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A Proposed Scheme of Fishing Quota Allocation to Ensure the Sustainable Development of China's Marine Capture Fisheries

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The sustainable development of marine capture fisheries (MCFs) plays a significant role in food security, economic development, and employment stability. The lack of information on the sustainability of MCFs, along with the inadequate management of fisheries output controls, has weakened China's efforts towards a national catch limit target of no more than 10 million tons from capture fisheries until 2020. Furthermore, overfishing and fishery conflicts still exist. In order to try and resolve the above problems and achieve the sustainable use of fishery resources, an evaluation of the development status of these fisheries based on the coupling coordination model has been undertaken. The results show that the social, economic, and biological systems of MCFs in coastal areas of China interact with each other while their development is not coordinated, and regional differences exist. This study integrates the socioeconomic indicators using the catch-share program as a breakthrough methodology to resolve inconsistencies. The results under different allocation schemes suggest that the multifactor scheme is more equitable than the single-factor scheme, which enhances the fairness of the initial distribution.

Keywords: catch share, socioeconomics, entropy method, coupling coordination, sustainability

1 INTRODUCTION

In recent decades, the issues of marine capture fisheries (MCFs) have attracted worldwide attention (Pearce, 1991; Pauly et al., 1998; Grafton et al., 2008). According to FAO data, the total global capture fisheries production reached 96.4 million tons in 2018, among which marine fisheries contribute about 87%. Marine fisheries have expanded rapidly, and around one-third (34.2%) of fish stocks were reported to be at biologically unsustainable levels in 2017 (FAO, 2021), with overfishing recognized as a serious global problem. As the largest fishery producer, China has strongly expressed its responsibility and commitment to sustainable resource utilization by undertaking a series of management actions. On January 12, 2017, the Ministry of Agriculture and Rural Affairs (MARA) of the People's Republic of China set out targets for controlling the number of fishing vessels and reducing the amount of marine fishing in the 13th Five-Year Plan (2016–2020) (MARA, 2017). Subsequently, MARA issued the notice of the national fishery development plan in the 14th Five-Year Plan (MARA, 2022), which strengthens fishery ecological construction and promotes fishery transformation.

A collapse of fishery stocks in China due to overfishing and environmental pollution, among other factors, is challenging management arrangements (Liu and De Mitcheson, 2008). To achieve the sustainable use of fishery resources, there is a need to evaluate the development status of MCFs. The coupling coordination model is used to analyze the coordinated development level of systems, and it includes two important indicators: coupling degree and coupling coordination degree. The coupling degree is the level of interaction that reflects the relevance between subsystems (Liu et al., 2002), whereas the coupling coordination degree reflects the level of coordinated development within the subsystems (Fang et al., 2016). The coupling coordination model has been applied maturely in aspects of urbanization and related ecological relationships (Li W. et al., 2021), and in social and economic security (Li Q. et al., 2021). In recent years, it has been gradually applied to the marine field (Lin, 2020). Resource development cannot be at the expense of social and economic sustainability (Heal and Schlenker, 2008). Research on the development status of the comprehensive MCFs will assist in avoiding investment redundancy and thus improve resource utilization.

The property rights of marine fish are ambiguous in the absence of legislative controls, with many resources considered to be common property and open access (Gordon, 1954). Therefore, unmanaged fisheries experience competitive "race-to-fish" issues that affect sustainability outcomes. For decades, the blind pursuit of high fishing yields has resulted in problems such as excess input, declining fishery resources, declining quality of catches, poverty of fishermen, and ecological damage, which has severely constrained the process of sustainable development (Pomeroy et al., 2016; Spijkers et al., 2018; Tsilimigkas and Rempis, 2018; Chen and Zhou, 2020). However, it is difficult for resource users to maintain public resources through self-control, which by necessity must be regulated by the government (Ostrom, 2009). In order to protect fishery resources, a series of fishing regulations have been put forward, including gear restrictions, fishing vessel management, fishing ground access, and fishing period management (Shen and Heino, 2014; Su et al., 2020). These traditional fishery management arrangements are focused on controlling fishing effort and opportunities rather than limiting catch and do not address the issue of property rights (Gao and Gao, 2008; Su and Chen, 2021).

To address overfishing, both the excess fishing effort and the competitive race-to-fish practice should be reduced (Griffith, 2008). Total allowable catch (TAC) allocations, based on maximum sustainable yield (MSY), is the yield management program that determines the maximum yield of a specific fish species or fishery in a given area of water (Karagiannakos, 1996). Allocations based on a TAC can be used to allocate catch shares as a form of property rights (National Oceanic and Atmospheric Administration (NOAA), 2017). Catch-share management programs are one tool that can effectively eliminate the biological impacts of competing fishing and achieve catch limit targets (Costello et al., 2008; Griffith, 2008; Melnychuk et al., 2012). However, disputes over catch share management programs still exist. MCFs are an integrated industry encompassing catching, processing, and trading. However, according to Lynham's research (Lynham, 2014), almost all fisheries in the world are allocated based on historical catches. Therefore, the fairness of the initial distribution has been questioned.

The main segment of catch-share implementation is the fishing quota allocation. As mentioned earlier, the aspects of socioeconomics cannot be ignored in the sustainable development framework (Bennett et al., 2021). This study brings socioeconomic factors and historical catches into these frameworks, constructs the allocation scheme of a catch-share program, improves the rationality and fairness of the initial allocation, and ensures a better balance between socioeconomic benefits and the sustainability of fishery resources. This model provides the basis for the implementation of a catch-share management program in China and provides new perspectives for other countries to improve their catch-share programs.

2 MATERIALS AND METHODS

2.1 Regional Areas and Data

For the regional areas analyzed herein, 11 regions are examined: Liaoning, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, and Hainan (**Figure 1**). They are coastal areas of China, which represent the range of development states of China's marine capture fisheries to a certain extent.

The data are from China's Fishery Statistical Yearbook from 2010 to 2019 (Bureau of Fisheries of the Ministry of Agriculture, 2011-2020). Multiple indicators are included, the magnitude of which is different. Considering the above facts, the min–max method to standardize the data is taken. The details are in Sections 2.3 and 2.4.

Positive data,

$$X_{S+} = \left(Xij - \min X.j\right) / \left(\max X.j - \min X.j\right)$$

Negative data,

$$X_{S-} = \left(\max X.j - Xij\right) / \left(\max X.j - \min X.j\right)$$

2.2 Entropy Method

The entropy method is an objective weighting method that determines the index weight according to the information provided by the observed values of each index (Shannon, 2001; Weng et al., 2022). The smaller the information entropy of the index, the greater the amount of information provided by the index and the greater the weight. First, the original data are standardized according to formulas (1.1) and (1.2), where X_{ij} is the value of index j of the i scheme.

$$A = \begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \vdots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{bmatrix}_{n \times m}$$

Estimate the proportion of scheme i under index j ,

$$P_{ij} = \frac{X_{ij}}{\sum_{n=1}^{n} X_{ij}} \left(j = 1,2,\cdots m \right)$$

Based on the concept of entropy, the entropy of the index j is estimated:

$$e_j = -k * \sum_{i=1}^{m} P_{ij} \ln\left(P_{ij}\right)$$

where $k > 0$. ln is the natural logarithm, $e_j \geq 0$, k is related to the number of sample s M , generally, let $k=1/lnm$, then $0 \leq e \leq 1$. For the indicator j , the greater the difference of X_{ij} , the greater the effect on the scheme evaluation and the smaller the entropy. The difference coefficient $g_j=1-e_j$, namely the larger g_j is, the more important the index is.

Estimate the weight of index j ,

$$W_j = \frac{g_j}{\sum_{j=1}^{n} g_j} \quad j = 1,2,\cdots n \; ; \; 0 \geq W_j \leq 1$$

2.3 Coupling Coordination Degree Model

MCFs are complex multilevel systems. The development of any subsystem will affect the coordinated development level of the whole system. Based on the coupling coordination theory, the model for the sustainable development of MCFs is constructed. The calculation process is as follows.

The comprehensive level function of each subsystem is defined as below,

$$f\left(x\right) = \sum_{i=1}^{n} \alpha_i x_i \quad g\left(y\right) = \sum_{i=1}^{n} \beta_i y_i \quad h\left(z\right) = \sum_{i=1}^{n} \gamma_i z_i$$

Where $f(x)$, $g(y)$, and $h(z)$ represent the comprehensive evaluation function of the biological, economic, and social systems of MFCs in the study area, respectively; x_i , y_i , and z_i are the standardized data describing the index i under the biological, economic, and social systems; α , β , and γ are the corresponding weight of each index under the biological, economic, and social systems.

The coupling degree model is then,

$$C = \sqrt[3]{\frac{\left(f\left(x\right) * g\left(y\right) * h\left(z\right)\right)}{\left[\left(f\left(x\right) + g\left(y\right) + h\left(z\right)\right)/3\right]^\wedge 3}}$$

Where C is the coupling degree, a key indicator reflecting strong and weak relationships between subsystems. The value range of C is 0–1. The closer the value of C is to 1, the greater the coupling degree is and the closer the relationship between the subsystems is. On the contrary, the closer the value of C is to 0, the smaller the coupling degree is, allowing the system to be in a state of disorderly development. In short, the correlation degree of the systems can be judged according to the coupling degree.

Taking the D value to reflect the overall coupling coordination of the regional areas, its calculation formula is as follows:

$$D = \sqrt{C * T}$$

$$T = af\left(x\right) + bg\left(y\right) + ch\left(z\right)$$

T is the comprehensive evaluation index, and the three dimensions of biology, economy, and society are regarded as equally important, taking $a=b=c=1/3$.

Based on the existing research on the sustainable development of MCFs and combined with the development status and the opinions of experts in relevant disciplines (Garcia et al., 2000; Ding, 2017; Xu et al., 2021), 13 indicators are selected to build an evaluation system for the sustainable development of MCFs in China's coastal areas (**Table 1**). Although these indicators do not cover all aspects of measuring fishery sustainability, they represent frequently reported indicators and are easy to compare among fisheries. The weight of each index is objectively calculated by the entropy method.

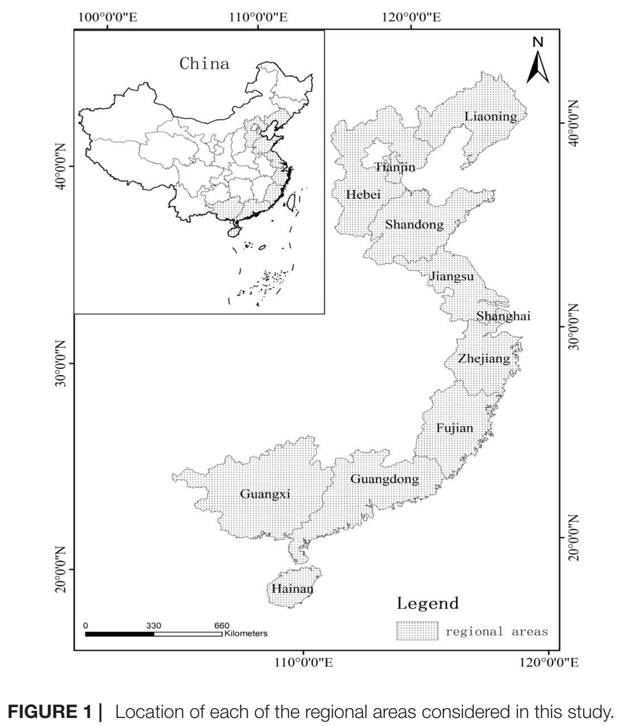

FIGURE 1 | Location of each of the regional areas considered in this study.

TABLE 1 | Index system of sustainable utilization of marine capture fisheries.

Target layer	Criterion layer	Index layer	Unit	Nature of index	Weight
Coordinated development of marine capture fisheries	Biological (*X*) system	Mariculture production (X_1)	Tons	Positive	0.31
		Marine catch per ton of marine motorized fishing vessels (X_2)	Tons	Positive	0.09
		Marine catch per kilowatt of marine motorized fishing vessels (X_3)	Ton/kW	Positive	0.08
		Marine catch per marine motorized fishing vessels (X_4)	Tons	Positive	0.25
		Proportion of marine fish catch in the total marine catch (X_5)	%	Positive	0.27
	Economic (*Y*) system	Economic output value of mariculture (Y_1)	10,000 RMB	Positive	0.35
		Economic output value of marine fishing (Y_2)	10,000 RMB	Positive	0.30
		Per capita net income of fishermen (Y_3)	RMB	Positive	0.22
		Fishery disaster and economic loss (Y_4)	10,000 RMB	Negative	0.13
	Social (*Z*) system	People engaged in marine fishing (Z_1)	Individual	Negative	0.20
		People engaged in marine fisheries (Z_2)	Individual	Positive	0.38
		Proportion of marine fishing employees in marine fishery population (Z_3)	%	Negative	0.11
		Proportion of marine fishery employees in fishery population (Z_4)	%	Positive	0.31

2.4 Catch Share Based on Biosocioeconomic Index

Catch-share systems represent one approach to the management of fishery resources in the world (Melnychuk et al., 2012), and China is currently in the preliminary experimental stage of formulating a fishing share allocation policy. This study, combined with the socioeconomic dimension, explores the allocation of fishery resources under different dimensions, optimizes the allocation of resources, and enhances the awareness of sustainable development.

First, the value of socioeconomic biological indicators in the study area is defined as,

$$B_i = W_b X_b \quad E_i = W_e Y_e \quad S_i = W_s Z_s$$

X_b , Y_e , and Z_s are the standardized data value of biological (*B*), economical (*E*), and social (*S*). W_b , W_e , and W_s are the weight value of X_b , Y_e , and Z_s . B_i , E_i , S_i are the biological (*B*), economical (*E*), and social (*S*) index values of province i .

The socioeconomic biological comprehensive value Q_i of province i is,

$$Q_i = B_i + E_i + S_i$$

The allocation proportion of the fishing share of province i can then be obtained,

$$P_i = \frac{Q_i}{\sum_{i=1}^{m} Q_i}$$

Based on the research of Ostrom (2009) and Partelow (2018), combined with the actual situation of MCFs in China's coastal areas (Li et al., 2019), the socioeconomic and biological indicators of the catch share are selected. The average data of indicators related to MCFs from 2010 to 2019 are used (see **Table 2**).

3 RESULTS

3.1 Definition of Coupling Coordination of MCFs

Based on the above, the mean value of the coupling degree (*C* value) (**Figure 2**) of MCFs in 11 coastal areas of China was calculated. On the whole, the coupling degree has been on the rise over the last decade; the annual coupling mean value is at a high level, and the lowest coupling value also reached 0.8726 (close to 1), which is in the stage of high-intensity coupling. In total, the biological, economic, and social systems under MCFs are highly correlated.

Based on Liao's research (Liao, 1999), the classification standard is set (**Table 3**). The coupling coordination degree involves two categories in this study, namely, basic coordination [0.3, 0.6) and good coordination [0.6, 0.8), which are subdivided

TABLE 2 | Index system of constructing catch shares.

Province	Capture value of marine fishing (10,000 RMB)	Capture of marine fishing (tons)	Numbers of traditional fishers (individual)
Tianjin	136,238.32	32,202.30	5,348
Hebei	423,434.32	236,336.90	135,751
Liaoning	1,328,769.50	905,643.70	368,466
Shanghai	192,614.78	17,799.80	4,866
Jiangsu	1,535,288.20	536,052.10	180,713
Zhejiang	3,840,264.10	3,097,457.30	384,758
Fujian	3,009,395.12	1,876,309.70	737,006
Shandong	3,423,969.18	2,141,482.20	970,005
Guangdong	1,333,430.02	1,427,151.60	511,192
Guangxi	941,020.85	632,162.60	251,344
Hainan	1,647,259.38	1,155,426.00	196,540

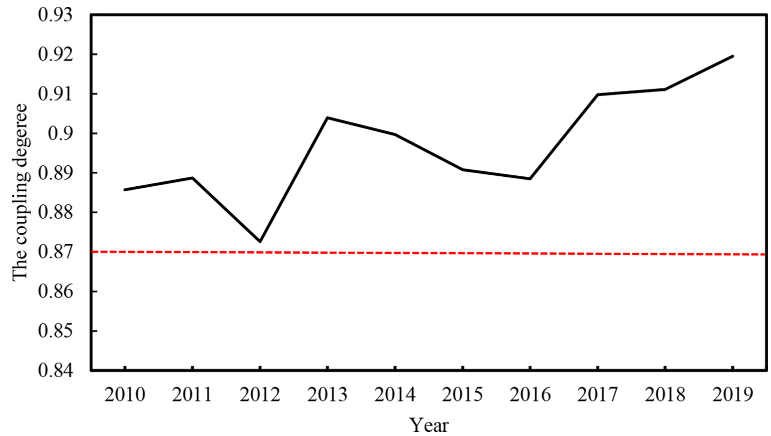

FIGURE 2 | Mean coupling degree of marine capture fisheries coordinated development subsystem in 11 coastal areas of China from 2010 to 2019.

into five subcategories: mild disorders [0.3, 0.4), on the verge of disorders [0.4, 0.5), barely balanced development [0.5, 0.6), primary balanced development [0.6, 0.7), and intermediate balanced development [0.7, 0.8).

According to the classification standards, the range of the coupling coordination degree (*D* value) of MCFs in 11 coastal areas of China is from 0.3769 to 0.7703 (**Table 4**). Specifically, 1 is at the level of mild disorders, 11 at the level of being on the verge of disorders, 6 at the level of barely balanced development, 67 at the level of primary balanced development, and 25 at the level of intermediate balanced development. In total, the mean value of the overall coupling coordination degree is at the level of primary balanced development, which shows that the current development structure of MCFs in China is unreasonable, the input of production factors is redundant, and the unexpected output is excessive, resulting in the loss of fisheries' ecological and social efficiency and a low overall utilization rate.

The spatial pattern map of the coupling coordination degree is drawn using ArcGIS. The coupling coordination degree of MCFs in China is different spatially (**Figure 3**). Specifically, the coordinated development of Tianjin, Hebei, and Shanghai with the 11 coastal areas is relatively weak. The *D* value of Shanghai has been on the verge of disorder classification level except in 2016. The comprehensive development levels of Shandong, Zhejiang, Guangxi, and Hainan are relatively good (in comparison to other regional areas only), and the remaining areas are basically at the primary balanced development level. In short, the sustainable development level of China's MCFs is uneven in regional development, and the overall level needs to be improved.

In conclusion, the social, economic, and biological systems in the MCFs of China are highly interrelated and interactive, with excessive investment in production factors, mismatched social and economic benefits, a low overall coordinated development level, and uneven spatial development. We need to seek breakthroughs in high-quality and balanced development.

3.2 Catch Share

Based on **Table 2**, the objective weights of socioeconomic and biological indicators of catch shares are determined by the entropy method, which is 0.33 (social), 0.32 (economic), and 0.34 (biological), respectively. To explore the effects of catch-share management programs under different indicators, the allocation scheme is extended to seven scenarios (**Table 5**). Scenario 1 is an objective preference decision obtained by the entropy method. Scenarios 2, 3, and 4 highlight society, economy, and biology, respectively, and keep the weight of the remaining indicators lower than the preference indicators. Scenario 6 is a traditional allocation decision used by most fisheries, based only on historical catch data. Scenario 5 includes only social indicators, and scenario 7 includes only economic indicators.

There are obvious differences in the proportion of catch-share allocations under the different decision preferences (**Figure 4**). The seven scenarios can be divided into single factor and multifactor, with scenarios 1–4 belonging to multifactor

TABLE 3 | Classification standard for the degree of coupling coordination.

Interval	[1, 0.1]	[0.1, 0.2]	[0.2, 0.3]	[0.3, 0.4]	[0.4, 0.5]	[0.5, 0.6]	[0.6, 0.7]	[0.7, 0.8]	[0.8, 0.9]	[0.9, 1]
The coupling coordination (D)	Extreme disorders	Serious disorders	Moderate disorders	Mild disorders	On the verge of disorders	Barely balanced development	Primary balanced development	Intermediate balanced development	Good balanced development	High-quality balanced development
Color										
Main categories	Low coordination			Basic coordination			Good coordination		Excellent coordination	

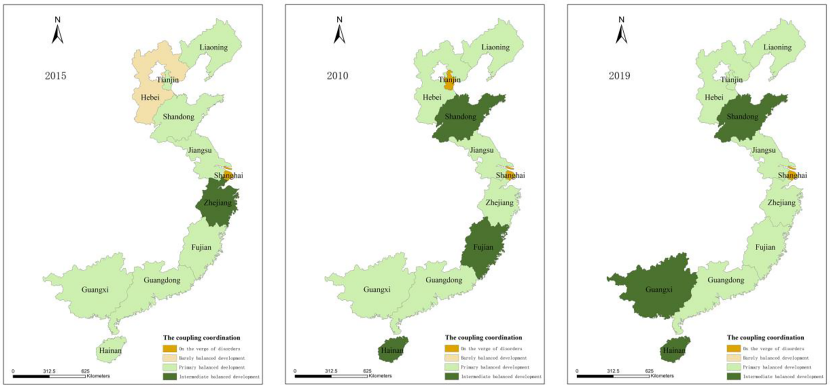

FIGURE 3 | Coupling coordination degree of China's 11 coastal areas in 2010, 2015, and 2019.

scenarios, and scenarios 5–7 belonging to single-factor scenarios. On the whole, the distribution proportion under the multifactor scenario is steadier, and the multifactor scenarios (scenarios 1–4) are significantly better than the single-factor scenarios (scenarios 5–7). Considering social factors only, the percentage shares of Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, and Hainan are 0.14%, 3.62%, 9.84%, 0.13%, 4.82%, 10.27%, 19.67%, 25.89%, 13.65%, 6.71%, and 5.25%, respectively. While biological (historical catch data) factors only are considered, the percentage shares of Tianjin, Shanghai, Zhejiang, and Hainan increase to 0.27%, 0.15%, 25.69%, and 9.58%, respectively, whereas Hebei, Liaoning, Jiangsu, Fujian, Shandong, Guangdong, and Guangxi decrease to 1.96%, 7.51%, 4.45%, 15.56%, 17.76%, 11.84%, and 5.24%, respectively.

Throughout the allocation of catch shares in China's 11 coastal areas, under the multifactor scenario, the variation in the range of percentage shares is 0.12% to 2.18%, and under the single-factor scenario, the variation range is 0.62% to 15.42%. Under the multi-factor scenarios, the percentage shares change within a relatively small range, and this is likely to be more easily accepted by decision-makers as it has more general feasibility (**Figure 4**). Within the multifactor scenarios, the percentage shares among coastal areas are different. Taking Shandong Province as an example, the percentage shares under scenario 1 is 19.43%. The percentage shares of other scenarios are 20.09% (scenario 2 increased by 0.66%), 19.37% (scenario 3 decreased by 0.06%), 19.00% (scenario 4 decreased by 0.43%), 25.89% (scenario 5 increased by 6.46%), 17.76% (scenario 6 decreased by 1.67%), and 19.22% (scenario 7 decreased by 0.21%). The range of change under single-factor scenarios is greater than that of multifactor scenarios (**Figure 4**).

In order to objectively compare the percentage shares, this study uses the entropy method to determine the weight of socioeconomic biological indicators, which are 0.33 (social), 0.32 (economic), and 0.34 (biological). The weight obtained based on the entropy method is close to the equal weight distribution weight, so this study does not set the equal weight distribution scenario. After verification and changing the indicators selected above, the indicator weight will be different, but it will still arrive at the same result that the allocation stability of multifactor scenarios is better than that of a single-factor scenario.

TABLE 4 | The coupling coordination of marine capture fisheries in 11 coastal areas of China.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	AVG
Tianjin	0.4613	0.5045	0.4758	0.7056	0.6824	0.6641	0.6532	0.5968	0.6111	0.6214	0.5976
Hebei	0.6101	0.6247	0.5914	0.5958	0.6009	0.5942	0.6189	0.6726	0.6710	0.6493	0.6229
Liaoning	0.6671	0.6572	0.6300	0.6835	0.6810	0.6769	0.6764	0.6690	0.6857	0.6637	0.6691
Shanghai	0.4923	0.4632	0.4700	0.4377	0.4311	0.4016	0.3769	0.4521	0.4560	0.4818	0.4463
Jiangsu	0.6536	0.6353	0.6133	0.6192	0.6195	0.6204	0.6331	0.6481	0.6257	0.6629	0.6331
Zhejiang	0.6987	0.6912	0.6632	0.7087	0.7017	0.7025	0.7296	0.7018	0.6814	0.6886	0.6967
Fujian	0.7154	0.6923	0.6335	0.6944	0.6965	0.6937	0.6718	0.6823	0.6858	0.6715	0.6837
Shandong	0.7266	0.7303	0.6839	0.7231	0.6959	0.6866	0.6848	0.7234	0.7415	0.7703	0.7166
Guangdong	0.6667	0.6441	0.5729	0.6683	0.6671	0.6605	0.6508	0.6724	0.6562	0.6352	0.6494
Guangxi	0.6984	0.7287	0.6954	0.7150	0.7178	0.6972	0.6949	0.7104	0.7076	0.7194	0.7085
Hainan	0.7067	0.6869	0.6561	0.6818	0.7012	0.6910	0.7068	0.7075	0.7023	0.7049	0.6945
AVG	0.6452	0.6417	0.6078	0.6576	0.6541	0.6444	0.6452	0.6579	0.6568	0.6608	0.6471

*The coupling coordination level corresponding to the colors in the table refers to the classification standard in **Table 3**.*

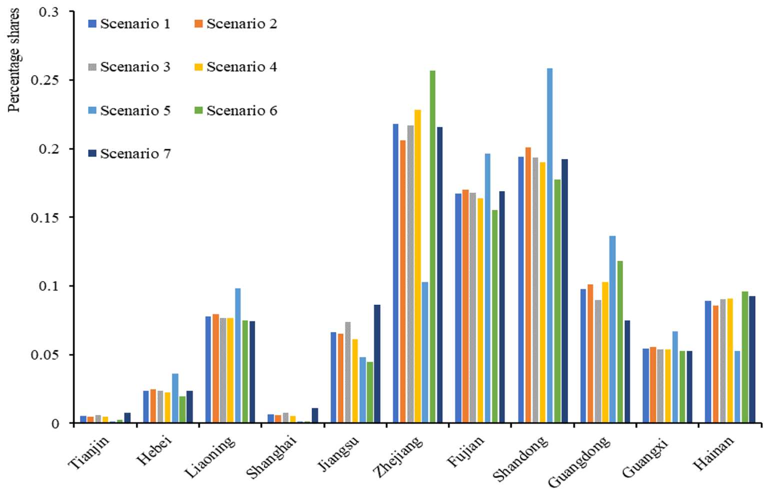

FIGURE 4 | Proportion of catch share in 11 coastal areas of China under each of the different scenarios.

4 DISCUSSION

Fisheries management is not just a consideration for the fisheries sector, but it is also socially and economically important (Desa, 2016; Arkema and Ruckelshaus, 2017). This study integrates the social, economic, and resource framework by using the coupling coordination model. The results of this study clearly show that the sustainable development of China's coastal MCF is at the primary coordinated development level from 2010 to 2019. Moreover, the individual level of each of the 11 coastal areas is different. These results indicate that mechanisms to control output and improve quality and efficiency need to be considered when formulating fishery management policies (Einarsson and Óladóttir, 2020).

Sustainable development is widely regarded as the ideal goal of fisheries management. Although there is no consensus on what measures can achieve this goal, the privatization of fishing property rights to avoid Harton's Tragedy of the Commons (Hardin, 1968) is clear. Specifically, fishing can be described as a competitive economic pursuit. Driven by interests, fishermen will exploit the loopholes of the existing traditional fishery management policies. For example, after the end of the fishing moratorium in the summer season, the effect of the fishing moratorium disappeared instantly due to the significant investment of fishing vessels. Regional conflicts have often arisen without effective management (Glaser et al., 2019), although rational allocations can reduce them.

TABLE 5 | Weight of relevant dimension indicators under different decision preferences.

Scenarios	W_s	W_e	W_b
Scenario 1 (object using entropy method)	0.33	0.32	0.34
Scenario 2 (social preference)	0.50	0.25	0.25
Scenario 3 (economical preference)	0.25	0.50	0.25
Scenario 4 (biological preference)	0.25	0.25	0.50
Scenario 5 (social only)	1	0	0
Scenario 6 (biological only)	0	0	1
Scenario 7 (economical only)	0	1	0

Regional conflict is inevitable because of the problem of overfishing, coupled with the lack of practical physical barriers at the sea boundary (Liu and Molina, 2021). Therefore, in the absence of management controls global marine fishery resources face depletion. As one of the potential ways to improve fisheries management, catch-share management programs have been applied in European and American countries (Hilborn, 2007). Rock shrimp management in New Zealand (Yandle, 2006) and sablefish management in British Columbia, Canada (Grafton et al., 2007), both adopted catch-share programs, resulting in the restoration of fishery resources. In addition, the implementation of catch-share management in the New England multispecies bottom fish fishery (Scheld and Anderson, 2014) has produced positive market benefits. In contrast, the outcomes of the southeast Australian fisheries catch-share process (Tilzey and Rowling, 2001) did not have a positive impact due to dissatisfaction with the allocation proportion. The above examples show that catch-share programs must adapt to local conditions, and the allocation depends on the development of fisheries in the study area.

As the most significant contributor to global marine fishery production, China's fisheries management is seeking to limit and control the total amount of resources extracted *via* catch limits (Han, 2018). The goal of catch limits cannot be satisfied by traditional fisheries management measures alone. It needs to specify property rights to resolve the race to fish. Catch-share programs that are well designed can help prevent overfishing and promote stability and ecological management (Gutiérrez et al., 2011). We studied the sustainable development of fisheries based on the catch-share programs through comparative studies of 7 scenarios. The result shows that the multifactor allocation method based on economic, social, and biological is more stable than the single-factor method, improving the fairness of fishery resources.

The management of fishers is the key to ensuring the implementation of the policy (Fulton et al., 2011). In research on fishers' views on fisheries management, competitive race-to-fish practices and overcapacity are typical results of the lack of property rights management (Hospital and Beavers, 2014), but there are still doubts about the mechanisms involved in allocating catch shares. Fair initial distribution is the premise for fishermen accepting that program. Therefore, catch-share programs need a rigorous distribution design. By taking economic, biological, and social indicators into account, this study reduces the doubts about the unfair initial distribution. Catch share allocates fishery resources to individuals or communities, and this ends open access, so fishermen with a certain proportion of the fishery resources or share will benefit from any improvements (Fujita and Bonzon, 2005). With the preservation of their allocation within their interests, they will promote fishery improvement through the self-implementation mechanism and peer pressure.

5 CONCLUSION

It goes without saying that MCFs are important to fisheries and supply chains alike. We demonstrate that the socioeconomic and biological systems of marine capture fisheries in China's coastal areas are inseparable by coupling analysis. This study has shown that multifactor mechanisms to control output that also improve quality and efficiency need to be included in the formulation of fishery management policies. Furthermore, compared with the scheme based on historical catch only, it increases the fairness of the initial distribution.

As the largest producer, China contributes 15.05% of the total global capture fisheries production (offshore 12.32%, pelagic 2.73%) (Bureau of Fisheries of the Ministry of Agriculture, 2011-2020; FAO, 2021), and the sustainable utilization of marine capture fisheries in China is attracting much attention globally. Marine fisheries management in China has involved multiple elements, from pursuing economic growth to food security to fisheries resource conservation, and more recently, focusing on ecological functions and environmental quality. So far, China has not been very successful in resolving overfishing issues and other fisheries problems in its own waters.

In order to achieve sustainable use of resources, China has taken a series of actions and will continue to take action on fisheries reform. New approaches to marine fisheries governance and policy implementation are necessary. The catch-share program in this study, taking into account social, economic, and ecological sustainability, is a new perspective to reducing overfishing and fishery conflicts.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials. Further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

HL is the first author of this paper and participated in the design of experimental methods, actual investigation and research, experimental data analysis, visualization of experimental results, and writing the first draft. DP and H-JY have put forward many constructive ideas and proposals that further enriched the draft resolution and made it more comprehensive. YM and YZ participate in the generation of research concepts, the acquisition of research funds, the supervision and guidance of research topics, and the review and revision of papers. All authors contributed to the article and approved the submitted version.

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