CCICED
SPECIAL POLICY REPORT

Global Ocean Governance and Ecological Civilization

Establishing China's Sustainable Fisheries Policy

2021

September,2021

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Executive Summary

Marine fisheries are one of the main ways for humans to develop and utilize the ocean, and are closely related to the production, life, and even survival and development of hundreds of millions of people around the world. As a major marine fishing country in the world, China has played an important role in promoting industrial development and maintaining world food security; on the other hand, it also shoulders a major responsibility in protecting the marine ecological environment, conserving fishery resources, and ensuring the sustainable development of fisheries industry. Due to continuous overfishing for decades, as well as environmental pollution, climate change and other factors, China's coastal fishery resources have severely declined. In recent years, China has continuously improved its fisheries policy, and it has continuously explored more effective management policies and modes in terms of fishing capacity control, attempts to promote quota fishing management, and the development of green aquaculture. These attempts have been positive and beneficial and have produced some economic and ecological benefits.

However, China’s marine fisheries have a huge catch volume and employ a large number of employees, involving complex and diversified range of fishery operations, fishing species, and fishing waters, which prove to be highly challenging to manage and regulate. The current management system and mechanisms, measures and strategies still need improvement. To this end, the China Council for International Cooperation on Environment and Development (CCICED) established the "Global Ocean Governance and Ecological Civilization" special policy study (2020-2021), with one of the task teams (TT1) "Establishing China's Sustainable Fisheries Policy" aiming to compare and analyze the implementation of China's marine fishery policies. The outcomes of this study will provide an important reference for China to improve fisheries policy and management, better balance ecological protection and fishery development, and to enhance its ocean governance capabilities during the "14th Five-Year Plan" period. To achieve these goals, the following policy recommendations are hereby put forward:

(1) Strengthening marine fishery resource assessment, natural capital accounting and management system optimization

(2) Build and strengthen foundational research and management insitutions for climate resilient fisheries

(3) Advancing sustainable fishery development with nature-based solutions

(4) Strengthening the protection of fishery resources in coastal Trawling-Prohibited Zone (TPZ)

(5) Continuously improving the implementation of Total Allowable Catch (TAC) policy in China

(6) Enhancing the sustainable management of China’s fish supply chain

(7) Scientific and standardized recreational fisheries management to promote the sustainable and healthy development of recreational fisheries

(8) Exploring the fishery resource protection mode of community participation and joint management

(9) Promoting sustainable fishery development by green finance

1. China's coastal capture fisheries

China's marine fisheries have developed rapidly since 1949. Marine fishing output exceeded 10 million tons in 1995 and reached 14.775 million tons in 2000[1], ranking at the forefront of the world's marine fishing countries (Figure 1). However, with the enhancement of fishing capacity and the continuous growth of fishing output, China's coastal fishery resources have experienced a serious decline; fishes with larger size and higher economic value have gradually been replaced by small pelagic fishes. This section will briefly describe the status of China's coastal fishing industry and discuss the main challenges it faces at present.

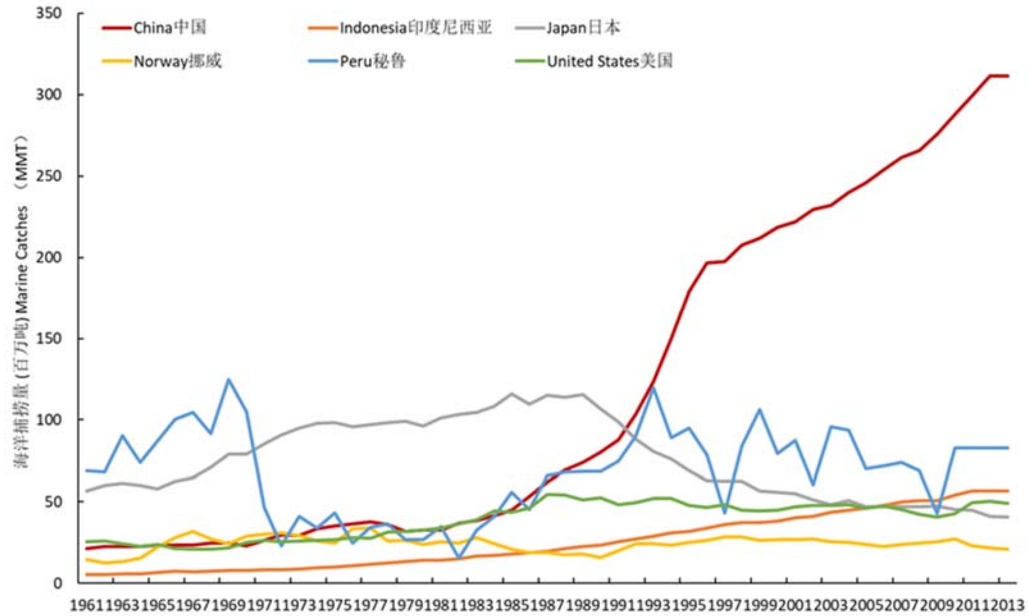

Figure 1 The World's Largest Marine Fishing Countries and their Catch Changes

1.1 Overview of the fishing economy

(1) Fishing boats

Fishing boats operating in China coastal oceans are classified by power. According to China's Fishery Statistical Yearbooks[2], in 2019, there were 147,000 marine fishing vessels in China with a total power of 13.547 million kilowatts (kW). Among the vessels, fishing boats larger than 441 kW accounted for 2.1%, fishing boats between 44.1 kW and 441 kW accounted for 33.7%, and fishing boats less than 44.1 kW accounted for 64.2%. 56% of the marine fishing vessels used drift gillnets; those boats are often small, accounting for only 28% of total fishing power. Another 18% of fishing boats used trawling; these boats are larger in scale, accounting

1 Fisheries Statistic Year Book in China
2 Bureau of Fisheries, Ministry of Agriculture, 1949-2020.

for 43% of power. Net fishing ranked the third, with the number of fishing boats and horesepower respectively accounting for about 8% and 4% of the total.

With the advancement of marine fishing capacity control policies, the total number and total power of marine fishing vessels in China began a downward trend after peaking in 2013 and 2015, with annual decline rates of 3.6% and 1.5%, respectively, as shown in Figure *2* and Figure 3. Among them, the number and power of fishing boats of less than 44.1 kW have dropped most significantly, from 130,000 and 2.09 million kW in 2012 to 90,000 and 1.44 million kW in 2019, with the rates of decrease at 28.5% and 31.3% respectively; The number and power of fishing boats of 44.1 to 441 kW decreased slightly. The number and power of fishing boats with power greater than 441 kW have increased, from 1,737 and 1.16 million kW in 2012 to 3,023 and 2.79 million kW in 2019, with an increase of 74.0% and 135.3% respectively. Due to the difficulty in defining artisanal fisheries and the lack of separate production statistics, coastal fisheries are represented by fishing boats with a power of less than 44.1 kW and their production. Box 1 outlines the overall situation of net fishing in China's marine fisheries.

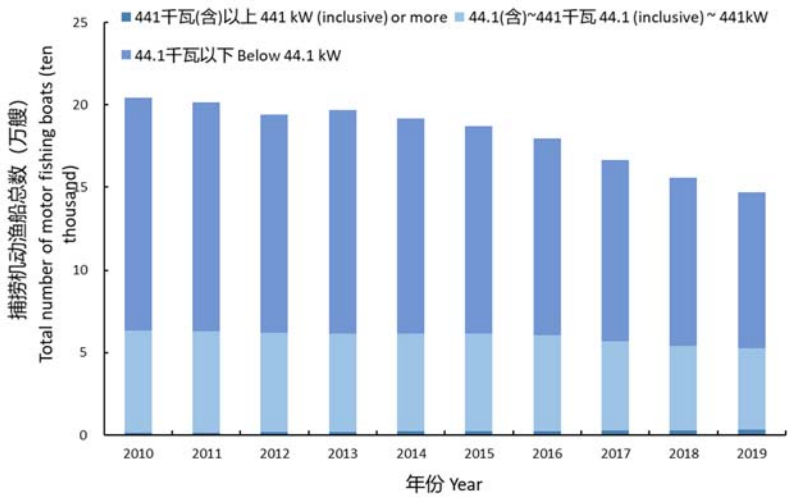

Figure 2 The Total Number of Motorized Fishing Vessels in China (10,000)

Box 1: Overview of China's Marine Stow Net Fishery
Between 2012 and 2018, the average fishing output of stow net fishing vessels was 1.5 million tons, accounting for approximately 12.2% of the average domestic marine fishing output. During the same period, the fishing output of stow net fishing boats in 2012 was 1.64 million tons, and then declined year by year, to 1.22 million tons in 2018, with a decreasing rate of 25.4%. From the perspective of fishing output in coastal provinces and cities, Zhejiang Province has the highest stow net production, with an average output of 610,000 tons during 2012-2018, followed by Fujian Province, with an average output of 330,000 tons, and Jiangsu Province, with an average output of 220,000 tons. Other provinces that have high

outputs include Shandong Province (170,000 tons), Liaoning Province (76,000 tons), Hebei Province (50,000 tons), and Hainan Province (35,000 tons). The outputs of other provinces and cities are less than 10,000 tons.

The main species caught by stow nets are shrimps, crabs, juvenile and miscellaneous fish, among which juvenile fish have a relatively high proportion. The 2014 Jiangsu coastal fixed stow net fishery production survey showed that each month’s catch was mainly composed of shrimps, prawns, large jellyfish, and Portunus crabs. In addition, various young fish and shrimps (usually used for feed production, classified as "Other" catches) are the main sources of fixed stow net production. The cumulative percentages of the above-mentioned catch species are over 70% each month, and the half-month cumulative percentages exceed 90% (Liu, 2020).

In 2010, a survey of stow net fishery in the main fishing ports and villages in the Yellow and Bohai Sea showed that there were 4 modes, 7 patterns and 19 types of stow nets for fishing in the Yellow Sea and Bohai Sea, with a total number of 690,000 sets. Except for the special stow nets for jellyfish and prawns, the minimum mesh sizes of other stow nets are between 4~30mm, which is relatively small, and the catches are mainly small yellow croaker, small miscellaneous fish, eagle claw shrimp, shrimp, and crabs (Sun, 2012).

The analysis of stow net fishery status in the Fujian sea area shows that the stow net fishing has poor selectivity for catches and the composition of the catch species is a complex with about 370 species. Among them, fish account for 77% of the total species, crustaceans account for 20%, and cephalopods account for 3%. Small-scale bulk fish and shrimps include seven starfish, wheat rhinoceros, small male fish, prawns, hairy prawns, etc., which together account for 40% to 50% of the catch. Medium-sized economic shrimps such as Chinese tube whip shrimp, eagle claw shrimp, red prawn, hastelloy imitation shrimp, etc. account for 8% to 10%. The main economic species such as hairtail, two long spiny bream, blue trevally, pomfret, and other juvenile fish larvae account for 20% to 25%, of which hairtail juveniles account for more than 50% of the economic juvenile and larval catch (Zhang, 2005).

According to the survey of stow net operations in northern South China Sea, the main types and styles of existing stow nets include five modes and five types, namely: stow net with vertical rods, double-pile truss rods, double-anchor single rods, stow net with vertical rods, single-pile vertical rods, multi-pile vertical rods, double-pile winged single-bag stow net with vertical rods, double-anchor single rods, and Zhang Gang stow net. Among them, double-pile vertical rod netting, double-anchor vertical rod netting, thin vertical rod netting, and single-pile truss netting are the main ones. These nets are small and non-selective. The catch is small economic fish and shrimps. Bycatch of juveniles and juveniles of a variety of economic fish is also very prominent. In some seasons, the proportion of juveniles in commercially importantstow net catch is as high as 80% or more (Yan, 2014).

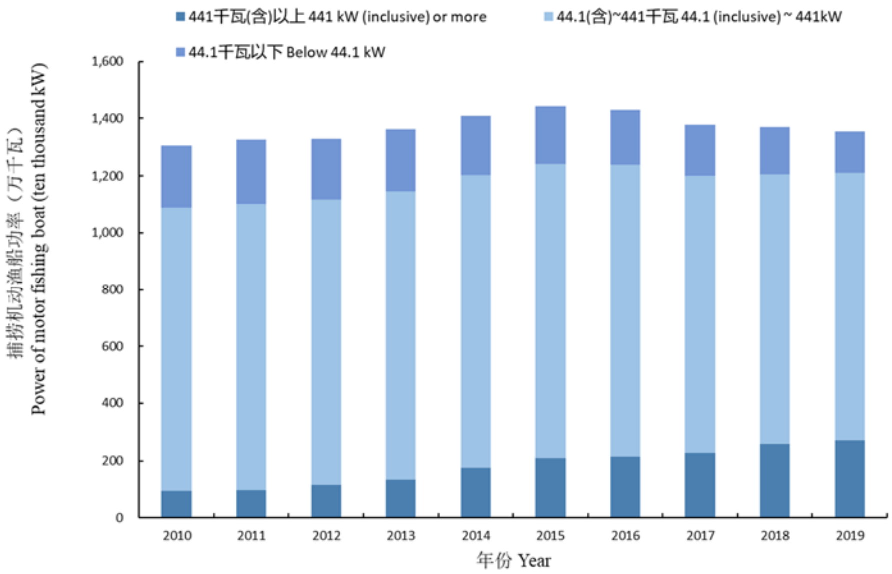

Figure 3 The Total Power of Fishing Vessels in China (10,000 kW)

(2) Output

In 2019, China's marine fishing output was slightly over 10 million tons, 21.1% down from 12.7 million tons in 2012. Among the marine fishing regions, fishing output in the East China Sea area is the highest, with an average output of 4.8 million tons from 2012 to 2019, accounting for 40.2% of the total coastal fishing output in China. The average output of the South China Sea and the Yellow Sea was 3.5 million tons and 2.9 million tons, accounting for 29.1% and 24.6% of the total fishing output respectively. The Bohai Sea has the lowest output of 902 thousand tons, accounting for about 7.6% of the total coastal fishing output in the country.

In terms of types of net fishing, China's marine fishing has the highest trawl output, with an average output of 5.7 million tons from 2012 to 2019, accounting for about 48.2% of the country's total coastal fishing output. The second is gillnet, with an average output of 2.7 million tons, accounting for about 22.4% of the total output. The average outputs of other fishing gear such as nets, purse nets and fishing tackles were 1.5 million tons, 98 thousand tons and 1.2 million tons, accounting for approximately 12.3%, 8.3%, and 10.3% of the country's total marine fishing output.

Fish account for the the largest catches, with an average of 8.3 million tons from 2012 to 2019, accounting for about 69.9% of the country's total marine fishing production. The second is crustaceans, with an average output of 2.211 million tons, accounting for about 18.7% of the country's total marine fishing output. The third is cephalopods, with an average output of 655 thousand tons, accounting for about 5.5% of the country's total marine fishing output. The other species totaled 879 thousand tons, accounting for about 7.4% of the country's total marine fishing output. Box 2 specifically introduces the composition of China's marine catches.

Box 2: Composition of China's Marine Catches

Among all fish catch, hairtail (*Trichiurus lepturus*) has the highest production, with an average of 1.0 million tons from 2012 to 2019, accounting for about 8.8% of the total fish yield. The second largest is anchovy (*Engraulis japonicas*), with an average production of 818 thousand tons, accounting for about 6.9% of the total fish yield. The third is blue trevally (*Decapterus maruadsi*), with an average output of 553 thousand tons, accounting for about 4.7% of the total fish output. There are also varieties of fishes with higher yields, such as mackerel (*Scomber japonicus*), Spanish mackerel, golden thread (*Nemipterus virgatus*), conger eel (*Muraenesox cinereus*), and small yellow croaker.

Among the crustaceans, the average production of shrimp and crabs from 2012 to 2019 was 1.5 million tons and 742 thousand tons. The production of hairy shrimp (*Acetes chinensis*) and portunus was the highest, accounting for 17.6% and 20.7% of the total crustacean production respectively, followed by eagle claw shrimp and mantis shrimp which accounted for 10.9% and 10.0% of the total crustacean production respectively. The production of prawns accounted for about 9.7% of the total production of crustaceans, while the production of scylla and *Charybdis japonica* is relatively low.

The production of sleeve-fish is the highest among the cephalopods, with an average output of 349 thousand tons from 2012 to 2019, accounting for about 53.3% of the cephalopod production. The second is squid, with an average output of 135 thousand tons, accounting for about 20.6% of the cephalopod output, followed by octopus, with an average output of 119 thousand tons, accounting for about 18.2% of the cephalopod output.

(3) Fishery Economic Output

According to China's Fishery Statistical Yearbook[1], in 2019, the total output value of China's fishery economy was about 260 million yuan, of which the fishery output value was about 130 million yuan, accounting for 49.0% of the total output value. In the fishery output value, marine fishing accounted for 16.4% of the total amount of approximately 21.16 million yuan, ranking the third. The two largest production activities are freshwater aquaculture and marine aquaculture, with output values of 61.86 million and 35.75 million yuan, accounting for 47.8% and 27.6% of the fishery output value, respectively. From 2012 to 2019, China's total fishery output value continued to grow, with an average annual growth rate of 5.2%. As a general trend, the output value of freshwater aquaculture and marine aquaculture has been increasing year by year, with annual growth rates of 5.7% and 6.7%, respectively. The output value of marine fishing fluctuated greatly and declined twice after 2015 and 2018 respectively. In all provinces, regions, and cities across the country, coastal provinces such as Shandong, Guangdong, Fujian, Jiangsu, Hubei, and Zhejiang have a relatively high total fishery output value, together

[1] Bureau of Fisheries, Ministry of Agriculture, 1949-2020.

accounting for 71.4% of the country's total fishery output value in 2019.

1.2 Fishery resources

China's coastal fishery resources are relatively rich with diverse species. China has recorded 2,028 species of marine fish, more than 1,000 species of crustaceans (more than 40 species of krill, more than 600 species of crab, and more than 300 species of shrimp), and more than 90 species of cephalopods, of which only a few species that are large in quantity have become the main fishing targets (Cheng et al., 1987; Lu et al., 1995). According to the China's Fishery Statistical Yearbook, in the past half century, the main fishing targets in China's coastal waters have changed significantly, as shown in Table 1.

Table 1 China's Main Coastal Marine Fishing Species Since the 1970s

Years	Species in China's Fishery Statistical Yearbook
1970s	Large yellow croaker, small yellow croaker, hairtail, herring, mackerel (mackerel, blue trevally, horse mackerel), jellyfish, cuttlefish, mudfish, sea bream, flounder, prawns, hairy prawns
1980s	Large yellow croaker, small yellow croaker, hairtail, cuttlefish, scorpionfish, mackerel, snapper, grouper, conger eel, herring, horse puffer, mackerel, blue trevally, mullet, golden thread, jellyfish, shrimp, hairy shrimp, eagle claw shrimp
1990s	Large yellow croaker, small yellow croaker, hairtail, bludgeon, mackerel, pomfret, snapper, mackerel, blue trevally, anchovy, sardine, Pacific herring, moray, grouper, barracuda, golden thread, horse noodle Fugu, prawns, hairy prawns, eagle claw prawns, swimming crabs, blue crabs, cuttlefish jellyfish
2000s	Conger eel, flathead, anchovy, sardine, herring, cod, grouper, snapper, blue trevally, white croaker, yellow croaker, kingfish, large yellow croaker, small yellow croaker, square head fish, jade tendon, hairtail, golden thread, barracuda, mackerel, mackerel, tuna, pomfret, mackerel, horse mackerel, mullet, prawn, hairy prawn, eagle claw shrimp, mantis shrimp, pike crab, blue crab, scorpionfish, squid, octopus, jellyfish
2010s	Conger eel, slug, anchovy, sardine, herring, cod, grouper, snapper, blue trevally, white croaker, yellow croaker, king croaker, large yellow croaker, small yellow croaker, *Collichthys lucidus*, square head fish, Jade tendon, hairtail, golden thread, barracuda, mackerel, mackerel, tuna, pomfret, mackerel, horse mackerel, mullet, prawns, hairy shrimp, eagle claw shrimp, mantis shrimp, portunus, blue crab, squid, octopus, jellyfish

However, with the enhancement of marine fishing capacity and the expansion of fishing scale, China's fishery resources have begun to decline significantly. Small pelagic fishes have gradually begun to replace fish with larger individuals and higher economic values. For example, major fishery resources in the Bohai Sea at the end of the 1950s, such as small yellow croaker, hairtail, and prawns, all declined significantly, as shown in Table 2. The dominant species of fishery resources in the Yellow Sea have also undergone major changes. In the 1950s and 1960s, the fishery resources in the Yellow Sea were still dominated by high-quality demersal and near-demersal fish with high economic value, such as small yellow croaker, hairtail, and flounder. After entering the 1970s and 1980s, Pacific herring, blue-spotted mackerel, and mackerel became the dominant species. By the end of the 1990s, yellow anglerfish and fine-striped lionfish, which have low economic value, gradually became the dominant species in the Yellow Sea (Dai et al., 2020).

Table 2 The Composition of the Main Fishery Resources in the Bohai Sea after the 1950s (Tang et al., 2003)

Year	Main Fishery Resources (in order of biomass from high to low)	Proportion of Total Biomass
1959	Small yellow croaker, hairtail, Chinese prawn, yellow crucian carp, and ray	82.5%
1982	Yellow crucian carp, mussel squid, anchovy, small yellow croaker, blue-spotted mackerel, mantis shrimp, sea bass, hole ray, yellow croaker, bluefish, silver pomfret, white croaker, *Collichthys niveatus*, eagle claw shrimp Man's needle-free squid, etc.	82.1%
1992	Anchovy, yellow crucian carp, spotted catfish, small yellow croaker, mantis shrimp, musket squid, *portunus trituberculatus*, sea perch, red-nosed anchovy, and ray, etc.	82.5%
1998	Spotted catfish, yellow crucian carp, silver pomfret, blue-spotted mackerel, mantis shrimp, *portunus trituberculatus*, red-nosed anchovy, small yellow croaker, etc.	81.0%

Studies have confirmed that overfishing is the main reason for the decline of fishery resources, changes in the composition of dominant species, and decline in species biodiversity. Four seasonal bottom trawl surveys from 1959 to 1999 showed that the fishery resources, dominant species composition, and community structure of Laizhou Bay have undergone major changes during the 40 years. Its species diversity index began to show a downward trend after reaching its peak in 1982. This shows that external disturbances such as moderately intensive fishing may increase the diversity of fish, but excessive fishing would reduce the diversity index (Jin et al., 2000). The fishery bottom trawl survey conducted in the waters of Laizhou Bay from August 2009 to 2013 also found that the fishery resources of Laizhou Bay are declining year by year, with obvious replacement of dominant species, significant changes in community structure, and a downward trend in species diversity (Yang, 2016).

In addition, the bottom trawl survey conducted in the coastal waters of the northern South China Sea during the four seasons from 2014 to 2015 showed that fishing activities before and after the fishing moratorium have a significant impact on the diversity index of the South China Sea. High-intensity fishing activities before the fishing moratorium greatly changed the structure of fishery resources, and its adverse effects onfish populations has impacts on sustainability. In the short interim of the initial period of the fishing ban, the fishery resources could not be quickly improved and fully recovered, and the community diversity was still low. However, after the two and a half months of the fishing moratorium, the fishery resource communities can be restored and supplemented to a certain extent and the overall situation can reach a relatively stable state (Cai, 2018).

While accelerating the decline of fishery resources, excessive fishing will also further interfere with the ecological balance and ecological health of the marine ecosystem, causing serious ecological and environmental disasters. Box 3 illustrates the impacts of overfishing on the marine ecological environment and fishery economic production, taking jellyfish disasters frequently occurring in the East China Sea and the Yellow Sea in recent years as examples.

Box 3: Overfishing, Decline of Fishery Resources and Jellyfish Outbreak

Under the influence of global climate change and human activities, the structure and function of marine ecosystems have undergone great changes, and marine red tides, green tides, white tides (medusa/jellyfish outbreaks) and other ecological disasters continue to occur. Since the end of the last century, large-scale medusa outbreaks have occurred in the northern East China Sea and the Yellow Sea for several years, and the number has increased year by year in recent years, which has seriously affected the marine fishery production in the East China Sea and the Yellow Sea during the summer and autumn fishing seasons, as well as the production and livelihoods of traditional fishermen. Before the mid-1990s, China's coastal medusa outbursts occurred sporadically and did not attract people's attention (Zhang, 2011); however, under multiple pressures such as rising global temperatures, increasing coastal human activities, and overexploiting of fishery resources, China's coastal ecosystem has undergone great changes (Cai, 2010; Tang, 2009). The 2003-2016 Bulletin of the State of the Marine Environment in China showed that there were a number of incidental blockage of the power plant's water intake network due to jellyfish outbreaks, reduction of coastal fishing catches, and injury to people at beaches during the period from 2003 to 2014. Among them, the abnormal proliferation of *Cyanea nozakii* in the Liaodong Bay, Bohai Sea in 2004 caused a reduction in jellyfish production by about 80% and fishery production by more than 60% (Ge, 2004).

At present, the main types of medusa disasters in the coastal areas of China are *Cyanea nozakii*, sand jellyfish, Aurelia, Aequorea, etc. Many scholars have discussed the mechanism and causes of medusa outbreaks, which proved to be very complex. They are supposed to be affected by both environmental factors and human activities. In addition, medusa shows fast growth, strong regenerative capacity, and capability of rapid reproduction such as asexual reproduction. These factors have jointly affected the medusa outbreaks. Ding et al. (2006) believed that the occurrence of medusa is related to the atmospheric environment (light intensity, greenhouse effect, El Niño phenomenon), marine environment (seawater thermocline, surface current, eutrophication), alien species invasion, and predation (impact of plankton and fishery) and other factors. There are currently two arguable explanations regarding the impact of overfishing.

One view is that overfishing has led to a decrease in the number of euryphagous fish that feed on medusa so that the predation pressure on medusa is reduced. The decrease in the number of omnivorous fishes also provides a rich environment for the growth and development of food organisms so that the actual trophic level of large jellyfish in the marine ecosystem has been raised continuously, and it has become the top predator of plankton in the sea. The abnormal accelerated growth of medusa further squeezes the coastal fishery resources, resulting in pravelent outbreaks of large jellyfish. Another view is that the summer fishing moratorium coincides with the peak of the growth of large jellyfish. The reduction of fishery activities reduces human interference, thus providing favorable conditions for large jellyfish outbreaks (Cheng, 2004). Although the relationship between the over-utilization of fishery resources and the outbreak of medusa is still inconclusive, maintaining the structural stability of coastal ecosystems is of paramount importance.

1.3 Fisheries challenges

Firstly, although China is now a major fishing country in the world, and its volume of fishery catch and aquaculture production far exceeds that of other countries in the world, the supply gap in the domestic seafood market is still increasing. On one hand, this is due to the decline of fishery resources caused by overfishing. On the other hand, it is due to the change in the demand structure caused by the expansion of the middle class. In recent years, the needs of Chinese residents have gradually shifted towards high-quality and safe seafood products. Compared with farmed, freshwater, and domestic aquatic products, people have shown greater interest for wild, marine, and imported seafood (Fabinyi et al., 2016). However, currently, about 80% of the catches in the China Marine Economic Zone are low-value small pelagic fish such as anchovies and mackerel (Crona et al., 2020). This imbalance between supply and demand will lead to structural overcapacity and shortage in China's fisheries industry.

Second, the fishery law enforcement system is not robust. In recent years, China has continuously stepped up its crackdown on illegal fishing and has introduced a series of special law enforcement action plans for the fishery administration. However, various illegal fishing behaviors still occur. This is because China's fisheries administration supervision force is still relatively weak and the supervision measures are insufficient. On the other hand, the lack of sound legal foundation for the punishment and disposal of illegal fishing boats[1], the unclear division of responsibilities between departments, and the insufficient coordination of cross-provincial law enforcement further weaken the effectiveness of China's fishery law enforcement

[1] http://www.yyj.moa.gov.cn/gzdt/201912/t20191218_6333402.htm

Third, the rapid development of the coastal economy has brought tremendous environmental pressures to the marine ecosystem. A large number of pollution from agricultural and industrial sources have destroyed the habitats of many wild fish species (Cao et al., 2017). In 2019, China still has 90,000 km^2 of seawater that does not meet the national first-level standard for seawater quality[1]. The destruction of the marine environment has further accelerated the decline of fishery resources, resulting in economic losses of more than US$500 million per year (CCICED Task Force, 2013). In recent years, with the continuous tightening of fishing capacity, China may rely more on freshwater and coastal aquaculture in the future to fill the ever-expanding gap in the supply and demand of seafood. How to manage and control the potential marine environmental impacts of large-scale aquaculture will be a major challenge in the process of China's sustainable fishery development.

Fourth, climate change is inducing rapid changes for the marine resources in China's waters. Sea surface temperatures in the Bohai Sea, Yellow Sea, and East China Sea have significantly increased over the past century, with some of the strongest warming (~1.96°C) in the East China Sea (Cai, 2011). Sea level rise (SLR) rates for Chinese coastal areas are projected to be 3.1-11.5 mm/year by 2050, which is higher than the global SLR rate of 3.2-80 mm/year by 2050 (Cai et al., 2008). Such rates imply severe coastal flooding and potential loss of remaining coastal wetlands (He et al., 2012). Modeling studies have estimated that between 18 and 25% of mangrove habitats would be lost by 2100 following the present trend in SLR (Li et al., 2015). An increase in hypoxic areas in the Yellow Sea and East China Sea is anticipated (Tang, 2009) and ocean acidification has been increasing in the nearshore waters of the Bohai Sea and the Yellow Sea (Huo et al., 2013). Acidification has been intense in the bottom waters of the central Yellow Sea, with rates that approached the critical thresholds for shell and skeleton dissolution (Zhai et al., 2014).

These physical changes in China's waters have resulted in major changes in the abundance and distribution of marine species in the region. At lower trophic levels, a northward expansion of warm-water zooplankton species was recorded around the Yangtze River estuary (Kang et al., 2012). In general, poleward shifts in marine species' suitable thermal habitat (STH) are projected. Among some notable studies, Cheung et al. (2008) projected that small yellow croaker (*Larimichthys polyactis*), one of the most important fishery resources in the Yellow and East China Seas, would shift into the Yellow Sea and even invade the Bohai and Japan Seas. Dai (2004) showed that 13 new, warmer water species now occurred in the Taiwan Strait, which previously occurred more southward in the South China Sea, and that 25 fish species, which were previously caught only in the southern part of the Taiwan Strait were now also caught in the northern Taiwan Strait. Altogether, a growing body of literature presents clear evidence that climate change that is already underway presents many challenges for China's fisheries. Its impacts on coastal marine habitats and shifting of marine species pose risks on fishing

[1] http://english.mee.gov.cn/Resources/Reports/soe/SOEE2019/202012/P020201215587453898053.pdf

communities in China and along its supply chains. To effectively mitigate these risks, funding and research are required to develop a scientifically informed adaptation plan.

An additional challenge is recent and potential new catastrophic events, causing serious disruptions for the entire China aquatic products supply chain. Catastrophic events are occurring more frequently, and the scope and duration of their impacts continue to exceed historical records. In particular, the novel coronavirus pneumonia (Covid-19) outbreak resulted in a global epidemic and triggered a serious public crisis, with great impacts on all links along the China and global fishery supply chain, including catch fisheries, aquaculture, processing, transportation, and wholesale and retail sales markets. While some disasters are short-term, others can last for years. Although China has actively taken countermeasures to mitigate the impact of Covid-19 and achieved good results, there is a need to strengthen the early warning system and long-term impact assessment of the disaster.

2. Coastal capture fishery management system

2.1 Top-level design of China's fishery management

The 18th National Congress of the Communist Party of China clarified the overall layout of China's coordinated promotion of economic construction, political construction, cultural construction, social construction, and ecological civilization construction. Under the guidance of the ecological civilization construction, the proposal of Marine Ecological Civilization (MEC) has further promoted the transformation of China's fishery management mode (Hanson, 2019). Marine ecological civilization emphasizes the use of healthy marine ecosystems to support the prosperity and development of the blue economy (Winther and Su, 2020). Through intensified policies, it aims at strengthening the protection and restoration of coastal and marine ecosystems and improving the utilization efficiency of fishery resources[1]. To this end, China issued a series of policy documents during the "13th Five-Year Plan (FYP)" period, emphasizing marine environmental protection, the sustainable use of fishery resources and the establishment of eco-friendly mariculture. The 14th FYP was released in 2021. The annual plan and the 2035 long-term goal outline (draft) emphasize the creation of a sustainable marine ecological environment, the optimization of the layout of coastal green aquaculture, the construction of marine ranches, the development of sustainable coastal fisheries, and the synergy between the development of the blue economy and marine protection[2].

Fishery management in China is guided by the Fishery Law of the People's Republic of China (hereinafter referred to as the Fishery Law). The law was passed at the 14th meeting of the Standing Committee of the Sixth National People's Congress of the People's Republic of China

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[1] MoA, http://www.moa.gov.cn/ztzl/xysjd/201710/t20171010_5836798.htm
[2] The draft outline of China’s 14th Five-Year Plan http://www.xinhuanet.com/politics/2021-03/05/c_1127172897.htm

in 1986 and came into effect on July 1st, 1986[1]. The Fisheries Law stipulates:

- The fishery administrative department of the State Council (that is, Bureau of Fisheries of the Ministry of Agriculture and Rural Affairs (BoF, MARA)) is in charge of the national marine fishery management; except for the sea areas designated by the State Council and the special fishing grounds under the supervision and management of the fishery administrative department of the State Council and its subordinate fishery supervision and management institutions, other sea areas shall be supervised and managed by the fishery administrative departments of the people's governments of adjacent provinces, autonomous regions, and municipalities. Based on this regulation, the Fisheries Administration of the Ministry of Agriculture and Rural Affairs[2] is the highest-level fishery management agency in China. The Fisheries Administration is responsible for formulating national fishery strategies, drafting relevant rules, regulations, and standards, and supervising the implementation of various fishery management policies. All inland or marine fishing, aquaculture, processing, and trade activities that occur at home or abroad are under the jurisdiction of the Fisheries Bureau. The local government manages regional fisheries through local fishery departments.
- The state encourages and supports the development of coastal and deep-sea fishing industries and rational arrangement of freshwater and coastal fishing power; enterprises or individuals engaged in freshwater and coastal fishing must apply for fishing licenses from the fishery administrative department. Among them, fishing licenses for large-scale marine trawling and purse seine operations shall be approved and issued by the fishery administrative department under the State Council; fishing licenses for other operations shall be approved and issued by the fishery administrative departments of the local people's governments at or above the county level. Units and individuals engaged in fishing in fresh water and coastal waters must operate in accordance with the type of operation, location, time limit, and quantity of fishing gear specified in the fishing license and abide by the relevant regulations on the protection of fishery resources.
- It is forbidden to electrocute and poison fish; it is not allowed to fish in the restricted fishing areas during the closed fishing period, and it is not allowed to use prohibited fishing gears, fishing methods, and nets smaller than the minimum mesh size specified for fishing; it is forbidden to fish for aquatic organisms with important economic value.

With the Fishery Law and fishery administrative departments as the core, fishery management is also closely related to marine protection and environmental and industrial governance. The State Oceanic Administration under the Ministry of Natural Resources (SOA, MNR) supervises marine strategic planning, the development of the blue economy, and the protection of marine

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[1] The Fisheries Law has been amended five times in 2000, 2004, 2009, 2013, and 2020.

[2] Transformed to The Ministry of Agriculture and Rural Affairs in 2018.

rights and interests. To promote sustainable use of marine resources, the government promotes a marine functional zoning system to optimize the layout of marine-related industries, especially to identify coastal and coastal areas that allow capture fisheries and mariculture. The impact of fisheries on the environment is supervised by the Marine Ecology and Environment Department under the Ministry of Ecology and Environment (MEED, MEE). The Department of Marine Ecology and Environment is responsible for organizing the formulation of the total emission control of various marine pollutants, supervising and implementing the pollutant discharge permit system, determining the pollution holding capacity of the ocean, and proposing total and concentration control targets for various major marine pollution sources. In addition, Bureau of Fisheries of the Ministry of Agriculture and Rural Affairs (BoF, MARA) and the National Development and Reform Commission also play important roles in China's fishery reform process.

2.2 Fishery management system based on the input control

In order to use fishery resources more rationally and adjust the fishing intensity, China has established specific management systems for fishing vessels, fishing gear, fishing time, and regions under the guidance of the Fisheries Law. Such systems focus on avoiding unreasonable fishing methods and excessive investment in fishing capacity, thereby protecting the sustainable prosperity of fishery resources and the benign development of the fishing economy.

(1) Fishing gear management system

To effectively reduce the adverse effects of overfishing on living marine resources, China has enacted strict regulations controling the permitted fishing gear. To protect juvenile fish, juvenile shrimps, and juvenile crabs, China prohibits the use of fishing gear with mesh sizes smaller than the limits set by the national regulations. Issued by the then Ministry of Agriculture in 2003, "the notification on the implementation of marine fishing nets with a minimum mesh size of the system" clearly defines the newest mesh size of gill net for fishing pomfret, Japanese Spanish mackerel, hairtail, and Chinese herring and the size of the trawl nets used in different sea areas. Since 2009, a special survey of national fishing gear and fishing methods and the compilation of a catalog have been organized, and the "National Catalog of Marine Fishing Gear" has been completed, dividing all 85 types of marine fishing gear into three categories, including permitted (30 kinds), prohibited (13 kinds) and transitional (42 kinds), and sets the minimum mesh size, gear specifications, and the number of nets to carry by each boat, respectively.

In 2013, "notification on the implementation of the minimum mesh size system of permitted fishing gear and transitional fishing gear for marine fishing" was issued; since June 1st, 2014, the system of permitted fishing gear and transitional minimum mesh size of fishing gear was fully implemented in the Bohai Yellow Sea, the East China Sea, and the South China Sea. On the other hand, China prohibits the use of fishing methods that destroy fishery resources such as electric fishing, explosive fishing, and poison fishing, and has issued specific notices on prohibited fishing gears for marine fishing. Based on existing national regulations, in 2014, the former Ministry of Agriculture further issued the “Notification on the prohibition of the use of Thirteen Kinds of Fishing Gear”, such as Double-Ship Single-Piece Multi-Bag Trawling, which completely banned the use of thirteen kinds of fishing gear, such as Double-Ship Single-Piece Multi-Bag Trawling, in the Yellow Sea, the Bohai Sea, the East China Sea, and the South China Sea.

(2) Protection of aquatic germplasm resources

China first proposed the concept of aquatic germplasm resource protection zone in the “China Aquatic Biological Resources Conservation Action Program” in 2006. The third part of this outline requires the establishment of an aquatic germplasm conservation zone in the main breeding areas of aquatic germplasm resources with high economic value and genetic breeding value, and to develop appropriate management practices, strengthen and standardize the management of protected areas. Since 2007, China actively promotes the construction of aquatic germplasm resource conservation areas and in 2011 promulgated the "Interim Measures on Aquatic Germplasm Resources Conservation Area" in (hereinafter referred to as the "Interim Measures"), systemizing the establishment and management of aquatic germplasm resources of protected areas. The “Interim Measures” proposes to specify the key aquatic species specified by the state or local, unique aquatic germplasm resources, the original seeds of important aquaculture objects, and other species with high economic value and genetic breeding value. The main growth and breeding areas of aquatic germplasm resources shall be protected areas, and special protection periods shall be set for the key stages of their growth and breeding. During the special protection period, fishing, blasting operations, and other activities that may cause damage to the biological resources and ecological environment in the protection area are not allowed.

Up to 2021, China announced it has validated eleven groups of 535 state-level aquatic germplasm resource conservation zones in total. These protected areas can protect hundreds of national key protected fishery resources and key habitats such as spawning grounds, feeding grounds, overwintering grounds, migratory channels, etc., and initially constructed the protected area network of aquatic germplasm resources covering various sea areas and major inland rivers and lakes.

(3) Fishing licenses

To protect and rationally utilize fishery resources, adjust the fishing intensity, maintain production order, and protect the legitimate rights and interests of producers of fishing, the former State Fisheries Administration released the "Interim Provisions on Several Issues fishing license" in 1980 and began to implement a license system in July 1980. The "Fisheries Law" introduced in 1986 regulates that “Any unit or individual that intends to engage in inland water or coastal fishing must first apply to departments of fishery administration for fishing licenses. Units and individuals engaging in inland water and coastal fisheries must conduct their operations in accordance with their licenses concerning the types of operation, location, time limits, and quantity of fishing gear, and they must also abide by the relevant regulations on the protection of fishery resources."

With the promulgation of the "Management Rules on Fishing Licenses" in 1989 and "Fishing Permit Regulations" (hereinafter referred to as the "Regulations") in 2002, China gradually established the fishery license system. According to the latest revision of the Regulations in 2019, China has implemented a total of eight types of fishing licenses. Marine fisheries, high seas fisheries, and inland fisheries fishing licenses are respectively applicable to fishing operations in the waters under the jurisdiction of China, high seas, and inland waters. Special (concession) fishing licenses are applicable to fishing operations in specific waters, specific times, or for specific species, or fishing operations that use specific fishing gear or fishing methods. The other four types of permits are used for temporary fishery operations, recreational fishery operations, fishery operations conducted by foreign vessels in waters under the jurisdiction of China, and auxiliary fishing vessel operations.

(4) Fishing season closure in summer

China's seasonal moratorium system first began in 1980. The former State Fisheries Administration in 1980 and 1981 issued the "Notice of Collective Trawlers Fishing Moratorium and the Joint Inspection of the Proportion of Young Fish in the State-run Fishing Vessel" and "Provisional Regulations on the Protection of the Aquatic Resources of the East Sea and Yellow Sea Area", which requires a two-month moratorium on collective trawlers in the Yellow Sea area from July to August each year, and a four-month moratorium on collective trawlers in the East China Sea from July to October. Since then, China has continuously adjusted the scope, period, and specific requirements of the fishing moratorium according to the endowment of fishery resources and production conditions. As of 1999, China's fishing moratorium system has covered the Bohai Sea, Yellow Sea, East China Sea, and South China Sea (not including latitude 12° south of the Sea). The fishing moratorium system implemented in 2007 is called by Chinese "the strictest regulations in history " of the fishing moratorium. The system put fishing start time advanced to May 1st and extend the moratorium period 1 month, keeping the pressure crackdown situation for fishing violations. During the annual fishing moratorium in 2017, there were a total of 7,427 cases of prosecuting illegal, 10343 people involved, of which involved 1,369 were transferred to judicial processes. More than 7,000 "Sanwu" ships and more than 400,000 extreme nets were cleaned up and banned[1].

(5) Dual control of fishing boats

In order to control fishing intensity and conserve and rationally utilize marine resources, China has started to strengthen the total amount control of marine fishing intensity since the Eighth Five-Year Plan and the Ninth Five-Year Plan and implemented the dual control of fishing boats. Subsequently, in 1999 and 2000, the "zero growth" and "negative growth" policies were

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[1] http://www.cjyzbgs.moa.gov.cn/gdxw/201904/t20190428_6220380.htm

introduced for marine fisheries. The dual control of fishing vessels sets a clear control target for the number of vessels and power of marine fishing vessels nationwide. For example, the "Views on Implementing Marine Fishing Vessel Control System in 2003-2010" proposed that the number of national marine capture fisheries boats and power would be within 193,000 and 1,142.7 kW in 2010. However, affected by factors such as employment pressure in coastal areas, subsidies for conversion of fishermen, and unmatched fishing employment policies, the effect of the implementation of the dual control system for fishing vessels is not satisfactory. In 2010 there were still 205,000 coastal fishing vessels in China.

To solve this dilemma, China reiterated the goal of dual control of fishing vessels in 2010 during the 12th Five-Year Plan period and issued Several Opinions on Promoting the Sustainable and Healthy Development of Marine Fisheries in 2013, emphasizing the strict execution of marine fishing moratorium, fishing access, aquatic germplasm resources protection system at the same time, in particular, to clarify pilot of coastal fishing quotas, strict control of the coastal fishing intensity, and to improve its marine fishing vessels control system, and gradually reduce the number of fishing vessels and total power. On this basis, the former Ministry of Agriculture issued the Notice on Further Strengthening the Control of Domestic Fishing Vessels and Implementing the Total Management of Marine Fishery Resources in 2017, with a view to further improving the scientific and refined level of utilization and management of marine fishery resources. The Notice requires reducing 20,000 marine fishing motorboats and 1.5 million kW power, reducing domestic marine capture production to less than 10 million tons by 2020. As mentioned above, the number of China's marine fishing vessels has been decreasing since 2013 and has dropped to 147,000 ships in 2019.

2.3 China's fishing quota pilot

To strengthen the total marine fishery resource control, the Ministry of Agriculture and Rural Affairs started total allowable catch (TAC) pilots in 2017 in Zhejiang and Shandong provinces and in 2018 extended the range to Liaoning, Fujian, and Guangdong provinces. Relying on the special fishing license system during the fishing moratorium period, these 9 coastal provinces (municipalities) have been carrying out the quotas experimentally, as shown in Table 3.

Although the species, distribution methods, and specific requirements of these TAC pilot projects are different, they still have many similarities. First, almost all pilots use special fishing licenses to limit the total catch under TAC, while special licenses regulate the fishing time, waters, and species for fishermen. Second, most of the pilots began from single-species quotas. Although the pilots in Fujian involve four different types of *Portunus* crabs, they are not treated differently during the quota allocation and monitoring process. Third, most of the pilot projects have improved catch monitoring by implementing fishing logs, fishery observers, and fishing quota early warning systems.

These pilots not only actively accumulated significant experience in implementing TAC systems for its deployment nationwide, but also identified the potential problems and obstacles.

Table 3 Basic situation of China's quota fishing pilot

Province	Launch year	Species	Pilot waters	Quota Allocation
Shandong	2017	Jellyfish	Laizhou Bay	Olympic-style free competition fishing
Zhejiang	2017	*Portunus trituberculatus*	Linhai, Sanmen (Zhebei Fishery)	Assigned to the cooperatives, the cooperatives manage themselves
Liaoning	2018	Prawns	Pulandian	Individual Vessel Quota (IVQ)
Fujian	2018	Red Star Portunus Crab (*Portunus sanguinolentus*), Sword-holding Crabs (*Amphitrite gladiator*), distant water portunus, *Portunus trituberculatus*	Xia Zhang sea area	Olympic-style free competition fishing
Guangdong	2018	Smooth river blue clam (Potamocorbula laevis), loose pattern cherry blossom Clam (Tellina virgata Linnaeus), white blue clam	Zhujiang Kou	IVQ
Hebei	2019	Jellyfish	Tangshan, Cangzhou	IVQ[1]
Jiangsu	2019	Jellyfish	Yancheng, Nantong, Qidong	
Shanghai	2019	Jellyfish	Hangzhou Bay	IVQ[2]
Guangxi	2020	Portunus	Qinzhou	IVQ 20 pilot fishing boats, with an average quota of 600 kg per boat during the pilot period[3]

First China's fishery resources survey and basic evaluation have deficiencies and it is difficult to offer a clear basis catch for TAC. The determination of the upper limit of fishing depends on the status of fishery resources and its ability to maintain stable populations. However, due to the lack of survey data, the existing pilots mainly set the upper limit of fishing based on the historical catch and trade volume in the last two to five years. Although China began marine fishery resource assessment as early as the 1950s, the assessment focuses on the entire waters, rather than specific species. The lack of systematic data basis for fishing species made it difficult to determine the quotas of the total catch limit. In addition, artificial enhancement of fishery resources, which has become popular in recent years, would further increase the difficulty of evaluation.

[1] TAC policy in Hebei
[2] TAC policy in Shanghai
[3] TAC policy in Qinzhou sea water

Second, the pilots have not yet established a real-time, accurate, and efficient capture and monitoring system. The existing fishing log management reporting system mainly relies on self-reporting and lacks external verification and confirmation. The associated fixed-point landing transactions can complement each other with the fishing log of the fishing boat. However, during the transportation of catch, the catches from multiple fishing boats are often mixed, and it is difficult to distinguish the sources. To improve the effectiveness of catch monitoring, Shandong, Zhejiang, and Liaoning have all piloted fishery observer systems, but the effectiveness of this method and its implication on fishery costs are still uncertain.

Third, because the majority of China's fisheries have a characteristic of multipe fish species, it is difficult for the main pilot work at this stage to focus on a single species to gain experience for the TAC across the country. In addition, with the expansion of the scope of TAC control, if the exclusiveness of fishing in the controlled waters and possible cross-regional fishery management issues are guaranteed, it will be an important challenge that will be faced in the development of the TAC system in the future.

Finally, the legal basis for the implementation of TAC in China is still not solid. Although the revised "Fisheries Law" in 2000 has put forward the implementation of the fishing quota system, the relevant supporting documents have not been published. The specified regulations on log management of fishing, boat inspection, and designated transaction mechanisms are still missing. In addition, although China has defined fishing licenses as a kind of property right, according to the "Fishing License Management Regulations", the Ministry of Agriculture still prohibits the transfer and trading of fishing licenses. This limitation will affect the further development of the Individual Transferable Quota (ITQ) system in the future in China.

For the more detailed description of the pilot implementation of China, Box 4 and Box 5 quote Zhao's (2020) master thesis "A study on the implementation of quota system of China's marine fisheries", which gives an overview of the work carried out and the problems encountered during the trial of quota fishing in Zhejiang Province and Fujian Province

Box 4: Portunus trituberculatus fishery in the northern Zhejiang fishery

1. Preliminary preparations for the pilot

1) Fish species selection

Taking into account the simplicity and feasibility in developing and implementing the quota pilot, the species chosen by Zhejiang Province was *Portunus trituberculatus*. The longitude of pilot waters is 122°30' to 123°, and the latitude is 30° to 31°, which is the fishing waters of specific projects of the northern Zhejiang crab fishing grounds under the jurisdiction of Zhejiang Province. The duration for this pilot was 16 September, 2017 – 31 March, 2018. The life cycle of *P. trituberculatus* is short, its fishing season is relatively fixed (the main fishing season is Oct - Jan), and it is an important species of high economic value in the East

China Sea; moreover, the pilot area is in the protected areas for Zhejiang crab conservation. Therefore, it will be relatively easy to select the *P. trituberculatus* fishery in the northern Zhejiang fishing ground for pilot projects in the early stage of the fishing quota trial.

2) Determine the fishing subject

The fishing boats participating in the pilot fishing boats adopt the method of independent application for public screening. The fishing boats applying for the special fishing license for Portunus crabs must meet the following conditions: the applicant must hold a "marine fishery fishing license"; the fishing boat must be a fixed gillnet fishing boat; the applicant must have household registration certificates or identity certificates in Linhai or Sanmen; fishing vessels applying for special fishing across regions must provide long-term operating certificates in the waters; fishing vessels applying for fishing vessels must have complete certificates and no illegal production activities in the previous year. After the final review, a total of 108 fishing vessels in Linhai and Sanmen participated in the pilot, including 93 fishing and production vessels and 15 auxiliary transport vessels.

3) Formulate TAC

The Zhejiang Institute of Marine Fisheries has conducted investigations and monitoring of the resources in the pilot waters. Together with the Zhejiang Ocean and Fisheries Bureau, based on the number of fishing vessels and fishing output from 2011 to 2016 (data provided by the cooperatives where the pilot fishing vessels are located), combined with other relevant information from fishery management experience, it was finally determined that the TAC of Portunus trituberculatus in the pilot waters in 2017 was 3,200 tons.

2. Allocation of fishing quota

The allocation of TAC in Northern Zhejiang fishing of trituberculatus used quota groups. Pilot vessels were divided into 3 cooperatives (Linhai 2, Sanmen 1). According to the principles of fairness, impartiality, and openness, the Taizhou Municipal Bureau of Oceanography allocated TAC to cooperatives based on historical operations. Among them, the Sanmen Cooperative was 500 tons, and the two Linhai cooperatives were 1,800 tons and 900 tons respectively. After the quotas are allocated to cooperatives, how to use them in the specific cooperatives was independently planned by the cooperatives.

3. Supervision and management of fishing quota

To better monitor the completion of quotas, the following six systems have been formulated: (1) A fixed-point transaction system: fishing vessels must go to designated fishing ports onshore or conduct fishing transactions with designated fishing vessels at sea, and record the catch; (2) The fishing log system adopts the " paper + electronic " fishing log double report. Fishing vessels must truthfully record the catch in the paper fishing log and report the catch using the electronic fishing log APP in time; (3) Incoming fishing notification system: the fishing vessel entering the fishing must notify the cooperative where it is located. The notification content mainly includes the entry or exit of the fishing ground during each voyage, the daily position of the boat and the reprinting of the catch trade, etc.; (4) Observer system: the first to implement the maritime observer system, each voyage appoints 2 observers to go to sea to observe and record marine production, transaction reprinting, etc.; (5) Supervision system: fishing vessels implement grid management, and fishing vessels uniform special numbering, carry out joint maritime law enforcement at the provincial, municipal, and county levels during the pilot period, and conduct regular inspections and surprise inspections of pilot fishing vessels; (6) a reward and punishment system: the pilotset up subsidy funds for fishing vessels and encouraged fishermen to consciously abide by relevant management regulations. For violations, the corresponding subsidy or quota will be deducted.

According to the survey, north of Zhejiang fishery catches during the pilot for trituberculatus fishing quota was 1,612 tons which was 50.39% of the annual TAC; the actual production time was October 1st, 2017 to January 15th, 2018, shorter than the planned pilot time. In addition, in the process of quota supervision, the implementation effect of some systems is not satisfactory: affected by the quality of fishermen, maritime signal problems, etc., the completion rate of electronic fishing logs is not high, and paper fishing logs also have non-reporting and false reports. There is a big difference between the paper and electronic fishing log data. The transactions of supporting fishing vessels is made at sea, but it is difficult to supervise, and there is a phenomenon of "the highest bidder wins"; and the level of rewards and punishments is not enough to deter the occurrence of violations.

Box 5: Quota pilot for Portunus in the Xiazhang waters of Fujian Province

1. Preliminary preparation

1) Fish species selection

After considering the characteristics of its fishery resources and the status of fishing operations, Fujian Province finally selected the Xiazhang waters after many comparisons, investigations, and studies (specifically located in the 282 fishing area and 283 fishing area within the line of the machine wheel bottom trawling prohibited fishing zone in Fujian jurisdictional waters) as the 2018 annual catch quota pilot waters; the pilot time is from August 1st, 2018 to April 30th, 2019; the pilot species was Portunus, but in fact was a mix of four varieties, including Gazami crab, Red swimming crab, Blue swimming crab, and Three spot swimming crab. The portunus has a short life cycle, fast growth, and a large amount of resource replenishment. The Xiazhang sea area is also considered to be one of the main fishing grounds for the swimming crab. Zhangzhou, one of the main swimming crab fishing and trading centers in China, is also located here. The development of the quota system provides a certain degree of convenience.

2) Determine the fishing subject

Cage pot fishing gear mainly uses bait to catch crabs. It is currently the most effective type of fishing operation that utilizes crab resources. According to the survey of relevant projects in Fujian Province, among the catches of cage pot operations in the Xia-Zhang sea area, the output of portunus has reached 50%, so the pilot special fishing vessel operation method is designated as cage operation. Fishing boats must make an independent application in advance, and only those who meet the conditions (type of cage pot operation, local household registration, etc.) can be eligible for special fishing. In the end, 106 caged fishing boats in Longhai were approved to have pilot fishing qualifications. The Longhai Municipal Bureau of Oceans and Fisheries issued a unified fishing quota special fishing license and fishing vessel flags and stipulated that fishing operations must be carried out during the pilot period with special permits and flags.

3) Develop TAC

The Fujian Fisheries Research Institute conducted a survey on the annual catches of the fishing boats used to catch portunus. According to the relevant catch data from 2013 to 2017, the maximum sustainable yield (MSY)[1] was estimated using mathematical models. MSY is a term for resource management, meaning to maximize the output of certain living resources without affecting the sustainable use of them. At the same time, combined with some social surveys carried out on the shore, taking into account factors such as biology and ecological safety, it was finally determined that the TAC of portunus in 2018 was 400 tons.

2. Allocation of fishing quotas

During the pilot period, the fishing quota of portunus was not allocated to fishing boats, but the Olympic-style free competition fishing method was used to use the fishing quota within the TAC total control. During the pilot period, fishing vessels participating in the pilot were free to catch, but the relevant management personnel had to record daily catch statistics for all vessels. When all fishing vessels's catch totaled 95% of TAC, it issued fishing vessels quota warnings and no longer allowed fishing vessels to leave the port for production. When the TAC quota was reached, all production fishing vessels were immediately recalled.

3. Supervision and management of fishing quotas

[1] Maximum Sustainable Yield (MSY) is defined as the highest average catch that can be continuously taken from an exploited population, or stock, under average environmental conditions. MSY is based on the ecological concept of sigmoid population growth toward the carrying capacity of the ecosystem for the respective species. The surplus in numbers and biomass produced for population growth can be caught sustainably and reaches a maximum (MSY) at intermediate population size. (Tsikliras & Froese, Encyclopedia of Ecology, 2019)

During the pilot period, the management department took the following measures to monitor the implementation of quotas: (1) The fishing log system requires the use of paper fishing logs and electronic fishing logs to report on the fishing production status at the same time. Fishermen must fill in the report truthfully and report it every voyage; (2) In the fixed-point trading system, the fishery authority has designated three fishing ports as trading places in advance and requires all pilot fishing boats to trade in these three places and record the trading situation at the same time; (3) Law enforcement cruise: during the pilot period, the fishery authority organized special law enforcement actions to investigate and deal with production fishing vessels that have violated regulations.

However, according to field investigations, the results of theTAC portunus pilot in Fujian Province in 2018 were not satisfactory. The main points are as follows: (1) The prerequisites for fishing restrictions were not guaranteed. During the pilot period, the fishing boats were mixed and there were vessels from Longhai, Dongshan, and Quanzhou, and there are also gillnets and trawl operations. Although 106 cage fishing boats have applied to participate in the fishing quota pilot, during this period only a few of 20 were operating, and according to the local cage fishermen report the yield of gillnets is higher than theirs, which has caused great inconvenience to quota supervision; (2) fixed-point trading has not been implemented. Although there are designated special fishing ports and auxiliary ships for trading in advance, the fishermen are still in the state of autonomous trading in the actual process; (3) The fishing logs were not properly completed and the reporting was not timely. The electronic log entry rate was very low, according to comparison of the output data from two monitoring vessels. The authenticity of fishing log data reported by the fishermen needs to be studied; (4) Law enforcement in the sea is difficult. The pilot sea areas involve Xiamen, Zhangzhou, Haichang, Longhai, and other areas, and the law enforcement power of a single department is weak.

3. The institutional framework of China's marine ecological economy

3.1 Marine protected areas and ecological red lines

A marine reserve is a representative marine or coastal natural zone designated for special protection by a country or a social organization to protect marine natural resources and the ecological environment. It is one of the measures to protect marine biodiversity and prevent the deterioration of the marine ecological environment. The earliest construction of marine reserves in China can be traced back to the Snake Island Nature Reserve designated in 1963. The former State Oceanic Administration formulated the "Outline for the Construction of Marine Nature Reserves" in 1988, and established the first batch of marine nature reserves with the approval of the State Council in 1990. According to different protection objects, marine reserves can be roughly divided into marine ecosystem protection areas, endangered rare species protection areas, natural historical relics protection areas, special natural landscape protection areas, and marine environmental protection areas, etc. (GB/T 17504-1998). Marine nature reserves are managed at national and local levels. National marine nature reserves established with the approval of the State Council refer to marine nature reserves with significant domestic and international influence as well as significant scientific research and protection value. Local marine nature reserves refer to marine nature reserves which have great influence in the local area, have important scientific research value and certain protection value, and are established with the approval of the people's governments of coastal provinces, autonomous regions, and municipalities directly under the Central Government.

As of 2020, 271 marine nature reserves of various types have been established in the waters under China's jurisdiction, with protected areas of about 124 thousand km^2 and a 4.1% coverage of the coastal ocean areas under China's jurisdiction. The protection targets include rare and endangered marine biological species including dugongs, harbor seals, and Chinese white dolphins; typical ecosystems such as mangroves, coral reefs, coastal wetlands; marine natural historical sites, etc. All the eleven coastal provinces, autonomous regions, and municipalities have marine nature reserves, and a network system of marine nature reserves has been initially formed. Since 2018, China has integrated marine protected areas into the natural reserve construction system with national parks as the main body.

However, China's current marine protected area management system still has certain limitations. First of all, despite the relatively large number of protected areas, they account for only 4.1% of China's total ocean area, which is lower than the 10% target set by the Convention On Biological Diversity and the target of “5% of the coastal ocean under China’s jurisdiction being protected by 2020” set by the National Marine Major Function Zone Planning (2015)[1]. Second,

[1] The State Council, 2015. National Marine Major Function Zone Planning. http://www.gov.cn/zhengce/content/2015-08/20/content_10107.htm

in the absence of top-level coordination, the distribution of many marine protected areas is inconsistent with the priority areas identified in the National Biodiversity Strategy and Action Plan, and the protective effect is poor. Third, the delineation of existing protected areas has not yet fully considered the connectivity of the ocean and the differences in the utilization of different habitats by organisms. The ocean has high mobility and connectivity, which determines that many marine organisms have a relatively large range of movements, and there are many types of river-sea migration. Organisms may use different types of habitats at different stages of their life history, and their spawning grounds, nursery grounds, and feeding grounds may be distributed in different waters such as estuaries, seagrass beds, mangroves, and tidal flats. If only part of these areas are protected, it means that only part of the life history stage is protected, and the goal of comprehensive protection of marine life and ecosystems cannot be achieved. Therefore, only by setting up protected areas with appropriate and sufficient area and scope can the purpose of continuation and expansion of the protected populations be achieved.

To strengthen the protection of marine ecosystems, the former State Oceanic Administration has integrated marine protected areas and aquatic genetic resource reserves, and delineated the Red Line of Marine Ecological Protection (red-lining) under the framework of marine functional zoning. The Red-line is the bottom line of marine ecological security. By delimiting important marine ecological function areas, ecologically sensitive areas, and ecologically fragile areas as the key control areas, it strictly controls the space boundaries and management boundaries in terms of natural ecological service functions, environmental quality and safety, and natural resource utilization, in order to maintain marine ecological functions, environmental quality and safety, and the sustainable use of natural resources, and to promote the balanced development of economy, society, and the environment. Red-lining is an important institutional innovation for environmental protection in China.

The red-line protection is essential to the health of the marine ecosystems. The red line includes marine aquatic genetic resource reserves, special marine reserves, important coastal wetlands (such as mangroves, coral reefs, and seagrass beds), islands, natural landscapes, historical and cultural relics that need special protection, concentrated distribution area of rare and endangered species, and important fishery waters. In a way, the Redline is similar to marine protected areas (MPA), which includes marine natural reserve and MPA for historical and cultural conservation. Fishing is usually permitted in a MPA in China. National park is an MPA with the highest protection status, but only a small percentage of MPA can be consolidated into the national park system.The Bohai Sea is the first region in China to adopt the marine ecological red line system. In the four provinces (municipalities) adjacent to the Bohai Sea, the coverage of the marine ecological red line is about 10% (Tianjin) to 45% (Liaoning) of the sea area under its jurisdiction. Drawing on the experience of the Bohai Sea, China will further expand the scope of the pilot red-lining and plans to achieve a Red-line coverage of more than 30%.

3.2 Nature-based coastline restoration plan

China has nearly 3 million km^2 of sea area and 32,000 km of coastline, and has more than 20,000 recorded marine species. The stretch of the coastal zone is full of various high-productivity habitats, including mangroves, seagrass beds, coral reefs, seaweed forests, and tidal flat wetlands, etc., which provide various important ecological services functions. For example, mangroves can filter pollutants in the water, provide important timber and food resources for coastal communities, store large amounts of carbon sinks, and are a natural barrier against erosion and severe storms.

Coastline protection and restoration is another key area of China's marine ecological protection. Coastline protection is of particular importance to endangered and rare marine life. Most of China's marine endangered and rare species use coastal wetlands as their main spawning, breeding, and feeding areas. The protection of natural coastlines can also reduce the vulnerability of coastal communities and improve the ability to respond to and adapt to the effects of climate change. China’s “Thirteenth Five-Year Plan for the Development of the National Marine Economy” released in 2017 set a binding goal for the country’s marine environment and coastal protection for the first time, that is, to maintain 70% of coastal waters in good quality and protect at least 35% of coastline by 2020. The Fourteenth Five-Year Plan and the 2035 Long-Term Target Outline (draft) released in 2021 further emphasized the 35% coastline protection target.

In recent years, China has actively promoted the restoration of coastlines such as "returning fish farms to beaches" and "returning farms to sea". In the process, nature-based solutions have received more and more attention. Nature-based solutions adhere to the restoration principle of “emphasis on nature and light on engineering”, and avoids the restoration mode of artificial landscape creation through a large number of engineering measures. These solutions include protecting, restoring, and sustainably managing ecosystems, improving the resilience and adaptability of ecosystems, reducing disaster risks, and building green infrastructure, thereby simultaneously protecting biodiversity and improving human well-being. For example, by building oyster reefs to absorb wave energy, the coastline can be protected from wave erosion and storm damage, seawater can be filtered to improve water quality, and breeding habitats for economic species can be provided. In addition, some studies have shown that coral reefs are more effective than traditional breakwaters in reducing the height and energy of waves. These nature-based solutions can provide solutions for the protection of coastlines from the perspective of ecological protection.

Nature-based solutions can play an important role in the restoration of mangroves in China. In China, a large number of mangrove wetlands were converted into aquaculture ponds in the 1980s. The reduction of mangrove wetlands has severely damaged the local biodiversity, and the polluted waste generated by aquaculture has made most wetlands lose their ability to recover naturally. During the "13th Five-Year Plan" period, China began to promote the work of "returning ponds and returning wetness" and proposed to build and restore 18,800 hectares of mangrove forests by 2025 on the basis of clearing and retreating ponds in nature reserves (National Forestry and Grassland Administration, 2020). At present, Beihai and other places are exploring the use of nature-based solutions to restore mangroves in abandoned ponds. The local staff designed a mangrove-Wutang snakehead multi-nutrient level composite ecosystem, using natural productivity and bait to proliferate economic organisms under the mangroves and implement sustainable resource harvesting to achieve the continuous improvement of the ecosystem and sustainable economic organisms. At the same time, it plays an extremely important role in purifying seawater, preventing wind and waves, maintaining biodiversity, and fixing carbon and storing carbon (Nature-Based Solutions Facilitation Team, 2019).

In addition to coastline restoration, nature-based solutions also play an important role in the process of marine ecology and environmental protection. For example, sustainable marine aquaculture based on integrated multi-trophic aquaculture (IMTA) can utilize cultured organisms of multi-trophic levels such as filter-feeding shellfish, macroalgae, and benthic animals to recycle the residual bait and biological waste in the system toreduce nutrient loss as much as possible, thereby increasing the capacity of the breeding environment and the sustainable production level of the entire system. The development of China’s IMTA model is in a leading position in the world. In the future, it will continue to improve the carbon sequestration capacity of cultured organisms by screening aquaculture species with a high carbon sequestration rate, increasing the production of seaweeds and shellfish, and providing more other ecosystem services. China cultured 2.5 million tonnes of seaweed in 2019, which, estimated by their tissue C content, removed 668,200 tonnes of C (or 2.45 million tonnes of CO_2) from the ocean through harvest. In addition, in the process of building marine ranches, China should also replaced artificial reefs by selecting suitable bioremediation species (such as macroalgae, filter-feeding shellfish, and sedimentary predators) to promote carbon absorption in coastal waters and try to use nature-based solutions to protect the marine ecological environment.

3.3 Green mariculture

Mariculture contributes to 40% of the total global marine fishery production (SAPEA, 2017), while China’s marine aquaculture production accounts for more than 60% of the global total output. China's mariculture industry boasts its long history, large scale, and huge species variety. There are about 70 species of marine organisms are listed in the official fishery statistics, including finfish, shrimps and crabs, molluscs, seaweed, sea cucumbers, and other species. A considerable part of the aquaculture species grow through photosynthesis or filter-feeding on plankton, which means no artificial feeding is needed during the aquaculture process; only about 15% of fish and crustaceans need to be fed.

Quality improvement, waste water treatment, volume reduction, and income increase are major strategies to China's fishery development and are also the general direction of green development for the industry. In 2020, Document No.1 of the Central Committee of China

Communist Party made an important deployment of "promoting green and healthy aquaculture". The Ministry of Agriculture and Rural Affairs immediately issued the document, “Notice on the Implementation of the ‘Five Actions’ for Green and Healthy Aquaculture in 2020”, making specific requirements in five aspects, including promoting ecological and healthy aquaculture modes, promoting aquaculture waste water treatment modes, reduction in application of aquaculture chemicals, replacement of trash fish with formulated feed, and enhancement of genetic resources etc. In recent years, the National Aquatic Technology Promotion Station has promoted eco-friendly aquaculture technologies such as recirculating aquaculture, integrated multitrophic aquaculture, as well as rice-fish co-cultivation to the whole country. Among them, the seawater pond (or inshore) integrated multi-trophic aquaculture technology mode is based on different physiological and ecological characteristics of fish, shrimp, and shellfish, by taking advantage of the complementary characteristics of polyculture species in the water layer, feeding habits, and living habits. The three-dimensional ecological farming mode may consist of fish in the water column, shrimp on the bottom and molluscs in the bottom of the pond. In the process, an important issue to be solved in the development of green mariculture is how to balance the relationship between the growth of the aquaculture industry and the protection of the ecosystem.

（1） Marine aquaculture space planning

As an important way of using the sea, the development of marine aquaculture needs to meet the requirements of the national, provincial, and municipal marine functional zoning. Marine functional zoning is a unique marine spatial plan in China. Marine functional zoning is revised and supplemented every ten years or so to keep the content of the plan consistent with China's marine ecological protection goals and promote the sustainable development of marine industries including mariculture. According to the Fisheries Law revised in 2013, people's governments at all levels are responsible for strengthening the overall planning and management of water areas, standardizing the use of water areas, and determining which areas can be used for mariculture. If enterprises and individual farmers decide to use waters and tidal flats for aquaculture activities, they need to apply for aquaculture license and sea area use license from or above government at the county level. Furthermore, from 2018 to 2020, coastal cities and counties across the country have comprehensively delineated the “three zones” for aquaculture (aquaculture permitted, restricted and prohibited areas), and have successively compiled regional aquaculture plans for water areas and tidal flats (2018~2030).

However, in the case of insufficient coordination of the top-level design of fishery management in China, there are serious overlaps and conflicts between mariculture zoning and marine ecological protection red lines. Article 3 of the 2017 Marine Environmental Protection Law imposes that the state shall delineate marine ecological protection red lines for important ecological function areas, ecologically sensitive and vulnerable areas, and implement strict protection. However, the current Fisheries Law does not provide for the relevant management of the marine ecological protection red line, resulting in a serious overlap between China's mariculture areas and marine nature reserves and protected red line areas. Thus, the question of how to comprehensively consider the needs of fishery development and marine protection, and formulate reasonable aquaculture zoning, is an important topic of concern to the academic community and the industry. Box 6 introduces the cooperation between China and Europe researchers on aquaculture spatial planning.

Box 6: China and Europe's cooperative research on ecosystem-based aquaculture spatial planning
The Aquaculture Spatial Planning Decision Support System (APDSS) was developed in 2019, as an outcome of the Key Programme for International Cooperation on Scientific and Technological Innovation, Chinese Ministry of Science and Technology "Sino-EU Cooperative Research on Ecosystem-based Spatial Planning for Aquaculture" (2016YFE0112600). APDSS was developed for Sanggou Bay, a typical marine aquaculture site in northern China, based on the functions of the GIS system. By integrating historical observation data, and physical-oceanography, and ecosystem models, APDSS can provide decision support for aquaculture spatial planning and production management through environmental data browsing, policy and environmental suitability evaluation, aquaculture organism growth prediction and carrying capacity evaluation, as well as economic benefit calculation. On the basis of national and local Marine Functional Zoning plan, and according to its compatibility with aquaculture, Sanggou Bay sea areas are divided into aquaculture permitted, restricted and prohibited areas by APDSS. At the same time, according to the physiological and ecological characteristics of cultured organisms, evaluation was made by whether the value of these environmental parameters in the sea areas can meet the growth needs of the organisms, so that the suitability of sea areas for aquaculture is evaluated. APDSS has both desktop and internet applications, with similar data and graphic display functions. (Liu et al., 2021).

（2） Treatment of mariculture waste water

The treatment of waste water is one of the key points in the development of green mariculture. The Marine Environmental Protection Law of the People's Republic of China (revised in 2017) clearly stated that "the state establishes and implements a total pollution control system in key ocean areas, determines the total discharge control index of major pollutants, and allocates discharge control quantities to major pollution sources". At the beginning of 2019, ten ministries and commissions, including the Ministry of Agriculture and Rural Affairs, jointly issued the "Several Opinions on Accelerating the Green Development of Aquaculture Industry", further proposing to "develop ecological and healthy aquaculture modes, improve water recirculating and intake/discharge treatment facilities, support ecological upgrade and transformation of waste water treatment facilities such as water ways, ponds and subsurface wetlands; furthermore, promote the treatment of aquaculture waste water, promote the introduction of aquaculture waste water pollutant discharge standards, and carry out the environmental impact assessment of aquaculture in accordance with the law."

In line with the promulgation and implementation of the above policies, China has organized experts since 2017 to revise the current "Freshwater Pond Aquaculture Water Discharge Requirements" (SC/T9101-2007) and "Marine Aquaculture Water Discharge Requirements" (SC/T9103-2007). Coastal provinces and cities are also actively conducting surveys of fishery pollution sources, formulating and implementing technical plans for aquaculture waste water treatment, and selecting typical aquaculture companies to carry out technology research and development, application and demonstration. Although some results have been achieved in the implementation of the work mentioned above, many problems have also been exposed. As the pollution discharge of aquaculture has characteristics of low pollutant concentration, large quantity of drainage, and non-point source discharge, it is difficult to meet the treatment requirements of aquaculture waste water by referring to the prevention and treatment of point source pollution and sewage treatment methods. In addition, the formulation of aquaculture waste water discharge standards has not taken the latest research results at home and abroad into consideration, and the regulations on aquaculture species, modes of operation, water quality, and nitrogen and phosphorus budgets are relatively outdated. The discharge characteristics and development trends of aquaculture waste water should be considered collectively in order to develop a more flexible, comprehensive, targeted, and practical discharge standard for aquaculture waste water.

3.4 The growth of recreational fisheries

China's recreational fishery started in the 1990s, slightly later than developed countries such as in Europe and the United States, but it has developed rapidly and has become a new bright spot in the development of the modern fishery economy. The "Twelfth Five-Year Plan for National Fishery Development" issued by the Ministry of Agriculture in 2011 included recreational fisheries in the fishery development plan for the first time and clearly listed it as one of the five major industries of modern fishery in China. During the "Thirteenth Five-Year Plan" period, China further proposed to form a modern fishery industry system featuring coordinated development of aquaculture, fishing, processing and circulation, enhanced fisheries, recreational fisheries, along with the integration of primary, secondary and tertiary industries. To objectively reflect the development of recreational fisheries across the country and lead the sustainable and healthy development of recreational fisheries, China launched nationwide monitoring of the development of recreational fisheries in 2017 and issued the "Report on the Development of China's Recreational Fishery Industry" in 2018. Following this, China's recreational fishery has begun to embark on a standardized development path.

In 2019, recreational fisheries were included in the Fisheries Law (Revised Draft). The law adds "recreational fishery" related content to Article 39, and encourages governments at or above the city level to formulate specific management methods for recreational fisheries. As of now, Shandong Province, Zhejiang Province, Fujian Province, Liaoning Province, Dalian City, Weihai City, and other regions have issued regulations on the management of recreational fishing vessels, but there is still a lack of monitoring and specific requirements for fishing gear, catch types, catchable specifications, and catch reports. In addition, the "Measures for the Management of Recreational Fishing Vessels (Draft for Solicitation of Comments)" drafted by the Ministry of Agriculture and Rural Affairs is seeking opinions from all parties.

China's recreational fisheries are divided into five categories: recreational fishing and gathering industry; tourism-oriented recreational fishery; ornamental fish industry; fishing tackle, bait, ornamental fish, fishery medicine; aquarium equipment; and others. As shown in Figure 4, the output value of China's recreational fisheries in 2019 was mainly derived from tourism-oriented recreational fisheries, recreational fishing activities, and gathering industries, which were 44.62 billion yuan and 28.42 billion yuan, respectively, accounting for 47.30% and 30.13% of the national recreational fishery output value. In total, the two categories account for 77.43% of the national recreational fishery output value, while other categories account for relatively small proportions.

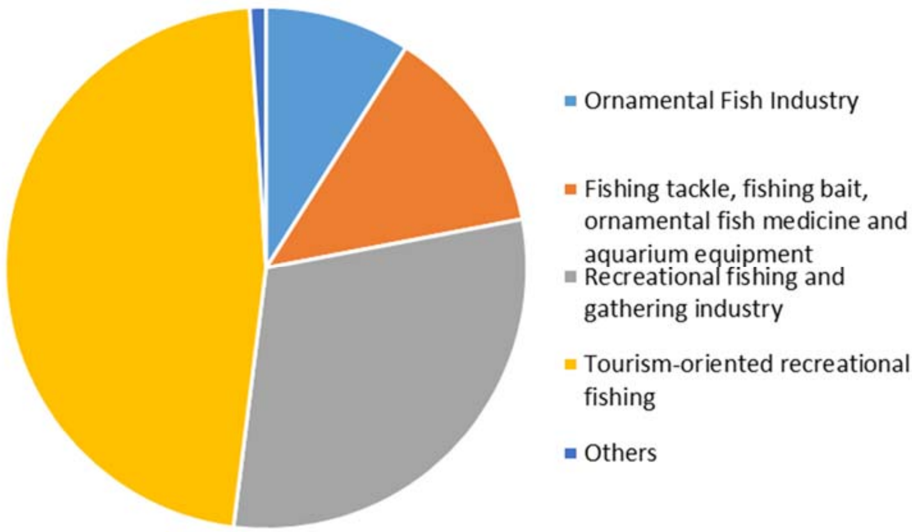

Figure 4 China's national recreational fishery industry structure in 2019

According to the data of China Fishery Statistical Yearbook, since the implementation of recreational fishery monitoring statistics in 2003, the output value of recreational fishery in China and its proportion in the total fishery economic output value show an overall upward trend (Figure 5), with an average annual growth rate of 19.6%. In 2019, the annual output value of recreational fisheries in China reached 94.32 billion yuan, accounting for 3.8% of the total output value of China's fishery economy. From the perspective of industrial geographic distribution, the development of recreational fisheries across the Eastern and Western provinces is quite different (Figure 6). In 2019, the output value of recreational fishery in 11 coastal provinces[1] was approximately 60.232 billion yuan, accounting for 63.86% of the national recreational fishery output value; the recreational fishery output value of 20 inland provinces was approximately 34.086 billion yuan, accounting for 36.14% of the national recreational fishery output value.

Figure 5 The output value of recreational fishery and its proportion in the total economic output value of fisheries industry in China from 2003 to 2019 (Data source: "Monitoring Report on China's Recreational Fishery Development (2020)")

In recent years, the output value of China's recreational fishery and its proportion in the total output value of the fishery economy have increased year by year, and its position in the fishery economy has become more and more important, gradually becoming a new driving force for the growth of China's fishery industry. By analyzing the economic benefits of recreational fisheries and commercial fisheries in the United States, it can be found that although the total output of recreational fisheries is only 2% of commercial fisheries, its total output value is 13 times that of commercial fisheries, and thus recreational fisheries are more cost-effective. China has vast domestic waters, diverse fishery production forms, as well as a profound fishing culture, and collectively, they serve as superior conditions for the development of recreational fisheries. With the continuous increase in the income of Chinese urban and rural residents, the continuous change of lifestyles, along with the increasing demand for culture, tourism, leisure, and experience, recreational fisheries have a great potential for development. The number of recreational fishery operators nationwide has increased rapidly from 110 thousand in 2017 to 134,000 in 2019. Within two years, the number of tourists received nationwide increased from

[1] Including Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, Hainan.

220 million in 2017 to 274 million.

Figure 6 Distribution of the output value of all recreational fisheries in 2019 (Data source: "Monitoring Report on China's Recreational Fishery Development (2020)")

Taking advantage of the development opportunities of China's rural revitalization strategy, the recreational fishery will be deeply integrated with culture, technology, ecology, tourism, poverty alleviation, science popularization, and information to form a comprehensive development pattern of recreational fishery with food, housing, transportation, travel, education, and purchase; this development of diversified leisure business will create a broad world for the development of recreational fisheries. At the same time, however, the development of recreational fisheries also needs to avoid problems such as inadequate understanding, incomplete management systems, lack of laws and regulations, and destruction of the natural environment. It is necessary to strengthen system construction, standardize management, increase resources and environmental protection, and improve the comprehensive quality of the participants to promote the sustainable development of recreational fisheries.

3.5 Sustainable use of fishery resources

In recent years, marine fishery resources are facing increasing human and environmental pressures, and many countries, regions, and non-governmental organizations are taking action to maintain the sustainable development of marine fishery (Yu et al., 2011). China should give full attention to its advantages of marine environment and resources, carry out ecological farming, strengthen scientific and technological innovation, and improve the level of fishery production equipment; Implement sustainable fishery certification, reduce the impact of aquaculture on the environment and society, ensure the healthy and sustainable development of aquaculture, and restore and develop the fishery biological population with the most ecological, economic and cultural values.

（1） Traceability System for Aquatic Products

Since 2003, China has explored the establishment of a traceability system in the aquatic field. The prevention and control of cold chain food safety during the 2020 COVID-19 pandemic has further promoted the traceability management of domestic aquatic products, including extensive coverage of traceability requirements and technological progress. The establishment of a complete traceability management system is the focus of the development of sustainable fisheries. China has a long-standing unsound and unsystematic traceability quality management status, but with the development of E-commerce and the improvement of consumer awareness, some retailers have begun to establish traceable seafood supply chains through information technology.

At present, China’s aquatic product traceability hardware conditions are at a relatively advanced level, but the relevant information in the traceability system has not yet been linked to sustainable development, and it is impossible to identify whether aquatic products on the market come from overfishing areas, whether they are endangered species, and whether they are derived from illegal, unreported and unregulated fishing (IUU), etc.

In April 2017, stakeholders in the international aquatic product industry jointly established the Global Dialogue on Seafood Traceability (GDST) platform, which aims to confirm the key data of the traceability system, coordinate global interoperability of software technical parameters, and improving the policy consensus of various countries; this is to push towards the formation of a voluntary traceability standard or framework for the aquatic product industry with broad consensus and recognition. In the platform, the World Wide Fund for Nature and the Global Food Traceability Center lead 11 industry-leading GDST member companies and associations as the steering committee, linking more than 80 companies and organizations, and international seafood supply chain companies, technical experts, non-governmental organizations, and civil society stakeholders to jointly promote the development of GDST global industry standards. After three years of consultation, the GDST Interoperable Aquatic Product Traceability System Standard Guide Version 1.0 was released on March 16, 2020 (Referred to as "Aquatic Product Traceability Guide"). With the adoption and implementation of the aquatic product traceability guidelines, the efficiency, interoperability, reliability, and enforceability of aquatic product traceability will be greatly improved, helping companies to obtain and share the required origin (of products) along with other essential information, and ultimately help establish a more transparent and reliable aquatic product supply chain in the industry to support the relevant needs of consumers and the government and promote the sustainable and healthy development of the industry. Since its establishment, GDST has been actively cooperating with Chinese stakeholders, including the China Aquatic Products Circulation and Processing Association, Hong Kong Convention and Exhibition Centre, and Luen Thai Fishing Venture, as well as other companies; altogether, the members contributed to the Chinese power and jointly promoted the formulation of aquatic product traceability guidelines.

（2） Sustainable Fisheries Certification

In recent years, China's aquatic product production and processing industry has developed rapidly, and the output value of foreign exchange earnings from exports has ranked first in the trade of bulk agricultural products for many years. As an operable and identifiable means, a certification is a favorable tool for leveraging the coordinated development of marine protection and industrial economy through the market. Carrying out aquatic product certification can enhance its brand competitiveness in domestic and foreign markets, improve the sustainability of fishery production and the added value of products, and effectively reduce the pressure on fishery resources. At present, the domestic aquatic product standard system mainly includes the international Best Aquaculture Practices, the Aquaculture Stewardship Council, the Marine Stewardship Council, as well as domestic organic products and green products[1]. Among them, the strict certification standards for organic products are conducive to protecting the environment and ecological diversity, giving consumers more choices, and allowing businesses with good production conditions to obtain higher benefits. Compared with organic certification, green products are less strict, more in line with the reality of China's agriculture, and are conducive to promoting fishermen to improve their breeding environment.

Both international and domestic certification standards have their pros and cons. Due to the higher professionalism and comprehensiveness of international certification, in recent years, it has rapidly gained recognition and markets such as E-commerce platforms, international retail brands, star-rated hotels, and catering chains in the Chinese market. After some domestic aquaculture companies have obtained international certification, they have also been recognized in the export market, and their output and sales have increased; however, the actual operability of international certification in developing countries is low, and many product requirements are too high, making it difficult for domestic producers to achieve higher sales in a short time. Although the application of domestic standards is relatively high, due to the lack of strict supervision of certification, there are many fake organic and green-certified products

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[1] The Best Aquaculture Practice (BAP) certification established by the Global Aquaculture Alliance (GAA) is an authoritative third-party aquatic product certification that is trusted in the international market and widely adopted by the end market. Aspects to its authoritative standard are aquatic food safety, sustainable development, and social responsibility and animal welfare. The Aquaculture Stewardship Council (ASC) aims to manage global standards for responsible aquaculture; the two main goals are environmental friendliness and social responsibility. The Marine Stewardship Council (MSC) supports the development of China’s regional sustainable fisheries and expands the number of certified aquatic products in China by promoting sustainable wild capture fisheries standards, production and marketing chain-of-custody standards and eco-labeling projects, and is committed to creating a more sustainable China's aquatic product market.

on the market, and consumers' recognition of these certified products is not high.

There are still certain obstacles to promoting sustainable fishery development in China through sustainable fishery certification. First, the scope of certification is still limited. Small businesses are subject to financial and technological constraints, and generally do not apply for certification. Large companies have strong funds, but most of them will apply for certification only when they are facing export demand. At the same time, the fishery and aquaculture improvement projects and certifications at this stage are mostly promoted from the procurement side, which has certain opportunistic characteristics and lacks strategic and long-term planning. In addition, China’s coastal fisheries tend to be mainly consumed locally or domestically, and the market and supply chain are distributed and fragmented, and there is little demand for certified sustainable products. Therefore, certification methods based on foreign trade-based supply chain mechanisms are more difficult to implement in terms of promoting the sustainable development of China's coastal fisheries.

In response to the challenges mentioned above, feasible development directions for China in strengthening the construction of aquatic product traceability systems and sustainable fishery certification have been put forward in Box 7.

Box 7: The Development Direction of Sustainable Utilization of China's Fishery Resources

The production of domestic seafood is the cornerstone of local food security. Led by the government, explorations should be made in the traceability and quality supervision of seafood products to establish a sound legal system with reference to mature foreign experience. It is necessary to fully mobilize the market mechanism to improve the efficiency of resource allocation, explore professional sustainability standards, and take advantage of the rapid development of the national traceability platform to support the industry and GDST and other global frameworks to communicate and connect, while focusing on the inclusion of the following key data: 1) Fishing area; 2) Fishing method; 3) Whether the fish species is in the list of endangered species (National Key Species Protection List, IUCN Red List of Endangered Species, Sustainable Seafood List, etc.); 4) Whether the fishing vessel is registered, etc. Through the collection, recording, storage, and full traceability of information, solve the problem of information asymmetry, simultaneously reducing the quality and safety risks of seafood products and improving the efficiency of supervision. Make full use of internet technology to improve the traceability management of production and processing, establish a reasonable sales model by understanding market demand, carry out targeted marketing activities, and create a new model of "smart seafood supply chain".

In addition, with the increasing development of China's aquatic production and processing industry, aquatic products are gradually moving closer to internationalization, and the export volume of aquatic products is growing rapidly; China needs to develop a local sustainable certification model. This can be done by referring to the improvement of fishery in different regions of the world, systematically sorting out and analyzing the development of sustainable certification, and formulating a blueprint for sustainable fishery development. To establish a certification system that suits China's national conditions (in a step-by-step manner), refer to international certification standards and management methods, improve quality standards and credit systems, fully consider the different needs of large-scale enterprises and small businesses, and implement voluntary and market-oriented principles.

The construction of a sustainable certification system requires understanding the supply chain and consumers' attitudes and understanding of certification, strengthening policy support and publicity and guidance, jointly promoting sustainable aquatic product certification and selection with the industry, and improving the linkage between the upstream and downstream of the supply chain; furthermore, innovative incentive mechanisms can attract more companies to participate in certification spontaneously. In addition, collaborative work within the industry and the public can be done to crack down on illegal and counterfeit certified products, create a safe and secure consumer environment, and vigorously popularize certification information; this can not only convey knowledge about aquatic products to consumers, and enhance consumers' ability to distinguish between various products, but also help improve consumers' recognition of certified aquatic products to continuously increase their market share.

To promote a truly green fishery supply chain, the following aspects should be considered:

- Whether the fish caught species are endangered species;
- Whether fishing or aquaculture seriously affects natural habitats (invading wetlands, tidal flats, protected areas, etc.);
- Whether the fishing comes from legal fishing and traceable sources, there is no IUU risk;
- Whether it comes from the Fishery Improvement Project (FIP/AIP) or has obtained credible and responsible certification;
- Whether there are avoidable losses and wastes (such as bycatch of endangered species and juvenile fish), etc.;

In the process of building a green supply chain, the upstream and downstream industries should be encouraged to recognize and promote together to ensure that the linkage of the supply chain is used to leverage the best production practices to help protect the ocean. Especially for issues with relatively weak awareness of the domestic industrial chain, such as the definition of species-based risks and sustainability, fishery improvement projects with a relatively long time span, etc., support from marine protection, fishery policies, public procurement, and industry promotion, can include:

- Carrying out benchmarking and sorting of domestic and foreign fishery improvement and certification, and strengthening policy promotion, including basic research, data storage, mechanism benchmarking, and scale expansion, so as to support the integration of China's fishery management with internationally accepted indicators;

- Encouraging industry associations and market entities to give greater recognition to credible improvement projects, and prioritize the inclusion of credible improvement project products in public procurement;
- Supporting organizations such as industry associations to build a sustainable platform that includes a comprehensive system, including all aspects of the green fishery industry chain and standard benchmarking;
- Strengthening international exchanges and interactions, enhancing international integration, and supporting a more sustainable international supply chain and trade of aquatic products.
- Raising public awareness/green lifestyles of sustaianble choices, and link sustainability to human health benefits.

4. Consensus and suggestions

4.1 Strengthening marine fishery resource assessment, natural capital accounting and management system optimization

Effective protection of China's marine ecological resources and fishery resources requires an understanding of their value and importance. First of all, China should give priority to the development of scientific research and tools related to the development of marine and fishery resources. Through marine resource surveys, the species diversity, population number and distribution of index species, breeding period, ecosystem connectivity, and habitat fragmentation should be ascertained. Furthermore, China should promote the standardization of scientific methods and technologies to provide a basis for the scientific delineation of protected areas and the design and implementation of protection management plans. China should also conduct baseline research on marine ecosystem value accounting, strengthen cooperation between provincial governments and research institutions, and identify the marine ecological hotspots with the highest natural capital to provide the strongest protection measures.

Second, China should focus on studying the nation’s marine economic activities and development plans, understanding their dependence on and interrelationships with marine capital, and correctly assessing the impact of coastal development and various activities on marine natural capital. If conditions permit, it is also possible to conduct relevant research on the economic development of coastal communities to provide a scientific basis for the subsequent sustainable development of fishery and industrial transformation.

Third, in terms of marine natural capital management, China should strengthen high-level communication and cooperation between the central and provincial governments, collaboration between different administrative departments, and international exchanges and cooperation. Priorities should be given to the creation of marine national parks, build an effective ocean protected areas network system to increase marine protected areas and the protection of key species and habitats.

4.2 Build and strengthen foundational research and management insitutions for climate resilient fisheries

Climate change has clear impacts on the distribution and productivity of marine fisheries resources in China, as well as on the livelihoods of its fishers and coastal communities. We recommend that China strengthen its work related to climate change and fisheries in the following ways. First, policymakers should examine how marine resource management goals must adapt to changing ecosystem dynamics as climate changes. Climate change resilience should be built into marine management approaches, including funding and investment in necessary science to identify appropriate management benchmarks, monitor changes in species abundance and distributions over time, and develop forward looking policies to minimize risks under uncertainty. This should include a national climate-fisheries adaptation strategy, integrating climate adaptation to national and local fisheries planning, priotitizing fisheries and coastal communities in national climate adaptation initiatives, and developing both medium and long-term plans for fisheries to effectively respond to climate change. Second, China should strengthen the resilience of marine ecosystems by establishing effective fisheries management today, reducing cumulative stresses placed on marine ecosystems from both climate and non-climate stressors, planning for sea level rise impacts on coastal communities and habitats, and protecting and restoring diverse habitats that are critical for species likely to remain present in the region as well as those likely to move in. Third, China should seek opportunities to build and strengthen international institutions to ensure adequate authority to manage new fish stock distributions and inclusivity of affected countries. This requires collaboration and agreement on basic science concerning fish stocks, regional agreements on management goals for changing fish stock portfolios, establishing access and resource sharing agreements that adapt to changing conditions. Such collaboration will enhance China's capacity to adapt to climate change and its ability to participate in relevant international affairs.

4.3 Advancing sustainable fishery development with nature-based solutions

Nature-based solutions restore the ecological environment with natural structure and strength, maintain the balance of the ecosystem, and reduce the cost of operation and maintenance. Therefore, in the process of promoting sustainable fisheries development, China can encourage nature-based solutions from many aspects, including exploring relevant scientific foundations and technologies, designing clear indicators, standards and management mechanisms, and large-scale application of pilot results, supporting the development of long-term and profitable business models, etc. When developing and designing nature-based solutions, we should also refer to relevant principles (WWF, 2020) and standards (IUCN, 2020) that are already available internationally, and formulate implementation plans and management systems that comply with China. For example, China's implementation plan should improve climate response capabilities and ecosystem functions (climate change adaptation or mitigation, support for ecosystem functions, etc.); set achievable and measurable goals based on science; reflect the nature and society synergies while protecting nature and balancing other social goals; design and implement with coastal communities and stakeholders to understand their most pressing challenges and establish joint responsibilities; ensure that project results can be quantified through strong monitoring, evaluation, and reporting framework, reflecting measurability and accountability.

4.4 Strengthening the protection of fishery resources in coastal trawling-prohibited zone (TPZ)

Bottom trawling can create serious damage in marine ecosystems and can cause devastating effects on benthic organisms and ecological communities. It is the most unsustainable fishing method. In 1955, China issued an order on the prohibited fishing zone line of the Bohai Sea, the Yellow Sea, and the East China Sea. It stipulated that the prohibited fishing zone line should be composed of 17 base points. Since 1981, all locomotive bottom trawl nets are prohibited from entering the TPZ. However, despite being repeatedly banned, bottom trawling has yet not been eliminated in China's coastal waters (including those within the TPZ). According to "China Fishery Statistical Yearbook", nearly 50% of China's coastal fishing output comes from poorly selective trawling operations. Therefore, it is recommended that trawling operations should be prohibited in the TPZ, while the structure of coastal fishing operations should be adjusted to gradually reduce the amount of trawling, and increase the scale of angling and gillnet fishery to a reasonable level.

4.5 Continuously improving the implementation of TAC policy in China

Based on the experience of the nine pilots of quota control in coastal provinces (cities), strengthening the single species resources survey and total allowable catch assessment of major economic species in China coastal oceans. Explore ways to gradually expand the total catch control to all major economic species, such as small yellow croaker, striped bass, blue-spotted horse mackerel, mackerel, conger eel, *Collichthys lucidus*, and Pacific pleated squid. Explore a new model of TAC that is suitable for China's coastal multi-species fisheries, and improve the feasibility of full implementation of the TAC in China. Based on the pilot experience, improve the catch monitoring system of coastal fisheries by integrating the supervisory power of fishery, maritime affairs and market affairs administrations, to guarantee the orderly implementation of

TAC. Finally, the central and local legislation of the TAC should be strengthened to provide legal guarantee for the smooth implementation of the system nationwide.

4.6 Enhancing the sustainable management of China's fish supply chain

China's aquatic products market is characterized by a wide range of producers, a wide variety of products, and a variety of marketing channels. In order to achieve the whole process of protection and management from source to table, it is suggested that China should develop unified recognition standards as soon as possible, such as Fishery Improvement Program (FIP), Aquaculture Improvement Program (AIP), Sustainable Fishery, and Sustainable Aqualculture Standards. On the basis of extensive industry and market research, absorbing the parts of the existing international standards that can be used as reference, developing standards for the characteristics of different fish species for domestic sales and export sales, and eventually publishing and promoting the application of the standards by authoritative institutions, and developing regulatory measures for the new standards on the basis of the existing regulatory system to effectively guarantee a high quality implementation. On the other hand, the traceability management of Chinese aquatic products should also be increased. In this process, we should not only learn from international advanced experience, but also make use of platforms such as GDST for international benchmarking to promote sustainable development of the industry with traceability management.

4.7 Scientific and standardized recreational fisheries management to promote the sustainable and healthy development of recreational fisheries

In recent years, with policies to reduce China's active fishing vessels and marine catch and relocate fishermen, while higher incomes among China's urban and rural residents alike are shifting preferences for culture, tourism, and leisure, China's recreational fisheries have developed rapidly and become a new highlight in the modern fishing economy. The growth in recreational fishing takes advantage of China's rural revitalization strategy. However, it reveals several problems, such as poor understanding of the industry and necessary management responses, an unsound management system without needed laws and regulations, and potential impacts on the natural environment. There is a need to strengthen management institutions by demonstrating the feasibility of TAC and area-based management systems in recreational fishing, implementing science-based and standardized management systems, strengthening monitoring, catch and effort reporting, and stock assessments, and increasing resource and environmental protections. Policymakers also should seek to cultivate the knowledge of recreational fishing practitioners, promote the sustainable development of recreational fisheries, and enable fishermen to obtain sustainable economic benefits while participating in protection of fishery resources.

4.8 Exploring the fishery resource protection mode of community participation and joint management

In the past, the protection of fishery resources was mostly promoted through a top-down approach, which required high government resources and had limited management effectiveness. It is recommended to integrate community and social resources and explore a common management model for fishery resource protection. For example, give full play to the enthusiasm of the local community, organize training, publicity, and other activities to popularize in-depth knowledge of the ecological functions, environmental economic value, and other knowledge, obtain the recognition and support of the local residents, and guide the local residents to assist in ecological resources (such as the location of major fishing grounds, the distribution of important local natural resources, etc.) and cultural research, and carry out community-participated resource protection work through their production and life. Experience may be drawn from the river keeper model for public welfare litigation, for which citizen science helps protecting coastal areas and reporting violations. Another example is the introduction of local communities, enterprises, and fisheries organizations, in establishing protected area observer monitoring networks, encouraging local fishery practitioners to participate in monitoring and observation, gradually expanding the number of participants in protection work, improving the quality of protection personnel, and expanding protection projects from point to point, enlarge the scope of influence, strengthen the ecological environment supervision and management capabilities of marine protected areas, and achieve the goals of marine ecological environment and resource protection. On this basis, people with certain experience and willingness to support the work of protected areas and sustainable industrial transformation can be organized to form a network of leaders, enhancing the sense of belonging of local residents, and driving their support and participation in conservation work. In addition, under the premise of orderly management and environmental protection, it is necessary to cultivate the quality of recreational fisheries practitioners, promote the sustainable development of recreational fisheries, and enable fishermen to obtain sustainable economic benefits while participating in the protection of fishery resources.

4.9 Promoting sustainable fishery development by green finance

At present, China has incorporated marine protection into the green financial system. For example, the Green Industry Catalog issued by the National Development and Reform Commission in 2019 has listed marine eco-friendly projects and technologies (seawater pollution control and marine ecosystem restoration) as key support objects. In the context of the rapid development of global green finance, China's sustainable fishery development also needs to use green finance tools to innovate models to provide more financial incentives for naturally active fishery projects. For example, develop fishery financial institutions, issuing special loans without a mortgage for sustainable fishery production, or subsidizing fishery loan interest from financial institutions; establishing a fishery guarantee insurance system to solve the problem of insufficient guarantees for fishery producers' loans; strengthen financial institutions reputational risk supervision, by reminding them of potential reputational risks that may be caused by illegal fisheries and providing technical guidelines; learn from international protection experiences, using innovative mechanisms to absorb social capital into sustainable ocean projects, promote green financial tools, and expand funding sources.

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