation of market mechanisms, such as sale and purchase transactions, mortgages, and pledges, making it difficult to safeguard the rights of all parties to the transaction.

4.2. Unclear Attribution of Ocean Carbon Sink Resources

The issue of the delimitation of ocean carbon sinks, particularly fishery carbon sinks, differs from land-based carbon sinks because of their high mobility. The concept of fishery carbon sinks was initially proposed by academician Tang Qisheng, who argued that all fishery production activities that do not involve baiting serve as carbon sinks. He further suggested that energy transfer through the food chain continuously moves from lower to higher fishery resources, forming what is termed a fishery carbon sink [52]. Fishery carbon sinks can be categorised into coastal fishery carbon sinks and pelagic fishery carbon sinks

based on different production areas. Among these, pelagic fishery carbon sinks are most susceptible to disputes over delimitation [53].

The United Nations Convention on the Law of the Sea defines the relevant attribution of fisheries resources on the basis of Figure 6, as follows: Article 2 of the UNCLOS provides that the coastal State, on the basis of its sovereignty, enjoys undisputed sovereignty over the fishery carbon sinks within its territorial sea. In an exclusive economic zone, Article 56 (1) (a) of the UNCLOS states that "within the exclusive economic zone, the coastal State has sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or nonliving, of the waters overlying the seabed and the seabed and its subsoil". On the basis of this sovereign right, the coastal State is prohibited from carrying out activities such as fishing, conservation, and management of fishery resources in its exclusive economic zone, but it must be emphasised that this sovereignty is not an absolute exclusionary jurisdiction. With regard to the continental shelf, Article 77, paragraph 1, of the UNCLOS grants the coastal State the sovereign right to explore the continental shelf for the purpose of exploiting its natural resources. The scope of "natural resources" is subsequently defined in Article 77, paragraph 4, as including living resources belonging to "sedentary species", which comprise benthic clams, sea anemones, etc. Therefore, the coastal State has sovereign rights on its continental shelf for the purpose of harvesting sedentary fishery resources. High seas fishery resources have the legal attribute of "commons" and are typical natural resources in areas beyond national jurisdiction. They are characterised by the principle of free access, in contrast to the jurisdiction of the coastal State over its coastal waters. The Convention on the Law of the Sea simply divides the maritime space into zones, ignoring the distinction between law and nature. This institutional design has no regard for the natural attributes of the oceans themselves and their fishery carbon sinks. Marine organisms, such as fish stocks in the oceans, are constantly on the move and cannot be stopped by man-made boundaries. How this part of an ocean carbon sink should be divided among states remains a question.

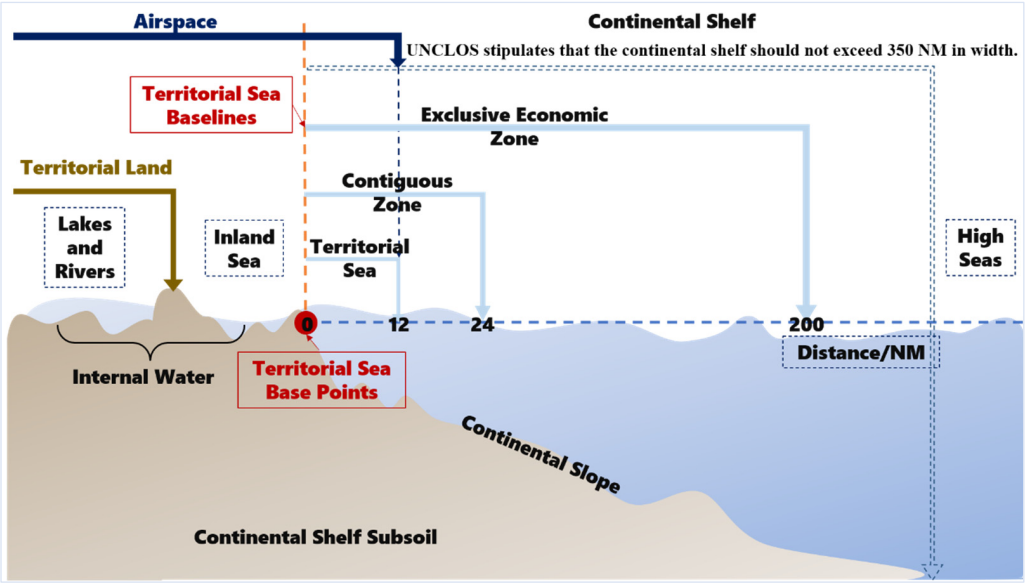


Figure 6. Schematic representation of the spatial structure of maritime areas under national jurisdiction according to the United Nations Convention on the Law of the Sea.

The delimitation of carbon sinks in pelagic fisheries poses a series of challenges and difficulties. On the one hand, the complexity of marine environments has resulted in the uneven distribution of fishery carbon sinks across the seas of many countries, which has led to possible differences and disputes in the sovereignty claims of different countries over fishery carbon sink resources. If the ownership of fishery carbon sinks is unclear or disputed, the relevant ocean carbon sinks cannot be traded at all. On the other hand,

differences in the laws, regulations, and policies of different countries in the management of marine resources and environmental protection complicate the harmonisation of laws and policies among countries in maritime delimitation. The lack of uniform management rules and mechanisms may result in countries adopting different management approaches when dealing with fishery carbon sink resources and may even lead to the overexploitation of resources and environmental damage, devaluing the carbon sink resources in such transactions.

4.3. Barriers to Data Sharing on Ocean Carbon Sinks and Lack of Data Transparency

The core idea of ocean carbon sink trading is to reward these active ecosystems for their carbon sequestration capacity by providing them with financial resources. Therefore, ocean carbon sinks that can be traded on the market must be monitorable, traceable, and valuable for ecological services. The field of ocean carbon sink trading must be underpinned by a large amount of data related to ocean carbon sink assets. However, the issues of sharing and the transparency of such data have been challenges in this field.

Firstly, there is the issue of data sharing. In order to ensure the development of a blue carbon trading and market system, it is necessary to establish complete monitoring, verification, assessment, and reporting mechanisms that meet the certification requirements of the carbon sink market during the blue carbon product development stage. Among them, the monitoring mechanism, as the key, must determine the amount of blue carbon sequestration, new increases in carbon sinks, and changes in the ecosystem biomasses of trading projects. China has yet to establish a nationwide monitoring system and an evaluation mechanism specifically for blue carbon resources, and, thus, it cannot ensure that blue carbon resources are reportable and verifiable. Data on ocean carbon sinks are usually collected and retained by different organisations, research teams, and government departments. This fragmentation and siloing of data may lead to limited data sharing. A lack of widespread sharing of data may lead to information asymmetry, which may affect the decisions made by market participants and the fairness of transactions. In addition, there may be differences in data formats and standards among different sources of data, making data sharing and integration more difficult. This, coupled with the fact that the processes for the formation and movement of ocean carbon sinks are quite complex and require integrated research among different disciplines, as well as the difficulty in establishing effective, scientific measurement models, makes the problem of sharing data related to ocean carbon sinks even more prominent.

Secondly, data transparency is also an important issue in the field of ocean carbon sink trading. The essence of the problem related to the opacity of ocean carbon sink data lies in the lack of transparency and traceability of the source and in the collection, processing, and release of such data. In ocean carbon sink trading, the accuracy and credibility of carbon emission data and marine ecosystem data are crucial in the assessment of carbon sink projects and trading decisions. However, the complexity of data collection, the fragmentation of data ownership, and political and commercial factors (e.g., some stakeholders may manipulate data for undue gain or be reluctant to disclose data to protect commercial confidentiality or political interests) contribute to the problem of data opacity, leading to the inability of market participants to accurately assess the values and risks associated with carbon sink projects, which may lead to unfairness in the market. Some participants may take advantage of information asymmetry to gain undue advantage, while others may suffer losses due to insufficient information. A lack of transparent data makes it difficult for investors to assess the true values and potential risks of carbon sink projects. This may lead to lower investor confidence in carbon sink projects, which, in turn, reduces investment in the carbon sink trading market. Lack of data transparency also creates management difficulties for regulators and relevant government departments. The lack of accurate and credible data makes it difficult for regulators to supervise and manage the carbon sink market, which may lead to confusion and instability in the market.

4.4. Lack of Laws and Regulations Related to Ocean Carbon Sink Trading

In 2007, with the approval of the State Council, China issued the National Programme for Addressing Climate Change, marking the first comprehensive policy document aimed at tackling climate change in China. Consequently, China has embarked on a path of low-carbon economic development tailored to local conditions. While China has made significant efforts in carbon trading legislation, ocean carbon sink trading legislation still faces numerous urgent challenges due to the nascent stage of the carbon trading market.

There is a notable absence of legislative protection for ocean carbon sinks, which are the focal point of such transactions. Currently, Chinese legislation predominantly addresses land-based carbon sinks, leaving a legislative gap in the protection of ocean carbon sinks [54]. The Law of the People's Republic of China on Marine Environmental Protection and the Fisheries Law of the People's Republic of China, as well as the Measures for the Management of Marine Specially Protected Areas and the Measures for the Management of Marine Nature Reserves, all address marine environmental protection. However, their legislative objectives primarily focus on the protection of marine aquatic resources and the preservation of the economic interests of the marine system. For instance, the Marine Environmental Protection Law was initially enacted to safeguard marine resources and prevent marine pollution damage, aiming to maintain and improve the marine ecological environment. However, it lacks provisions specifically addressing the protection of ocean carbon sinks. Similarly, the Law of the People's Republic of China on the Protection of Wetlands only mentions enhancing the ecological function of wetlands and their role as carbon sinks in Article 39. While the protection of ocean carbon sinks is inherent in the framework of laws governing marine environmental protection, the existing legislation fails to explicitly designate this vital carbon sink resource as a legal interest warranting specific protection. Consequently, there is a lack of focused attention on ocean carbon sinks within current legal frameworks. The ramifications of damaging ocean carbon sinks are profound and complex, with restoration and remediation efforts presenting considerable challenges. Mere "corrective action orders" are insufficient to offset the damage to rights and interests, and fines imposed are often inadequate to restore the ecological properties and carbon sequestration capacities of ocean carbon sinks to their original states, let alone compensate for the array of ecological losses stemming from their destruction. In the carbon trading market, issues arising from ocean carbon sinks as transactional objects can lead to disputes among parties, resulting in transaction failures. Moreover, such disputes have the potential to undermine the stability of and confidence in the entire carbon trading market.

The deficiencies in the legal framework governing the ocean carbon sink trading market are a significant impediment to carbon sink trading in China. Market norms for ocean carbon sink trading should establish a system or set of rules that all parties must adhere to throughout the trading process [55]. A sound legal system of the trading market is the basic condition for engaging in ocean carbon sink trading. If the ocean carbon sink trading market is not sufficiently defect-free, the entry of ocean carbon sinks onto the market is bound to be restricted, not to mention the acceleration of trading, so that whether ocean carbon sinks are used for public welfare purposes or for profit, the transactional costs borne by users will greatly increase. Chinese legislation on ocean carbon sink trading, and carbon trading legislation in general, is enacted at too low of a legislative level. The State Council, ministries, and commissions, as well as provincial and municipal governments, are generally constrained by rules and regulations, and there have been no laws passed on the regulation of ocean carbon sink trading at the level of the National People's Congress and its Standing Committee. This is a far cry from the legal requirements of a mature carbon market. Although China has made principle provisions related to the content of ocean carbon sink trading contracts, there is no standardised contract text used in actual trading. In particular, there is no standard contractual reference for the agreement of economic terms, the interpretation of terms used, the application of laws, and methods of dispute resolution. As a result, normal ocean carbon sink trading activities have been hindered or affected, and disputes over the rights and interests of ocean carbon sinks have easily arisen.

4.5. Single Variety of Ocean Carbon Sink Transactions and an Incomplete Market Trading System

The role of financial instruments should be given full play in the trading of ocean carbon sinks, and the liquidity of carbon sinks should be activated to help realise the value of ecological products. However, the reality is that, in practice, China still has a narrow range of carbon sink projects, a single trading product, insufficient financialisation of the market, and a lack of professional talent.

The projects available for trading on the Chinese ocean carbon sink market primarily focus on the protection and restoration of marine wetlands, such as marine grasslands and mangrove forests. These projects aim to increase the storage by ocean carbon sinks and reduce corresponding carbon emissions by safeguarding and restoring marine wetlands. However, other forms of ocean carbon sink storage within marine ecosystems, such as coral reef protection, phytoplankton carbon storage, and fishery carbon sinks, have seen limited adoption and are not yet widely applied in the Chinese ocean carbon sink market. Specifically, financial products on the ocean carbon sink trading market predominantly consist of spot transactions, with carbon financial derivatives, like carbon futures, carbon options, and carbon funds, being relatively rare. The lack of innovation in financial products for ocean carbon sinks contributes to the limited activity of the ocean carbon sink trading market.

A robust ocean carbon sink trading system relies on well-established intermediary institutions and a large number of professional practitioners. The financial intermediary service system plays a crucial role in the development of the ocean carbon sink trading market. Leveraging their own strengths, these institutions provide buyers and sellers with the professional intermediary services necessary for transactions, thereby attracting more production enterprises, government departments, nongovernmental organisations, and individuals to participate in ocean carbon sink transactions. The service systems provided by ocean carbon sink financial intermediary organisations mainly include carbon banks, carbon funds, carbon insurance provision, carbon asset management, carbon credit rating, third-party certification, and legal service provision specialised in carbon trading. In China, the current service systems offered by carbon financial intermediary organisations are still very incomplete, and financial intermediaries are unfamiliar with the areas involved in ocean carbon sink exchanges. Chinese intermediary organisations that can provide such services are even rarer, making it difficult for them to undertake the development and sale of a large number of projects. Many of the ocean carbon sink projects that have been undertaken have been supported by the government, acting as an intermediary, but professional intermediary service organisations must be involved in order to achieve greater development in the future. The absence of financial intermediaries directly leads to a lack of professional technical analysis and risk assessment in the ocean carbon sink trading market, and it is even more challenging to perform the functions of price discovery, hedging, and risk diversification in the ocean carbon sink trading market. The ocean carbon sink financial field is a high-end composite industry; practitioners must be proficient in finance, environment, energy, English, and other aspects of the required integrated talent. They should be familiar with financial theories and operational rules, as well as national industrial policies, energy policies, and related laws and regulations, in addition to the need to understand production processes, technical specifications, corporate energy audits, and energy-saving projects in related industries. Such talent is extremely scarce in China.

4.6. Insufficient Public Participation and an Imperfect Regulatory System for Ocean Carbon Sinks

Awareness is the precursor of action. Inadequate concepts and awareness have obstructed the smooth progress of ocean carbon sink trading in China. Not only is there a lack of awareness of ocean carbon sinks among the general public but also among government departments, to a certain extent.

From the perspective of the general public, the concept of ocean carbon sink trading, or even carbon trading, is still far from penetrating the lives of the general public. The low-carbon economy advocated by the state has yet to be further developed among the

public [56]. Compared with foreign countries, relatively, China has much greater leverage to reduce carbon emissions. Because of this, China should pay full attention to the voluntary emissions reduction trading market in the carbon trading system so that it can motivate more enterprises and individuals to pay for emissions reduction. The initial purpose of the ocean carbon sink trading market is to reduce the cost of emissions reduction and to promote emissions reduction in relevant subjects. However, in the context of the inadequate and unbalanced development of many regions and groups in China, the purpose of the ocean carbon sink trading system should be in line with the social development goal of common prosperity, so that it reflects a richer connotation of development. Research and practice have shown that carbon emissions from the lives of residents in late-developed regions will increase rapidly with the rise in economic levels. Failure to take effective measures will greatly offset the effectiveness of emissions reduction on the production side. Therefore, to achieve the "dual-carbon" goals, it is necessary to adopt a two-pronged approach for a few key emitters and a large number of micro-individuals. The concept of a carbon inclusive mechanism (CIM) was first proposed by the Guangdong Development and Reform Commission (DRC) in 2015, which refers to quantifying and assigning a certain value to the energy-savings and carbon-reducing behaviours of small- and microenterprises, households, and individuals in the community, positively guiding them through a combination of commercial incentives, policy encouragements, and trading of certified emission reductions (CERs) to promote universal participation in the low-carbon transition. This concept is also applicable to the field of ocean carbon sink trading, and based on the role of ocean carbon sinks in the dual-carbon and common wealth goals, the mechanism of universal participation should be an important potential channel for the realisation of the ecological value of ocean carbon sinks. People's subconsciouses do not cognitively associate the promotion of low-carbon development with ocean carbon sink trading. Without accumulating small streams, there is no river. If the general public, as the basis of the country, do not have a knowledge reserve on ocean carbon sink trading, the ocean carbon sink trading system cannot be constructed smoothly. In addition, the opacity of the ocean carbon sink trading mechanism also has a great impact on public participation. It is difficult for the public to obtain information about a carbon sink's assets, emissions reduction plans, and methods of distribution on their own. With an ocean carbon sink, a special commodity that has a profound impact on public interest, it is often difficult for the public to distinguish the pros and cons of trading. The lack of such key information can dampen the enthusiasm of the public to participate in carbon sink trading and hinder the regulation of ocean carbon sink trading.

From the perspective of governmental agencies, work related to ocean carbon sinks in China has been carried out relatively late. The current market is mainly focused on forestry carbon sink projects, with fewer projects involving ocean carbon sinks and practical experience that is still lacking. The ocean carbon sink trading market is a trading mechanism constructed via public power; it is not a natural commodity. If public power fails to follow "moderationism", this will lead to the destruction of the trading order. Firstly, there is a lack of awareness of low-carbon concepts in the government, with various departments and levels of government attaching differing degrees of importance to the low-carbon economy and ocean carbon sink finance, as shown by the fact that national ministries and commissions are more active than local governments, the State is more active than enterprises, and government officials are more active than the general public. Most government departments do not have sufficient knowledge related to low-carbon economies and ocean carbon sink trading, and they do not yet have a clear understanding of how and what policies should be introduced. Secondly, as the government may be involved in the development of ocean carbon sink projects, as a party to transactions, there is the risk that various departments may harbour or pass the buck to each other. The rules regulating the ocean carbon sink market are usually formulated by internal government departments, which are often responsible for the implementation of specific regulatory measures. This may easily lead to a situation in which "being a player and a referee at

the same time" can occur, which does not guarantee the neutrality of their regulatory status and leads to a loss of objectivity in the regulatory results. Thirdly, in the process of market-based ocean carbon sink trading, buyers and sellers usually pay too much attention to the economic benefits brought about by the development of ocean carbon sink projects while neglecting the ecological efficiency of marine ecosystems themselves.

5. Countermeasures and Recommendations to Improve the Ocean Carbon Sink Trading Market

In order to ensure the sustainable and effective operation of the ocean carbon sink trading market, a series of safeguarding measures need to be implemented to better resolve the problems and obstacles that exist in the trading of ocean carbon sinks.

5.1. Clarify Property Rights to Ocean Carbon Sinks and Separate Their Rights of Use and Ownership

According to the Coase theorem, resources can be optimally allocated in the market under the premise of clear property rights. Property rights arrangements are an effective incentive, providing owners with stable economic expectations. Only by establishing an asset management system based on property rights constraints can ocean carbon sink resources and their property rights be managed as a kind of asset for input and output in accordance with the laws of the market, realising the transformation of their existence value into use value. Therefore, in order to maximise the role of the ocean carbon sink trading market, it is necessary to clarify the property rights of ocean carbon sinks [48].

The positioning of ocean carbon sinks is closely linked to the public interest. The creation and operation of ocean carbon sink transactions cannot be separated from the exercise of administrative power and, at the same time, reflects the consistency of the subjective will of the parties to the transaction. Because of this, the positioning of the property rights of ocean carbon sinks needs to break the theoretical barrier of "public law versus private law". China should avoid single rigid mindsets characterised as "non-public is private" or "non-private is public" and accurately examine the specific operational process of the carbon trading market system. It should use legal theory and professional knowledge to understand the nature of ocean carbon sinks and clarify their natural features from a more appropriate perspective, taking into account both public and private interests. In this regard, the dual-order theory of German law can provide appropriate theoretical explanations and path analyses for the determination of the legal attributes of ocean carbon sinks, which can not only highlight the logical self-consistency on the basis of the independent value of ocean carbon sinks and the form their benefits take but also take practical care of the real needs of society. Chinese territorial waters are owned by the state, and the state enjoys absolute dominance over marine resources. In other words, the oceans have not been the subject of private property rights for a long time, but have always embodied the colour of public power. With the increasing exploitation of the sea, the subject of rights is objectively required to occupy and use a specific sea area for a long and stable period of time, which leads to the gradual generalisation of exclusive-use sea areas.

Property right refers to the sum of a series of property rights, with property ownership as the main body, including ownership and its derived rights of possession, use, income, and disposal and other legal rights. Ownership is the foundation and core of property rights, and there is no property rights without ownership. Property rights, on the other hand, are economic rights derived from ownership, without which the interests of ownership cannot be realised. Therefore, the ownership and use of maritime areas can be divested. Ownership remains with the state, reflecting the authority of public law. The right of use can be transferred among individuals, ensuring the vitality of the market. Therefore, only by ensuring the content and ownership of property rights in ocean carbon sinks can they be traded smoothly on the market.

5.2. Strengthen International Cooperation on Ocean Carbon Sinks and Formulate Harmonised Management Rules and Standards

The nature of ocean carbon sinks inevitably leads to the fact that they often cross national boundaries, which makes international cooperation an essential solution.

First, countries can strengthen cooperation by establishing bilateral or multilateral agreements and participating in international organisations. Differences in laws and policies among countries may affect the consistency of resource management and protection. Therefore, countries need to enhance coordination and communication on laws and policies and seek common solutions. This can be achieved through the signing of bilateral or multilateral cooperation agreements and participation in relevant international organisations to promote legal and policy coherence and coordination. These agreements and organisations can provide a platform for resource management, scientific research cooperation, regulatory standards, etc., to ensure the sustainable development and protection of resources. Resource-sharing mechanisms in transnational maritime areas and policy coordination mechanisms, etc., can be established to resolve resource disputes that may exist among different countries, thereby achieving the goal of a win–win situation.

Secondly, countries can try to formulate unified management rules and standards to ensure the rational use and protection of resources. These rules can cover such aspects as fishing quotas, designation of protected areas, and means of regulation so as to promote the rational use and protection of resources. For example, a uniform fishing quota system should be established in international waters to ensure that all countries can fish in accordance with the principle of sustainability and avoid the risk of overexploiting resources.

Thirdly, countries should strengthen scientific research and the development of monitoring technologies. Scientific research and monitoring technologies are the basis for effective resource management and protection. Countries can strengthen cooperation in scientific research and jointly carry out resource surveys and assessments in order to obtain accurate data. At the same time, they should also promote the development of monitoring technology, including remote sensing technology and underwater observation equipment, in order to improve the precision and coverage of marine environmental monitoring. A mechanism for scientific research cooperation in transnational marine areas should be established to jointly carry out resource surveys and assessments to obtain more accurate data and provide a scientific basis for resource management and protection.

In the context of international environmental protection law, countries are equal to each other as subjects and enjoy the same rights and obligations to protect the environment. In response to the challenges of fishery carbon sinks in the context of maritime delimitation, countries have worked closely and in consultation with each other to protect ocean carbon sinks as common properties belonging to all countries of the world. Countries have an obligation to protect the integrity and sustainability of fishery carbon sinks, promote the sustainable development of ocean carbon sinks, and ensure the orderly operation of ocean carbon sink trading.

5.3. Facilitate the Construction of a Data-Sharing Platform for Ocean Carbon Sinks and Improve the Comparability and Credibility of Ocean Carbon Sink Data

In ocean carbon sink trading, the issues of data sharing and transparency are important topics related to the sustainability of projects and the healthy development of the market. In order to address these issues, they need to be considered and responded to in comprehensive manners at multiple levels.

First, there is a need to establish unified data standards and certification mechanisms to ensure the accuracy and credibility of data. This includes unified standards for data collection, processing, and dissemination, as well as validation and auditing of data by independent third-party certification bodies. This will improve the comparability and credibility of data and reduce the risks associated with opacity.

Secondly, the construction of a national data-sharing platform for monitoring and assessing ocean carbon sinks should be promoted. It should absorb the monitoring and assessment data on ocean carbon sinks obtained by various departments in different parts of the country and establish a coordinated and unified mechanism for regular data submission and application. With the goal of "monitoring the capacity of carbon sinks, visualising the process of carbon sinks, predicting the potential of carbon sinks, and assessing the value of carbon sinks", relying on an "integrated sky–air–ground observation network" consisting of satellite remote sensing monitoring systems, unmanned aerial vehicle remote sensing monitoring systems, on-site sampling and monitoring, and in-situ online observation equipment, the platform will collect data from multiple sources. Relying on the multisource data collected by the satellite remote sensing monitoring system, unmanned aerial remote sensing monitoring system, on-site sampling and monitoring and in-situ online observation equipment, it will make use of the Internet of Things (IoT), cloud computing, numerical simulation, and other advanced technological means, providing services such as monitoring of carbon flux and storage, ecological protection and restoration, regulation of carbon emissions, and regulation of resource use. The government, scientific research institutions and enterprises jointly promote the establishment of an open data-sharing platform to provide a platform for all parties to share resources, which can integrate and make public marine ecosystem data and carbon emission data, and provide open interfaces to facilitate participants' access to and use of data. At the same time, it establishes unified rules for data access and use to facilitate the government and enterprises to better grasp the carbon flux data and provides data support for the government to formulate policies and enterprises to develop in a low-carbon manner. Intelligent monitoring systems, informatisation of service platforms and normalisation of surveys and assessments will be achieved to promote data sharing and transparency.

Thirdly, data protection and privacy safeguards should be strengthened. While promoting data sharing, there is also a need to strengthen data protection and privacy safeguards. Sound data privacy protection laws and regulations and security measures should be established to ensure the lawful use of data and the protection of individual privacy so as to increase participants' trust in data sharing.

Fourth, the introduction of blockchain technology can ensure data traceability. Blockchain technology can be used to build a decentralised, tamper-proof data recording system that can help ensure the traceability and transparency of data related to ocean carbon sinks. Through blockchain technology, a credible platform for data storage can be established to improve the trustworthiness and transparency of data, thereby reducing the risks associated with data opacity.

5.4. Improve Relevant Laws and Regulations in Terms of Ocean Carbon Sink Protection and Ocean Carbon Sink Trading

Inadequate legislation is a key source of legal conflicts and disputes in judicial practice. In order to avoid or reduce legal conflicts in the judicial practice of marine ecological environmental protection and governance, consideration can be given to resolving them through the enactment and amendment of relevant laws and regulations.

With regard to the improvement in the law on marine environmental protection, the ecosystem of ocean carbon sinks should be considered as part of the environment and a legal system for the protection of ocean carbon sinks should be constructed. As a natural resource, ocean carbon sinks should enjoy the same treatment as other natural resources in the human living environment. For example, typical and representative near-coastal ecosystems, such as mangrove forests, coastal wetlands, and seagrass beds, should have their value explained at the legal level. Relevant content related to the protection of ocean carbon sinks should be added to existing laws on marine environmental protection. Taking Australia, which is rich in marine carbon sinks, as an example, the Great Barrier Reef, one of the largest coral reef systems in the world, and the numerous seagrass beds in the northeastern coastal area are important ocean carbon sinks. In order to protect these

valuable ocean carbon sinks, Australia has introduced a series of regulations and policies, such as the Environmental Protection and Biodiversity Conservation Act and the National Wetland Policy [57]. Indonesia [58] and Brazil [59] have also formulated similar laws and regulations for ocean carbon sink protection. Drawing on foreign experience, China should integrate the protection of ocean carbon sinks into the overall protection of marine ecosystems. For example, the Marine Environmental Protection Law should clearly define ocean carbon sinks and include them in the scope of protection, and the Wetland Protection Law, whose legislative purpose is anchored in the maintenance of ecological functions and biodiversity, can further emphasise the role of the restoration of degraded wetlands as a source of carbon sinks. When ocean carbon sinks are damaged, the application of the marine ecological compensation system and the litigation mechanism for compensation for damage to marine environments and ocean carbon sinks should be considered on the basis of existing legal provisions. On the one hand, Article 35 of the Marine Environmental Protection Law clearly provides for the establishment of a compensation system for marine ecological protection, and detailed arrangements concerning the main compensation body for ocean carbon sinks, scope of compensation, compensation standard, source of funds, and method of compensation can be added. On the other hand, Article 114 of the Marine Ecological Environment Protection Law determines the qualifications for the main body put forth by a plaintiff in a lawsuit requesting compensation for damage to the marine environment, as well as the arrangement of the order of precedence, so that more detailed planning can be made for the conditions of prosecution, procedural requirements, and assumption of responsibility when it comes to the damage to ocean carbon sinks. In addition, it has strengthened the effective connection between legislation relating to the protection of ocean carbon sinks and the Basic Law on Oceans, as well as resolved the legal application of both.

Special legislation on the development of ocean carbon sink projects and on the construction of an ocean carbon sink market is an important aid in promoting the construction of a blue carbon sink market. The Chinese Law on Responding to Climate Change and Regulations on the Administration of the National Unified Carbon Sink Market has entered the legislative argumentation and preparation stage, which provides an opportunity for special legislation on ocean carbon sink market construction. The protection, development, and utilisation of terrestrial carbon sinks have relatively sound legal and management systems, with the Leading Group on Climate Change, established under the leadership of the Forestry Bureau, serving as the lead and coordinating department for green carbon management. The Interim Measures for the Management of the Chinese Green Carbon Fund policy has been introduced at the legislative level to attain the environmental benefits. Unlike legislation related to land-based carbon sinks, the development of the Chinese ocean carbon sink market does not yet include a complete legal system. Therefore, drawing on the land-based carbon sink legislation model is a feasible way to promote the development of legislation concerning the ocean carbon sink market. Adoption of the "central law → special law → local law" model of coordinated protection legislation should be considered. Taking into account the real needs for the development of the Chinese ocean carbon sink trading market, a legal system for "ocean carbon sink trading" should be stipulated in a special chapter of the national unified carbon sink market management regulations that may be issued in the future. The legal object in carbon market transactions, participation, procedural norms, regulatory measures, responsibilities, and other content should be clearly defined. Secondly, special legislation for each type of ocean carbon sink project should be formulated. The State Oceanic Administration (SOA) and the Fisheries Bureau of the Ministry of Agriculture (MOA) will take the lead in formulating management regulations or implementation rules for coastal ecosystem carbon sinks and fishery carbon sink projects, respectively. Finally, legislation should be refined and supplemented according to local realities to realise the linkage between central and local authorities. The protection and development of ocean carbon sinks has obvious regional characteristics, so it is necessary for local authorities to improve and optimise the top-level design according to development

needs. This is conducive to the coordination of central and local legislation, which can jointly serve in the development of the Chinese ocean carbon sink trading market.

5.5. Promote the Innovation of Financial Products for Ocean Carbon Sinks and Deepen the Financialisation of the Ocean Carbon Sink Market

The development and expansion of the ocean carbon sink financial system are necessary for China's domestic carbon financial market. The establishment of a complete ocean carbon sink financial system not only includes the expansion of carbon sink projects and the innovation of financial products but also deepening of the degree of financialisation of the ocean carbon sink market and optimising the composition of market participants, thus further enhancing the cohesion of the ocean carbon sink market.

Firstly, development and utilisation of ocean carbon sinks should be increased. Coastal areas are encouraged to formulate plans for the development of the ocean carbon sink economy, accelerate the layout of the ocean carbon sink economy, vigorously develop ocean carbon sink projects, such as those related to marine ecological restoration, ocean pastures, seagrass bed carbon sinks, and fishery carbon sinks, and encourage and attract social capital to participate in the development of ocean carbon sink projects [60].

Secondly, the development of financial derivative products for ocean carbon sinks should be actively pursued. As the carbon trading market continues to grow and mature, the experience and risk tolerance of market participants have improved. At this time, China can refer to the successful, practical cases of foreign trading markets and forestry carbon sinks, accelerate the exploration of the financialisation of the ocean carbon sink trading market, and carry out studies on ocean carbon sink financial derivatives and ocean carbon sink products, such as carbon sink compensation products, carbon sink futures, carbon sink funds, carbon sink bonds, carbon sink trusts, and standardised carbon sink pledges. Various methods and concepts for transforming the economic benefits are integrated into the value realisation of ocean carbon sink products such that the Chinese ocean carbon sink carbon trading market can move towards a more mature and advanced stage [61].

Thirdly, the degree of financialisation of the ocean carbon sink market should be deepened. The smooth operation of the ocean carbon sink trading market involves a large number of links and professions, especially from the perspective of financial derivatives, which have greater extensiveness and professionalism. Traditional enterprises generally lack the relevant knowledge, experience, and ability, so it is necessary to form a complete ocean carbon sink trading service industry chain and carbon trading collaboration network, with the exchange at the centre amid relevant institutions. Relevant organisations include carbon asset management companies, carbon credit rating agencies, carbon auditing services, legal services for carbon trading, carbon financial information services, and carbon trading insurance services as intermediary service providers involved in ocean carbon sink trading. They provide a bridge for the development of ocean carbon sink projects and promote transactions of ocean carbon sinks. In particular, current development of the financial market has reached a saturated state; in this context, the creation of carbon finance has generated new opportunities for the financial industry. We should seize this opportunity to attract participants in ocean carbon sink trading, expand the functions of the ocean carbon sink trading market, and promote the innovation and reform of green ocean carbon sink finance.

Fourth, China should focus on developing an echelon of ocean carbon sink talent. China should establish a joint training mechanism for government, industry, research, and academia to cultivate specialised and interdisciplinary talent with expertise in marine, finance, management, and other fields [62]. University–enterprise cooperation, among other ways, can be used to jointly promote continuous improvement at the theoretical research level and in the practical skills held by ocean carbon sink trading talent, as well as by organising and carrying out multilevel, wide-ranging, multifield, multithematic, and diversified training activities nationwide. A mechanism to unveil the list of marshals in the field of ocean carbon sink methodology research and other aspects should be developed, which will also encourage

research institutes and universities that have leverage to actively conduct relevant theoretical and practical research by increasing the provision of financial and intellectual supports for the smooth development of ocean carbon sink market transactions through various means, such as directives and funding for scientific research projects and operational projects.

5.6. Reinforce Government Regulation of Ocean Carbon Sink Trading and Incentivise Public Participation in Ocean Carbon Sink Trading

A complete trading market must comprise ocean carbon sink producers, demand enterprises, trading platforms, local governments, and the general public [45]. Therefore, it is necessary to give full play to the subjective initiatives of the government and the public to better serve the smooth operation of the ocean carbon sink trading market.

First, the government should strengthen its organisational leadership, incorporate ocean carbon sink trading into national and local development plans, and establish a three-tier regulatory system comprising government agencies, industry associations, and exchanges. Government agencies should regulate the ocean carbon sink trading market from an overall perspective, improve laws and regulations related to ocean carbon sink financial products, and propose regulatory improvements to the work of ocean carbon sink industry associations and ocean carbon sink exchanges. An ocean carbon sink industry association is a self-governing organisation in the ocean carbon sink trading project industry, which implements self-management of ocean carbon sink trading and self-restraint through its constitution. The regulation of ocean carbon sink exchanges includes the formulation of systems for ocean carbon sink trading, settlement, delivery, and breach of contract, thereby regulating ocean carbon sink trading activities. There should be established an information disclosure system for the oceans, such as a system to account for and manage the assets of ocean carbon sinks, development of physical statistics, exploration of value accounting, preparation of balance sheets for ocean carbon sinks, and the establishment of a unified and authoritative mechanism for releasing and sharing information on the monitoring, reporting, accounting, and evaluation of ocean carbon sinks, and the formation of a relevant database. The government should make the database available to the public and randomly check dynamic changes in the database to ensure the accuracy of the information. Such an information disclosure system for ocean carbon sinks provides the main parties involved in ocean carbon sink trading with relevant information, which is conducive to more rational and objective judgements of the ocean carbon sink trading market.

Secondly, the general public should be motivated to participate in ocean carbon sink trading. Although the ocean carbon sink trading market is currently dominated by production-oriented enterprises, voluntary emissions-reduction trading mechanisms in China will continue to innovate and play a role in the future, along with the increasing demand for carbon offsets in various fields, such as corporate production and personal clothing, food, housing, and transport, as well as the diversification of participants, such as financial institutions and individuals. The public needs to be actively guided and educated to develop their own awareness of environmental protection. Strengthen publicity and education on the rule of law related to ocean carbon sink protection, and the government and environmental public welfare organisations should actively organise public welfare activities for ocean carbon sink protection and publicise the importance of ocean carbon sink protection with the help of the media, the Internet, and other platforms. The public can be guided to participate in ocean carbon sink protection legislation, administrative decision making, public interest litigation, and other activities, gaining a deeper understanding of the rule of law path of ocean carbon sink protection, enhancing their awareness of compliance with the law on ocean carbon sinks, and being active, law-abiding citizens. Yokohama, Japan, is the first city in the world to implement a blue carbon offset certification programme for seagrass meadows, macroalgae beds, and macroalgae farming. A blue carbon offset certification system was established under the guidance of the Yokohama City Action Plan to Combat Global Warming, whereby blue carbon is purchased by companies, organisations, or individuals that produce greenhouse gases [63]. Drawing on Japan's practical experience,

we can develop a carbon inclusive big data platform and rely on WeChat 8.0.50, Alipay 10.6.6, or other cultural and tourism platforms' small programmes or new modules to enable groups with carbon offset needs to make convenient online purchases and issue electronic certificates of credit for carbon purchases at the same time. An ocean carbon sink fund and a supporting system for the management of the value of ocean carbon sinks should be established, with the requisite publicity and advocacy to attract high-income groups to purchase ocean carbon sinks. A programme should be designed for the use of carbon credits, and the construction of low-carbon signs and guidance in scenic spots should be strengthened. For communities, families, and individuals, green and low-carbon consumption needs can be stimulated for all aspects of clothing, food, housing, and transportation, such as setting up incentives in the form of points for designated commodities to form green and low-carbon behavioural habits. High-emission enterprises can offset their own emissions by purchasing ocean carbon sink points and credits from the voluntary emissions reduction market and the carbon inclusion market. This will provide the necessary financial replenishment for the continuous operation of the market and provide a socially acceptable measurement standard for emissions reduction behaviour.

6. Conclusions

From the above analyses and discussions, it is concluded that the construction of an ocean carbon sink market in China is progressing slowly. The fact that ocean carbon sink trading has only been piloted in some parts of China and has not yet been carried out on a large scale is the result of a combination of factors. There are obstacles within the legal system and deficiencies in trading products, as well as a lack of interest among ideological fields. The results of this study show that a single solution is not enough to develop and improve upon a sound ocean carbon sink trading market, which requires the joint efforts of the government, market, and all aspects of the public. As the builder of the ocean carbon sink market, the government should clarify the property rights of ocean carbon sinks and further improve the laws, regulations, and policy system of ocean carbon sink trading. Although the ocean carbon sink trading market is still in the primary stage, it should further deepen the financial system of ocean carbon sinks, promote the innovation of financial products, and cultivate high-quality professionals. The public should cultivate a good sense of environmental protection, actively participate in ocean carbon sink trading, and improve the regulatory mechanism of ocean carbon sink trading. As a result, the role of ocean carbon sinks in addressing climate change will be better utilised and a win–win situation in terms of economic and environmental benefits will be realised, thus contributing to the realisation of China's dual-carbon goals.

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Appendix A

Table A1. Released ocean carbon sink policy in China.

Year	Organisation	Document Name	Summary of Relevant Content
2013	State Oceanic Administration	Twelfth Five-Year Plan for the Development of the National Maritime Programme	It is proposed that important marine ecosystems, such as mangroves, coastal wetlands, and salt marshes, be protected and restored.
2014	Chinese Academy of Science	Chinese Blue Carbon Programme	The connotation includes the integration of land and sea, emissions reduction and sink enhancement, ecosystem health, and sustainable development of coastal economy and society.
2015	Central Committee of the Communist Party of China and State Council	Opinions on Promoting Ecological Civilisation	The document points out the need to increase ocean carbon sinks and other means by which to respond to global climate change, which marks the formal inclusion of blue carbon protection in Chinese national strategic planning.
	Central Committee of the Communist Party of China and State Council	General Programme for the Reform of the Ecological Civilisation System	It is proposed to "gradually establish a national system for controlling the total amount of carbon emissions and a mechanism for decomposing and implementing such emissions, and establish an effective mechanism for increasing carbon sinks in forests, grasslands, wetlands and oceans".
	State Council	National Marine Thematic Functional Area Plan	It is clearly proposed to promote the green development of the ocean economy, raise the threshold for industrial access, actively develop and utilise marine renewable energy, and enhance the function of ocean carbon sinks.
2016	State Council	Work Programme for the Control of Greenhouse Gas Emissions in the 13th Five-Year Plan	The document proposes research and development of affordable low-carbon technologies in key areas, such as oceans and seas, and the active development of national low-carbon pilot projects.
	State Oceanic Administration	National Blue Carbon Sink Study: Feasibility Study for National Blue Carbon Initiatives	The document provides a summary compendium of blue carbon from an industry perspective, current status, measurement, monitoring, and blue carbon's strengths and potential in China, layer by layer, demonstrating the progress of cross-sectoral blue carbon scientific research in China and the process of industrial development.
	State Council	Programme on Wetland Conservation and Restoration Systems	A set of systems is proposed to improve the wetland protection and management system, as follows: implementing control of the total area of wetlands, implementing wetland protection and restoration projects, enhancing the carbon sink function of wetlands, and exploring the establishment of a wetland ecological benefit compensation system.
	State Oceanic Administration	Guidance on Strengthening the Management and Conservation of Coastal Wetlands	Guidance includes strengthening the protection of important natural coastal wetlands, carrying out the restoration and repair of damaged coastal wetland ecosystems, strictly managing the development and utilisation of coastal wetlands, and strengthening the investigation and monitoring of coastal wetlands.
	Ministry of Finance, State Oceanic Administration	Circular on Central Financial Support for the Implementation of Blue Bay Remediation Actions	The notice indicates that it will promote steady improvements in offshore water quality, restoration of damaged shorelines and bays, increasing the area of coastal wetlands, and effective control of the scale of reclamation to gradually achieve the goal of building a marine ecological civilisation with "clear water, green shores, clean beaches, beautiful bays and beautiful islands".
	Ministry of Ecology and Environment	China Climate Change First Biennial Update Report	For the first time, an enumeration of China's efforts to develop blue carbon in the oceans in response to climate change is provided.
2017	National Development and Reform Commission, National Oceanic Administration	Scenarios for Maritime Cooperation in Belt and Road Construction	The Blue Carbon Initiative for the 21st Century Maritime Silk Road was launched with the aim of establishing an international blue carbon cooperation mechanism.
	State Oceanic Administration Central Comprehensive Deep Reform Leading Group	Several Opinions on Improving the Strategy and System of Main Functional Areas	It is stated that it is necessary to explore the establishment of a "blue carbon standard system and trading mechanism".
	State Oceanic Administration, Fujian Provincial People's Government	Pingtan Declaration	China has formally proposed to encourage blue carbon research, exchange, and cooperation.

Table A1. *Cont.*

Year	Organisation	Document Name	Summary of Relevant Content
2018	Ministry of Ecology and Environment	China Climate Change Second Biennial Update Report	The report introduces the basic situation of the country, its natural conditions and resources, the national GHG inventory, other relevant information for achieving the objective of the Convention, and basic information on the Hong Kong Special Administrative Region's response to climate change.
	Ministry of Agriculture and Rural Development	Implementing Opinions on Supporting the Green Development of Agriculture and Rural Areas in the Yangtze River Economic Belt	Opinions put forward to promote the restructuring of aquaculture and support the development of carbon sink fisheries.
	State Council	Enhancing the Protection of Coastal Wetlands and Strictly Controlling Reclamation.	The document requires the strengthening of marine ecological protection and restoration, the accurate evaluation of wetland protection, use, ownership, ecological status, and function, etc., and the analysis and formulation of technical specifications for appraisal and assessment of ecological damage, compensation, and restoration of coastal wetlands.
2019	General Office of the Central Committee of the Communist Party of China and the State Council	Hainan Implementation Programme for the National Ecological Civilisation Pilot Zone	It clearly proposes to carry out pilot projects on ocean carbon sinks, conduct research on the blue carbon standard system and trading mechanism, and explore the establishment of an international carbon emissions trading venue in compliance with the law.
	Central Committee of the Communist Party of China and State Council	Outline of the Plan for the Development of the Guangdong–Hong Kong–Macao Greater Bay Area	Emphasis was placed on strengthening the protection and restoration of wetlands, comprehensively protecting internationally and nationally important wetlands in the region, and carrying out joint cross-border protection of coastal wetlands.
	Chinese Association of Marine Engineering Consultants	Weihai Initiative of the Marine Ecological Economic Forum 2019	The initiative released research results on the kelp farming carbon sink methodology, which is the first ocean carbon sink methodology in China. It also introduced the route of the Blue Carbon International Fund landing in Weihai, etc. A consensus was reached on six aspects, including basic research and top-level design, system construction and mechanism innovation, standardisation construction, and scientific and technological innovations for the development of a marine ecological economy.
	State Council	United Nations Climate Action Summit: Chinese Position and Actions	The document introduces Chinese policy ideas for international cooperation to address climate change and the achievements of Chinese initiatives in addressing climate change.
2020	Ministry of Natural Resources, National Forestry and Grassland Administration	Special Action Plan for the Protection and Rehabilitation of Mangrove Forests (2020–2025)	The document requires comprehensive protection of existing mangrove forests in Zhejiang Province, Fujian Province, Guangdong Province, Guangxi Zhuang Autonomous Region, and Hainan Province. It promotes the construction of mangrove nature reserves, gradually completion of the clearance of developmental and productive construction activities, such as breeding ponds in nature reserves, and the restoration of the ecological functions of mangrove nature reserves. Ecological restoration of mangrove forests must be implemented, mangrove forests created in areas suitable for restoration, nurturing and improvements in quality should be implemented in degraded areas, mangrove forest areas should be expanded, and the quality and function of mangrove ecosystems improved. By 2025, 18,800 hectares of mangrove forests will be created and restored, of which 9050 hectares will be created and 9750 hectares will be restored.
	National Development and Reform Commission, Ministry of Natural Resources	Master Plan for Major Projects for the Protection and Restoration of Nationally Important Ecosystems (2021–2035)	The plan focuses on typical ecosystems such as mangrove forests, coral reefs, and seagrass beds; strengthens the comprehensive remediation and restoration of important habitats; and reinforces the protection and restoration of natural shorelines and coastal wetlands.
	Ministry of Agriculture and Rural Development	Highlights of Green Development in Agriculture and Rural Areas for 2020	The document calls for the vigorous development of large water surface ecological fisheries, encourages the development of carbon sink fisheries, and supports the development of deep-sea aquaculture.

Table A1. *Cont.*

Year	Organisation	Document Name	Summary of Relevant Content
2021	The Third Institute of Oceanography of the Ministry of Natural Resources, Guangdong Zhanjiang Mangrove National Nature Reserve Administration, Beijing Entrepreneurs' Environmental Protection Foundation, and 32 Other Enterprises and Institutions, as well as Public Welfare Organisations	Blue Carbon Ecosystem Conservation and Restoration Initiative	The document proposes to strengthen the protection and restoration of blue carbon ecosystems and enhance the capacity of coastal zones to adapt to and mitigate climate change; support the development and implementation of policies, management, and financial incentives for the protection, restoration, and sustainable use of blue carbon ecosystems; promote the development of blue carbon sink projects, fully realise the value of blue carbon ecosystems; establish a viable mechanism for the use of carbon trading proceeds to maintain ecological protection, restoration, and sustainable development of communities; encourage social funds to participate in various forms in the protection and restoration of blue carbon ecosystems, and strengthen international cooperation to jointly promote the implementation of blue carbon based climate change solutions. Encourage social funds to participate in the protection and restoration of blue carbon ecosystems in various forms, and strengthen international cooperation to jointly promote the implementation of climate change solutions based on blue carbon ecosystems. We jointly call on all sectors of society to pay attention to and participate in the research, protection, and restoration of blue carbon ecosystems, and actively promote blue carbon trading and other forms of mechanisms for realising the value of ecological products, so as to contribute to the achievement of carbon-neutrality in China by 2060.
	Central Committee of the Communist Party of China and State Council	Opinions on the Complete and Accurate Comprehensive Implementation of the New Development Concept for Peak Carbon and Carbon Neutral Work	The opinion proposes to consolidate and enhance the carbon sink capacity of ecosystems; stabilise carbon sequestration in existing forests, grasslands, wetlands, oceans, soils, permafrost and karst; strengthen grassland ecological protection and restoration; strengthen the protection of wetlands; promote the protection and restoration of marine ecosystems as a whole, and enhance the carbon sequestration capacity of mangroves, seagrass beds, and salt marshes, relying on and expanding the natural resources survey and monitoring system; establishing a monitoring and accounting system for ecosystem carbon sinks, carrying out background surveys of carbon sinks in forests, grasslands, wetlands, oceans, soils, permafrost, and karst; assess carbon stocks; and implementing the monitoring and assessment of ecological protection and restoration of carbon sink projects and their effectiveness.
	State Council	Peak Carbon Action Programme to 2030	The programme proposes the establishment of a monitoring and accounting system for ecosystem carbon sinks; the conduct of background surveys of carbon sinks in forests, grasslands, wetlands, oceans, soils, permafrost, and karst; the assessment of carbon stocks and the analysis of potentials; and the implementation of the monitoring and assessment of the effectiveness of ecological protection and restoration in terms of carbon sinks. It will strengthen research on basic theories, basic methods and cutting-edge subversive technologies for carbon sinks in terrestrial and ocean carbon sinks.
	7 Ministries and Agencies, including Zhangzhou Development and Reform Commission, Municipal Natural Resources Bureau, Municipal Bureau of Ecology and Environment, Fujian Province	Action Plan for Blue Carbon Private Law Protection and Ecological Governance in Zhangzhou City (2021–2025)	In conjunction with the "dual-carbon goal", the plan improves the mechanism and promotes relevant supportive publicity and educational activities in the areas of blue carbon private law protection, administrative governance, jurisprudential research, and technical support.
	Guangdong Provincial Government Office	The 14th Five-Year Plan for the Development of the Marine Economy of Guangdong Province	Document calls for fostering blue carbon sink industry, exploring ocean carbon sink trading
	Fujian Provincial Government	Three-Year Action Programme on Accelerating the Construction of "Maritime Fujian" and Promoting the High-Quality Development of the Marine Economy (2021–2023)	The programme stresses the need to seize the high ground of ocean carbon sinks, carry out in-depth scientific research on ocean carbon sinks, and promote ocean carbon neutral pilot projects.
	Hainan Provincial Department of Natural Resources and Planning	Opinions on the Establishment of a Sound Marine Ecological Early Warning and Monitoring System	The proposal to "implement monitoring and assessment of ocean carbon sinks" focuses on the monitoring of carbon stocks in typical ocean carbon sink ecosystems, such as mangrove forests and seagrass beds, and the establishment of a basic database of the province's blue carbon sink resources.

Table A1. *Cont.*

Year	Organisation	Document Name	Summary of Relevant Content
2022	Shandong Provincial Government	Shandong Province's 14th Five-Year Plan to Address Climate Change	The plan establishes that Shandong has an inherent advantage in the development of ocean carbon sinks, and supports Weihai in exploring the construction of a blue carbon trading platform to promote the conversion of ocean carbon sinks from resources into assets.
	Shandong Weihai Government	Weihai 14th Five-Year Plan for Addressing Climate Change	The plan calls for actively promoting the inclusion of ocean carbon sinks in the national carbon market and exploring the development of a pilot blue carbon market for trading.
	Ministry of Natural Resources	Methodology for Accounting for the Economic Value of Ocean Carbon Sinks and Instructions for its Preparation	A methodology for assessing the capacity of ocean carbon sinks and accounting for the economic value of ocean carbon sinks is proposed, which is applicable to the assessment of the capacity of ocean carbon sinks and the accounting for the economic value of ocean carbon sinks with regional comparisons.
	Wenzhou Science and Technology Bureau	Wenzhou Science and Technology for the Sea and Blue Carbon Innovation Action Programme	The programme focuses on the key development direction of Wenzhou's marine industry, takes the enhancement of scientific and technological innovation capability as an important engine, promotes the integration of the innovation chain with the industrial chain, creates an open, synergistic and efficient marine science and technology innovation system, seizes the scientific and technological high ground in the fields of ocean clean energy, ocean carbon sink, ecological environmental protection, ecological aquaculture and processing, and bio-resource development, etc., and accelerates the high-quality development of the marine economy to assist in the national Innovative city construction.
	Hainan Provincial Department of Natural Resources and Planning	Pilot Work Programme for Ocean Ecosystem Carbon Sinks in Hainan Province (2022–2024)	The document calls for pilot projects to explore the realisation of the value of ecological products from ocean carbon sinks.
	Guangxi Autonomous Region Oceanic Bureau	Work Programme for Early and Pilot Works on Blue Carbon in Guangxi	It is necessary to comprehensively complete, step by step and in a planned manner, the carbon stock survey and carbon sink accounting work of the three major blue carbon ecosystems in Guangxi, promote the development and completion of blue carbon trading, and explore the establishment of a blue carbon trading service platform and other major objectives and tasks, so as to continually enhance the function of Guangxi's mangrove forests in disaster mitigation and prevention, vigorously promote the realisation of the value of ocean carbon sinks, and continue to build a firm and important ecological barrier in the south.
2023	Shenzhen Municipal Administration of Market Supervision	Guidelines for Accounting for Ocean Carbon Sinks	The guide screens out 7 types of carbon sinks, including mangroves, salt marshes, shellfish, algae, and phytoplankton, and 11 carbon sink indicators, confirming the values of 17 emission factors applicable to accounting, and constructs accounting methods and quality control guidelines, as well as a demonstration template for ocean carbon sink accounting in coastal areas. The guide is of strong practical significance in promoting the marketisation, standardisation, and normalisation of ocean carbon sink resources in the new area, which will effectively promote the transformation of the values of ocean ecological resources in new areas, providing a scientific basis to carry out ecological transfer payments.
	Ministry of Natural Resources	Methodology for Accounting for Ocean Carbon Sinks	These guidelines define ocean carbon sinks as "the processes, activities and mechanisms by which mangroves, salt marshes, seagrass beds, phytoplankton, macroalgae, shellfish, etc., absorb and store atmospheric carbon dioxide from the air or seawater".
	Development and Reform Commission, Department of Natural Resources, Department of Ecology and Environment, Zhejiang Province	Guidance on the Enhancement of Zhejiang Province's Ocean Carbon Sink Capacity	Guidance on the in-depth implementation of the carbon peak and carbon neutral national strategy and the Zhejiang Provincial Party Committee and provincial government's "exploring the development of the ocean blue carbon, and continue to enhance the ecosystem carbon sinks" requirements, focusing on the enhancement of the capacity of ocean ecosystem carbon sinks to create an important growth pole for carbon neutrality, combined with the actual situation in Zhejiang Province.
2024	Office of the Ministry of Natural Resources	Technical Procedures for Assessing the Effectiveness of Blue Carbon Ecosystem Protection and Restoration Projects in Increasing Sinks (Trial)	The methodology for evaluating the sink enhancement effectiveness of the three types of blue carbon ecosystem protection and restoration projects, namely, mangrove forests, coastal salt marshes, and seagrass beds, is standardised, which will be used to guide evaluations of the effectiveness of sink enhancements in the restoration of the blue carbon ecosystems at the national level and to quantitatively evaluate the contributions of marine ecosystem protection and restoration projects to the strengthening of the capacity to enhance ocean carbon sinks.

Appendix B

Table A2. Practical cases of ocean carbon sink trading in China.

Year	Location	Trading Overview
2021	Zhanjiang, Guangdong	The Third Institute of Oceanography of the Ministry of Natural Resources, the Guangdong Zhanjiang Mangrove Forest National Nature Reserve Administration and the Beijing Entrepreneurs' Environmental Protection Foundation (SEE Foundation) jointly held a signing ceremony in Qingdao, Shandong Province, to mark the signing of China's first "Blue Carbon" project transaction.
	Xiamen, Fujian	The Xiamen Property Rights Trading Centre (Xiamen Carbon and Sewage Rights Trading Centre) has set up the country's first trading service platform for ocean carbon sinks, cooperated with a team of academicians in the field of domestic ocean carbon sinks, developed an orderly methodology system for ocean carbon sinks, and innovatively carried out trading in "blue carbon", so as to further give full play to the superimposed effect of the integrated development of the ocean economy and the green economy.
	Fangchenggang, Guangxi	Guangxi Fangchenggang District Rural Credit Cooperative Union issued an "ocean carbon sink loan" of RMB 500000 for Guangxi Xiaozao Agricultural Science and Technology Co., Ltd., to support the enterprise's use of the by-products of steam, warm water and flue gas from the nearby thermal power generation enterprises to carry out micro-algae farming and processing, and to produce EPA, a nonfish oil source, with the loan being secured by the enterprise's carbon sinks from micro-algae farming. The loan is also secured by the carbon sinks of the enterprise's microalgae farming.
	Dongtou, Zhejiang	The Agricultural and Commercial Bank of China issued an "ocean carbon sink loan" of RMB 150,000 to a local seafood farmer, which was specifically used for the farmer to expand the breeding area of seaweed and periwinkle, as well as for the green transformation and upgrading of the breeding technology.
	Qingdao, Shandong	Industrial Bank of Qingdao Branch issued a "Wetland Carbon Sink Loan" of RMB 20 million to Qingdao West Coast Culture and Tourism Group Co., Ltd., on the basis of the pledge of Tangdao Bay wetland carbon sinks, which was specifically used for the protection of ocean carbon sinks, such as dredging of the shoreline of the wetland park.
	Qingdao, Shandong	Industrial Bank of China Qingdao Branch, through a third-party institution, monitored and analysed the soil area, vegetation area, and multiyear average water resources of the wetland project of Qingdao Jiaozhou Bay SCO Demonstration Zone Development Co., Ltd., comprehensively assessed its carbon sequestration capacity, and issued a "Wetland Carbon Sink Loan" of RMB 18 million for the enterprise, with the forward income right of the Jiaozhou Bay wetland's carbon reduction as a pledge for the calculation. The enterprise was granted a "Wetland Carbon Credit" of RMB 18 million, which was specially used for the enterprise to purchase high carbon sink wetland crops that increase carbon absorption.
	Weihai, Shandong	Weihai Rongcheng Agricultural and Commercial Bank of Weihai City issued an "ocean carbon sink loan" of RMB 20 million to Weihai Evergreen Marine Science and Technology Co., Ltd., which was specially used for the enterprise's kelp and wakame farming, promotion of multinutrient level integrated aquaculture model, and green intensive aquaculture industry chain.
	Weihai, Shandong	The Shandong branch of the Agricultural Bank of China issued a RMB 13 million "ocean carbon sink loan" to an ocean enterprise in Weihai.
2022	Shantou, Guangdong	Taking the ecological product of ocean carbon sinks as an entry point, Shantou Branch of ICBC has landed the first pledge loan of expected revenue right of ocean carbon sinks in the province, which is also the first pledge loan of expected revenue right of ocean carbon sinks in the national ICBC system.
	Fuding, Fujian	The country's first mangrove blue carbon ecological protection insurance has been piloted in Fuding City, which will provide the city's mangrove forests with RMB 18.75 million of loss risk protection. The insurance policy is taken out by the Forestry Bureau of Fuding City, and the payout can be used not only for rescuing and repairing the subject matter of the insurance policy, but also for the necessary and reasonable expenses related to rescuing the mangrove forests in order to improve the mangrove forests' blue carbon ecological environment.
	Xiamen, Fujian	Yunwan Village and Yanxia Village of Nanri Township and Xiamen Property Rights Trading Centre Co. Ltd., signed the nation's first village collective ocean carbon sink trading contract at the Yanxia Village Department.
	Fuzhou, Fujian	Lianjiang County, Fuzhou, Fujian Province, released the first national ocean fishery carbon sink construction system The first digital RMB ocean carbon sink financing in the country, Lianjiang County released the ocean fishery carbon sink system in accordance with the "1 + 3 + 1 + N" mode of construction, i.e., to carry out research on the mechanism and mechanism of ocean fishery carbon sinks; to designate three standards: technical specifications for monitoring, technical guidelines for accounting, and technical guidelines for value assessment; to establish a trading platform for ocean fisheries; and to implement a number of projects and projects to gradually realise the ecological value of the ocean carbon sinks.
	Weihai, Shandong	The Weihai Branch of China Industrial Bank issued a loan of RMB 10 million for a seaweed farming carbon sink pledge loan to a seawater aquaculture company in Rongcheng City. This is the first ocean carbon sink pledge financing business within the system of Industrial Bank, and other useful innovations and explorations of the bank in serving the development of the green economy.
	Weihai, Shandong	The village of Dongzogdao, Rongcheng City, Weihai, Shandong Province, has taken out the country's first ocean carbon sink index insurance policy for 100 acres of contiguous seagrass. The insurance company will be responsible for compensating for the weakening of carbon sinks caused by changes in the specific marine environment.

Table A2. *Cont.*

Year	Location	Trading Overview
2023	Hainan	The first three "ocean carbon sinks" in Hainan "land supermarket" system ocean carbon sink shelves. This means that Hainan Province operating sea resources integration a big step forward, the supply of sea resources elements more standardised and facilitated. The above three "ocean carbon sinks", distributed in Hainan Danzhou, Wenchang, Changjiang and other cities and counties, with a total area of 752.57 hectares. Open Hainan "land supermarket" system, enter the ocean carbon sink shelves, can be a detailed query ocean carbon sink project location, afforestation area, expected emissions reduction, project activities and other information.
	Yangjiang, Guangdong	Under the guidance of the People's Bank of China Yangjiang City Central Sub-branch and the higher level banks, ICBC Yangjiang Branch has successfully landed the first pledge loan of expected revenue right of ocean carbon sinks in Yangjiang City.
	Shenzhen, Guangdong	The country's first carbon sink for mangrove protection was auctioned in Shenzhen, and the proceeds of the auction will be paid to the Shenzhen Municipal Government to feed the protection and restoration of mangrove forests.
	Guangxi	Guangxi's first "blue carbon" (ocean carbon sinks) transactions in the Beibu Gulf Property Rights Exchange Group Guangxi (China–ASEAN) blue carbon trading services platform listing transactions, marking the implementation of the national blue carbon early and pilot work in Guangxi has made substantial progress.
	Cangnan, Zhejiang	The first mangrove blue carbon transaction in Zhejiang Province landed in Cangnan, where the Cangnan County Yanpu Township Government and Vision (Cangnan) New Energy Co. Ltd., signed an agreement on the transfer of the total amount of carbon sinks over a ten-year period. This provides a model for the value assessment and trading process of mangrove blue carbon.
	Xiangtangshan, Zhejiang	Zhejiang Yi Forging Precision Machinery Co., Ltd., successfully won the auction of one year of carbon sinks of Xiangshan Mountain Hukang, which is the first time in the country that blue carbon was traded, in the form of auction.
	Zhoushan, Zhejiang	Zhoushan City's first ocean carbon sink project transaction intention signing, the seller is ShengsiShanhaiQiguan Ocean Science and Technology Development Co., Ltd., and the buyers are Zhoushan City Organ Affairs Management Centre and Zhejiang ZhenengZhongcheng Coal Zhoushan Coal and Electricity Co. This move opens the way for Zhoushan City to explore a new path to build blue carbon wealth for the people.
	Xiangtangshan, Zhejiang	The first "Blue Carbon" seagrass insurance project in China landed in Xiangshan, Ningbo, where PICC Ningbo Xiangshan Branch provided risk protection for one year's seagrass farming carbon sinks in Xihu Port for Xiangshan Xuwen Seaweed Development Co.
	Yancheng, Jiangsu	Jiangsu Yancheng Wetland Rare Bird National Nature Reserve and Tencent completed the signing ceremony of the Blue Carbon Ecosystem Carbon Sinks Trading Jiangsu Yancheng Binhai Salt Marsh Ecological Restoration Carbon Sink Project. This is Chinese first salt marsh carbon sinks trading project, marking Chinese salt marsh blue carbon trading "zero breakthrough" for the realisation of the ecosystem value of sustainable development, has a pioneering role in demonstration.
	Yantai, Shandong	Yantai seawater aquaculture ocean carbon sink index insurance launch and ocean ranch insurance claims ceremony was held, Yantai Ocean Development and Fisheries Bureau and Taiping Property and Casualty Insurance Yantai City Central Branch signed a cooperation agreement, marking the province's first policy municipal seawater aquaculture ocean carbon sink index insurance officially landed in Yantai.
	Binzhou, Shandong	Under the guidance of the Binzhou Central Sub-branch of the People's Bank of China, the Binzhou Banking and Insurance Supervision Branch, the Binzhou Municipal Bureau of Ocean Development and Fisheries, and the Binzhou Municipal Ocean Development Research Institute, the Business Department of Bank of Weifang Binzhou Branch has successfully issued a loan of RMB 500,000 in the form of pledge of the expected revenue right of ocean carbon sinks to a company in Wudi County. This is the first green financial loan issued by Weifang Bank Binzhou Branch with the expected revenue right of ocean carbon sinks as the pledge.
2024	Shanwei, Guangdong	Under the guidance of Shanwei Branch of the People's Bank of China, Shanwei Branch of the Agricultural Bank of China recently successfully landed the city's first pledge loan for the expected revenue right of ocean carbon sinks, exploring a new mode and new path for financial support for the development of Shanwei's ocean economy.
	Yancheng, Jiangsu	The first "shellfish marine blue carbon sinks loan (clam loan)" in Jiangsu Province has been successfully implemented in Dafeng District, Yancheng City. Postal Savings Bank Yancheng Dafeng Sub-Branch issued a loan of RMB 10 million to Jiangsu Haiyi Industrial Co., Ltd., for a period of one year, specifically for the company to buy clam seedlings.
	Weihai, Shandong	ICBC Weihai Branch issued an RMB 50 million pledge loan for the project of oyster integration development demonstration zone in Rushan Bay, Rushan City. This is the first loan for the project of pledging the expected income right of ocean carbon sinks in Shandong Province, which effectively revitalises the value of ecological products of carbon sinks in the oceans, and explores a new path of high-quality and sustainable development for financial support of the development of the ocean economy.

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