China Council for International Cooperation on Environment and Development

A Sustainable Blue Economy Toward Carbon Neutrality

CCICED Special Policy Study Report

CCICED

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Executive Summary & Recommendations

The oceans, seas, and coasts provide opportunities for a wide range of economic activities to take place, and today the ocean economy consists of an extensive network of interlinked established and emerging sectors. The oceans, seas, and coasts also offer a wide array of opportunities to mitigate CO_2 emissions, which can substantially contribute to reaching global and domestic carbon neutrality goals. Sustainable Blue Economy (SBE) and ocean-based carbon mitigation are tightly intertwined and connected. A sustainable ocean governance based on adaptive ecosystem-based integrated management approaches will be key to solving the current and ongoing climate and nature crisis while at the same time allowing for the further development of sustainable ocean economies.

This report examines a suite of ocean-based solutions for carbon neutrality and identifies issues hampering the application of these solutions. Also, the report discusses the synergy between carbon neutrality and sustainable blue economy, and in this context also covers issues such as accounting systems of ocean industry. This report also considers how the reduction of marine plastics in the marine environment can and should be an integral part of an SBE. Finally, it addresses how changes in fishery governance can contribute to an SBE. Through thorough reviews, this report put forth the following policy recommendations that would contribute to transforming the current ocean economy into an SBE that would contribute toward the carbon neutrality goals at the same time.

We recommend that development of a SBE should be identified as a key strategic development goal of the nation and as a part of the nation's carbon peak and neutrality goals. The use of great breakthroughs in global ocean technologies, in particular digital technologies and their industrialization and large-scale application, to support the growth of the SBE in the blue economy and promote carbon neutrality should be encouraged in this endeavour. It is also fundamentally important to refine current management systems to better account for and balance both ecological and socio-economic goals and to establish a multi-level integrated ocean management (IOM) system covering the central to local authorities from a socio-economic-nature complex ecosystem perspective. **We furthermore recommend that the concept of SBE be fully included as part of China's strategy in its international cooperation frameworks**.

We also recommend establishing and improving the sustainability-oriented ocean economy accounting and statistics framework along with an accurate and comprehensive accounting for CO_2 emissions of the marine industry sector. Furthermore, we encourage the strengthening of financial support for the blue economy by establishing blue finance frameworks and, through this, promote the sustainable blue transformation of the ocean economy.

We recommend taking steps to strengthen coordination and funding of international cooperation in scientific and economic research pertaining to SBE and ocean-based carbon mitigation mechanisms. We suggest promoting a comprehensive international cooperation in marine and carbon neutrality science, technology, education, investment, trade, etc., in particular through the Belt and Road Initiative (BRI), using this as a steppingstone to international cooperation in the wider global context.

We recommend that China, in light of the ongoing multilateral negotiations on a global plastics treaty, should take action and actively adopt appropriate policy instruments to control and manage sources of plastic pollution to the ocean. This could include polices relating to effective extended producer responsibility, implementation of reuse models, the creation and use of recycled plastic over new plastic, and the development of viable alternatives to plastic that have smaller environmental footprints and should consider the use of private/public partnerships, financing mechanisms etc. **We also recommend scientific studies that identify the most polluting plastic objects and sectors, plus their leakage hotspots and flows into the ecosystem**, particularly technologically innovative, interdisciplinary, collaborative, and action-based research.

We recommend that steps be taken to further transform China's fisheries industries into a more sustainable and equitable model that also contributes to the carbon neutrality goals. This can include eliminating harmful fishing vessel fuel subsidies, reducing excess fishing capacity, and promoting the transformation of fuel-intensive marine fishing gear and fishing methods to operations with a lower carbon footprint, and enabling gender-inclusive fisheries governance**.**

1. Framing the Issue

As the ocean economy takes off in new tangents beyond traditional areas such as shipping, fishing, and hydrocarbon extraction, it is critical that the short-term growth in the ocean economy should not come at the expense of the long-term prosperity of the ocean, including the key roles the ocean plays in regulating our climate and providing critical habitats for a diverse array of marine animals and plants. In December 2022, the parties to the United Nation (UN) Convention on Biological Diversity reached an agreement to set a global target to effectively conserve and manage at least 30% of the world's lands, inland waters, coastal wetlands, and oceans, with emphasis on areas of particular importance for biodiversity and ecosystem functioning and services. In March 2023, the UN agreed on text to ensure the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction (BBNJ). June 2023 also saw the second round of the formal negotiations for a UN treaty to end plastic pollution—an important steppingstone in the process—which aims to have a treaty ready for adoption in 2024.

Recognizing that a healthy ocean environment is a prerequisite for the growing ocean economy, an integrated ocean management (IOM) approach is proposed to strike a balance between environmental, economic, and societal goals, and between short-term economic gains and long-term prosperity based on marine ecosystem services. In the past, IOM has been an overarching concept for the China Council for International Cooperation on Environment and Development's (CCICED) Special Policy Studies on Ocean governance (Ocean SPS).[1] This report is a first building block of the Ocean SPS's contribution to CCICED work in phase 7 and this, as well as following work on ocean governance, will continue to take a comprehensive and sustainable approach and will strive to address climate change and work to balance trade-offs between growth of the ocean economy and environmental protection.

Existing and potential new economic activities related to oceans, seas, and coasts—the so-called ocean economy—cover a wide range of interlinked established and emerging sectors. The value of the global ocean economy today is an estimated US$ 2.5 trillion annually (UNCTAD, 2021), equivalent to the size of the world's seventh-largest economy. China's ocean industry has been estimated to be around RMB 3.8 trillion (US$ 0.5 trillion) in 2021 and RMB 3.9 trillion in 2022 (China Marine Economic Statistics Bulletin), accounting for approximately 3% of China's overall gross domestic product (GDP). According to projections from the Organisation for Economic Co-operation and Development (OECD), the blue economy could by 2030 outperform the growth of the global economy as a whole, both in terms of value added and employment. The long-term potential for innovation, employment, and economic growth offered by the ocean economy is promising.

The ocean offers a wide array of potential ocean-based climate mitigation options that can contribute to carbon neutrality goals, including, but not limited to, the grooming of carbon-efficient ecosystems ("blue forests " or "blue carbon"), the use of the ocean's inherent energy potential, minimizing the carbon footprint of ocean-based activities such as shipping, protecting and potentially enhancing the ability of ocean sediments to store carbon (carbon capture and storage, or CCS), as well as reorienting food policy and fisheries management to value aquatic foods from fisheries and aquaculture as key sources of low-carbon ocean-based protein and micronutrients.

This report has three parts. First, in Chapter 2 we discuss ocean-based solutions to contribute to achieving carbon neutrality and present some key aspects relating to the potential for ocean-

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[1] See reports from the work at www.cciced.eco, particularly the 2020 report *Integrated and Ecosystem-based Ocean Management* (https://cciced.eco/wp-content/uploads/2020/12/cciced-2020-en-tt1-integrated-ecosystem-based-ocean-management.pdf).

based solutions for such measures in the short term, mid term, and long term. We identify issues hampering the application of these solutions, and the synergy between carbon neutrality and SBE (SBE), including accounting systems for ocean industry; based on these, we present policy recommendations.

Second, in Chapter 3 we consider how reduction of plastics in the marine environment can and should be an integral part of an SBE. We present the issue of plastics ending up in the marine environment and examine the gaps in knowledge, policy, and legal frameworks associated with the entire life cycle of plastics that are contributing to this fate. Further we explore policies and international cooperative approaches for incorporating recycling of marine plastics into the blue economy and carbon neutrality frameworks.

Third, in Chapter 4 we address how changes in fishery governance and management can contribute to an SBE. We explore the status of illegal, unreported, and unregulated (IUU) fishing and harmful fisheries practices. We also address the role of aquaculture in carbon sequestration. Further, we examine the existing national and international policy frameworks on marine biodiversity conservation (such as the World Trade Organization's (WTO's) Agreement on Fisheries Subsidies) and explore the potential for and challenges associated with integrating fishery governance within an IOM framework.

It should be noted that the suite of policy areas and topics covered in this report on the synergies between ocean economies and carbon neutrality connect to and are relevant for topics and discussion taking place within other CCICED Special Policy Studies. Consequently, a holistic view and approach are required across the CCICED agenda to build policy recommendations that utilize the benefits of these synergies.

2. Carbon Neutrality as an Opportunity for Transformation Into Sustainable Blue Economy

2.1. Introduction

The ocean "economy" or "blue economy" covers a wide range of interlinked established and emerging sectors, such as marine energy, seafood production, coastal tourism, and marine biotechnology that have a direct or indirect link to the oceans, the seas, and the coasts. They are typically categorized into two pillars, the sum of the economic activities of ocean-based industries, and the assets, goods, and services provided by marine ecosystems.

The proliferation of the blue economy in political discourse has gained traction in recent years; however, there remains no standardized definition (Wuwung et al., 2022). The World Bank's definition of the blue economy is the "sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health."[2] But such definitions do not offer principles or guidance for how to ensure and implement multiple bottom line goals including sustainability in economic development, gender and social equity, and environmental conservation. At its core the blue economy refers to socio-economic development through ocean-related sectors and activities with minimal environmental and ecosystem degradation (World Bank et al., 2017). The concept of the "blue economy" thus sets new requirements for the sustainable development of the ocean economy. To emphasize the sustainable component of the blue economy and to differentiate from components of the ocean economy that are at least partially prone to being unsustainable (e.g., offshore oil and gas industry), we adopt the term "SBE" (SBE) throughout the report, through this highlighting the necessity of asserting that sustainability be upheld in carrying out blue economic activities.

The ocean already significantly moderates our planet's climate (Gattuso et al., 2015). It has absorbed the majority of the heat generated from increased emissions over the past century and about one quarter of the CO_2 emissions (Doney et al., 2014). Together this has greatly impacted the ocean, leading to increased temperature and acidity, changes in ocean circulation, reduced oxygen levels, and the loss of biodiversity (Doney et al., 2012).

Carbon neutrality is a state of net-zero carbon dioxide emissions in which emissions are equal to the removal of carbon from the atmosphere (Rogelj et al., 2021). This can be achieved through both reduction of carbon emissions and sequestration of carbon, generally in natural systems. Given the out-sized role the ocean is already playing in the global carbon cycle, ocean-oriented solutions for both emissions reduction and carbon removal must be part of the strategy for achieving carbon neutrality. These carbon neutrality goals, when achieved, are well aligned with the vision of sustainability inherent in the goals for an SBE and could be an efficient facilitator to transform the ocean economy as a whole into an SBE.

This chapter is structured to explore overarching issues with the current ocean economy with respect to carbon neutrality to identify opportunities for transformation to an SBE. We will examine the current ocean economy framework, identify needs and tools associated with carbon neutrality goals, and how co-existence and synergies across ocean industries can strengthen both the blue economy and the development toward carbon neutrality. Most importantly, we will demonstrate how an SBE can help bolster economic growth while also contributing to achieving the UN Sustainable Development Goals (SDGs).

2.2. Status

2.2.1. Carbon Neutrality and Ocean-Based Solutions

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[2] www.worldbank.org/oceans

The emission of anthropogenic CO_2 into the atmosphere since the Industrial Revolution has led to an unprecedented climate crisis (e.g., Gruber et al., 2019; IPCC, 2021, 2022). In response to the crisis, the Paris Agreement[3] defines a preferred climate-warming target of 1.5 ℃, which requires immediate actions toward emission reduction and carbon neutrality by mid-century. More than 130 countries have signed the Paris Agreement and proposed emission reduction roadmaps to achieve carbon neutrality. China has pledged to reach a carbon emission peak by 2030 and to achieve carbon neutrality by 2060, showing China's strong will to strengthen its national strategy of sustainable development, and its ambition, as part of the global force, to fight against the ongoing climate crisis.

The ocean is vital in meeting this carbon neutrality goal at both the international and national levels because it is the primary and sustained carbon sink, accounting for an overall uptake of around 37% of the fossil fuel CO_2 emissions, or around 25% of the combined fossil fuel burning and emissions due to changes in land use between 1850 and 2019 (Friedlingstein et al., 2020). Ocean-based climate solutions essentially include both carbon dioxide removal (CDR) and reduction of carbon emissions (low-carbon transformation) in the ocean economy. The former can either be nature-based (e.g., ecosystem restoration or management of marine species for their role in carbon sequestration) or geoengineering-based (e.g., ocean alkalinization, afforestation). There are a range of CDR approaches that are being planned, and some that are already underway. The ocean thus offers a wide array of potential ocean-based mitigation options that can contribute to carbon neutrality goals, including but not limited to, the grooming of carbon-efficient ecosystems ("blue forests"), the use of the ocean's inherent energy potential, minimizing the carbon footprint of ocean-based activities such as shipping, the use of the ocean floors' ability to store carbon and reusing carbon in marine production, as well as restructuring of fishery supply chains and human consumption of aquatic products toward low-carbon ocean-based protein and other sources of nutrition. These activities will create more jobs, foster several new ocean economic sectors, and contribute to the goal of carbon neutrality while driving the growth of the ocean economy and improving the marine environment. Hoegh-Guldberg et al. (2019) further projected that ocean-based mitigation options could reduce the "emissions gap" by up to around 21% for a 1.5 ℃ pathway and by around 25% for a 2.0 ℃ pathway.

2.2.2. *Ocean Economy*

The value of the global ocean economy is an estimated US$ 2.5 trillion annually, equivalent to the size of the world's seventh-largest economy. According to OECD projections, by 2030, this "blue economy" could outperform the growth of the global economy as a whole, both in terms of value added and employment. China is a vital player in the global production, consumption, and trade of maritime products. In 2022, China's gross ocean industry product reached 3,8 billion yuan and RMB 3.9 trillion in 2022 (China Marine Economic Statistics Bulletin), accounting for approx. 3% of China's GDP, the same proportion as the previous year.[4] China is the leading aquaculture and ship producer in the world, accounting for approx. 58% (2020) and around 45% (2021) of the global total seafood and ship production (gross tonnage), respectively (FAO, 2022; UNCTAD, 2021). However, the transformation of the current mode of the ocean economy in China and worldwide at large into a sustainable one remains a tremendous challenge. We contend that the carbon neutrality goal being established as a national development strategy provides unique

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[3] https://unfccc.int/process-and-meetings/the-paris-agreement

[4] Note that China's gross marine product reached 9,462 billion yuan in 2022, an increase of 1.9% over the previous year, accounting for 7.8% of China's GDP. However, in the gross marine product statistics are included a significant amount of the upstream and downstream industry related to ocean industry, as well research, education, and governmental management contribution to the ocean economy. We provide the statistics for the more limited ocean industry for comparability and relevance in context of the policy study.

opportunities for the current ocean economy to be transformed into an SBE.

In this chapter, we briefly provide overviews of five substantial sub-sectors of the ocean economy, specifically marine mineral resources and offshore oil and gas, maritime transport, ocean renewable energies (ORE), food production and other supply chain issues, and offshore carbon capture, utilization, and storage (CCUS), which may provide significant opportunities to transform into an SBE.

Marine Mineral Resources and Offshore Oil and Gas

In the past 40 years, the exploitation of China's seas and oceans for marine mineral resources, as well as oil and gas resources, has played a key role in providing access to energy and raw materials necessary for China's economy.

Mining the seabed is an important potential component of China's future maritime economy. Current activity within China is predominantly focused on marine aggregate extraction, including sand and gravel, which are largely extracted from the seabed for the construction industry, beach nourishment, and sea defence walls. The demand for resources of this kind is likely to increase, although it should be noted that the ability to remove sand from coastal areas could become more restricted in the future due to effects on habitat and contribution to shoreline erosion. The sector has developed technologies, infrastructure, and operational skills of significant value to an SBE.

The oil and gas subsector is a highly capitalized industry. A large portion of current China's oil and gas production takes place offshore, mainly in the Bohai Sea and the northern South China Sea, and to a lesser extent in the East China Sea. Offshore oil and gas projects are expected to continue to be a major source of hydrocarbon resources in the coming decades. The generation of hydrogen offshore along with offshore oil and gas extraction has a number of advantages. Both hydrogen transportation and storage can be done on a large scale and at a relatively low cost. Furthermore, offshore oil and gas platforms could be repurposed for renewable hydrogen production. This offers an advantage to upstream oil companies looking to transform their operation and exploit their knowledge of how to operate in harsh marine environments. Within the oil and gas sector, companies are increasingly investing in digital and environmentally friendly solutions. The focus on energy and the environment is on offshore wind and hydrogen infrastructure, as well as fuel cells for maritime solutions. Suppliers from the oil and gas industries play an important role in this transition. It is worth noting that the oil and gas sector is a high-risk field that could cause catastrophic environmental consequences.

There are also great opportunities in both the mineral resources sector and the oil and gas sector to play a crucial role in the transition to an SBE, both in terms of enhancing the availability of critical materials needed for the development of low-carbon technologies, and by minimizing impacts on the marine environment and supporting climate mitigation through the adoption of climate-neutral, circular, responsible, and resource-efficient approaches. This is in significant part because of the prioritization of renewable energy developments and a move toward decarbonization.

Maritime Transport

Maritime transport has been a significant driving engine of the global economy and has increasingly been an important component of the ocean economy during the past few decades due to economic globalization and the rapid growth of international trade (Du et al., 2015). To date, as the most cost-effective transport method for covering long distances and moving large quantities of goods (Barberi et al., 2021), over 90% of the cross-border trade is via maritime shipping though the COVID-19 pandemic has upended maritime transport and created unprecedented challenges for professionals across the sector. It is also of great concern that maritime transport also makes a significant impact on the environment. It is reported that the greenhouse gas emissions associated with the shipping sector increased from 977 Mt in 2012 to

1,076 Mt in 2018, which will continue to increase by about 130% by 2050 (IMO, 2021). In addition to the impacts on global warming, emissions from the marine transport sector also contribute significantly to air pollution globally (Wang et al., 2008). Around 15% of global anthropogenic NOx and 5%–8% of global SOx emissions are from oceangoing ships (Corbett et al., 2007). In line with the increasing maritime transport demand, port development, and shipbuilding are important elements within maritime transport and contribute to pollutant emissions. While ports promote local economic development and employment, they also have a negative impact on the environment (Braathen et al., 2011). Similarly, the shipbuilding industry is known as one of the most environmentally challenging industries with chemical and hazardous material exposures and is termed a high-energy consumption, high-material consumption, and high-pollution industry (Rahman et al., 2015).

Like most other industries, maritime shipping has a great potential to be transformed by a range of technology innovations that aim to make operations greener, cheaper, and more efficient. Given that maritime transport is intrinsically international, the implementation of regulations, policies, and incentives involves a multitude of cooperating governments within a network of interacting stakeholders. One of the key motivators for collaboration may be the enhancement of economic and financial benefits for environment, and climate-benefiting activities, i.e., tax reductions, grants, and funding obtained, for example, once a significant reduction in emissions is demonstrated.

Ocean Renewable Energies

Ocean renewable energy (ORE) is one of the emerging sectors of the ocean economy of international interest. Offshore wind (both bottom-fixed and floating), tidal, wave, solar, and hydrogen represent the most viable opportunities to significantly expand renewable energy capacity for many coastal and island countries. During the last decade, for example, the wind energy sector saw a strong increase in offshore wind technologies due to growth in capacity, expanding site availability, and significant cost reductions, supported by important technological advances, such as in wind turbine reliability. Offshore wind could grow further by building on lessons learned in the onshore wind sector and competitive tendering. In 2021, China’s offshore wind power added 16.9 million kilowatts of grid-connected capacity, 5.5 times the previous year, and the cumulative installed capacity jumped to the world's first.[5] Facilitating and sustainably deploying ORE can thus significantly contribute to the decarbonization of the energy system, which is essential for achieving China’s carbon neutrality goals.

However, there remain potential ecological and social risks facing the large-scale development of ORE. We have seen the negative impacts on valuable nature reserves and conflicts with agriculture and urban areas caused by onshore wind and solar farm construction due to the lack of sufficient spatial planning and efficient power transmission deployment. The lessons should be learned from the beginning when deploying ORE, along with recognition of potential risks and preparation of corresponding solutions. Besides the acceleration of R&D in the core technologies, there are still knowledge gaps to fill and science-based policy changes needed to drive this process. Some of the key questions that need to be addressed include but are not limited to:

(1) How to ensure that ORE projects can effectively avoid areas of high conservation value, including migratory marine mammal, fish, and bird corridors and account for future climate change?
(2) How to clarify the examination and approval authority of the best use of the sea areas, allocate different uses scientifically, and foster good solutions for co-existence?
(3) How to strengthen the cross-sectoral collaboration among different authorities, including

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[5] https://www.gov.cn/xinwen/2022-06/07/5694511/files/2d4b62a1ea944c6490c0ae53ea6e54a6.pdf

energy planning and ecosystem and marine resource management, to incorporate the impacts of ocean health into project approval and management?

(4) How to accelerate research on and implementation of effective ecological restoration and compensation mechanisms as well as develop a fuller understanding of any negative outcomes for the ecosystem and society (e.g., equity considerations)?

(5) How to promote innovative integration of energy projects with other industries, taking into account the well-being of local communities and gender and social equity?

Food Production and Other Supply Chain Issues

Chapter 4 of this report addresses the role of the marine capture fisheries and mariculture industries in the overall context of carbon neutrality in more detail. Therefore, here we provide some background on how these industries contribute to the climate problem and briefly outline some of the key opportunities to promote transformation of the sectors to be more sustainable and less carbon intensive.

Parker et al. (2018) estimated that globally, marine capture fisheries generate around 179 million tonnes of CO_2-equivalent GHGs annually (~4% of global food production), of which fuel combustion accounts for over 70%. Advances in fishing technology have spurred the development of more powerful engines that have increased the demand for fossil fuels, and it has been estimated that fuel costs can account for up to 60% of total fishing costs (Greer et al., 2019). Additionally, the use of particular gear types, such as trawl nets, contributes substantially to GHG releases, directly through emissions from fishing vessels and indirectly via the disturbance of bottom sediments that hold carbon.

Reductions in fishing effort or an improvement in the fuel efficiency of trawling vessel engines could help reduce the sector's carbon footprint. In particular, the UN Food and Agriculture Organization (FAO) has estimated that reduction of vessel emissions by 10% to 30% is achievable with more efficient engines and larger propellers, better vessel shape and hull modifications, speed reductions, and use of efficient LED lights, especially for fisheries that use lights to attract fish. The use of fishing gear that requires less fuel for harvesting traditional species, such as purse seines, gillnets, and longlines, may significantly reduce GHG emissions. For towed fishing gear, measures to reduce emissions include multi-rig gear, efficient otter boards, off-bottom fishing, high-strength materials, and large mesh sizes and smaller diameter twines.

Aquaculture is becoming an increasingly important source of seafood in many countries and regions, and the expansion of aquaculture means that this sector will contribute to increasing GHG emissions, which contribute to global warming and climate change (Poore & Nemecek, 2018). Results of quantitative research analyzing both the entire globe and China (as the leading producer) consistently illustrated that feed production was the main source of GHG emissions from aquaculture (MacLeod et al., 2020; Xu et al., 2022). Key improvements in the aquaculture sector include reducing the use of energy-intensive feeds, improving feed management, and, where appropriate, considering the development of regenerative aquaculture practices that may help mitigate climate impacts and provide substantial co-benefits (e.g., biodiversity and habitat enhancement, livelihood improvements).

Fuel use and GHG emissions should be important considerations in devising both aquaculture and fishery management strategies and other related management controls. Efforts should be made to reduce carbon emissions through an energy transition to green (e.g., hydroelectricity, geothermal, wave energy or nuclear power) or greener (e.g., natural gas or biogas) sources for farms, fleets, and supply chains. Some fisheries management measures may have significant impacts on GHG emissions, both positive and negative. In general, fisheries management that reduces fishing effort, especially of fuel-intensive gear, and enhances fish stocks may be one of the most effective ways to reduce fuel use and GHG emissions (Waldo et al., 2014; Ziegler &

Hornborg, 2014).

Additionally, it will be important to incentivize robust fishery management, which can steer more sustainable production and consumption both directly through adaptive management interventions that are responsive to climate impacts (Gaines et al., 2018) and indirectly through taxes and subsidies. Fisheries development subsidies should be redirected to support the upgrading of facilities for safer production and reduced post-harvest losses, as well as supporting strong sustainable management measures and the conservation of key fisheries resources. Human health and food-softer policies, such as dietary advice that considers environmental impacts and nutritional needs (Golden et al., 2016), can also help. More investigation should be conducted on impacts of small-scale fishery and aquaculture entities due to lack of baseline information and effective management, while they potentially contribute considerably to fishery resource depletion and GHG emission. Finally, collaborations with industry associations and research institutions to develop and promote seafood transparency, traceability, and sustainability standard and certification, as well as apply supporting policy tools that adopt these standards with guidance documents for financial risk management can help to drive the financial services process to incentivize the transformation to sustainable seafood production and supply chain practices.

Offshore CCUS

CCUS may contribute significantly to cutting emissions, especially in hard-to-abate sectors with limited or no other alternatives. China has installed the first offshore CCUS project "Enping" in the northern South China Sea. If this project can demonstrate that offshore CCUS is safe and feasible, then it will facilitate learning and potentially reduce costs in subsequent projects. Pending favourable outcomes from the Enping project, planning is underway on subsequent full-scale offshore CCUS projects, which will integrate a complete chain of individual CO_2 providers, a flexible transport solution, and an open-access storage infrastructure that offers companies across China the opportunity to store their CO_2 safely and permanently underground.

The following projects are expected to include the capture of CO_2 from industrial sources (i.e., waste-to-energy and steel) and the transport of liquid CO_2 from these industrial capture sites to an onshore terminal on China's east and southeast coast. From there, the liquefied CO_2 will be transported by pipeline to an offshore storage location under the seabed in the East or South China Sea, meant for permanent storage, although it should be noted that there are challenges that need to be overcome to ensure efficient and safe pipeline transport. The first phase of these projects (e.g., Guangdong Dayawan) will most likely be started before 2030. The transport and storage operators (i.e., CNOOC, Shell, and Exxon Mobil) have signalled their ambitions for a first phase, with a minimum storage capacity of 10 Mts of CO_2 per year.

The Asian Development Bank and Chinese Academy of Sciences have estimated a theoretical storage potential of 500–800 billion tonnes of CO_2 in geological structures on China's offshore sedimentary basins. China will pursue an active industrial policy and facilitate socio-economically profitable offshore CCUS in its territorial waters. As investigations in offshore CCUS are made for time horizons of 30 years, policies that promote a stable business framework that encourages low-carbon investments must be in place well before implementation.

2.3. Challenges and Opportunities

There are numerous challenges and opportunities that need to be met and optimized in the effort to improve the sustainability of the ocean economy through synergies with carbon neutrality goals. In the following, we will touch upon some of these.

2.3.1. Science & Technology

Currently, there are critical gaps in our understanding of whether most ocean-based CDR techniques would offer significant drawdown potential of CO_2 and their effect on overall GHG fluxes. This is a limitation in terrestrial systems as well, but it is a particular issue in the marine realm due to difficulties with underwater observations and complexities inherent in measuring the air-sea gas exchange at the ocean's surface. Understanding the impacts of ocean-based CDR on natural and human systems and ensuring that the benefits presented by CO_2 removal are not outweighed by risks to human and ecosystem health, livelihoods, food security, and environmental justice are of paramount concern. Inherent in the deployment of any ocean-based CDR is the need to evaluate whether the societal impacts of these actions would be equitably distributed and whether territory-wide spatial study would be conducted to explore the potential of carbon neutrality to drive national actions.

MRV (Monitoring, Reporting, Verification) Mechanism

A significant challenge for all ocean-based CDR pathways is monitoring, reporting, and verification (MRV) of the quantity and durability of carbon stored, especially considering the unpredictability of climate change and human development patterns. There are also substantial uncertainties surrounding emissions of other GHGs, including methane, from mangroves and salt marshes; in some cases, these emissions could severely limit the climate mitigation potential of these ecosystems (Rosentreter et al., 2021). The amount of carbon that fish and marine mammals help sequester from the atmosphere has not been quantified with precision, making animal-based pathways the least ready for deployment of the natural CDR methods. However, there is ample scientific evidence that conserving existing fish and large marine animal populations produces multiple co-benefits and can help us avoid substantial new CO_2 emissions from the ocean.

Overall, ocean-based CDR is a nascent field and is garnering a lot of attention. However, CDR cannot substitute for rapid and deep cuts in greenhouse gas emissions. The development and potential use of these techniques can be only one piece of a comprehensive and equitable climate strategy.

2.3.2. Policy

Blue Finance

The World Bank's International Bank for Reconstruction and Development (IBRD) has issued two sets of "sustainability bonds" (World Bank & Credit Suisse Sustainability Bond and World Bank & JP Morgan Sustainability Bond) with strong considerations of the need to safeguard marine and coastal ecosystems. In addition, some coastal countries and regions have issued blue bonds, such as the "Seychelles Blue Bond," "Nordic-Baltic Blue Bond," "The Nature Conservancy Blue Bonds for Conservation," and "Fiji Blue Bond." While these blue bonds could be considered a part of blue finance, there is a need for frameworks or resources to detail how to better utilize these tools to facilitate the transformation of ocean economy and drive conservation of critical marine ecosystems.

Evaluating Marine Ecosystem Services

International policies on evaluating marine ecosystem services, in particular carbon storage potential, are largely derived from the 1992 United Nations Framework Convention on Climate Change (UNFCCC), which requires parties to promote the sustainable management of sinks and reservoirs of all GHGs in the oceans and other coastal and marine ecosystems. Building on this, in 2015, the Paris Agreement reaffirms "the importance of protecting and enhancing, as appropriate, the sinks and reservoirs of greenhouse gases referred to in the Convention" (Preamble) and states in Article 5 (1) that "Parties shall take action to protect and enhance, as appropriate, the sinks and reservoirs of greenhouse gases referred to in Article 4 (1) (d) of the Convention." Australia and the United States have also begun to include blue carbon in their numerical reduction targets and have supplemented their calculations with blue carbon based on the 2013 wetland-related elements of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Japan has implemented several blue carbon offset credit projects for seagrass meadows and is piloting carbon crediting projects for natural and cultivated macroalgae beds.

International policies and programs that aim to assess and protect multiple marine ecosystem services other than carbon sinks are centred around the UN SDG of restoring marine ecosystems for a healthy and productive ocean (SDG 14). Other global instruments include: 1) "The Ramsar Convention on Wetlands" (1971); 2) "The World Heritage Convention" (1972); 3) "The Convention on Biological Diversity" (1992); 4) "The Sendai Framework for Disaster Risk Reduction 2015-2030" (2015); 5) "The 2030 Agenda for Sustainable Development" (2015); 6) "The United Nations Decade of Ocean Science for Sustainable Development (2021–2030)" (2017); and 7) "The United Nations Decade on Ecosystem Restoration" (2019). Europe, North America, and Australia have implemented marine ecosystem protection projects based on their own legal or permitting frameworks, such as Managed Coastal Realignment Comprehensive Everglades Restoration Plan in Florida (U.S.), which is based on the "Environmental Resource Permit (ERP) program – the joint application process for DEP/Water management districts," and the Tomago Wetland restoration project in Australia, based on "NSW Department of Primary Industries section 37 Fisheries Permit P07/13."

Assessing the Impact of Benefits When Implementing Specific Interventions/Solutions

The policy for assessing the impact of benefits when implementing specific interventions/solutions is derived from the technical standards of the UN Clean Development Mechanism (CDM). Some non-governmental organizations (NGOs) have also developed assessment policies based on these standards, i.e., the Verified Carbon Standard (VCS), which is a more detailed version. Specifically, the policies used for blue carbon benefit measurement in the CDM mechanism include 1) Afforestation and reforestation (A/R) medium- and large-scale CDM project activities "Afforestation and reforestation of degraded mangrove habitats" (AR-AM0014); and 2) small-scale afforestation and reforestation CDM projects "Activity Afforestation and reforestation project activities implemented on wetlands" (AR-AMS0003). The main policies used by VCS to account for the benefits of blue carbon sinks in relevant projects are the 1) "Estimation of Baseline Carbon Stock Changes and Greenhouse Gas Emissions in Tidal Wetland Restoration and Conservation Project Activities" (VMD0050), sub-methodology of "REDD+ Methodology Framework" (VM0007); 2) "Methods for Monitoring of Carbon Stock Changes and Greenhouse Gas Emissions and Removals in Tidal Wetland Restoration and Conservation Project Activities" (VMD0051); 3) Methodology for Coastal Wetland Creation (VM0024); and 4) "Methodology for Tidal Wetland and Seagrass Restoration" (VM0033).

Policies on Including Blue Carbon in NDC Commitments

Blue carbon ecosystems (coastal ecosystems that sequester carbon) are valued for their climate mitigation and adaptation benefits. Countries have begun to properly account for blue carbon ecosystems in their nationally determined contributions (NDCs), national greenhouse gas (GHG) inventories, national adaptation plans (NAPs), and other high-level climate-related policies.

Including blue carbon in NDCs or other commitments can allow developing countries to meet their mitigation targets while freeing up resources to invest in needed sustainable economic development, as many of the countries that have rich blue carbon resources and have contributed little to climate change also have relatively low per capita income levels and GDPs.

2.3.3. Legal Framework

With the Convention on Biological Diversity (CBD) COP15 and UNFCCC COPs 26 & 27, ocean issues have been provided with a framework for actions of climate governance, which will clearly affect the legal and policy direction of marine-based carbon neutrality. So far, however, China has not included marine-based actions in its NDC, which could hamper the transformation of the ocean economy to a SBE.

Legal Framework for Maritime Transport

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the dominant legal instrument for the prevention and control of environmental damage caused by pollutant discharges from ships. The International Maritime Organization (IMO) has also introduced mandatory constraint regulations and policies for shipping carbon emission reduction, mainly through the revision of relevant contents of MARPOL.

At the national level, the Maritime Bureau of China issued the Measures on the Management of Energy Consumption Data and Carbon Intensity of Ships in November 2022, which stipulates the requirements for the management of China's ship energy consumption data and carbon intensity, and applies to ships of Chinese nationality with 400 gross tons or more and foreign ships entering and leaving China's ports.

Legal Framework for Offshore Renewable Energies

At the international level, none of the treaties that China has acceded to are directly related to this field. At the national level, the Renewable Energy Law of the People's Republic of China (the Renewable Energy Law) should be applied as a fundamental legal instrument. The Renewable Energy Law provides rules for renewable energy from perspectives of resources surveys and development plans, guidance for the industry and technical support, promotion and application, price management and expense compensation, economic incentives and supervisory measures, and legal responsibility. However, the Renewable Energy Law was adopted in 2005 and revised in 2009. At that time, carbon neutrality was not yet a national strategy, and the development of renewable energy was much less developed than nowadays. Therefore, the Renewable Energy Law lacked beneficial guidance for the exploration and utilization of ocean renewable energy in the context of carbon neutrality strategy.

Legal Framework for Fisheries Management

At the international level, the United Nations Convention on the Law of the Sea (UNCLOS), the CBD, the WTO Agreement on Fisheries Subsidies (the WTO Fishery Subsidies Agreement), and the Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (the BBNJ Agreement) should be applied to China. In particular, the WTO Fishery Subsidies Agreement adopted in June 2022 marks a major step forward for marine fisheries sustainability by prohibiting harmful fisheries subsidies, which are key contributors to the widespread depletion of the world's fish stocks (see further discussion in Chapter 4). At the national level, the Fisheries Law of China applies. Unfortunately, the Fisheries Law does not adopt ecosystem-based integrated ocean management as a general approach. This may affect the synergistic and holistic management of fisheries resources and marine ecosystems.

Legal Framework for Offshore CCUS

At the international level, the UNCLOS, the CBD, and the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Substances (the 1972 London Convention) and its 1996 protocol should be applied to regulate the implementation of the offshore CCUS projects. Assuming also that CO_2 will be transported across borders for cross-border storage, the application of the Basel Convention may also be spurred. At the national level, the Marine Environment Protection Law is mandated to consider the environmental impact of offshore CCUS projects. However, obstacles and problems may be encountered in the specific application of the law because only if the offshore CCUS projects are identified as marine engineering construction projects can the law be applied in accordance with the provisions of Chapter VI, titled "Prevention and Control of Pollution Damage to the Marine Environment caused by Marine Engineering Construction Projects." In addition, there is no systematic legal framework for the full life cycle of offshore CCUS in domestic law, which is very important to support the technological progress and industrial development of offshore CCUS.

2.4. Chapter-Specific Recommendations

High-level recommendations:

- Set SBE as a strategic development goal of the nation and as part of Carbon Peak & Neutrality goals and include it in international cooperation frameworks.
- Evaluate the use of global ocean technologies, in particular, digital technologies, to support the growth of the sustainability measures and promote carbon neutrality in blue economy. Adopt policies and measures on tax incentives, industrial matching, entrepreneurial support, talent attraction and training, etc. to encourage and support the development of marine science and technology, in particular, digital technologies (e.g., digital twins of the ocean) in the blue economy and carbon neutrality. More importantly, promote the industrialization and large-scale application of such emerging technologies vigorously.
- Refine management systems to account and balance for both ecological and socio-economic goals. Establish a multi-level integrated ocean management system covering the central to local authorities from the socio-economic-nature complex ecosystem perspective.
- Develop frameworks and metrics for holistically accounting for sustainability and socio-economic outcomes, and strengthen financial support for the blue economy. Assess the existing national "Green Industry Guidance Directory" and green financial policies and examine the need to establish a new framework of blue finance. Encourage financial institutions to develop diversified financial products to support the low-carbon transformation of the ocean economy. Improve the role of government-guided funds in promoting the blue transformation of the ocean economy.
- Seek opportunities for international cooperation in scientific and economic research. Promote comprehensive international cooperation in marine and carbon neutrality science, technology, education, investment, trade, etc., through bilateral and multilateral platforms and mechanisms, such as the BRI, as well as Boao Forum for Asia (BFA), World Economic Forum (WEF), etc.
- Strengthen SBE-related research and education, in particular, SBE-related interdisciplinary research and education.
- Account for CO_2 emissions from the marine industry accurately and comprehensively.

Specific recommendations:

- Develop a research code of conduct for ocean-based CDR that addresses fundamental principles of scientific integrity (e.g., transparency and dissemination of results), fairness and equity (e.g., public consultation), and responsible research (e.g., minimization of potential harms and assignment of responsibility) across all ocean-based CDR methods. Recipients of federal grants should be required to follow this code of conduct and there should be plans to incentivize uptake by scientists performing CDR research supported by private funding. Furthermore, translate the fundamental principles into domestic laws at the right time to strengthen the regulation of ocean-based CDR.
- Accelerate the transformation to low-carbon marine industrial practices.

3. Blue Economy and Marine Plastic Reduction

3.1. Introduction

Global plastic production and consumption have grown exponentially since the 1950s and are set to triple by 2060 if business continues as usual (OECD, 2022). Since most of the discarded plastic products end up in the ocean, plastic pollution is recognized as a severe anthropogenic issue in coastal and marine ecosystems across the world. Furthermore, different processes in the life cycle of plastic-related products also involve emissions of GHG (Sharma et al., 2023). Through more research, the impacts of plastic and associated chemical manufacturing and plastic pollution on human health and the environment are increasingly clear (UNEP, 2022). Numerous studies have confirmed the source, fate, and impact of marine plastics. Research has focused mainly on 1) estimating the volumes of plastics flowing into the oceans; 2) the major sources of marine litter and plastic pollution; 3) the pathways and fate of plastics within the oceans; 4) the impacts of marine litter and plastic pollution, including microplastics and chemical leachates, on marine life, ecosystem functioning, and behavioural processes; and 5) the risks that microplastics pose to human health. The global economic cost of marine plastic pollution to maritime industries, tourism, fisheries, and aquaculture, together with coastal cleanup costs, are estimated to have been at least $6 billion, but potentially $19 billion or more in 2018 (UNEP, 2021b). Currently, the most urgent issue is how to reduce plastic waste flowing into the sea and promote the healthy development of the blue economy.

Therefore, this chapter reviews the pollution status and sources of marine plastic in China based on existing research literature and provides an overview of the impact of plastic litter on marine ecosystems. The social and economic impact of plastic waste, especially on the blue economy, is described. The gaps in scientific research, policy systems, and legal framework of marine plastics are presented. Based on the presentation of existing knowledge of impacts, and the gaps in the law and regulations, several countermeasures and actions, including environmental technology and commercial solutions, are proposed to tackle this urgent environmental problem.

3.2. Status

3.2.1. Scale of the Marine Plastics Debris in China

According to the "National Urban and Rural Construction Statistical Yearbook 2017" issued by the Ministry of Housing and Urban-Rural Development of China, research into the treatment of urban and rural solid waste in China shows that the proportion of mismanaged waste of large and small cities in China are 1.00% and 3.89%, respectively, which is close to the level of developed countries. A recent study showed that harmless treatment rate of urban domestic waste had reached 99.7% in 2020, where treatment mainly involves sanitary landfill and incineration (Huang et al., 2022). In addition, it was noticed that the composition of mismanaged plastic waste in China is very different due to the intervention of scavengers who collected most of the easily recyclable plastics, such as plastic bottles. The contribution of those activities was not taken into account in the annual statistics, which will decrease the mismanaged plastic waste ratio. Therefore, the average rate of mismanaged plastic waste in urban and rural areas in China could be lower than the 23.25% estimated by Borrelle et al. (2020) without consideration of the economy status of coastal China. According to the national urban-rural population ratio, a reasonable estimate of the rate of mismanaged plastic waste in national urban and rural areas could be between 3% and 8%. According to the ratio of the urban population to the rural population in coastal areas from China's annual statistical data in 2019, it is estimated that the proportion of mismanaged plastic waste in coastal areas of China is about 1.3%. On this basis, it can be estimated the amount of mismanaged plastic waste in coastal areas could be about 55,000 metric tons, and about one-third of some plastic waste may leak into the ocean (Bai et al., 2018).

In another case, following the methods of Borrelle et al. (2020), we estimate the ratio of mismanaged plastic waste to be approximately 7% in 2016, then the total volume of plastic waste discharged into the water environment (rivers, lakes, and seas) in China ranged from 378,300 to 469,000 metric tons, with an average of 424,300 metric tons. After deducting the retention of rivers and lakes, less than one-third of it, or less than 150,000 metric tons, enters the ocean.

Besides this modelling approach, another study used material flow models and field survey data to estimate the annual output of mismanaged plastic waste in China. They estimated that the annual amount of plastic waste exported to the environment was less than 560,000 metric tons in 2011. The study also indicated that from 2011 to 2019, the amount of plastic waste entering the sea in China showed a rapid downward trend as a whole (Bai et al., 2018).

3.2.2. Source Analysis of the Marine Plastics Debris

RIVERINE INPUT

Rivers have long been considered to be the major source of plastic waste contributing to the ocean. With the implementation of the national ecological environment management river chief system and improvement of waste harmless disposal and classification management, the latest monitoring research shows that the annual amount of plastic waste entering the ocean from the Yangtze River, the largest river in China, is now at about 10%–20% of previous estimation by Lebreton et al. (2017) (Zhao et al., 2019; Mai et al., 2020; Meijer et al., 2021). Moreover, the total amount of plastic waste entering the sea from all other rivers in China is only 50%–60% of that of the Yangtze River.

COASTAL HOUSEHOLD GARBAGE SPILL

The leakage of coastal plastic waste into the ocean in China is mainly from people's daily activities, tourism, and leisure activities (various types of foam blocks, plastic beverage bottles, food packaging bags, and other daily necessities such as plastic bags and water bottles). The relevant monitoring in China during 2021 shows that the average density of floating garbage in the Chinese coastal waters is about 3.6 kg/km^2. The plastic waste mainly floats and gathers in coastal intertidal and nearshore waters, as well as in the areas such as ports and docks, but the amount sinking to the seafloor is not yet well understood.

LEAKAGE FROM ACTIVITIES SUCH AS MARITIME COMMERCIAL ACTIVITIES

Even though most of the marine plastic waste was thought to be coming from land-based sources, the contribution of sea-based sources can’t be ignored. Varied substantially by region, sea-based sources could contribute 32%–60% of the total marine litter (GESAMP, 2021). Maritime commercial activities are among the most sea-based activities that generate plastic waste. However, the amount of plastic waste generated by those activities has not been rigorously quantified.

Plastic waste generated by commercial marine activities discharged into the ocean is the most difficult to manage and control and, therefore, of most concern on a global scale and in China. Leaked plastic waste, such as foam, fishing nets, fishing gear, plastic bottles, food packaging bags, and various daily plastic-based necessities, mainly comes from fishing boats, cargo and passenger ships, fish farming, and other related activities. According to survey results, a small part of such plastics floats to the coast and gathers in areas with weak hydrodynamic conditions, while most of it sinks to the bottom of the ocean or is transported to other areas with ocean currents. It is therefore important that plastic waste generated by marine commercial activities becomes a focus of future marine plastic waste management in China.

TRANSFER ACROSS OCEANS

Plastic waste leaked into the ocean from various sources will spread and be transported to other ocean areas with the currents and winds, including floating transfers in coastal and intertidal zones, as well as transport along the seabed. There is still a knowledge gap to know about the amount of plastic waste transported along the seabed, but it is likely of such magnitude that this should be given greater attention. Also, transnational ocean transfer of plastic waste is of concern. The simulation results of the marine plastic waste transport model demonstrate that ocean currents can carry floating plastic debris across great distances. The key pathways of microplastics from the coasts of Bohai, Yellow, and East China Seas were detected by applying the Lagrangian particle tracking method in a hydrodynamic model (Zhang et al., 2020). It was found that less than 18% of terrestrial microplastics was eventually transported from the coast to the Pacific Ocean, whereas the rest was mainly trapped in coastal waters owing to complex hydrodynamic processes (Zhang et al., 2020). These findings further highlight and emphasize the fact that marine plastic waste is a cross-border pollution that requires immediate attention.

3.3. Challenges and Opportunities

3.3.1. Impacts of Marine Plastics Debris on the Marine Ecosystem

Plastic pollution has reached almost every part of the ocean, from the sea surface to the deep ocean floor, from the poles to the coastlines of the most remote islands, affecting different types of ecosystems. Plastic pollution can cause direct harmful physical impact, as well as indirect chemical impact through leached or adsorbed substances (Silva et al., 2021). The nature of the impact of plastic debris and chemicals depends on the shape, body size, movement, feeding mode and habitat of the species, as well as on the type, shape, size, and density of the plastic items and fragments (Bucci et al., 2020), and the occurrence and the severity of impacts depend on exposure levels (Besseling et al., 2019).

Physical impacts of marine plastic include entanglement, plastic ingestion, colonization of plastic items by marine life, and contact or coverage (e.g., smothering) of organisms with plastics, with effects including restrained movement, injury, suffocation, mortality, dispersal of organisms by rafting, and spread of pathogens. Chemical impacts consider the effects of harmful chemical substances linked to plastic pollution, which result from direct uptake by ingestion or contact with contaminated water, air, sediment, or food. Microplastic particles are particularly concerned due to their relatively higher capacity in transporting and transferring hazardous pollutants. Some of the main harmful substances associated with plastics include bisphenol A (BPA), phthalates, flame retardants, metals, petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and organochlorine pesticides, which can pass from the intestinal tract to blood or organs and impact growth, physiological change, reproduction, and toxicity (Tekman, 2022). There are different mechanisms that enable the transfer of chemicals from plastics to organisms (Koelmans et al., 2016). They can leach directly from the ingested plastics into the body or into the environment from which they are taken up through the skin or gills or via the consumption of contaminated prey.

Impacts of Plastic Pollution on Species

Impacts of plastic pollution on main marine species groups including endangered species and commercial species:

- A spatial risk analysis for seabirds (Wilcox et al., 2015) using the global distribution of plastic debris and actual rates of plastic ingestion concluded that 59% of seabird species and 29% of seabird individuals had ingested plastic between 1962 and 2012.
- A global analysis of sea turtles estimates that 52% (340,000 individuals) of all turtles have already ingested plastics (Schuyler et al., 2016). Among the thousands of sea turtles that strand every year, 6% were found entangled in marine debris, of which 91% were dead (Duncan et al., 2017).
- Whales, dolphins, and porpoises have been subjected to both entanglement and

ingestion of macroplastics. The necropsies of whales stranded between 1990 and 2015 along Irish coasts revealed that 9% of whales had eaten plastic debris (Lusher et al., 2018).

- Phytoplankton capture carbon during photosynthesis. Zooplankton and other marine organisms then consume the phytoplankton and release the captured carbon in their fecal matter. The fecal matter is then excreted and sinks to the ocean floor, where it remains trapped for hundreds to thousands of years. However, ingestion of microplastic can make zooplankton fecal matter more buoyant (Wieczorek et al., 2019) and reduce zooplankton's ingestion rate (Cole et al., 2015), growth and reproduction (Cole et al., 2013), thus affecting the functioning of ocean as a carbon sink.
- In China, a study on commercial marine fish collected from Yangtze Estuary, East China Sea, and South China Sea concluded that all 21 species sampled ingested micro- or meso-plastics, with plastic fibre being the most common morphotype found in their stomach and intestines (Jabeen et al., 2017).

Effects of Plastic Pollution on Marine Habitats

Plastic pollution also affects major marine habitat types and impairs the ecosystem functions, including their ability to sequester carbon dioxide through primary production:

- One third of the investigated 159 coral reefs in the Asia-Pacific region were polluted with macroplastics (Lamb et al., 2018). Macroplastic debris is prone to be trapped in coral reefs and can smother large parts of coral colonies and promote coral disease (Lartaud et al., 2020, Lamb et al., 2015). Microplastic exposure of symbiotic algae (*Cladocopium goreaui*) suppressed nutrient uptake, photosynthesis, and increased cell death leading to a decreased density and size of the algal cells (Su et al., 2020).
- Since microplastics are found in seagrass habitats and within the invertebrates living on them, any herbivores or predators feeding on them likely also ingest microplastics, as shown for seaweed (Gutow et al., 2016). Laboratory studies showed that environmentally relevant concentrations of BPA impact the photosynthetic activity and thus the growth of the seagrass Cymodocea nodosa (Adamakis et al., 2018; Adamakis et al., 2021; Malea et al., 2020).
- Since 54% of mangrove habitats are located within 20 km of a river mouth, they are particularly prone to plastic pollution from land-based sources (Harris et al., 2021). In Java, mangrove trees suffered significant leaf loss and increased mortality as plastic pollution approached 100% coverage of the forest floor (van Bijsterveldt et al., 2021).
- Various studies on microplastics were conducted on coral reefs, mangroves, seagrass beds, and macroalgal ecosystems in the South China Sea. Microplastic abundances of up to 45,200 items/m^3 in coral reef surface waters, 5,738.3 items/kg in mangrove sediments, and 927.3 items/kg in seagrass bed sediments were reported. Pollution load index (PLI) measurements were also examined, which ranged from 3 to 31 in mangrove ecosystems, 5.7 to 11.9 in seagrass bed ecosystems, and 6.1 to 10.2 in coral reef ecosystems (Zheng et al., 2023).

3.3.2. Impacts of Marine Plastics Debris on the Blue Economy

Marine plastic waste is the most important component of all three types of marine litter (surface floating litter, beach litter, and seabed litter). As a typical problem of marine ecological pollution, marine plastic waste poses substantial challenges to the sustainable development of the blue economy. Its impacts on the blue economy usually include visual pollution affecting the development of coastal tourism, blocking the power system of ships, and undermining the safety of the marine shipping industry, as well as endangering biological health and affecting human exploitation and utilization of marine fishery resources (An et al., 2022). In the following, we will briefly describe the impacts of these three aspects and propose corresponding governance recommendations.

Impact on Coastal Tourism

Marine plastic waste is concentrated on coastlines and beaches where recreational activities are the main function, destroying the original natural scenery of these coastlines and beaches, and causing negative perceptions and experiences for tourists. (Jayasiri et al., 2013). For most studies of litter at tourist beaches, all types of marine litter are usually covered, and marine plastic litter has emerged as the most important contributor in the findings (Maione, 2021). For example, polyethylene plastic bags were the most abundant type of beach litter in a study at Cox's Bazar Coast, the most popular tourist destination in Bangladesh (Rakib et al., 2022). The scenic quality of the tourist beach of Santa Catarina Island, one of the most important international tourist locations in Brazil, is also deeply affected by litter pollution, with plastic waste being the most abundant component (Corraini et al., 2018). In China, according to the 2021 China Marine Ecological Environmental Status Bulletin, the amount of beach litter exceeded 100,000 items/km^3 at well-known coastal tourist sites across the country, such as Tangshan Bihai Bathing Beach, Jiaozhou Bay, Zhoushan, Xiamen Gulangyu Island, Shantou Qing'ao Bay, Huizhou Daya Bay, and Sanya Bay. The amount of plastic litter was also most prominent in the beach litter survey of the First Sea Bathing Beach, a major tourist beach in Qingdao, China (Pervez & Lai, 2022, Pervez et al., 2021, Pervez et al., 2020).

Although there are many studies quantifying floating litter on beaches and sea surfaces in coastal tourist attractions, the hidden economic losses to tourism due to its aesthetic damage are difficult to estimate, and the economic losses to tourist attractions following large litter accumulation events are more easily estimated (Jang et al., 2014). For example, marine litter accumulation events, including marine plastic litter, caused approximately $29 to $37 million USD in lost tourism revenue to Geoje Island, South Korea, in 2011 (Jang et al., 2014). The hidden economic loss of marine plastic litter to coastal tourism can be reflected in the choices of tourists. The cleanliness of the beach is the most important consideration for tourists when choosing a beach (Ballance et al., 2000, Tudor & Williams, 2006). Surveys of tourists at coastal tourist attractions in China have shown that the amount of beach litter significantly affects tourists' willingness to pay (Liu et al., 2022, Wei, 2021). In a study of the coast of the Brazilian state of Paraná, it was noted that the impact of stranded trash on tourist selectivity could reduce local tourism revenue by 39.1%, costing up to US$8.5 million per year (Krelling et al., 2017).

Based on the current situation of the impact of marine plastic litter pollution on coastal tourism, the following recommendations are made.

- Conduct litter monitoring. Establishing baseline studies on the coasts of important tourist attractions and conducting marine litter surveys at certain time intervals at the same sampling sites can provide data support for local policies and strategies to limit plastics (Rakib et al., 2022). China publishes the results of marine litter monitoring conducted annually in the China Marine Ecological Environmental Status Bulletin, which provides important monitoring data and scientific support for the optimization of China's marine litter management system.
- Coordinate stakeholders. Implement incentives for businesses along the coast to assist them in providing alternatives to plastic waste packaging, such as paper and organic material products, to reduce the large amount of plastic waste discarded due to human activities (Rakib et al., 2022).
- Optimize the assessment system. Include plastic waste pollution control in the assessment indicator system or incentive system for sustainable beach management (Kutralam-Muniasamy et al., 2022).

- Establish management subjects according to local conditions. In China, a community-based management system can be carried out to establish a community responsibility system (Pervez et al., 2021).
- Implement relevant policies and laws strictly. Enact plastic restriction policies and laws to ensure the enforcement of plastic restriction bans. Although some countries have enacted plastic restriction bans, plastic shopping bags are still in circulation due to weak enforcement, result in plastic waste at tourist beaches (Maione, 2021).
- Improve infrastructure and garbage collection and disposal systems. Lack of good infrastructure, garbage bins and adequate cleaning operations are among the reasons for the presence of large amounts of plastic litter at tourist beaches (Lima et al., 2022). The installation of infrastructure, such as sorting bins, is necessary (Pervez et al., 2021). On small emerging tourist islands with underdeveloped waste management infrastructure, plastic waste generation is closely linked to the off-peak and peak tourist season, with small recycling markets and difficulties in developing internal recycling, while recycling and illegal disposal practices persist, and there is an urgent need to improve infrastructure and waste collection and disposal systems (Maione, 2021).
- Raise public awareness. Several studies have concluded that recreational and tourist activities on beaches contribute to the accumulation of plastic litter (Jayasiri et al., 2013; Maione, 2021; Rakib et al., 2022). Therefore, there is a need to promote awareness of beachgoers to reduce casual plastic littering (Pervez &Lai, 2022). Increasing local public participation in treatment efforts can also help reduce plastic pollution at beaches (Pervez et al., 2021).

Impact on Marine Fisheries

Marine plastics have had an unpromising impact on the development of capture fisheries and aquaculture (Chen et al., 2021; Zhou et al., 2021). In a survey of 21 major marine species off the coast of China, all of them were found to contain plastic of varying degrees (Jabeen et al., 2017). Whereas a global consolidation of regional studies showed that a total of 323 out of 494 fish species tested were recorded to contain plastic, and more than 262 out of 391 commercial fish species were also detected to contain plastic (Markic et al., 2020).

Microplastics in the marine environment can enter the bodies of aquatic organisms through ingestion (Figure 1) and have a series of negative effects on various physiological processes, including inhibition of their growth and development, alteration of behaviours such as reproduction and predation, and disruption of the immune system. For example, in a comparative test of fish growth, it was found that the growth and survival probability of juvenile fish exposed to plastic were lower than those of the control group (Naidoo & Glassom, 2019); and a comparative analysis of predation videos of fish in areas without and with plastic confirmed that the presence of plastic did reduce the predatory behaviour of some fish (Menezes et al., 2022); in reproduction, plastic can cause a 38% decrease in oyster oocyte numbers and a 23% decrease in sperm velocity (Sussarellu et al., 2016); and immunological studies have found that plastic particles may trigger a stress response in the fish immune system and interfere with disease resistance in fish populations (Greven et al., 2016).

In addition, microplastics can also act as a stable adherent and a carrier of toxic and harmful substances, such as pathogens, in the water column (Stenger et al., 2021; Yu et al., 2022), further exacerbating the risk of these substances to aquatic organisms. For example, researchers detected 37 bacterial isolates in marine plastics off the west coast of Norway and confirmed the potential pathogenicity of these pathogens to fish by whole-genome sequencing (Radisic et al., 2020).

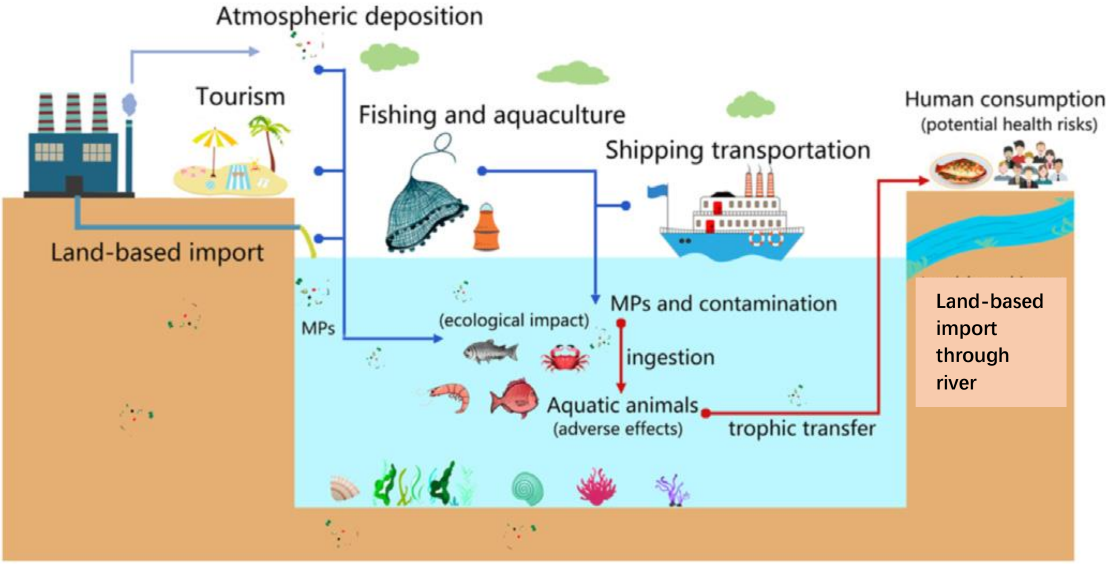


Figure 1 Marine plastic pathways in aquaculture systems (Chen et al., 2021)

Food is also one of the factors contributing to the increase in plastic levels in fish. The food here includes both artificial fish feed in the farming process and the natural prey of wild fish. Plastics are already prevalent in marine ecosystems, so it is difficult for fish to avoid ingesting them when they prey (Markic et al., 2020). Forage fish are also the main raw material for fishmeal, so this introduces plastics into fishmeal at the source, and the processing of fishmeal, especially milling, further contributes to the introduction of plastics (Mahamud et al., 2022; Walkinshaw et al., 2022). Studies have shown that the plastic content of fishmeal ranges from 0 to 526.7 n/kg, with Chinese fishmeal (337.5 +/- 34.5 n/kg) having a relatively high plastic content (Gündoğdu et al., 2021). In terms of specific farmed organisms, Atlantic salmon, for example, ingest between 1,788 and 3,013 artificial particles (including plastics) from aquaculture feeds during growth (Walkinshaw et al., 2022). On the other hand, in order to reduce the risk of fish diseases, medications are often used during aquaculture, and these fish medications (e.g., antibiotics) may also adsorb plastic particles due to their long-term exposure to plastic (Yu et al., 2022).

While the harmful effects of marine plastics on fisheries development are obvious, fisheries themselves are also an important source of marine plastics. In a study of floating raft cultivation systems in the Maowei Sea of Guangxi, China, for example, it was estimated that approximately 3,840 tonnes of plastic waste would be discharged into the sea within the next 4 years if left unchecked (Tian et al., 2022). Many aquaculture facilities contain plastic components, such as PVC pipes used in offshore nets and plastic floats in aquaculture rafts, which can be subject to natural wear and tear, extreme weather damage, or human disposal over time, causing the plastic components to fall off and enter the water column (Skirtun et al., 2022). Similarly, fishing gear used for a long time in fishing activities may also detach plastic components as it is worn out and discarded. And according to survey statistics, out of the 2.1 million tonnes of plastic fishing gear used in 2018, its loss is estimated to be up to 48,400 tonnes (Kuczenski et al., 2022).

As pointed out above, the loss of farming facilities and fishing gear is one of the main sources of marine microplastics, and therefore better maintenance of these plastic devices, improving their recycling rate, or adapting them from raw materials are important ways to reduce microplastic emissions from fisheries systems (Skirtun et al., 2022). In Australia, for example, the main loss areas of plastic fishing gear are ropes (47%), tank components (30.7%), and floats (22.3%), which can be maintained in a focused manner (Bornt et al., 2023). In the case of fishmeal and fish medicine, the absolute amount can be reduced by improving the manufacturing process and replacing raw materials, thus reducing the plastic content per unit during the production process; on the other hand, the absolute amount can be reduced by improving feeding efficiency, adjusting feed ratios, strictly controlling the amount of fish medicine or using related substitutes (Bae et al., 2020; Quinton et al., 2007; Reverter et al., 2014).

Impact on the marine shipping industry

Depending on the distribution of marine plastic litter, the main impact on shipping is caused by floating litter on the sea surface. Floating plastic litter—such as plastic bottles, ocean buoys, and discarded fishing gear—can cause propeller and rudder entanglement and blockage of water intakes and cooling systems, which in turn can reduce the stability and manoeuvrability of ships, and even cause ship destruction and collision, thus posing high costs and navigational risks to shipping (Hall, 2000; Hong et al., 2017; IMarEST, 2019). Among these, discarded, lost, and abandoned fishing gear is considered a significant portion of sea-based marine litter, especially with the more widespread use of synthetic material fishing gear, such as plastics, since the 20th century and the continued increase in global fishing (Gilman et al., 2021; Hong et al., 2017). Globally, approximately 5.7% of fishing nets, 8.6% of trap-type gear, and 29% of gear-related ropes enter the ocean intentionally or accidentally each year (Richardson et al., 2019). One study quantified the impact of derelict fishing gear on warships in Korean waters, highlighting that the threat is ever-present and will pose a greater hazard in bad weather (Hong et al., 2017).

Vessel losses and mass casualties due to floating debris entangled in propellers have been documented in established studies (Cho, 2005), but economic losses due to repair and maintenance costs are more common (Hong et al., 2017). For example, although China Hong Kong has an effective marine litter removal system in the harbour, damage to vessels and delay of work due to marine litter can cost operators of high-speed ferry services up to approximately US$19,000 per vessel per year (McIlgorm et al., 2009). According to statistics, marine plastic litter cost the shipping industry in 21 Pacific Rim economies about US$279 million in 2008, accounting for 22.14% of economic losses to the marine industry, less than the US$364 million (28.89%) for fisheries and US$622 million (49.37%) for marine tourism (McIlgorm et al., 2011). Another statistic shows that the cost of rescue due to marine plastics in the EU shipping industry was as high as €0.83 million to €2.189 million in 2012 (Welden, 2020).

Although the severity of the potential threat to shipping from marine plastic waste is well recognized, navigation risk-related issues are among the least productive of the studies on marine litter to date, and the evidence remains relatively limited (Hong et al., 2017; Zhao et al., 2022).

The future management of marine plastic litter will require international cooperation and multistakeholder efforts within countries (Borrelle et al., 2017; Wu, 2022), promoting a shift in plastic use to a sustainable circular economy (Gilman et al., 2021), improving solid waste recycling and management (Wu, 2022), taxing plastic products (Napper & Thompson, 2020), strengthening management of discarded fishing gear and support for environmentally friendly fishing gear (Hong et al., 2017), and enhancing publicity efforts and public participation (van Sebille et al., 2016). Domestically, the study suggests that China should improve the marine plastic waste management system, reduce plastic waste from the source into the ocean, strengthen the principle of tripartite governance among the government, producers, and consumers, strengthen the harmless disposal and recycling of used fishing nets and fishing gear, and encourage public participation in marine waste management, to contribute Chinese wisdom to the global governance process (An et al., 2022; Li & Li, 2022).

Case study: Blue Circle Project in Zhejiang Province

Oriented by high-quality development, Zhejiang Province has built a marine plastic debris governance system including "plastic debris collection at sea—high-value utilization on land—smart oversight of whole recycle chain," with the goals of reducing pollution and carbon emissions, resource recycling and income revenue for waste-pickers, formed a governance mechanism which is "government-guided, enterprise-led, with industry coordination and public participation," and created a passion for sustainable "blue circle" solution.

Government-guided: The government sets project objectives, makes internal monitoring data accessible for the enterprise through a digital management platform, and supervises and guides the enterprise to implementation.

Enterprise-led: The enterprises are responsible for the market-oriented operation, linking the waste-pickers from the coastal community with a chain of enterprises responsible for waste collection, transportation, regeneration, and manufacturing at the digital management platform, innovate "from sea to shelf" digital traceability system of marine plastics debris, and unlock reliable high-value trading channels.

Industry coordination: The project combines the recycling of marine plastic debris with the carbon credit needs of international leading enterprises, establishes a certification system for marine plastic source verification, confirmation and trading for whole chain of recycling, and forms value-added plastic credit trading.

Public participation: The government and enterprises have jointly built "Blue Alliance" and extract the industrial plastic credit value-added income in line with the blockchain contract, which forms a sustainable income distribution mechanism providing a financial incentive to the waste-picker, thus mobilizing the coastal community to be involved.

3.3.3. Knowledge and Policy Gaps for the Life Cycle of Plastic Governance

The causes of marine plastic pollution are closely related to a wide range of human activities. Since the production and consumption of plastics are so deeply entrenched in the social-economic system, a more comprehensive approach is urgently required for its governance beyond the narrow focus of the plastic litter or pollution in the marine ecosystem. Governing marine plastic pollution and litter hence needs “outside-the-box” thinking that looks at the entire life cycle of plastic products and related services. A life cycle approach to plastic ensures the identification of key hotspots in the plastic production, consumption, disposal, and recycling chain, by considering the social, environmental, health, and economic impacts caused by these activities. The problems and solutions are identified in each stage from the extraction of raw materials, and processing of secondary materials, to product manufacture, distribution, maintenance and use, and end-of-life management (UNEP, 2021a). Consequently, such life cycle understanding also calls for an integrated policy response to the multiple facets of the plastics crisis. There are two general trends of research on life-cycle plastic governance. One is the attempt to construct a “circular” plastic economy, and the other is to establish a global or regional convention or treaty on plastics (Nielsen et al., 2020).

As the focus of plastic governance is shifting toward the entire system, the research and policies are also shifting away from specific objects, such as plastic bags or cups, to addressing more complex production systems, such as food processing and textiles and tire manufacturing. With more plastic objects and sectors now included in the scholarly analysis, it is increasingly clear that different plastic products and services are characterized by highly contrasted material properties and flows in their life cycle. Such variety provides both challenges for the researchers and policy-makers due to the complexity of the plastic crisis, but also opportunities for innovative solutions emerging out of different perspectives. Policy-makers, researchers, and stakeholders can engage with specific plastics issues in a more holistic and complementary way. Strategies and policies are now taking into account the entire life cycle of plastics, and the multiplicity of objects that are made from them, to create the most impactful policies (Nielsen et al., 2020). However, more studies should be advanced in addressing the following knowledge and policy gaps and challenges:

- On the production side, how to channel investment on urgently needed innovations in new product designs, materials, and business models, such as bio-based and bio-degradable plastic substitutes that only account for less than 1% of the total production of plastics. Currently, most of the production-side regulations are based on the theory of extended producer responsibility (EPR), with various policy instruments applied in different countries that normally involve a monetary obligation or a component of financial penalties. EPR policies do reduce the cost of plastic waste management (particularly by saving public spending) and reduce pollution levels. Yet, there is little empirical evidence that these policies are pushing plastic producers to invest in innovative and sustainable solutions (Watkins et al., 2017). It raises the question of whether negative policy incentive is sufficient to promote innovative solutions and whether there is any room for positive policy incentives.
- On the consumption side, current studies and policies focus mainly on awareness and behavioural change of the customers. There are contrasting views regarding the effectiveness of these efforts and to what extent they can eventually change the consumption pattern of specific plastic products or services and their actual impacts on the scale of marine plastic pollution.
- As for plastic waste management, increasing the plastic recycling rate is particularly challenging for two reasons. First, a well-functioned waste management system consists of a series of highly complex tasks involving activities ranging from waste reduction, collection, and sorting to infrastructure development and monitoring systems (Hopewell et al., 2009). Second, countries vary significantly regarding the capacities to handle these tasks properly, particularly around mobilizing adequate investment and educating citizens to develop proper recycling behaviours (Thomas & Sharp, 2013). Some developing countries also face additional management challenges for their imported plastic wastes, which may further exacerbate oceanic pollution (Chau et al., 2020; Chen et al., 2021).
- Plastic pollution is broadly referred to in terms of the harmful effects and emissions resulting from the life cycle of plastic from production and consumption to management and disposal and is usually perceived as mismanaged and uncollected plastic waste that goes into the natural environment. The study and policy of plastic pollution focus on the source, scale, and impacts of the pollution. Regarding the pollution sources, the knowledge and policy gap is around the identification of the most polluting objects in the given context and the hotspots of their leakages. As for the scale, the distribution and flow of plastic litter in the marine system, particularly the pollution level on the seabed or in some remote areas, requires further investigation. Regarding the impacts, pollution affects both the ecosystem (such as climate change and marine biodiversity) and human societies (such as health and aqua-economic sectors), but more concrete evidence is needed on their magnitude and manifestations in different social and national contexts.
- The last issue concerns the proper distribution of obligations and costs of governing the marine plastic crisis among different countries at the international level and among different social groups within given national contexts. A plan for the just transition out of plastic pollution is urgently required (Schröder, 2020). Developing countries should

be supported by the developed countries in terms of finance and technology through international collaboration mechanisms, including the global plastic treaty being negotiated, with science-based targets and approaches in combating the plastic crisis. Green or blue finance, technology transfer, and capacity building should be the core elements of any international treaty on plastic governance. Meanwhile, coastal communities and groups that are most vulnerable and impacted by plastic pollution and mitigation policies, particularly women due to vulnerabilities resulting from gender inequality, should be identified and supported through dedicated social schemes.

3.4. Chapter-Specific Recommendations

There is no clear path and scientific basis for strategic options for ocean-based solutions at the national or regional level. New international conventions, such as the global plastics treaty, are being initiated, which will also bring new challenges and opportunities to the blue economy and carbon neutrality. Policy recommendations for addressing the future potential challenges and opportunities in China include the following:

- **Actively engage in the ongoing multilateral negotiations around the global plastics treaty**. Support the international negotiation contributing to a treaty that is scientifically based, includes effective measures with specific, implementable, and efficient global rules at the most appropriate stage in the life cycle of plastic with close consideration of gender equality in order to address the transboundary marine plastic problem. Besides global initiatives, China should also consider leading the efforts in establishing regional collaborative platforms for cross-border plastic governance institutions, such as with ASEAN countries along the existing Mekong cooperation mechanism.
- **Deploy appropriate policy instruments upstream of the plastic production industry** (such as effective extended producer responsibility) that internalize the full cost of plastics and incentivize waste reduction, implementation of reuse models, the creation and use of recycled plastic over new plastic, and the development of viable alternatives to plastic that have smaller environmental footprints. Primary plastic producers and related service providers should be requested to establish an effective and transparent plastic recycling and waste management plan. Meanwhile, positive policy incentives should be introduced for awarding innovative product designs, materials, and business models in the private sector.
- **Strengthen the control of plastic pollution in fishing activities**. Establish a production licence system for plastic fishing gear in accordance with industry standards, strengthen the promotion of environmentally friendly plastic fishing gear with high wear resistance, implement policy and a subsidy scheme for enabling and speeding up replacement of eco-friendly fishing gear; establish a collection and recycling mechanism for discarded fishing gear by providing financial benefits, and encourage fishermen to salvage “ghost fishing gear” from the sea, so as to better promote the industrialization of the value chain of plastic fishing gear recycling.
- **Facilitate cooperation between industries, civil society groups, and government**. Establish a systems-based approach that addresses plastic production, consumption, waste management, and recycling as a singular and coherent system that prevents plastic leakage into water systems or other mismanaged waste disposal mechanisms. Scale public and private finance on plastic waste management facilities through innovative green finance schemes, including public–private partnerships (PPPs) or green bonds and blue bonds market both domestically and internationally.

- **Develop an effective knowledge dissemination plan on waste sorting and collection among citizens**, but with specific strategies targeting different social groups, including women and men from a diversity of backgrounds, to enhance public awareness and knowledge regarding the scale and impacts of plastic pollution, particularly around the single-use objects as the most impactful sources of pollution.
- **Work actively to establish a dynamic marine plastic pollution monitoring and accounting system at the global scale**, so as to establish transparent marine plastics pollution reporting mechanisms to identify transboundary problems. Combine satellite remote sensing, drone remote sensing, and on-site monitoring system to dynamically monitor plastic leakage. Build a standardized and credible algorithm for identifying marine plastic floating zones, and develop a harmonized and standardized international standard for drone marine litter surveys.
- **Support multidisciplinary and collaborative research that involves new technologies (such as digital, AI, and satellite-based models) and action-based research** in order to identify the most polluting plastic objects and sectors, plus their leakage hotspots and flows into the ecosystem. Develop national or international collaborative study to comprehensively evaluate carbon emission from the plastic value chain at the national or global level, as well as support more in-depth research to understand the full impact of plastic pollution on the ocean’s function as a carbon sink.

4. Enhancing Blue Carbon and Reducing Carbon Footprint Through Fishery Governance

4.1. Introduction

Marine capture fisheries and mariculture bring abundant food and nutrient supply to human society and provide basic livelihoods for coastal populations, thus becoming an indispensable pillar of the blue economy. As global climate change impacts have intensified, the oceans are threatened with warming, acidification, sea level rise, and increased extreme weather events, which will inevitably change the production pattern of marine fisheries and redistribute global fishing and aquaculture potential (Cheung et al., 2009; Froehlich et al., 2018). At the same time, marine fisheries themselves emit a significant fraction of GHGs from food production. In the context of such reciprocal feedback, there is an urgent need for effective fisheries governance to reduce the carbon footprint of the sector, strengthen climate resilience, and enhance blue carbon sinks. Doing so will move marine fisheries toward becoming a fully SBE and, through this, enhance food security and livelihood security for a large global population.

For capture fisheries, GHG emissions from fuel use are the largest contributor to the overall carbon footprint of this sector. According to recent estimates, global marine fishing is responsible for 179 million tonnes of CO_2-equivalent emissions per year, of which fuel consumption contributes more than 70%, with the highest emissions from fishing crustaceans and the lowest from fishing small pelagic fishes (Parker et al., 2018). The carbon footprint of global mariculture has not been fully measured, but recent studies indicate that global marine and freshwater aquaculture together contribute 263 million tonnes of CO_2 equivalent emissions per year, with feed use being the largest source of carbon footprint and crustacean aquaculture being the most intensive due to high energy consumption (MacLeod et al., 2020). Notably, fisheries production processes can also facilitate the uptake or use of GHG in the water column by aquatic organisms, which in turn can move carbon that is converted into bioproducts out of the water column or settle on the bottom sediments, called carbon sink fishery (Tang et al., 2022). The culture of macroalgae and filter-feeding shellfish can play a role in carbon sequestration, and the fishing process can also alter the carbon flux pattern of the ecosystem in certain circumstances. Therefore, through appropriate fisheries governance, we can not only reduce the GHGs from fuel consumption and feed production through the transformation of production methods to improve the sustainability and climate resilience of fisheries but also develop carbon sink fisheries to mitigate climate change.

Based on available data and literature, this chapter maps out the current state of development of the fisheries sector in the context of climate change and clarifies its role in the development of blue carbon sinks. It also assesses the main challenges, including reducing the carbon footprint, regulating harmful production practices, and promoting gender equality and equity of rights in the context of climate change. The chapter also provides an overview of representative policy frameworks related to marine biodiversity conservation in areas beyond national jurisdiction (ABNJ), such as WTO fisheries subsidies and regional fisheries management organizations, to explore the feasibility of fisheries governance reforms. In addition, this chapter analyzes the trend of integrating fisheries governance, biodiversity conservation, and climate change response into IOM. The ultimate goal is to provide practical and forward-looking policy recommendations pertaining to fisheries governance in China, to respond to the strategic goals of achieving sustainable development of the blue economy and ensuring an effective response to the challenges of climate change.

4.2. Status

4.2.1. Current Status and Challenges Facing the Development of Fisheries That Are Climate-resilient and Promote

Carbon Footprint of Capture Fisheries and Mariculture

Capture fisheries and mariculture in the oceans are indispensable pillars of global food security and nutrition security, and these activities also emit significant amounts of GHGs. However, marine aquatic foods generally have lower GHG emission intensity per unit compared to terrestrial animal protein sources (Gephart et al., 2021). For marine capture fisheries, the fuel consumption of fishing vessels constitutes the largest part of the carbon footprint. Currently, global marine fishing consumes approximately 40 billion litres of fuel per year, directly generating 132 million tonnes of CO_2-equivalent emissions; when fishing vessel construction and maintenance, gear manufacturing, and cold chain logistics are included, the total annual emissions are 179 million tonnes of CO_2-equivalent emissions, accounting for approximately 0.5% of global anthropogenic carbon emissions (Parker et al., 2018). Besides, the location of carbon sequestration in the marine environment has significant overlap with the location of commercial fisheries on coastal shelves, making the ocean carbon pool vulnerable to fishing activities (Pusceddu et al., 2014).

The carbon footprint of mariculture is more complex and includes three components: on-farm, upstream (represented by feed production), and downstream (represented by processing and transport), where the upstream and downstream emissions are often greater than the farming process itself (Jones et al., 2022). For a more systematic view of the carbon footprint of mariculture, the loss of carbon sinks due to the encroachment of farming practices on typical coastal blue carbon ecosystems, such as mangroves and salt marshes, should also be considered. An inventory study shows that the global carbon footprint of aquaculture (both marine and freshwater) is 263 million tonnes of CO_2 equivalent per year, which is the same magnitude as that of capture fisheries, but this statistic only accounts for fish, shellfish, and shrimp farming and does not include emissions downstream of the industry (MacLeod et al., 2020). While feed production is the largest known source of carbon footprint for mariculture as a whole, when it comes to on-site production, crustacean farming has the highest emission intensity due to its high energy requirements, particularly when recirculating aquaculture systems (RAS) are used. On the other hand, the ability of marine algae and shellfish farms to act as carbon sinks cannot be ignored, which makes certain types of mariculture important components of the "negative ocean emissions" initiative (Zhang et al., 2021).

Some specific categories of marine aquatic foods (both captured and cultured products) have the highest level of climate efficiency among major animal protein sources (Gephart et al., 2021), and there are increasing calls to shift human diet structure from land to sea. In this context, reducing the carbon footprint of marine food production has become a hot topic for sustainable development and is key to forming a climate-smart global food production sector. For capture fisheries, reducing carbon emissions from fuel consumption is the most important course of action. Since new energy sources have not yet been widely promoted on fishing vessels, the current stage should rely on the phase-out of environmentally harmful fuel subsidies and fuel tax exemptions for fishing vessels, together with other forms of economic incentives, to promote a shift from fuel-intensive operations, such as bottom trawling and dredging, to those with a lower carbon footprint, such as gillnetting and longline fishing. This will be important, as the current fisheries management practices in China have given rise to competition and increases in fishing capacity because fishers are motivated to continuously increase engine power or vessel size to gain a competitive advantage. Overcapacity leads to overexploitation, which decreases catch per unit of fishing effort (CPUE), and increases the fuel consumption per unit of catch. Good fisheries management that reduces the need for competition can therefore significantly improve the efficiency of energy use and thus optimize the carbon footprint (Bastardie et al., 2022). In addition to reducing the number of fishing vessels and excess fishing capacity through vessel redemptions, fleets can be supported to improve fishing efficiency with scientifically set fishing limits and quotas and rationally issued permits. Currently, an increasing number of countries are focusing on reducing carbon emissions, enhancing sustainability, and improving fleet profitability or market competitiveness as synergistic development goals.

In the field of mariculture, the biggest opportunity lies in strengthening research on the potential for macroalgae and shellfish farms to act as carbon sinks and accelerating the implementation of incentive policies, such as fisheries carbon trading, so as to further promote farming practices with carbon sequestration and ecosystem restoration functions. In addition, promoting the development and application of alternative feeds to reduce the upstream carbon footprint of fed mariculture, and building supporting processing and distribution networks in aquaculture clusters to reduce the downstream carbon footprint of the whole industry, are both highly operational carbon reduction initiatives.

Carbon Sequestration by Capture Fisheries and Aquaculture

AQUACULTURE

China's mariculture is dominated by non-fed shellfish and macroalgae culture, which led academician Qisheng Tang to innovatively propose the concept of fisheries carbon sink (Tang et al., 2011). Fisheries carbon sink refers to the process and mechanism of promoting the "removal and storage" of CO_2 and other GHGs by aquatic organisms through fishery production activities such as aquatic algae culture, filter-feeding shellfish and fish culture, and fishing and stocking of fishery organisms. Fishery carbon sinks can also be called "removable carbon sinks" and "industrializable blue carbon" (Tang et al., 2022).

Recent studies recognize the carbon sink function of macroalgae and suggest that macroalgae can have multiple roles in climate change mitigation, producing large amounts of detritus, particles and dissolved organic carbon during their growth, a small amount of which can accumulate in the rocky substrates where the algae themselves grow, and the majority of which transported to the deep sea and its sediments by currents, thus being sequestered for a long time (Hill et al., 2015; Chung et al., 2017; Duarte et al., 2017). Macroalgae in China are mainly produced by mariculture. Regarding the carbon sink function of macroalgae, the initial focus was on their biomass, i.e., algal production as a "removable carbon sink" (Tang et al., 2011). Subsequent studies have further demonstrated that the water-air interface in kelp (*Laminaria japonica*) culture areas is a sink for atmospheric CO_2 (Liu et al., 2017; Han et al., 2021; Li et al., 2018). In addition, the carbon sink function of algae also includes the microbial, oceanic dissolved carbon (with recalcitrant dissolved organic carbon; RDOC), particulate carbon pool, and sedimentary carbon pool generated and increased during culture activities (Chen et al., 2020; Zhang et al., 2017; Xia et al., 2014; Zhang et al., 2012). Although the carbon sequestration mechanism of cultivated marine algae is promising, there may be issues relating to the usability of the resulting algae biomass, which also needs consideration in the bigger picture.

Compared with macroalgae, the source and sink effects of filter-feeding shellfish in the ecosystem are more complex. First, take a look at the carbon balance model of filter-feeding shellfish: $C=F+R+G$, in which C is feeding carbon, F is biodeposited carbon, R is respiratory carbon, and G is growth carbon. Shellfish accumulate organic carbon in the substrate as a result of filter-feeding and facilitate the coupling of sediment-planktonic systems (Frankignoulle et al., 1994). The source-sink effect of filter-feeding shellfish as a secondary producer in the ecosystem is also closely related to culture density, season and culture method (Bonaglia et al., 2017). Second, the source-sink effect of filter-feeding shellfish involves not only the metabolic process of organic carbon feeding but also the utilization and influence of calcification process on inorganic carbon system (Jiang et al., 2022). In addition, for filter-feeding shellfish, not only the GHG, such as CO_2, released by calcification and respiration should be considered, but also the physiological activities such as feeding, respiration, and excretion of buried shellfish can disturb the sediment, thus increasing the possibility of GHG release from the sediment (Stief & Schramm, 2010; Heisterkamp et al., 2010; Bonaglia et al., 2017). Tang et al. (2022) systematically discussed the characteristics of four carbon pools, namely, carbon used, carbon removed, carbon stored, and carbon released by aquaculture and their quantitative relationships, and then confirmed that shellfish aquaculture enhanced the carbon sink capacity of the aquatic ecosystem and was a carbon sink rather than a carbon source.

Case study: Fishery-Solar Complementary Project in China

The fishery-solar complementary projects adopt the structure of constructing a photovoltaic (PV) power generation system above aquaculture ponds and cultivating fish or other farmed species below the solar PV systems.

Figure 2. Fishery-Solar complementary projects in Nantong, Jiangsu
(Figure adapted from: https://www.gov.cn/xinwen/2023-02/17/content_5741939.htm#1)

The advantages of fishery-solar complementary projects are：

- Dual use of one site, increasing the economic value of the unit of land, improving land utilization, and relieving pressure on land;
- Providing shade for fishponds, lowering the surface temperature of water bodies, and reducing evaporation from water bodies;
- Inhibiting photosynthesis of some phytoplankton, reducing algae and bacteria reproduction, and improving water quality;
- Photovoltaic power system itself generates economic value.

In future, fishery-solar complementary projects will develop in the direction of scale expansion, specialized technologies, and intelligent management. Through the centralized and scientific management of the water underwater, it effectively solves the problem of treatment of breeding sewage in the breeding system, while building an intelligent monitoring system for the breeding system with the help of PV power station, which facilitates management. In addition, the income from PV power generation to the grid can be used for the daily maintenance of fishponds.

Reference: Tang et al. (2022a).

Fisheries carbon sinks have received wide attention, but so far there are no international and national standards for their monitoring and measurement, and it is impossible to comprehensively and systematically assess their carbon sink capacity and tradable volume. There is an urgent need to strengthen related work in the future; research is especially needed on potential carbon sink processes, and their monitoring techniques for the whole life cycle of mariculture products, the process and mechanism of shellfish calcification, the burial of organic debris and RDOC formed during aquaculture, in order to enrich and improve the theory of mariculture carbon sequestration and its measurement methodology. It is also worth noting that mariculture has the potential to act as a carbon sink both in the water and via the generation of products that have a lower GHG footprint or that can increase the uptake of GHGs on land (e.g., some building materials, seaweed additives for ruminants to reduce methane), with the application scenarios of the latter in need of further development.

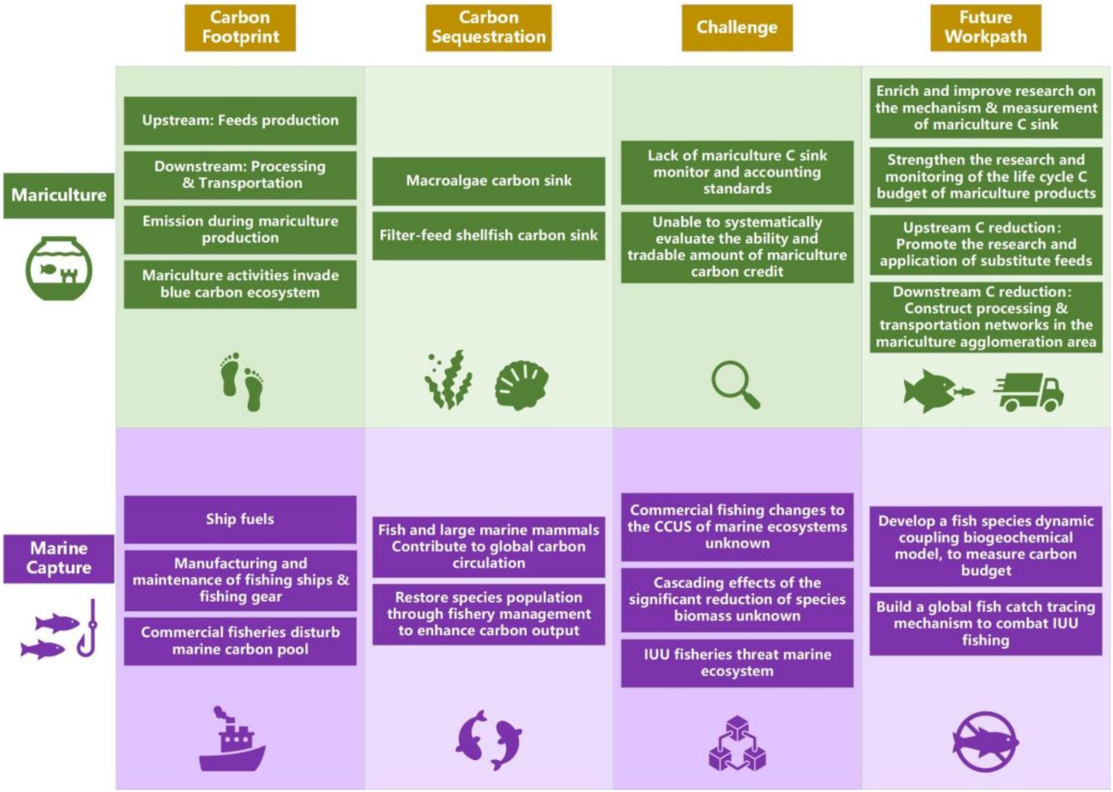
CAPTURE FISHERIES

Fish and large marine mammals contribute to the global carbon cycle through five main pathways: 1) they can act as a short-lived reservoir of carbon by storing it in their biomass, 2) through redistribution of carbon and nutrients throughout the ocean (especially to the deep sea) through vertical or horizontal migrations, 3) by mixing of water or resuspension of sediments (i.e., bioturbation), 4) by exporting carbon directly from the surface ocean to the deep ocean when the dead organisms sink to the bottom, and 5) in some fish, via intestinal precipitation of calcium carbonates, followed by export of large amounts of particulate inorganic carbon in fish feces to the deep ocean.

The elemental carbon in marine fish biomass is estimated to range from 120 million to 1.9 billion tonnes (Anderson et al., 2019; Bar-On et al., 2018; Bianchi et al., 2021.; Proud et al., 2019; Wilson et al., 2009). Although the total amount of carbon in the extant fish biomass is still highly uncertain, there is no doubt that commercial fishing has reduced fish stocks over time. The effects of fishing on the ability of fish to sequester carbon have not been well resolved in today's scientific studies, and this is an important direction for future research.

Fisheries management typically aims to sustain or rebuild depleted stocks back to target levels, such as maximum sustainable yield (MSY) or maximum economic yield (MEY). MSY is usually related to the level of abundance and spawning biomass, and is significantly reduced compared to the "virgin" stock size, usually by about 30% to 50% from the original biomass level. Even MEY, which is typically a higher biomass target, is still much lower than the unfished level. Driven by economic interests, global catches of more than 80 million tonnes per year have resulted in poorly understood, system-scale changes in the structure and function of marine ecosystems, including carbon processing and sequestration. These alterations may have direct effects on carbon processing (e.g., export of carbon from the surface to the deeper layers as carcasses sink) and indirect effects (e.g., implications on fish foraging that influence overall carbon sinking dynamics). In addition, large reductions in the total number of target species may induce ecological cascades, which are typically poorly understood.

At present, it is premature to attempt to set fisheries goals to assist in more rapid carbon drawdown given the large uncertainties in the knowledge of the five processes described above. However, it is important to more comprehensively understand the function of fish in the carbon sequestration process during the initial period of setting fisheries goals and to assess the alteration of the carbon cycle by fisheries production. Future research will require improved data collection and observation of stocks and physical ocean processes, as well as the development of coupled biogeochemical models that integrate fish population dynamics with physical and chemical oceanography.



	Carbon Footprint	Carbon Sequestration	Challenge	Future Workpath
Mariculture	Upstream: Feeds production Downstream: Processing & Transportation Emission during mariculture production Mariculture activities invade blue carbon ecosystem	Macroalgae carbon sink Filter-feed shellfish carbon sink	Lack of mariculture C sink monitor and accounting standards Unable to systematically evaluate the ability and tradable amount of mariculture carbon credit	Enrich and improve research on the mechanism & measurement of mariculture C sink Strengthen the research and monitoring of the life cycle C budget of mariculture products Upstream C reduction: Promote the research and application of substitute feeds Downstream C reduction: Construct processing & transportation networks in the mariculture agglomeration area
Marine Capture	Ship fuels Manufacturing and maintenance of fishing ships & fishing gear Commercial fisheries disturb marine carbon pool	Fish and large marine mammals Contribute to global carbon circulation Restore species population through fishery management to enhance carbon output	Commercial fishing changes to the CCUS of marine ecosystems unknown Cascading effects of the significant reduction of species biomass unknown IUU fisheries threat marine ecosystem	Develop a fish species dynamic coupling biogeochemical model, to measure carbon budget Build a global fish catch tracing mechanism to combat IUU fishing

Figure 3: Status, challenges, and future work path of capture fisheries and aquaculture

Challenges and Development Principles for Climate-Resilient Fisheries

Climate change amplifies uncertainty about the effectiveness of fisheries management and poses significant direct challenges to fisheries managers and practitioners around the world. In the context of a more dynamic and potentially more extreme climate scenario, re-examination and reassessment will be needed for all categories of traits and methods, such as stock assessments, Total Allowable Catch (TAC), catch composition, species migration patterns, and reproductive cycles. Therefore, at the request of the Canadian government during the 33rd session of the FAO Committee on Fisheries (COFI 33), FAO, with support from the Environmental Defense Fund (EDF), prepared a report entitled "Adaptive Management of Fisheries in Response to Climate Change." The report outlines practical solutions that fisheries managers are taking to address the challenges posed by climate change. These include 1) establishing effective fisheries management systems, 2) setting up participatory fisheries management systems, 3) promoting precautionary systems to address uncertainties and risks, and 4) adopting adaptive fisheries management systems. In addition, FAO has issued guidance on how to address fisheries and aquaculture in countries' National Adaptation Plans.

In 2022, during the COFI 35 meeting, member states urged FAO to continue this trend of focusing its work on climate change, by continuing the work on an Action Plan for Fisheries and Aquaculture under the FAO 2022–2030 Climate Strategy, and by increasing knowledge and awareness of the impacts of climate change on fisheries and aquaculture.

In recent years, China has been working to improve the sustainability and resilience of its fisheries, and the 13th Five-Year Plan, implemented in 2016, provides a robust policy platform for the conservation and restoration of China's marine ecosystems and fisheries (Cao et al., 2017). A notable example of recent progress is the launch of several TAC pilots in Zhejiang, Shandong, Fujian, Guangzhou, and other coastal provinces and cities. As environmental organizations dedicated to sustainable fisheries management, the Natural Resources Defense Council (NRDC), EDF, and the Qingdao Marine Ecology Research Society have worked with national and local fisheries departments and scientific institutions in China since the beginning of the TAC pilots. These organizations have helped exchange and share international experiences, provided technical support, promoted understanding of the TAC system and pilots, and participated in the work in Zhejiang and Fujian provinces. A report entitled "Progress of China's TAC System: Evaluation Report for Zhejiang and Fujian Pilots" was completed in 2021 and proposed 29 specific policy recommendations for further implementation of sound TACs in China. In particular, it includes the demands for 1) a logbook system to monitor catches, 2) verification of catches, 3) increased use of at-sea observers, and 4) effective enforcement and incentives for compliance and catch accounting. Overall, to enhance the climate resilience of China's ecosystems and fisheries, there is a need to implement forward-looking, science-based fisheries management, formalize the role of small-scale fisheries and secure fishing access for small-scale fishers, ensure policy consistency, fairness, and equity across provinces, establish educational programs for fisheries managers around impacts of climate change and stock assessment, and increase public access to scientific data and information (Cao et al., 2017).

Illegal, Unreported, and Unregulated Fishing and Other Harmful Fishing Practices

Illegal, unreported, and unregulated (IUU) fishing is one of the greatest challenges to global fisheries governance. The three activities involved in this term are not isolated from each other but rather intersect with each other. The annual catch of the IUU fishery ranged from 11 to 26 million tonnes, with an annual value of $1 billion to $23.5 billion at the time (Agnew et al., 2009); meaning that, on average, one out of every five fish caught in the global ocean may be from IUU fishing, and in certain regions, this ratio may be as high as one-half (Widjaja et al., 2020). Due to the lack of institutional constraints, IUU fishing often uses more harmful practices (which are often already prohibited by regulations), typically blast fishing and poison fishing, the use of which in reef fisheries can be fatal to corals (Petrossian, 2015). Such harmful practices also include electrofishing and the use of prohibited gear, violations of closed seasons or areas, targeted fishing of spawning stocks, intensive fishing in vulnerable habitats, overfishing beyond the carrying capacity of the ecosystem, and frequent bycatch.

Because IUU fishing is difficult to trace and often employs harmful practices, its presence inevitably leads to the failure of ecosystem-based fisheries management (EBFM) to achieve the desired management effectiveness and can increase the carbon footprint of marine fisheries. Studies have been conducted to analyze the impact of IUU fishing on carbon fluxes and found that the carbon sequestration function of the Southern Ocean ecosystem was significantly impaired when krill and toothfish fishing were not controlled (Trebilco et al., 2020). In nearshore waters, IUU fishing tends to have a high carbon footprint due to the abundance of fisheries in protected closed areas, which often involve coastal blue carbon ecosystems such as mangroves, seagrass beds, and salt marshes.

High economic returns, lack of governance mechanisms, and weak enforcement are considered to be the main reasons for the persistence of IUU fishing. Therefore, the current governance approach should focus on strengthening the monitoring, control, and surveillance (MCS) system, enhancing catch traceability, promoting the FAO Port State Measures Agreement (PSMA), and facilitating regional cooperation (Widjaja et al., 2020). For example, as the world's largest seafood importer, the EU attaches great importance to the fight against IUU. Within the framework of the Common Fisheries Policy, the EU introduced two major regulatory instruments, the IUU Fisheries Management Regulation in 2008 and 2009 (mainly for imported catch) and the Fisheries Control Regulation in 2009 (mainly for EU fishermen), making it one of the few regions that require traceability of imported and regionally produced catches. For catches landed in its waters, the EU has established a full chain traceability system from the fishing vessel to the consumer, with risk-based enforcement checks at all points. For imported catch, the EU has implemented a catch legality certificate system, which requires the provision of a catch legality certificate verified by the flag state, and the system is currently the most complete in the world in terms of the species covered, the information required, and the verification and control. Currently, standardized fishing logbooks and inspection and enforcement data are shared electronically among EU member states, greatly improving the effectiveness and efficiency of traceability and reducing human interference with information quality, but catch legality certificates are still paper-based. From 2014 to 2020, the European Maritime and Fisheries Fund (EMFF) has provided €580 million to strengthen the MCS, and the European Maritime, Fisheries and Aquaculture Fund (EMFAF) will provide at least about €800 million from 2021 to 2027, not including national matching funds from EU countries. Since seafood can enter the global supply chain through various links, it is important for the world, whether it is the flag state, coastal state, port state, or market state, to cooperate in building a global traceability mechanism for fishing catches, which is the core means to combat IUU fishing.

In summary, China should advocate and participate in a highly transparent global fishery and widely apply information technology within fisheries management to effectively track the location of fishing vessels and quantify catches (Long et al., 2020). By putting the responsibility for proving catch legality directly on the fishers, the cost of IUU fishing will evidently increase. As for the relevant international collaborative frameworks, the newly concluded WTO Fisheries Subsidies Agreement prohibits subsidies for IUU fishing. In addition, the global implementation of the PSMA and the global cooperation of regional fisheries management organizations will provide a strong institutional guarantee to combat IUU fishing.

Equal Rights in Fisheries: The role and contribution of small-scale fisheries and women in fisheries

SMALL-SCALE FISHERIES AND THEIR GOVERNANCE

In the context of climate change, small-scale fisheries (SSF) are more vulnerable to shocks due to their relatively fixed areas and modes of operation. Protection of vulnerable groups engaged in small-scale fisheries in coastal areas and the marine ecosystems on which they depend is an important issue in fisheries governance at present. SSF, or artisanal fisheries, contribute around 40% of the world's seafood production, or about 37 million tonnes annually. However, this contribution scales up significantly when we highlight key aspects of world fisheries production. For example, according to the FAO-sponsored study "Illuminating Hidden Harvests," in 2016, more than 60 million people worldwide were employed in small-scale fisheries, representing 90% of all employment in capture fisheries.

In China, small-scale fisheries are an essential part of the blue economy. As sources of aquatic foods and other products, SSF contribute significantly to enhancing people's well-being, maintaining food and nutrition security, protecting ecosystem health, securing livelihoods, reducing poverty, and enhancing social stability. Despite these contributions, SSF have not received the attention that they deserve from the Chinese government or from society (Xiong et al., 2022) likely due to the fact that very little research is directed at SSF (Zhao & Jia, 2020). Xiong et al. (2022) examine SSF in Shengsi County in Zhejiang Province and note several ways in which the Chinese government could improve the governance and management of SSF, in particular by 1) more clearly defining SSF and using these characteristics to set management goals, 2) by developing multidisciplinary data collection and monitoring systems targeted toward SSF, 3) working to develop cooperatives, and 4) working to strengthen the coordination and cooperation mechanisms among government departments at various levels.

WOMEN IN SMALL-SCALE FISHERIES

Climate change has disparate influences on different socio-economic groups and will have more negative impacts on women than men (UNFCCC, 2022). Climate disasters may expose people in small-scale fishing communities to loss of life or severe disability, reduced livelihoods, loss of property, and increased disease (FAO, 2017). In climate disaster events, men carry more of the work in post-disaster recovery construction, while women and children suffer more. For example, women are more likely to lose their lives or suffer from disabilities, lose economic income, take on more caregiving, experience gender-based violence, and be less likely to receive relief supplies, and children will have difficulty returning to school life quickly and may experience child abuse (FAO, 2017). Considering the differential damage caused by climate change to different groups, targeted support measures should be implemented for different groups. Currently, there are few female voices represented at all levels of decision making. However, under the same circumstances, women tend to make decisions that are more sustainable than men, and women representatives are more likely to adopt strict CO_2-reduction policies (UNFCCC, 2022) and contribute to climate change goals. To increase the resilience of small-scale fishers to climate change, a gender-inclusive approach to research and governance is essential.

About 50% of SSF workers are women (FAO, 2016) and about 90% of workers in the seafood processing industry are women (FAO, 2012). In SSF, most of the fishing activities are carried out by men, while women are responsible for gleaning, pre-harvest preparation (e.g., repairing fishing gear, preparing bait and food for trip), post-harvest work (sorting and processing the catch), and selling the catch. In addition, women usually take on more domestic work in fishing households, such as cooking, cleaning, laundry, and caring for the elderly, children, and the sick. Women in SSF often work in low-paying, low-skill, and low-stability jobs, such as seasonal or part-time work. In addition, females in SSF often perform unpaid fishing labour (e.g., harvesting fish or collecting shellfish for household consumption), which is considered an extension of household work that is not related to the fishing economy, contrasting to the paid fishing activities undertaken by males. As a result, women's contribution in SSF is often disregarded in official statistics.

Although women fishers are numerous and have access to different fishery resources (e.g., gleaning and seaweed harvesting) than men, they are typically excluded from decision-making processes regarding the allocation of these resources. This is partly due to the traditional perception of the fishing industry as a "male-dominated industry," and the resulting male-centred management model excludes women from institutional and decision-making processes, and partly due to gender power relations and social norms that limit women to domestic work (caregiver roles) and prevent them from leaving home for long distances or periods of time, which further limits their participation in decision making (Galappaththi et al., 2022). Without reforming the existing management system within male-centred organizations, increasing women's participation in the decision-making processes can merely improve the gender ratio in the groups of decision-makers, while women's meaningful participation, voices, and leadership continue to be hindered, leading to the inability of women to play effective roles and the deepening of gender stereotypes.

To promote women's meaningful participation, voices, and leadership within small-scale fisheries, the following recommendations are suggested:

(a) Increase sex-disaggregated data collection to include pre-harvest, post-harvest, and household fishing activities undertaken by women within fisheries data to further understand the gender-specific contributions of fishers in small-scale fisheries for targeted policy development.

(b) Carry out gender-specific training to upgrade the productive skills and knowledge of female fishery workers and to increase the capacity of women to cope with natural disasters and other changes.

(c) Carry out gender-inclusive governance reforms, increase women's participation in fisheries management decisions and research, fully incorporate women's experience and wisdom, promote fair distribution of resource use and management rights, ensure equal pay for equal work, and protect women's rights and interests through laws, regulations, and policies.

(d) Raise awareness of women's lack of agency in resource management and promote effective measures to address it, including the creation of more non-male-centred communication spaces and opportunities for women, especially in small-scale fisheries.

4.2.2. *Existing National and International Policy Frameworks on Marine Biodiversity Conservation*

Good governance of marine biodiversity is fundamental to ensuring the development of a sustainable climate-resilient and carbon-neutral fishery, both domestically and globally. In this regard, international cooperation and agreements are fundamental to facilitating transformation in policy frameworks and development modes.

Conservation and Sustainable Use of Marine Biodiversity Beyond National Jurisdiction

Marine areas beyond national jurisdiction (ABNJ), including the high seas and the international seabed area, account for 64% of the world's oceans and seas, and the development, conservation, and sustainable and equitable use of ABNJ biodiversity resources and the protection of marine ecosystems and biodiversity has become a key issue in global ocean governance for the international community. The legally binding international instrument on the conservation and sustainable use of BBNJ under UNCLOS was a response to the growing importance of this issue (see text box for background).

The main topics of BBNJ negotiations included:

- Marine genetic resources (MGRs), including benefit-sharing issues. This includes MGR collection/access, ex situ access and access to digital information on genetic sequences, transboundary issues, traditional knowledge, monitoring of MGR use, and the nature of benefit-sharing obligations, types and scope of benefits, sharing mechanisms, and uses. The draft agreement provides that the Parties shall be guided by the principle of the Common Heritage of Humankind under the Convention and the freedom of marine scientific research and other freedoms of the high seas, the principle of equity and fair and equitable benefit sharing.
- Area-based management tools (ABMTs), including MPAs. This includes identification of areas to be protected, international cooperation and coordination, proposal process, decision making, implementation, monitoring and review, etc. The Agreement provides the COP with the authority to decide on the establishment of MPAs or ABMTs and the adoption of related conservation management measures and measures compatible with those adopted by other relevant international legal instruments, frameworks and bodies (IFBs), and may recommend to the parties to the Agreement and to such IFBs to promote the adoption of relevant measures in accordance with their respective competencies when the proposed measures fall within the competence of other IFBs, and shall facilitate the relationship between the BBNJ Agreement and other IFBs, and shall facilitate the relationship among other IFBs. The COP shall respect and not prejudice the competence of other IFBs when making decisions.
- Environmental Impact Assessment (EIA). This includes EIA initiation thresholds and criteria, decision making and implementation, internationalization, monitoring and review, and relationship with other IFBs' EIA. The agreement confirms the basic principles of national decision making and country-led EIA, stipulating that when activities produce not only minor or transient environmental impacts or impacts that are unknown or poorly known, the results shall be screened and made public, and, if they are screened and deemed to cause serious pollution or significant harmful changes to the marine environment, then EIA shall be conducted. The state of activity shall monitor the authorized activities and report regularly and make the results publicly available, and the renewable technical body under the agreement may consider and evaluate the monitoring reports and establish criteria or guidelines for EIA.

BBNJ: UN’s first legally binding treaty regarding the protection of High Sea

On June 19, 2023, the United Nations formally adopted a historic treaty regarding the protection of life on the high seas (the Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction), which extends environmental protection to the oceans beyond national jurisdiction for the first time. The agreement fills gaps in the current ocean governance system in a number of ways, including establishing a legal mechanism for the establishment of marine protected areas (MPAs) on the high seas, strengthening the assessment and management of human activities in the high seas, agreeing on rules to ensure equitable access to and sharing of benefits associated with marine genetic resources (MGRs), and provisions to enhance capacity building and transfer of marine technology to developing countries.

The adoption of the BBNJ is an key milestone in the governance of the world's oceans, an important step in the protection of biodiversity, and a major step forward in sharing the benefits derived from the use of marine resources in a fair and equitable manner.

BBNJ historical process:

In 2004, the General Assembly adopted Resolution 59/24 establishing the Ad Hoc Informal Working Group to study issues related to the BBNJ. In 2011, the 4th meeting of the Working Group adopted a series of recommendations to initiate the BBNJ legal framework process, identifying a package of core topics to be addressed in a holistic manner: marine genetic resources, including benefit-sharing issues, delineation management tools, including MPAs, environmental impact assessments, and capacity building and transfer of marine technology, providing a critical first step in the negotiation of a BBNJ agreement. In 2015, the General Assembly adopted resolution 69/292 and established a Preparatory Committee to discuss the elements of the draft BBNJ agreement. After four sessions, in July 2017, the Preparatory Committee adopted the negotiating elements of the agreement recommended to the General Assembly and recommended that the General Assembly take a decision on the convening of an Intergovernmental Conference (IGC) as soon as possible. In 2018–2019, the first three BBNJ negotiation IGCs were held at UN Headquarters as scheduled. The 4th IGCs failed to reach agreement on the draft agreement due to significant differences among the negotiating parties on all topics. The 76th session of the General Assembly decided to convene the 5th IGC in August 2022. The text of the draft agreement was preliminarily agreed upon at the first resumed meeting of the IGC5 on March 4, 2023, and formally adopted in June. The agreement will enter into force 120 days after the date of submission of the 60th instrument of ratification, approval, acceptance, or accession.

- Capacity building and transfer of marine technology. This includes objectives, international cooperation, types, modalities, inventories, monitoring and review, etc. The Agreement provides for parties to ensure capacity building and transfer of technology for developing countries on an existing basis and within the limits of their capabilities by establishing a committee on capacity building and transfer of marine technology to address issues such as capacity building and transfer of technology and its monitoring and review.

After the BBNJ Agreement enters into force, the construction of marine genetic resources and high seas protected areas will work in the MGR Access and Benefit Sharing Committee and the science and technology agency established by the Agreement, and the COP will make decisions.

The science and technology agency will also play an important role in the EIA. ***It is recommended that China actively participate in the science and technology bodies and committees established by the agreement and increase the power input to gain more voice and influence.***

WTO Fisheries Subsidies Agreement

After 21 years of negotiations, the WTO reached an Agreement on Fisheries Subsidies (referred to as the Agreement in the following) at its 12th Ministerial Conference (MC12) in June 2022. This is the first multilateral agreement reached by the WTO in the past 9 years, the first WTO multilateral agreement focused on the environment, the first multilateral agreement on marine sustainability, and the second agreement reached since the establishment of the WTO, making an important contribution to the achievement of the UN 2030 Agenda for Sustainable Development.

The Agreement consists primarily of three subsidy disciplines and seven notification requirements that apply to exclusive marine fishing and subsidies for fishing-related activities at sea and do not apply to non-exclusive subsidies, inland water fishing and aquaculture, and intergovernmental payments through access agreements. In addition, the Agreement does not prevent members from providing qualified disaster relief subsidies. The subsidy disciplines under the WTO Fisheries Subsidies Agreement are broad-based to curb subsidies harmful to fisheries, e.g., prohibition of fishing for overfished fish stocks and includes a comprehensive notification mechanism to improve transparency.

Relative to the WTO fisheries subsidies negotiating objectives, there are currently no disciplines on fisheries subsidies that contribute to overcapacity and overfishing, and no full agreement on the special and differential treatment (SDT) for developing countries and least developed countries (LDCs), and follow-up negotiations are needed to reach a comprehensive agreement on fisheries subsidies. Article XII of the Agreement provides that if comprehensive disciplines on fisheries subsidies are not adopted within 4 years of the Agreement's entry into force, the Agreement will terminate immediately, unless the General Council decides otherwise.

The major subsidy disciplines of the Agreement are

- Prohibition of subsidies
- Special and differential treatment for developing countries
- Notification and transparency
- Technical assistance and capacity building for developing countries

The effective implementation of the Agreement will be conducive to reducing IUU fishing, mitigating overfishing of fisheries resources, promoting better maintenance of fisheries management order and better conservation of fisheries resources, and promoting the shift of fisheries subsidies in a beneficial direction. At the same time, the Agreement will also promote the protection of the rights and interests of developing countries, especially the LDCs, in the development of fisheries, leaving space for industrial development, which is conducive to the economic and social stability of local communities and promotes fisheries for the greater benefit of society and the well-being of the people.

If China approves the Agreement, it will promote the development of China's fisheries in a greener, more environmentally friendly, efficient, and orderly direction, which is in line with the basic policy of China's ecological civilization construction and the goal of high-quality development of fisheries. It will further optimize the structure and direction of the use of China's fisheries development subsidy funds; will be conducive to promoting the optimization of China's fisheries industrial structure and transformation and upgrading; will be conducive to promoting China's further strengthening of fisheries resources monitoring and assessment and fisheries statistics and related management; and promote the management of China's marine fishing industry more quickly toward refinement.

It is expected that the WTO Fisheries Subsidies Agreement will enter into force in 2 to 3 years. ***It is recommended*** *to seize the window period for the agreement to enter into force, accelerate the adjustment of offshore and distant-water fisheries management and subsidy policies, strengthen research and mechanisms to support compliance, and closely follow the negotiations, so that the agreement supports promoting the high-quality and sustainable development of China's fisheries*.

Regional Fisheries Management Organizations or Arrangements

Regional fisheries management organizations or arrangements (RFMO/As) are primarily subregional or regional organizations or arrangements with jurisdiction over specific areas and specific fishery resources, and often include global organizations or arrangements with jurisdiction over single fish stocks. Fishery resources under RFMO/As' jurisdiction are usually distributed both in waters under national jurisdiction and in adjacent high seas, or shared stocks distributed in waters under the jurisdiction of multiple countries, particularly straddling fish stocks and highly migratory fish stocks, and independent high seas stocks, anadromous spawning stocks, etc.

RFMO/A has been developed rapidly since the 1990s, and new organizations have been established; the functions and roles of the earlier established organizations have been strengthened. At present, 15 RFMOs, 2 single-species management organizations, and 3 RFMAs with high seas fisheries management functions have been established globally, covering almost all regions of the global ocean except the Southwest Atlantic.

The major functions of RFMO/As include: agreeing and complying with conservation and management measures; agreeing on fishing rights, such as allowable catch allocations or fishing effort levels, as appropriate; developing and applying minimum international standards for responsible fishing; reviewing the status of stocks and assessing the impacts of fishing operations on non-target and associated or dependent species; collecting and transmitting accurate and complete statistical data; promoting and conducting scientific assessments of stocks and related research; and establishing cooperative mechanisms for effective monitoring, control, and surveillance and enforcement, etc.

RFMO/A fisheries management is basically guided by the following principles: science-based fisheries management, which requires that fisheries management be based on the best available scientific evidence or information; application of the precautionary approach; fisheries management that considers ecosystems; non-contradiction (compatibility) between conservation and management measures; and development and use of selective fishing gear.

RFMO/A has developed fisheries management systems and measures, the main ones being: mandatory requirement for members or participants to provide fisheries statistics and reports, implementation of fishing logbooks, management of fishing vessel reports; implementation of total fishing control and quota management, including catch quotas and fishing input (number of fishing vessels, fish hold volume, etc.) quotas; requirement for flag states to implement fishing permit management for fishing vessels on the high seas, and for fishing vessels to establish files and implement a legal fishing vessel list system; fishing vessel and gear marking management; legal certification system for catch products; vessel position monitoring; technical management measures, such as closed seasons and closed areas, minimum fishing size restrictions, prohibition on the use of certain fishing aids and facilities; enhanced protection management of bycatch, incidental catch, and bycatch species; observer system; international measures for high seas boarding and inspection; trade measures; and environmental protection requirements for fishing vessels and operations, etc.

In terms of management rules, international fishery resource allocation is a core function of

RFMO/As. Some RFMO/As have adopted "fishing opportunity allocation criteria," which include compliance with relevant conservation and management measures and contributions to resource research as important indicators for quota allocation.

In terms of regulatory measures, enforcement will continue to improve, including increasing the proportion of observers assigned to fishing vessels, implementing a system of high seas boarding and inspection, and strictly regulating the transfer of catches on the high seas, and expanding from at-sea to port and market regulation, with the enforcement status of port states and consumer states further enhanced.

In terms of management concepts, ecosystem-based fisheries management will be gradually strengthened in terms of resource evaluation, fishing operations, and management measures; there is also a major trend to strengthen the regulation of bycatch, and bycatch species.

In terms of the structure of management participants, the increasing participation of NGOs and their deepening involvement will further influence the management decisions of RFMO/As.

The development of RFMO/A has brought high seas fisheries under international cooperative management, changing the situation that only flag states traditionally exercised high seas fisheries jurisdiction. Although management performance varies between RFMOs, they do provide a fundamental platform for high seas fisheries management and cooperation in the conservation and management of shared fish stocks between high seas fishing states and coastal states adjacent to the high seas, and between different coastal states. The traditional freedom of high seas fishing no longer exists, and conflicts between high seas fishing nations and coastal states, as well as between different coastal states, arising from fish stocks that cross national jurisdictional boundaries have been mitigated. Cooperation in the conservation and management of resources within and beyond national jurisdiction has been strengthened, and participation in RFMO/A efforts has become a prerequisite for access to exploitation opportunities for fish stocks under their jurisdiction.

Science is an important basic support for marine biodiversity conservation and fisheries management, and the international community is increasingly paying attention to and emphasizing science-based management and continuously promoting the linkage between science and management decisions. To play a more important role in international marine biological resources conservation and fisheries governance, and to realize the role change from participation to leadership, China must effectively increase investment, improve relevant scientific research capacity and technology, and strengthen relevant laws and policy research to provide strong support for the implementation of China’s ideas and programs.

RFMO/A has become the implementation body of international fisheries in a practical sense, especially high seas fisheries management, and its role in international fisheries governance will become increasingly important. At present, China has joined 8 RFMOs and is a member party of 2 RFMAs. ***It is recommended*** *that China should increase and deepen its participation in RFMO/A so that RFMO/A can become a fundamental platform for China to participate in international ocean governance and enhance China's voice and influence in equitable international ocean equity governance.*

4.3. Opportunities and Challenges

To ensure the maximum benefit and synergies between a sustainable blue fishery economy and achieving carbon neutrality, governance of marine fisheries should be effectively incorporated into the holistic and integrated ocean management (IOM) system. IOM simultaneously considers multiple uses, pressures, and values of the ecosystem to be managed, and contributes to reconciling relevant sectors and stakeholders with the objective of ensuring sustainability.

4.3.1. Current Progress and Potential Challenges

The use of marine fisheries resources is the oldest and most extensive form of exploitation of the oceans, and the sustainability of marine fisheries development has long been a global concern. Both capture fisheries and mariculture are important sources of GHG emissions. Meanwhile, capture fisheries, mainly through altered stock status, and mariculture, mainly through nutrient discharge and habitat modification, ultimately place significant pressure on the marine ecosystems (Gephart et al., 2021).

IOM aims to achieve sustainable development of the ocean by coordinating various ocean development activities, balancing conservation and exploitation of marine resources using EBFM (Pikitch et al., 2004), and supporting livelihoods and employment while maintaining the health and resilience of marine ecosystems (Winther et al., 2020). In contrast to the traditional sectoral management model, the goal of IOM is to coordinate potential conflicts among various ocean-related sectors and to fill the blind spots that are not covered by the functions of traditional management bodies. The inclusion of fisheries governance in IOM is not only to fully consider the compounding effects of fisheries on marine ecosystems but also to consider the long-term and stable development of fisheries as an important goal of IOM.

Internationally, IOM has already achieved advanced application that is worthy of reference for China. In the Coral Triangle, which comprises six countries, Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste, there are advanced practices for incorporating fisheries management into IOM (Winther et al., 2020). Its programmatic document, the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF), is implemented simultaneously by member countries and fully engages SSF communities as key stakeholders in the decision-making process. Small-scale fishing communities are fully engaged in the decision-making process, allowing for the establishment of an extensive network of MPAs, biodiversity conservation, and climate change adaptation, while also focusing on the sharing and sustainable use of fisheries resources and working to address the income, livelihoods, and food security of fishing populations (Green et al., 2014). It is important to note, however, that IOM always requires locally tailored strategies, and the practical framework of the Coral Triangle cannot be separated from the relatively flat, community-based system of management characteristic of small island states.

In China, there is still a lot of room to advance IOM. Since the institutional reform of the State Council in 2018, the functions of the former State Oceanic Administration are no longer independently retained, marine resources exploitation is integrated into the management of the Ministry of Natural Resources, marine ecological protection is integrated into the management of the Ministry of Ecology and Environment, and marine fisheries affairs are still managed by the Ministry of Agriculture and Rural Affairs. This reform trend has, in fact, changed the long-standing two-segment governance of land and sea in China, which is conducive to breaking the barriers between the marine sector and other sectors, eliminating the regulatory vacancy in the sea-land interface area, and shifting to a new pattern of integrated land-sea governance (Chen & Hu, 2021). As a traditional land power country, this integrated management model in China also enhances the influence of ocean management and helps to alleviate the pressure on the ocean from land-based human activities to some extent. However, this landmark reform is a continuation of the functional management (or industry management) model in the ocean, while diverging from the concept of IOM (Wang & Song, 2021).

In both marine capture and mariculture, China is the world’s largest producer, and includes various scales of production, from artisanal fisheries and coastal mariculture to distant-water fisheries and offshore mariculture, with different environmental footprints and development demands, making the situation extremely complex. Since fisheries affairs are managed under the Ministry of Agriculture and Rural Affairs, its management objectives are limited by its own departmental functions and tend to focus on the fisheries resources themselves rather than the broader marine ecosystem. From the perspective of marine resource exploitation and management, according to the China Marine Economic Statistics Bulletin 2021, marine fisheries account for only 5% of the country's gross marine product, although they are responsible for the livelihoods of a large population, and their claims are more likely to be ignored when they conflict with other marine-related industries. These institutional and structural characteristics pose significant challenges for the implementation of IOM in China, especially with respect to the inclusion of fisheries management.

4.3.2. Future Trends and Work Paths

Throughout the world, the concept of IOM has been widely recognized and implemented in many countries, and Norway has typical practical experience in addition to the aforementioned Coral Triangle. Over the past decade, the Norwegian Parliament has adopted and revised several integrated management plans for the surrounding marine areas, and a cross-sectoral working group, the Management Forum on Norwegian Sea Areas, which includes several marine sectors, has played a decisive coordinating role in the planning and decision-making process (Winther et al., 2020), in which fisheries, the mainstay of Norway's maritime industry, is naturally involved, along with oil, environment, shipping, mining, and others. For countries with more developed industries and large sea areas, this working mechanism has good implications.

China has just undergone a round of institutional reform of the central government component departments, and a short-term reorganization of departmental functions in the form of promoting IOM is unlikely. Although the 2018 institutional reform did not reflect the concept of IOM, it did promote a number of more pressing ocean management issues based on the principle of land-sea integration, such as the reform of the nature reserve system and "multi-regulation in one" territory spatial planning. It is worth noting that China has also experimented with IOM in some regions, such as Xiamen, where a leading group for integrated coastal zone management, led by the mayor and composed of relevant officials and experts, has been established since the 1990s to coordinate the needs of marine-related departments (Xue et al., 2004). With the development and maturity of ocean management systems, IOM will have a wide range of prospects in China, and the following recommendations can be summarized to better integrate fisheries management with a view to reducing the carbon footprint and protecting biodiversity.

In order to promote IOM in China's fisheries, ***it is recommended that:***

(a) At the central government level, drawing on the common "leadership group" working model in China, establish a coordinating working group led by the Vice Premier of the State Council and composed of multiple marine-related departments (National Development and Reform Commission, Ministry of Natural Resources, Ministry of Ecology and Environment, Ministry of Agriculture and Rural Affairs, Ministry of Science and Technology) to bridge the boundaries between the various marine administrations and solve marine issues in an integrated manner. At the same time, in the top-level design, clarify the strategic principles of prioritizing ecosystems and adequate adaptation to and mitigation of climate change; and clarify the pillar role of fisheries in marine-related activities to safeguard the livelihood and to maintain food security.

(b) At the local level, drawing on the practical experience represented by Xiamen, build a locally adapted implementation framework for IOM that adheres to science and is inclusive of stakeholders. Construct local regulations to promote the involvement of practitioners of different scales and types of capture fisheries and aquaculture in the management process of ocean affairs.

(c) Strengthen the synergy of law enforcement agencies, such as the coast guard and maritime safety and fishery administration, to continuously optimize the MCS work in marine fisheries and intensify the crackdown on IUU fishing. Meanwhile, gradually introduce carbon trading and marketable pollution permits in marine fisheries to phase out high-pollution and high-carbon footprint production methods by economic means. Actively carry out skills training for fishers at the grassroots level to promote their shift to jobs that require similar skills and can contribute ecological service values, such as restorative aquaculture and MPA patrol.

(d) For the WTO Fisheries Subsidies Agreement, FAO PSMA and other international cooperation matters that have far-reaching impacts on China's fisheries governance system, further integrate the management forces of relevant administrations to form a professional, multidisciplinary and inter-departmental work team. Enhance international compliance capacity with sound scientific knowledge and supporting mechanisms, and promote the incorporation of Chinese experience and wisdom in international fisheries governance.

4.4. Chapter-Specific Recommendations

Throughout the review and analysis presented in this chapter, it should be fully recognized that reducing carbon footprints and increasing climate resilience are not only necessary for the sustainable development of marine fisheries and mariculture but are also integral components of efficient ocean use to achieve carbon neutrality goals. This requires high-level policy-makers in major marine aquatic production countries, represented by China, to bring together the concerns and demands of different stakeholder groups at the domestic level, to lead government departments at all levels to implement strong policy governance, and to actively advocate and lead multilateral cooperation at the international level with the concept of a community with a shared future for humanity. The key principles that policy-makers need to implement include: 1) reduce carbon emissions from fishing vessels and incentivize the development of carbon sink fisheries; 2) further regulate harmful and carbon-intensive production practices, such as IUU fishing; 3) focus on the equal rights of marginalized groups in production and decision making and fully incorporate their experiences and wisdom in fisheries governance; and 4) incorporate fisheries governance into the strategic framework of IOM. Based on these principles, this chapter establishes a number of priority actions to achieve synergy between the high-quality development of marine fisheries and carbon neutrality.

Specifically, it is recommended to:

(1) Avoid fisheries management practices that spawn competition in fishing capacity, phase out harmful fishing vessel fuel subsidies, reduce excess fishing capacity, and promote a shift from fuel-intensive marine **fishing gear and practices** to those **with lower carbon footprints**.

(2) Promote research on the process and mechanism of fisheries as a carbon sink, and promote "**negative-emission mariculture**" that has the ability to sequester carbon, such as the cultivation of macroalgae and filter-feeding shellfish.

(3) Strengthen **fisheries supervision and enforcement**, apply big data technology to build a legality tracing mechanism for marine catches, and combine relevant international collaborative frameworks to combat IUU fishing and other harmful fishing practices.

(4) Build on the best available scientific knowledge to enhance the **climate resilience** of marine fisheries and the marine ecosystems on which they depend and to ensure fishing opportunities for small-scale fisheries.

(5) Carry out gender-inclusive fisheries governance reforms, promote the equitable distribution of resource use and management rights to fishers of all genders, and fully safeguard the **rights and interests of women in fisheries**.

(6) Increase input in participation in international agreements and processes related to marine living resources conservation and fisheries governance to ensure balanced voices and build

an efficient **global collaborative governance system**.

(7) Bridge the functional boundaries between the various ocean management administrations, fully incorporate the stakeholder groups in different fields, promote the linkage between science and technology and management decisions, and build an **integrated ocean management framework** tailored to local conditions.

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6. List of Abbreviations

ABMT: area-based management tools
ABNJ: areas beyond national jurisdiction
BBNJ: maritime biological diversity in areas beyond national jurisdiction
BRI: Belt and Road Initiative
CBD: Convention on Biological Diversity
CCICED: China Council for International Cooperation on Environment and Development
CCS/CCUS: carbon capture and storage/carbon capture, utilization, and storage
CDR: carbon dioxide removal
CPUE: catch per unit of fishing effort
EBFM: Ecosystem-Based Fishery Management
EDF: Environmental Defense Fund
EIA: Environmental Impact Assessment
EMFAF: European Maritime, Fisheries and Aquaculture Fund
EMFF: European Maritime and Fisheries Fund
FAO: Food and Agriculture Organization of the United Nations
GDP: gross domestic product
GHG: greenhouse gas
IGC: Intergovernmental Conference
IMO: International Maritime Organisation
IOM: integrated ocean management
IUU: illegal, unreported, and unregulated
MCS: monitoring, control, and surveillance
MEY: maximum economic yield
MGR: marine genetic resources
MPA: marine protected area
MSY: maximum sustainable yield
NDC: nationally determined contribution
NGO: non-governmental organization
NRDC: Natural Resources Defense Council
OECD: Organisation for Economic Co-operation and Development
PSMA: Port State Measures Agreement
RAS: Recirculating Aquaculture Systems
RDOC: recalcitrant dissolved organic carbon
RFMO/A: regional fisheries management organizations or arrangements
SBE: Sustainable Blue Economy
SDG: Sustainable Development Goals
SSF: Small-scale fisheries
TAC: total allowable catch
UN: United Nation
UNFCCC: United Nations Framework Convention on Climate Change
WTO: World Trade Organization