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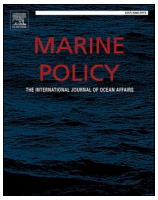

Sustainability comparisons in the triple bottom line for Chinese fisheries

Lijun Liu [a], Jingjie Chu [b,*], James L. Anderson [c,d], Jintao Xu [a]

[a] National School of Development, Peking University, Beijing 100871, China
[b] Environment, Natural Resources Management, and Blue Economy, The World Bank, Washington, DC 20433, USA
[c] Institute for Sustainable Food Systems, University of Florida, Gainesville, FL 32611, USA
[d] Food and Resource Economics, University of Florida, Gainesville, FL 32611, USA

A B S T R A C T

This paper uses Fishery Performance Indicators (FPIs) to compare nine Chinese fisheries in terms of their triple bottom line (ecological, economic, and community sustainability) with the top 10% performing fisheries within the global FPIs database. The results show the largest differences between the Chinese fisheries and top-performing fisheries globally are in ecological sustainability followed by harvest sector performance and economic performance. The gaps in community sustainability and post-harvest performance are smaller. The paper also compares the nine different Chinese fisheries with each other to assess their relative performance. Zhejiang province shows signs of better fishery management with its stronger enforcement and stricter measures to tackle illegal fishing and as a result, scores higher in ecological and some economic and social dimensions.

1. Introduction

China is the world's largest seafood producer, both in capture fisheries and aquaculture, accounting for 35% of global seafood production [1]. China is highly important in international trade. By value, China is the world's largest seafood exporter and the third largest importer [1,2]. China is also a significant distant water fishing nation [3,4] with a reported catch of 2.26 MMT in 2018 [1]. Hence, what occurs in the Chinese seafood sector is important not only for China, but also for global fisheries. However, there is a huge knowledge gap and little research readily available in English to assess the triple bottom line (ecological, social and economic sustainability) of Chinese fisheries. Recent reviews traced China's fisheries management history back to 1949, when People's Republic of China was established [5,6] and since 1978, the beginning of the Chinese Economic Reforms [7]. These works have characterized the evolution of the fisheries institutions from open access towards regulated restricted access; the transition from planned economy to market economy; and the shift of priorities from economic outcomes to environmental conservation and community welfare enhancement. Our work contributes to the understanding of how the fisheries perform on ecological, economic and community dimensions for different fishery management systems in China and how they perform relative to reference global fisheries. A better understanding of the current performance of Chinese fisheries could contribute to a more sustainable development of the fisheries in China and other parts of the world.

In recent years, China has committed to a new national strategy, namely the 'Ecological Civilization' as a response for China's environmental degradation and global climate change [8–10]. As part of this national transformation towards environmental sustainability, fishery and aquaculture management authorities have started putting more effort into balancing development and ecological conservation. The administration has gradually shifted its goals from quantitative growth to quality and efficiency improvement. A series of reform actions have been taken to push the institutional change to better defined rights-based fisheries management [5–7,11,12]. Will China's plans to reform fisheries help China approach the best managed fisheries in the world?

In this paper, the Fishery Performance Indicators (FPIs) [13] were used to assess nine Chinese fisheries to understand the evolving trends of the management system in China. We compare these nine fisheries with the top 10% performing fisheries (14 fisheries out of 145) in the global FPIs database for insights as to where the Chinese fisheries have been doing well and where improvements are needed.

This paper is organized as follows. In the next section, the methodology and the details of the nine Chinese fisheries are presented. The top performing fisheries in the FPI database have also been introduced as benchmarks for further comparisons. In the third section, the nine Chinese fisheries are compared with the top performing fisheries to identify gaps for improvement. Comparisons among the nine fisheries are also conducted focusing on the regional differences. Between these two sets of comparisons, a sub-section on Chinese fisheries management is inserted to prepare the reader with basics of Chinese marine fisheries management framework. The last section discusses possible explanations of the differences and potential implications.

* Corresponding author.

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2. Methods and data

The FPIs are a set of rapid assessment indicators designed to capture the ecological, economic, and community features of individual fisheries and their enabling conditions based on best knowledge available from both data and expert opinions [13]. The FPIs have been used to compare fisheries systems at a global scale [14], for specific species complexes [15] and for specific fisheries management projects [16]. Nine Chinese fisheries have been accessed, representing key characteristics of Chinese fisheries, such as fishery scale, species, region, and gear types (Table 1). The chosen Chinese fisheries do not represent a random sample, but were chosen based on existing projects and the authors' research network.

These nine Chinese fisheries were assessed by different researchers from 2014 to 2018 through desktop research as well as field trips, workshops, interviews with government officials, industry leaders, community representatives, and researchers of Chinese marine fisheries biology, ecology and policies. The FPI manual (in English and Chinese) was followed for the assessments [17].

These nine fisheries represent about 40% of Chinese total domestic marine fishery harvest. The South China Sea fishery alone counts for approximately 30% of the total domestic marine catch. Seven of these assessments focus on fisheries with specific gear (e.g., shrimp trawl) or a species group (e.g., swimming crab, mackerels, hairtail) within a province (first seven in Table 1). Two fisheries have been assessed at a broader scale and consider all fishing activities in the corresponding regions (Wanshan, small islands in Guangdong Province and the vast South China Sea, including Guangdong, Guangxi, and Hainan Provinces) (Fig. 1). Trawling is most commonly used in Chinese waters for almost all species. However, trawling accounts for small proportions of the catch in the gazami crab and mackerel fisheries in Zhejiang and thus catch from trawling was not included in the assessments.

Table 1
Summary of the nine Chinese fisheries assessed.

Location and fishery	Species	Gear type	Year assessed	Production volume (000 MT)
Zhejiang Swimming Crab	Gazami crab	Gillnetter/pot	2017	172
Zhejiang Mackerel	Chub mackerel, blue mackerel	Light luring purse seiner	2017	188
Zhejiang Shrimp Trawl	Spear shrimp, kuruma shrimp, razor mud shrimp, whiskered velvet shrimp	Shrimp trawl	2017	340
Zhejiang Hairtail	Hairtail, small yellow croaker, small pomfret, silver pomfret, Bombay duck	Double trawl/ single trawl/ canvas stow netter[^] / longliner	2017	404
Shandong Spanish Mackerel	Spanish mackerel, sting fish, chub mackerel, silvery pomfret, hairtail	Trawl and gillnet	2015	165
Fujian Swimming Crab	Red swimming crabs, three spot swimming crab, ridged swimming crab, crucifix swimming crab, and horse crab	Trawl and gillnet	2014	117
Guangdong Cuttlefish-Squid	Swordtip squid, Indian squid, miter squid, golden cuttlefish, needle cuttlefish	Longline, trawl and purse seine	2014	51
Guangdong Wanshan Islands	Finfish; multi-species	Trawl and purse seine	2016	8.2
South China Sea	Multi-species	All gears operating in the region	2015	3757[a]

Note: [^]Canvas stow netter: stow netter with canvas-made spreading devices.
[a] The figure was based on the total domestic marine catch of South China Sea reported in the China Statistic Yearbook for Fisheries and Aquaculture. This volume includes the catch from Guangdong Province, Guangxi Province, Hainan Province, and about 10% of the catch from Fujian Province [18].

The top 10% performing fisheries in the global FPI database were chose to be as a benchmark for comparison to see where Chinese fisheries gaps are compared to the best ones (Table 2). They were identified by ranking fisheries according to their total FPI score, calculated by giving equal weight to ecological, economic and social pillars.

After comparing the performances of Chinese fisheries and the top 10% performing fisheries, these nine Chinese fisheries have been grouped into two: those of Zhejiang Province and non-Zhejiang fisheries for further comparisons. The purpose for such comparisons is to identify whether Zhejiang fisheries perform differently with the other Chinese fisheries. Though not reflected in academic literature, Zhejiang is well-known by the practitioners for being more responsible for the fisheries management and having stronger enforcement capacity than other provinces along the Chinese coastlines. Zhejiang is also the first and only province in China with a provincial fishing ground restoration plan [20].

The FPI scores were crossed checked by the staff who manage the global FPI database to control quality and assure standardization in the scoring. One feature of the FPI approach is that the evaluator provides a quality score that reflects evaluator's confidence in the accuracy of each score.

For the Chinese fisheries the quality scores are either an 'A′ (assessor is certain of the score) or a 'B′ (assessor is certain the score is within one point) for 95.4% of the 68 output scores and 98.4% of the 54 input scores. Quality scores of 'C′ (assessor is highly uncertain of the score) are associated with 4.6% of the output scores and 1.6% of the input scores. The scores with 'C′ quality are most commonly associated with output indicators related to Fish Stock Health & Environmental Performance, Risks of the Harvest Sector, and Market Performance in the Post-Harvest Sector. The scores with 'C′ quality with input indicators are associated with Collective Actions, Management Methods, and Markets & Market Institutions. Zhejiang Swimming Crab and Zhejiang Mackerel fisheries

Fig. 1. The nine Chinese fisheries assessed are distributed along the Chinese coastline. Base map is retrieved from the Standard Map Service by Ministry of Natural Resources, P.R. China.

Table 2
Top 10% performing fisheries in the global FPIs Database.

Fishery	Assessment year
Iceland Nephrops Lobster	2010
Iceland Cod	2017
Australia Western Zone Abalone	2011
US Alaska Pollock	2013
Japan Wagu Lobster	2016
Australia Southern Zone Rock Lobster	2012
Japan Ofunato Set Net Salmon	2016
Australia Spencer Gulf Prawn	2011
Norway Purse Seine Herring and Mackerel	2010
Japan Toyama Bay Set-Net Yellowtail	2016
Norway Whitefish Trawl	2010
New Zealand Hoki	2011
Faroe Islands Distant Water Fleet Cod and Haddock	2018
US California Spot Prawn	2015

have the highest score quality (100% of the scores are either 'A' or 'B' quality) and the South China Sea fishery has the lowest score quality (92.6% of scores were 'A' or 'B' quality).

3. Results

3.1. Comparison of Chinese fisheries with top-performing fisheries

Fig. 2 shows the average scores in three pillars of sustainability as well as by sector for the Chinese fisheries and top 10% performing fisheries in the FPI database followed by a statistic test to see if there are significant differences between scores. It was found there were significant differences for the three sustainability pillars and harvest and post-harvest performance (Table 3). The Chinese fisheries scored statistically lower than the top-performing fisheries in all cases. The largest differences between the Chinese and top-performing fisheries are in ecological sustainability (average score of Chinese fisheries (ACF) was 3.02 and average score of the top-performing fisheries (ATF) was 4.47) followed by harvest sector performance (3.65 vs. 4.18) and economic performance (ACF 3.47 vs. ATF 3.98). The gaps in community sustainability (ACF 3.92 vs. ATF 4.26) and post-harvest performance (ACF 3.9 vs. ATF 4.15) are smaller but still significant.

Fig. 3 shows the average scores in the 14 output dimensions for Chinese fisheries and the top 10% performing fisheries. Statistically significant differences in means were found for 7 out of the 14 output dimensions (Table 4). The Chinese fisheries scored higher than the top 10% in three dimensions, post-harvest assets performance, managerial returns and local ownership, but the difference was not significantly different.

Significant differences in the performance of the Chinese fisheries systems compared to top-performing fisheries were in the dimensions of stock health (ACF 3.03 vs. ATF 4.47), harvest performance (ACF 3 vs. ATF 4.27) and international trade (ACF 2.86 vs. ATF 4.14), Product form

Table 3
Significance tests for differences in mean scores of the three pillars of sustainability and harvest and post-harvest performance for China and the top 10% performing fisheries.

	t	p-value
Ecology	−7.990	< 0.001
Economic	−5.706	< 0.001
Community	−2.524	0.020
Harvest sector	−4.933	< 0.001
Post-harvest sector	−3.420	0.003

(ACF 3.63 vs. ATF 4.13), health and sanitation (ACF 4.44 vs. ATF 4.95), local labor (ACF 3.06 vs. ATF 4.07) and career (ACF 3.33 vs. ATF 3.88). The generally poor condition of Chinese fish stocks is not surprising as most Chinese fisheries are overcapitalized, and the past effort to reduce fishing effort has not been effective or poorly designed such as the buyback program in early 2000s [21–23].

Given that China is the largest world's exporter of seafood, it is somewhat surprising that Chinese fisheries scored below the top-performing fisheries in international trade. Two reasons may contribute to the lower score. First, China is the world's largest consumer of seafood and several of the Chinese fisheries (e.g., swimming crab and hairtail) primarily target the domestic Chinese market instead of export market. In addition, several of the species caught in Chinese fisheries do not have well developed markets in high-income countries. Second, much of China's exports are from aquaculture, such as shrimp, and other high value exports are actually imports that are processed and re-exported [2,24,25].

Chinese fisheries scores were not significantly different from top-performing fisheries in dimensions of harvest asset performance (ACF 3.59 vs. ATF 3.74), risk (ACF 3.66 vs. ATF 3.78), post-harvest assets (ACF 3.83 vs. ATF 4.07), managerial returns managerial returns (ACF 4.43 vs. ATF 4.42), labor returns (ACF 3.22 vs. ATF 3.57), community services (ACF 4.63 vs. ATF 4.83) and local ownership (ACF 4.33 vs. ATF 4.11). It is interesting that despite the overfished status of several fish stocks and relatively weak harvest performance, Chinese fishers and processors are earning wages above regional averages, like the top-performing fisheries. It is also interesting to note that despite having a slightly higher proportion of local ownership in Chinese fisheries, the proportion of local labor is well below top-performing fisheries. It should be noted that the non-local labor for Chinese fisheries is not foreign immigrant labor, but Chinese labor from the nation's interior districts. This is due to the better economic development conditions along the coastal regions which motivate the migration of labors from other areas to the coastal areas and this is a general phenomenon for many sectors. It also fits in with the fact that fishers' wages have to be competitive, as is evident in a number of other countries [26].

Fig. 4 compares the average scores of the 15 input dimensions for the Chinese fisheries and the top 10% performing fisheries. The top-performing fisheries scored statistically higher than the Chinese

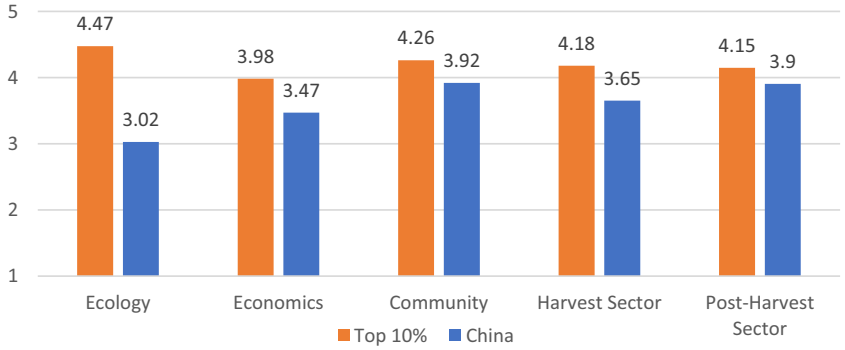

Fig. 2. China fisheries compared to the Top 10% in the Global FPI Database.

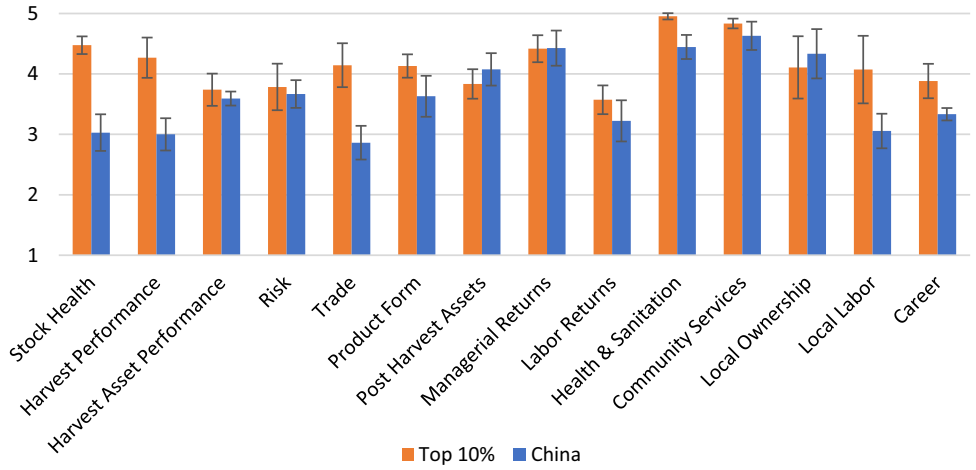

Fig. 3. Output comparison (Top 10% compared to selected China fisheries).

Table 4
Significance tests for differences in mean scores of output dimensions for China and the top 10% performing fisheries.

	t	p-value
Stock health	−7.990	< 0.001
Harvest performance	−5.557	< 0.001
Harvest asset performance	−0.939	0.360
Risk	−0.489	0.630
Trade	−5.248	< 0.001
Product form	−2.384	0.033
Post-harvest assets	1.240	0.231
Managerial returns	0.047	0.963
Labor returns	−1.566	0.138
Health and sanitation	−4.577	0.001
Community services	−1.524	0.159
Local ownership	0.644	0.526
Local labor	−3.043	0.008
Career	−3.409	0.004

fisheries in all input dimensions except for the gender and infrastructure dimensions, indicating that improvements can be made in many dimensions (Table 5). The largest differences between the Chinese and top-performing fisheries are in dimensions related to national governance and national economic conditions. This is reflective of the advanced economies and governance conditions that the top-performing fisheries operate in such as in the United States, Australia, Iceland, Norway and Japan. The Chinese fisheries also score low in harvest rights given none of the Chinese fisheries assessed are managed with harvest rights, such as catch shares. The score for access rights is low for Chinese fisheries given illegal fishing and excess capacity reduces exclusivity of fishing rights and Chinese licenses also have less transferability and flexibility.

The Chinese fisheries scored statistically lower in three out of the four community-related dimensions (collective action, participation and support, and leadership and cohesion), indicating cooperative, bottom-up management is limited in China's fisheries management. In general, fishers are not well organized in China. Fishery government officials will consult with key fishers or fish leaders for their feedback regarding policies occasionally, but it has not been systematic, and input has not reflected all fishers' opinion. The leadership score is low partly because some fishermen live in more urban areas which undermines the close relationship among fishers or fishing culture compared to many more underdeveloped rural fishing communities. The score of gender dimension indicate that men are the primary participants in the Chinese fisheries, and this is also the case for the top-performing fisheries worldwide. The Chinese fisheries scored lower on all management-related dimensions compared to the top-performing fisheries. This is not surprising as none of the Chinese fisheries assessed are currently managed using catch limits, the cornerstone of more advanced fisheries management. Chinese fisheries performed as well as the top 10%

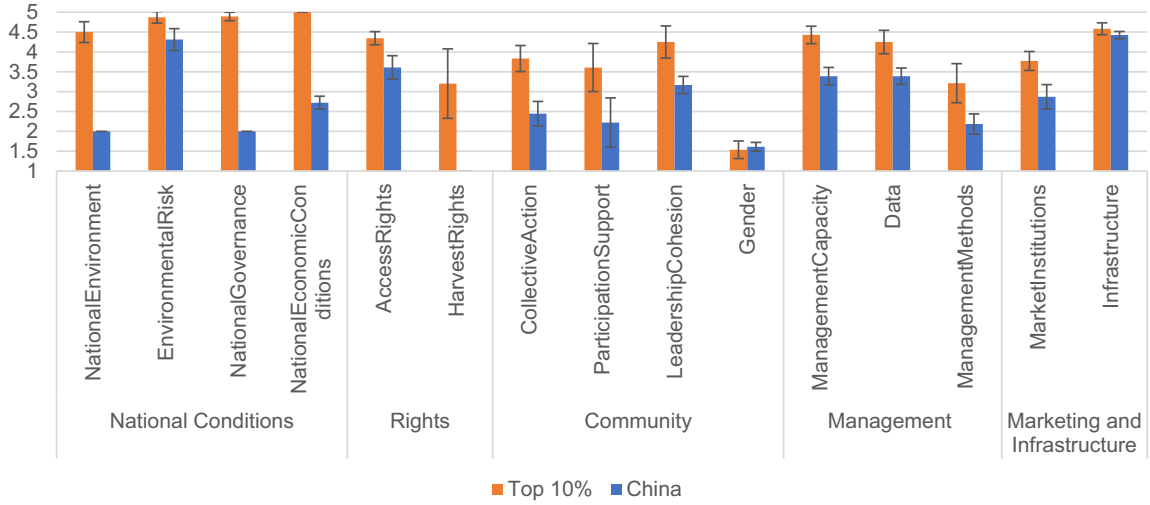

Fig. 4. Input comparison (Top 10% compared to selected Chinese fisheries).

Table 5
Significance tests for differences in mean scores of input dimensions for China and the top 10% performing fisheries.

	t	p-value
National environment	−18.028	< 0.001
Environmental risk	−3.329	0.006
National governance	−50.839	< 0.001
National economics	−25.931	< 0.001
Access rights	−4.027	0.001
Harvest rights	−4.754	< 0.001
Collective action	−5.767	< 0.001
Participation & support	−2.994	0.007
Leadership & cohesion	−4.426	< 0.001
Gender	0.573	0.573
Management capacity	−6.278	0.002
Data	−4.514	< 0.001
Management methods	−3.494	< 0.002
Markets & market institutions	−4.324	< 0.001
Infrastructure	−1.684	0.108

fisheries in the infrastructure dimension, reflecting China's efficiency in logistics and shipping services. The relatively high score in the infrastructure dimension of China's fisheries supports high post-harvest sector performance.

China has engaged in several measures that will close much of the gap between Chinese fisheries systems and the world's best. In the next section, we will explore some of these reforms to address the input factor limitations.

3.2. Chinese fisheries management

The FPI framework includes several components relevant to the essentials of fisheries management system. In this section, performances of the nine Chinese fisheries in the following components "Property Rights & Responsibility", "Community", and "Management" are discussed to illustrate the variation of China's domestic fisheries management.

3.3. Property rights and responsibility

The fishing access rights component of FPI is consist of six measures: "Proportion of Harvest Managed Under Limited Access", "Transferability", "Security", "Durability", "Flexibility", and "Exclusivity". The harvest rights component has a similar structure.

The nine Chinese fisheries received an average score of 3.6 for their fishing access rights, which is moderately strong but still significantly less than average score of 4.2 for the top performing fisheries in the FPI database. Specifically,

- Proportion of Harvest Managed Under Limited Access: Strong (average score of 4.33). Virtually all the nine Chinese fisheries assessed were managed with restrict access rights. It must be noted that fishing access rights in the FPI include both regulatory and *de facto* access rights
- Transferability: Weak (average score of 2.55). The fishing license itself is not allowed to transfer [27]. However, the key components of the license (i.e., fishing vessel and horsepower quota of the fishing vessel) can be transferred. Thus, the fishing access is transferable, within limits. There are some limits for the transition. For example, transfers from one province to another or transfers to trawlers, canvas stow netters and deep water seiners are not allowed [28].
- Security & Durability: Strong (average scores of 4.55 and 4.33 respectively). The fishing license is required for a renewal for every 5 years. Stakeholders (fishermen, administrators, and researchers) interviewed in this project suggest strong security and durability for the access rights. For trawlers, canvas stow netters and deep-water seiners, their licenses will not be renewed once the vessels reach certain age, which is a way for China to reduce those destructive fishing methods. If they want to keep fishing, they must change to more environment-friendly fishing methods to receive a license.
- Flexibility: Moderate (average score of 3.11). To receive a marine fishing license, the vessel registration and inspection information, fishing methods employed, and fishing grounds where the vessel will operate have to be specified [23].
- Exclusivity: Weak (average score of 2.77). This evaluation score is based on the facts that too many licenses were issued and the access rights are not exclusive. The total number for the fishing licenses issued is supposed to be determined by the conditions of the fisheries resource and environmental capacity. However, given that no Total Allowable Catch (TAC) system has been put in place so far, this prerequisite has not directly affect the fishing license distribution [6,7]. The number of fishing license is constrained mainly by the caps for fishing vessels and gears, which is referred as "double control" policy (caps for total count of fishing vessels and total engine power).

Harvest rights are becoming an increasingly important fisheries management tool globally [29]. However, all Chinese fisheries received a score of 1 for the measure "Proportion of Harvest Managed with Rights-Based Management", as virtually none of the harvest were managed with right-based management. The total allowable catch (TAC) system has been written into law since 2000 [6,27], but up to now no fisheries within the Chinese EEZ have been managed with harvest rights. Since 2017, there have been some attempts to introduce rights-based fishery management approach through experimental pilot projects. From 2017–2019, the four most important provinces for marine fisheries have launched five TAC pilots to cultivate the managerial capacity for rights-based fisheries management. Those projects are relatively small to their corresponding fisheries. For example, the first TAC pilot project launched was for the swimming crab fishery in Zhejiang Province in 2017. The total catch from this project was 1612 MT in 2017, less than 1% of the total catch in the province (177,183 MT). In preparation for the right-based management, the fisheries administration also has launched a pilot project for port-based fisheries management in 2019. Some of its expected deliverables from this pilot, including improving traceability of harvest and the quality of fishing logs and establishing a landing report system, are essential for right-based management.

3.3.1. Community

The fisheries communities were assessed for input dimensions: 'Collective Action,' 'Participation,' 'Leadership' and 'Gender.' The average for 'collective action' was only 2.4 compared to 3.8 for the top performing fisheries. However, the last five-year plan (2016–2020) for fisheries and aquaculture highlighted the promotion of harvester organizations in the fisheries communities [11]. The harvester organizations have a huge potential to influence the fisheries in management and marketing in China, but there is a long way to go. Fisheries cooperatives are common in the fisheries communities. Most of them handle used-to-be government business, like the harvest safety, vessel checks, etc., but only have limited voice on management and access. Coordination for harvest are conducted mostly via interpersonal networks rather than the organizations.

Stakeholder participation and support for fisheries management only scores an average of 2.2 compared to 3.6 for the top performing fisheries. Stakeholder meetings are rare and irregular. Some fishermen (very small portion of the community) would attend short consultation sessions initiated by either the fisheries managers or researchers for feedbacks for specific projects or policies. There is no industry financial support for management, as the administrations are not supposed to receive funds from industry.

Leadership in fisheries communities scored an average of 3.1

compared to 4.3 for the top performing fisheries. At village level, fishers or heads of the cooperatives have shown some level of leadership. However, when it comes to the provincial level, no strong leadership has been identified. The fishery communities perform generally well in terms of social cohesion. With the rapid urbanization in China, the fishery communities have been shrinking and less and less young people have stayed in fisheries in the recent decades, leading the average years of experience skewed towards older group.

Overall females have lower influence for business management and resources management, especially for the industrialized fisheries. Participation in harvest is not common. Women are more active in post-harvest sectors.

3.3.2. Management

This component in FPIs consists of three dimensions: 'Management Capacity', 'Data', and 'Management Methods.' Management capacity scored an average of 3.4 compared to 4.4 for the top performing fisheries. Within the Chinese EEZs, the jurisdictions have been divided into two parts by the "no-trawling" line. The provincial enforcement has jurisdiction over the waters to the continent side of this line, and the three Sea Regions (the Bohai & Yellow Sea, the East China Sea, and the South China Sea) enforcement bodies have jurisdictions of the state water offshore. The enforcement capacity is not enough overall. Among the coastal provinces, Zhejiang Province has the strongest capacity to regulate the fishing activities, but still understaffed and the challenge of coordination for the enforcement in the state water have been raised, especially with the frequent shifts of sea region enforcement bodies.[1] Most fishing vessels receive fuel subsidy and some subsidy for renewing the vessels. Chinese government have committed by 2019 to reduce the fuel subsidy to 40% of the level in 2014 and to cancel the fuel subsidy for three types of fishing vessels that pose high threats for the marine environment (paired trawler, canvas stow netter and deep water seiner) in 2020 [30].

The score on Chinese data system was moderate (3.4), but significantly lower than the top performing fisheries (4.2). Although a landing reporting system has not been established in Chinese domestic fisheries, fishermen are required to fill in fishing logs. However, there is no quality control for the logs. There are no national fisheries resource monitoring program, but some research institutes run regular fisheries-independent surveys and fisheries-dependent monitoring programs that collect harvest and fishing behavior information with small samples. Fish price data are collected in the major wholesale markets on a daily or weekly basis, varying by the markets and species. These data have not been fully utilized in management.

Management methods scored an average of 2.2, significantly less than the 3.2 for the top performing fisheries. Management methods vary in sea regions and provinces, but in general, input controls are mostly used, such as moratoria, area closures, and mesh size limit. Among these tools, the most important one is the summer moratorium. Additionally, China has been increasing MPAs and sanctuaries, with a target of adding 58 national fisheries resources protected areas and five provincial or national aquatic natural protected areas between 2015 and 2020 [11]. Mesh size limits have been put in place since 2014 [31], however through interviews with practitioners in the field, the enforcement is very challenging.

[1] The enforcement bodies of the sea regions have changed several times in the past few years. For example, in the East China Sea region, the East China Sea Bureau of Fisheries Enforcement, Ministry of Agriculture used to take responsibility of enforcement for the fishing activities in the offshore state water and would coordinate the several provincial enforcement bodies in task forces to combat IUUs. From 2015–2018, the fisheries enforcement body was the East China Sea Coast Guard. The Coast Guard since the government reconstruction in 2018, has been merged into the Armed Policy Force.

3.4. Chinese fisheries performance comparison

It is interesting to see differences among the nine Chinese fisheries. Fig. 5 shows they performed relatively well in the economic and community pillars with the exceptions of the economic score for Wan Shan Island, and the community score for the South China Sea fisheries (Fig. 5). Zhejiang is selected to compare with other fisheries because two reasons. One is because Zhejiang is considered as one of the best performing provinces in terms of marine fishery management in China. Two is that the assessment for Zhejiang's four fisheries were conducted in 2017, and the other fisheries were assessed between 2014 and 2016 before the China's acceleration of ecological civilization has been put into action plans for marine fisheries management reform [12].

When looking at output performance in details (Fig. 6), all Chinese fisheries are doing relatively well in the dimensions of harvest assets, risk, post-harvest assets, managerial returns, health and sanitation, and community services (over 3.5). Zhejiang received higher scores on average in stock health, harvest performance, trade, post-harvest assets, labor returns and local ownership and has fallen below in product form. This might be due to the following reasons. First, the assessed fisheries have different scopes. For example, the Wan Shan Island fishery only produces over 8000 MT of fish while South China Sea fisheries involved many more species and areas which is likely to contribute to the lower stock health scores. Second, Zhejiang coastal area may have better natural conditions with higher productivity. Third, three of the Zhejiang fisheries focus on fast growing and short life-span species (crab, mackerel, and shrimps) and received relatively good scores in ecological performance. The Zhejiang hairtail has a low score in stock health, but it is a recovering fishery with over twenty years of restoration effort. Since 1980s, Zhejiang has started a summer moratorium for trawlers in addition to several MPAs that protect important habitats for the hairtail [32]. The stock is expected to continue recovering. After investing in marine fisheries management and fisheries restoration since 2013 [20], there is some evidence to show a degree of recovery of Zhejiang's four most famous species, yellow croaker, small yellow croaker, hairtail, and spineless cuttlefish, which have been overfished for decades. In 2019, pelagic finfish landings in Zhejiang have increased four times compared to the landings in the late 1990s [20].

For the input conditions, it is not surprising to see Zhejiang scores higher on management related indicators, such as management and capacity, data, management methods, and access rights. The variation in Management Methods are introduced by the lower scores for MPAs and Sanctuaries in Wanshan and South China Sea fisheries. Two reasons might have caused such differences, the assessors bias and the fact that the South China Sea had shorter moratoria than other sea regions. Zhejiang generally scored lower than other Chinese fisheries in the collective action, participation & support, leadership & cohesion, and gender components (Fig. 7). The lower scores may reflect the fact that Zhejiang fishing fleets are more industrialized compared to other fisheries (average engine power of fishing vessels in Zhejiang is two times higher than the national average [19]) with less women participation and less organization.

4. Conclusions

China is the largest seafood producing country in the world and has a national objective to improve fisheries management. In this paper, we compare performance of nine Chinese fisheries with the top 10% performing fisheries in the global FPI database for the three pillars of sustainability as well as harvest and post-harvest performance. All measures indicate that there is a significant room for China to improve. Comparing with the top performing fisheries globally helps identify where the improvements are needed. Input factors such as strengthening harvest rights, stronger fishery community participation and leadership, improved management capacity (enforcement), management methods (setting TAC and spatial management) and data collection and analysis,

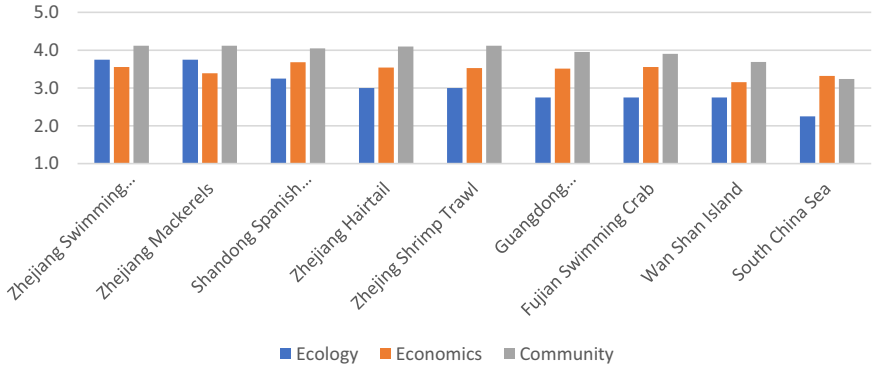

Fig. 5. Chinese fisheries performance in the three pillars of sustainability.

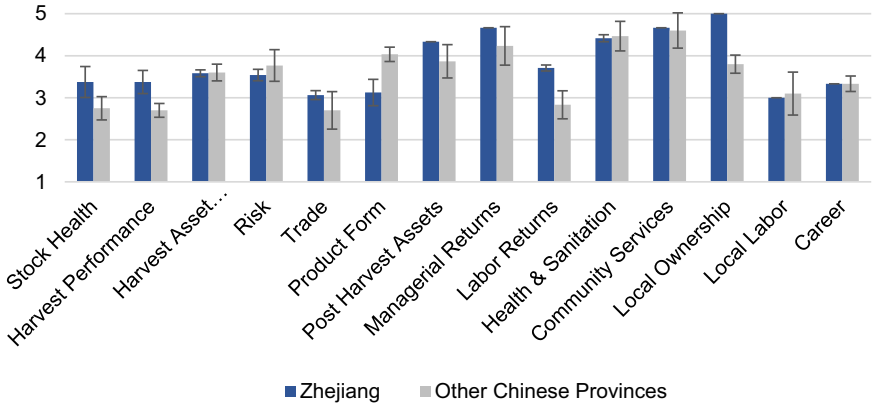

Fig. 6. Output comparison (Zhejiang compared to other Chinese fisheries).

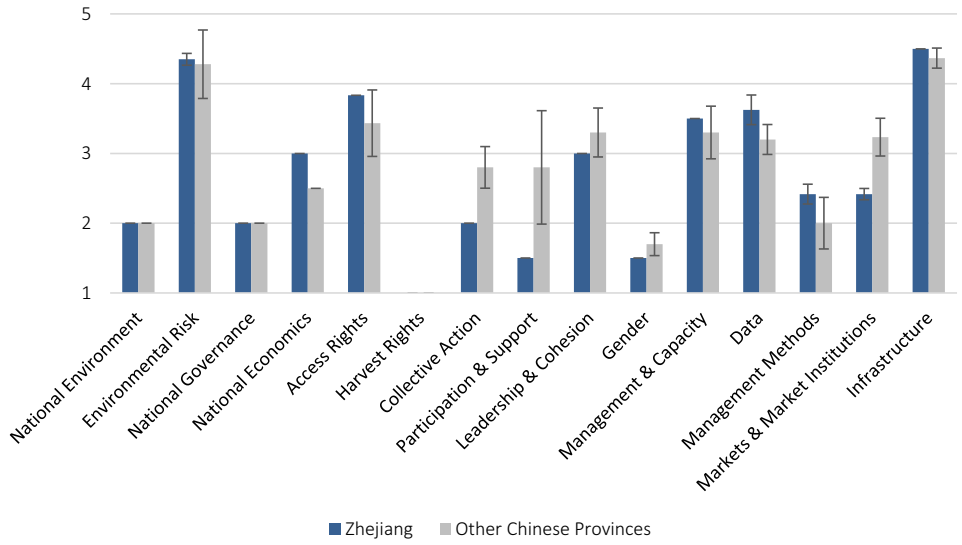

Fig. 7. Input table (Zhejiang Fisheries compared to other Chinese fisheries).

and better market institutions are all areas that if improved are likely to strengthen china's fishery management systems towards triple bottom line sustainability.

There are five pilot experiments on rights-based fishery management in China which will help identify what conditions are necessary to implement harvest rights effectively. This is a common approach for China before scaling up given each province or community has their own characteristics. These experiments will help educate and prepare fishery managers and researchers for the new management model. It will be interesting to use FPIs to assess these experimental rights-based fisheries in a few years, especially those which have implemented either Territorial Use Rights for Fishing (TURFs) or quotas to see if there is a significant difference in terms of their performance.

Among the nine fisheries management systems evaluated in China, Zhejiang Province performed better in most dimensions compared to other fisheries, including fish stock health, fishery harvest performance,

post-harvest performance, managerial returns, labor returns, and degree of local ownership. Some of their management experiences are regarded as role models for other provinces. However, the long-term effectiveness might be compromised by the lack of involving incentives and behavior changes of the fishers in the policy design. Concerns have been raised that once the enforcement has weakened, illegal fishing activities could rapidly come back [33]. As the FPI results suggested, more effort should also focus on the community level which will help achieve the long-term behavior change goal.

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