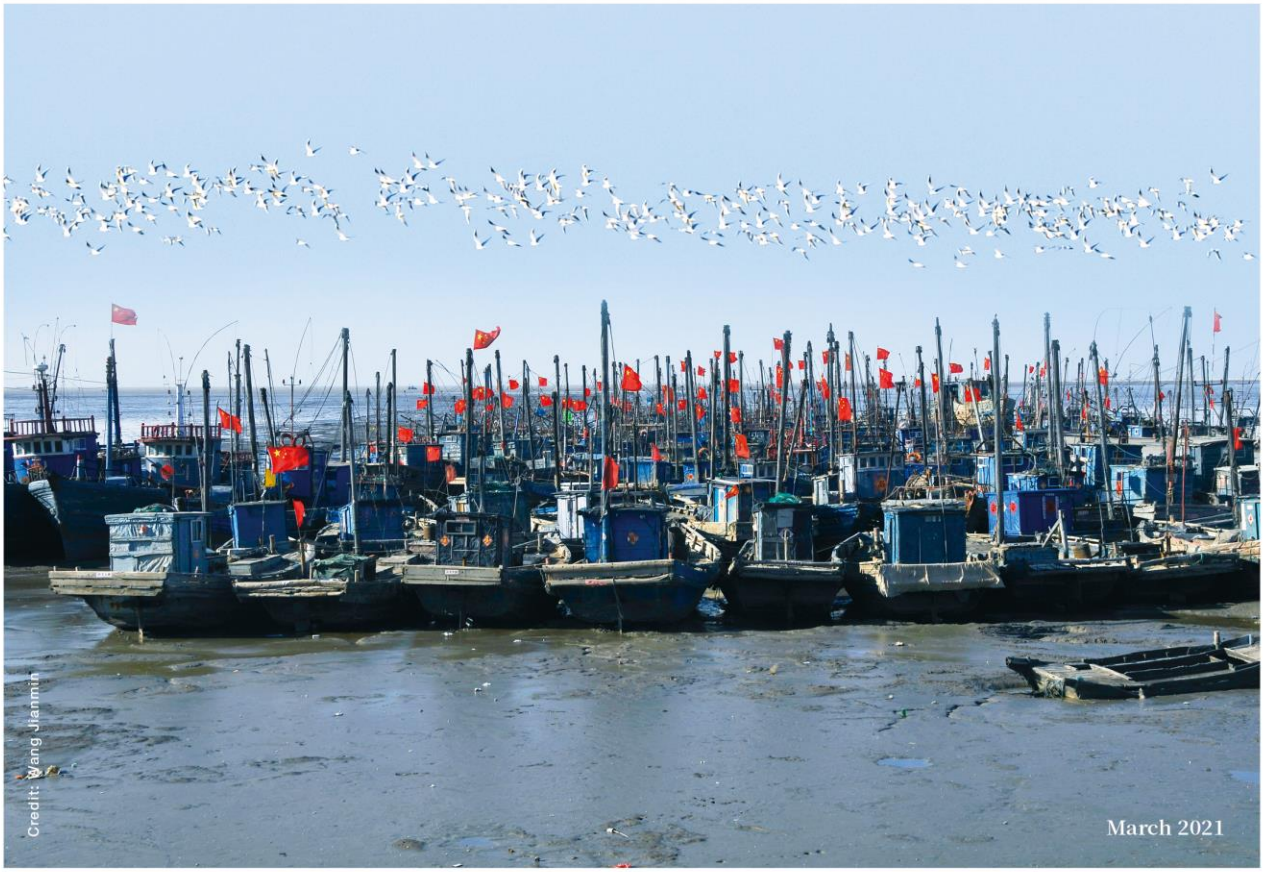
PROGRESS OF CHINA'S TAC SYSTEM:

EVALUATION REPORT FOR ZHEJIANG AND FUJIAN PILOTS

Natural Resources Defense Council
Environmental Defense Fund
Qingdao Marine Conservation Society



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Preface

Marine fisheries provide people with high-quality protein, employment opportunities, livelihood security and cultural identity. The industry plays an important role in supporting the economy and social well-being of coastal areas. Marine fishery resources are not only the material foundation of this industry but also indispensable part of the functioning and integrity of marine ecosystems. Maintaining the long-term sustainability of marine fisheries has huge economic, social and ecological significance.

China, the largest producer of marine fisheries in the world, has a long coastline and a huge marine fishing fleet. China has always attached great importance to the conservation and sustainable use of marine fishery resources. China has implemented management systems such as marine fishing permits, fishing vessel and horsepower quotas, fishing closure areas and seasons. China also has adopted management measures such as fishermen relocation, restrictions on fishing gear and fishing methods, juvenile fish protection and stock enhancement, ensuring "zero growth" and "negative growth" in marine catch volume. However, the use and management of fishery resources in China remains basic and inefficient. Fishing capacity still exceeds the carrying capacity of fishery resources, and the management of fishery resources still needs to be further strengthened.

In 2017, in order to improve the effectiveness of the conservation and management of marine fishery resources in the context of the country's vigorous efforts to promote the realization of ecological civilization, the Ministry of Agriculture and Rural Affair issued the Notice on Further Strengthening the Control of Domestic Fishing Vessels and Implementing Output Control of Marine Fishery Resources. The Notice proposes to implement total output control for fishery resource management and to explore the implementation of the quota system after further improving the "double control" of both the number and horsepower of marine fishing vessels. It requires that from 2017 onwards, Liaoning, Shandong, Zhejiang, Fujian and Guangdong provinces take the lead in the implementation of Total Allowable Catch (TAC) pilots, and that by 2020 each coastal province have at least one TAC pilot.

In 2017, Shandong and Zhejiang provinces took the lead in piloting TAC management, and in 2018, Liaoning, Guangdong and Fujian provinces followed suit. In 2019, the Ministry of Agriculture and Rural Affairs issued a notice requiring that all specially permitted fisheries during the summer moratorium be subject to TAC management. By 2020, at least one fishery in each of the 11 coastal provinces (autonomous regions and municipalities directly under the Central Government) has piloted TAC management, totaling 15 pilots.

These pilots experimented with TAC management for a variety of fisheries, explored and established relevant supporting systems and measures, as well as new models for vessel and resource management, reaffirmed the consensus on the fishery management reform in China, delineated a roadmap, and accumulated experience for the further and wider implementation of the TAC system.

As an output control system, the TAC system is a refined approach basis. The gap between what we have–a traditional fisheries management model, institution and experience—and what we want—the successful implementation of a TAC system, remains large in China. In light of the size of the marine fishing fleet, the multitude of fishermen, the diversity of fisheries, the variation in fishery business models, regional differences and other factors, implementation of the TAC system on a large scale still faces many difficulties and challenges. This complex reality calls for review, summary and analysis of previous pilots.

The Natural Resources Defense Council and Environmental Defense Fund are internationally renowned environmental organizations, and Qingdao Marine Conservation Society is a domestic non-government organization dedicated to the conservation of marine ecosystems and the sustainable development of fisheries. In the past few years, the three partner organizations have taken advantage of their international experience and network of experts in the field of TAC to actively cooperate with national and local fisheries authorities and research institutions to promote international exchanges, conduct research and spearhead public education regarding pilot implementation of TAC system in China.

Progress of China's TAC System: Evaluation Report for Zhejiang and Fujian Pilots, co-authored by the three organizations, selected three pilots in Zhejiang Province and Fujian Province and collected feedback from pilot participants. This report analyzes the catch monitoring and supervision systems in detail, describes the pilot experience and challenges encountered, and puts forward suggestions for improvement. The report found that the pilots actively explored a variety of management elements and accumulated valuable experience, but also highlighted challenges in determining allowable catch, catch reporting and statistics, management of transshipment vessels, laws and regulations, and other issues.

With the 14th Five-Year Plan impending, it is time to reflect on the experience of TAC pilots. Sharing the experiences of these pilots will provide useful references for the upcoming TAC reform.

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Natural Resources Defense Council (NRDC) is an international nonprofit environmental organization with more than 3 million members and online supporters. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. For over two decades, the NRDC has worked in China as a thought leader and trusted adviser to our partners. With a highly effective team of more than 30 members based in our Beijing office, we have worked hard at both the national and local levels to recommend, develop, and support the implementation of innovative laws, policies, technologies, and market tools that curb pollution and accelerate China's transition to a clean, low-carbon economy. NRDC's Beijing Representative Office is registered under the Beijing Municipal Public Security Bureau and supervised by the State Forestry and Grassland Administration of China. www.nrdc.org; www.nrdc.cn

Environmental Defense Fund (EDF) Founded in 1967 and headquartered in New York, EDF is one of the world's leading environmental organizations. EDF has more than 2.5 million members, a staff of nearly 700 professionals, and 12 offices around the world including the United States, China, United Kingdom, and Mexico. Areas that EDF works in include: climate and energy, oceans, ecosystems, health, etc. Since inception, EDF has been guided by principles of science and economics to find practical and lasting solutions to the most serious environmental problems. In 1997, EDF has formally operated in China and established extensive and mutual trust partnerships with Chinese governments, enterprises, and social organizations at all levels in the fields of environment, energy and climate. In June 2017, according to the Law of the People's Republic of China on the Administration of the Activities of Overseas Non-Governmental Organizations in China, EDF registered and established the Beijing Representative Office, which is the first overseas non-governmental organization with the Ministry of Ecology and Environment as its competent business unit. http://www.cet.net.cn/

Qingdao Marine Conservation Society (QMCS) is a Chinese NGO founded in 2017. QMCS is dedicated to promoting coastal and marine ecosystem conservation and advancing the sustainable seafood movement in China through scientific research, public and industry education, and the international exchange of information and knowledge. QMCS staff and members including marine ecologists, seafood experts, aquarium managers, educators, journalists, as well as sea and fish loving Chinese citizens. www.qmcs.org.cn/

Executive Summary

Total allowable catch (TAC) is a key feature of marine fisheries conservation and management for many countries and regional fishery management organizations. The Chinese Fisheries Law, as amended in 2000, establishes TAC as a fundamental part of the national fishery management system. However, due to various factors, it poses great challenges for the Chinese government in terms of implementation. As China entered the 13th Five-Year Plan period, the movement to realize Ecological Civilization—the Chinese government's term for the interconnectedness between humanity and nature—called for sustainable use of marine fisheries. In response, China launched its fishery management reform plan in 2017. In January of that year, the Ministry of Agriculture issued the *Circular of the Ministry of Agriculture on Strengthening Domestic Fishing Vessel Control and Implementing Total Amount Control Over Marine Fishery Resources,* proposing to establish a marine fishery resource-management system based on a combination of input and output controls. The circular required coastal provinces or municipalities directly under the central government to launch TAC pilots starting in 2017 and to have at least one pilot by 2020. By November 2020, a total of 15 TAC pilots had been launched.

In 2019 and 2020, the Natural Resources Defense Council (NRDC), Environmental Defense Fund (EDF), and Qingdao Marine Conservation Society (QMCS), in collaboration with Zhejiang Marine Fisheries Research Institute and Fujian Fisheries Research Institute, carried out an evaluation of the design and implementation of the first three TAC pilots in Zhejiang and Fujian. We hope this evaluation will provide useful information for Chinese decision-makers who are involved in building China's TAC system and fishery management reform program.

Main Findings

Finding 1: Zhejiang and Fujian made breakthroughs on a number of TAC elements and accumulated valuable experience.

The two provinces have made significant breakthroughs during their implementation of the TAC pilots. They have explored the TAC system by actively participating in international exchanges, learning from international experience, and sharing their own experience and insights both domestically and internationally. All pilots have undergone substantial discussion and examination regarding the fishery selection, implementation plan, and regulatory measures, and the provinces have coordinated and shared responsibility across fishery departments at the central, provincial, city, and county levels, as well as with scientific research institutes and fishing cooperatives. Scientists, policy makers, and enforcement officers in Zhejiang and Fujian are learning about the various elements needed

to make TACs work, identifying priorities, and taking the lead among coastal provinces in testing catch-monitoring tools—such as logbooks, at-sea observer systems, and onboard cameras—based on the characteristics of the fisheries. Through the pilots, the provinces have also recognized the importance of limited access, industry engagement, and fishery management plans. These lessons are an important measure of success. The three pilots have generated valuable experiences for the development of a national TAC system.

Finding 2: The pilots created a path toward scientific TACs.

At the time of pilot implementation, information on pilot species' abundance and catch history was too limited to set science-based catch limits. The TACs in all pilot programs were based on the recent historical catch, not a scientific assessment of stock status and productivity. In the absence of scientific information on fish stock abundance, catch history provided provincial policy makers with the most reasonable index of recent trends. Given the experimental nature of the pilots, it was prudent to set catch limits in line with fishermen's recent experiences. On the other hand, the pilot projects made progress in developing systems of data collection that could help support science-based TACs eventually, including catch accounting via logbooks, observer programs, and independent biological sampling. The pilots also showed that collecting information to support science-based TACs can be accomplished at a reasonable cost and would be a significant improvement over the status quo. Over time, as monitoring systems evolve during continued and future TAC pilots, data collection and stock assessment systems can be upgraded as scientific and administrative capacity improves.

Finding 3: Fishing logbooks proved a viable method to monitor catch on participating fishing vessels.

All three pilots developed new paper and electronic logbooks. The paper logbooks turned out to be the major tool for collecting catch data in the three pilot projects. These were the most well received by the fishermen because they were familiar to them and clearly prescribed in the Fisheries Law. The electronic logbooks were less popular. Unstable electronic connections, software problems, and low levels of literacy in electronic tools were the main reasons fishermen found them inconvenient to use. However, e-logbooks have obvious advantages over paper logbooks for scientists and fishery managers, such as machine readability, timeliness, and relatively complete information. They can also be conveniently processed and cross-checked with large amounts of data from other sources, saving time and human resources. Data reported electronically in real time also provide a mechanism for monitoring quota uptake and warning of potential quota overages. These are all desirable features to support TAC management. Continued improvement in both paper and electronic logbook functionality, and exploring the transition strategy from paper

to electronic, should be a priority in future pilot projects. Importantly, however, except for the juvenile anchovy pilot, project science directors were unable to routinely evaluate the accuracy of logbook entries, because they rarely collected multiple independent data streams on fishing-vessel catch for verification. Nonetheless, fishing vessel captains, observers, and science directors all believed fishermen did not misreport intentionally. The quotas were set relatively high, so there was little chance of exceeding them. Common sources of error do exist, including delays in data reporting due to the business of sea captains and the methods used to estimate the volume of catch.

Finding 4: Verification of reported catch is needed.

Self-reporting catch data using logbooks and hail-in/hail-out can provide important fishery-dependent information, but there are often problems of incomplete or false information. The accuracy of these data and stakeholder confidence in them can only be established through independent catch verification. In the swimming crab pilots of Zhejiang and Fujian, fishery managers planned to collect information from one or more of the following independent data streams: vessel monitoring systems (VMS), at-sea human observers, buyers' (transshipment vessels) reports, and dockside monitoring. However, the following difficulties were encountered: (1) at-sea observers' coverage was too low to objectively verify captains' catch-record reliability; (2) the requirement to deal with designated transshipment vessels was mostly ignored, and transshipment vessels' logbooks had a relatively low return rate; and (3) dockside monitoring was not implemented. The Zhejiang juvenile anchovy TAC pilot successfully collected independent data from observers, buyer trip tickets, and onboard cameras, but the fishery had only one buyer so verification was relatively easy. During experimental pilots, the provinces cannot be expected to achieve full verification of the catch, but they can work toward improved accuracy of and confidence in catch-monitoring systems by selecting appropriate independent data streams. Port-based monitoring (e.g., designated landing and offloading monitoring) is a necessary and operational option.

Finding 5: Transshipment poses challenges and opportunities for effective catch monitoring.

Due to economic and other factors, transshipment vessels play a key role in China's domestic fisheries. With no exceptions, the fishing vessels in the three pilots mainly relied on transshipment vessels to bring their catch either directly to port or, in the case of the juvenile anchovy fishery, to an at-sea processing vessel. The transshipment process can introduce significant loopholes in catch monitoring and verification, such as making the verification of fishermen's catch data impossible or enabling the landing of illegal, unregulated, and unreported catch. China has not yet formulated detailed management rules

for transshipment activities in domestic fisheries. The Zhejiang gazami crab pilot required fishing vessels and transshipment vessels to record transshipment activities in paper logbooks. However, our study showed that transshipment vessels' information was frequently missing in fishing logbooks and logbook recording by transshipment vessels was spotty. Other challenges included setting conditions for obtaining transshipment vessel permits. On the other hand, the transshipment process can contribute to catch management and monitoring systems if the vessels and amounts are recorded, thus providing a cross-check on the accuracy of the catches recorded in fishing vessels' logbooks. In addition, transshipment vessels can help provide information via hail-in or VMS data regarding the ports where the catch is being landed, which in turn can support a system of dockside monitoring. Requiring transshipment vessels to hail-in ahead of port arrival would help identify where the catch is being offloaded and permit dockside monitoring.

Finding 6: TAC pilot projects pioneered the very first at-sea observer programs in Chinese domestic fisheries, with a high degree of success.

Observers conduct biological sampling and record the time, location, catch, and catch per unit effort (CPUE) for future evaluation of stock health to help inform sustainable TACs. Our study found that in the early stage of experimenting with the TAC system, observers also played other roles, such as helping to train fishermen on how to keep logbooks. They observed the entire fishing operation on the vessels, helping people understand the fishery and providing insights on how to improve the pilot. In the juvenile anchovy pilot, observers played an essential role in monitoring bycatch, warning enforcement officers when the vessel exceeded acceptable bycatch levels, and identifying the need to shift fishing grounds. Although observers proved to be of great value, there were a number of challenges. For example, there was limited room for observers to work and sleep on the vessels in the gazami crab pilot, and sometimes the long duration of the work made it difficult for a single observer to observe all the catch while also getting sufficient rest. Key challenges for maintaining observer programs are a lack of qualified personnel, insufficient funding, and the lack of legal protection for observers. Their safety will continue to be a big concern until clear legal protections are in place. These combined factors resulted in low coverage of observers and sometimes an inability to deploy them altogether. The juvenile anchovy observer program, however, was improved and maintained for three years thanks to industrial investment and good working conditions, resulting in the collection of rich and consistent data.

Finding 7: Effective enforcement is necessary to ensure compliance.

In Zhejiang and Fujian's swimming crab pilots, there was some increased onboard inspection of fishing vessels by provincial, municipal, or county enforcement agencies, but

logbooks were not an enforcement priority compared to permits, fishing gear, and safety violations. Enforcement officers reported a common problem with paper logbooks not being completed in a comprehensive and timely manner, but due to a lack of guidance on assessing penalties for such behavior, no penalties were imposed. In addition, verifying the accuracy of logbooks was virtually impossible due to insufficient independent data streams. Enforcement officers were discouraged from strictly enforcing transshipment vessel logbook requirements; there are few regulations covering the operations of transshipment vessels and therefore no basis for enforcement. Additionally, there was no legal support for penalizing the sale of catch to non-designated transshipment vessels. In contrast to the swimming crab pilots, substantial enforcement resources were deployed during the juvenile anchovy pilot. Enforcement observers were present throughout the 1.5-month fishing season. They checked logbook entries in real time and worked closely with science observers to make sure vessels changed fishing grounds when the allowable threshold for bycatch was exceeded. The VMS tracks in this pilot were monitored daily to determine whether vessels fished only within the permitted area and landed their catch only at designated ports. At the time of this writing, no violations had been detected in this fishery.

Finding 8: The pilots demonstrated the importance of establishing incentives for compliance, including the requirement for accurate catch accounting.

Among all pilot projects, Zhejiang's juvenile anchovy pilot performed best in terms of compliance with management rules, achievement of goals, and gradual improvement. The comparative success of this pilot lies in the fact that this profitable fishery had set very high access conditions from the beginning and the government has allocated significant enforcement resources to ensure any violators (whether of logbooks or resource-protection requirements) will lose their permits the next year. In addition, the level of organization within the Zhejiang juvenile anchovy fleet as a cooperative is very high, with the processing vessels as the only buyer. The owner of the processing vessels has a deep understanding of the TAC system and sustainable fisheries. The owner turned the pilot rules into an internal business arrangement that was easily understood and accepted by fishermen. Such local leadership and incentives fostered good and transparent cooperation among the industry, fishery departments, and research institutes. By comparison, the level of organization in the other two pilots is much lower. In the Zhejiang gazami crab pilot, the access is limited and the maintenance of fishing permits is not much affected by vessels' compliance with the pilot rules. In the Fujian crab pilot, access could not be limited due to the fishing ground overlapping with other fisheries using different gears.

Main Recommendations

Recommendation 1: Conduct a comprehensive evaluation of the TAC pilots, establish step-by-step goals and a roadmap for the implementation of TAC management in China, and promote the TAC system in a planned, strategic, and scientific manner.

- Experience and lessons learned from the pilots should be summarized and challenges and areas for improvement should be identified.
- TAC pilots should be continued and gradually expanded to cover economically important finfish species and broader distribution areas. Technical and policy tools that support TAC management—such as electronic reporting and monitoring, designated ports for landing, a catch-traceability system, transferable quotas, and accountability measures—should continue to be tested and refined.
- In scoping out new pilots, the characteristics of the fishery should be investigated, and information—including with respect to fleet characteristics, fishing patterns, catch composition, and socioeconomic features—should be collected. Fisheries that have positive incentives for TAC management, involved local leadership, a high level of organization, and a limited access scheme should be top priorities.
- Supporting systems—such as catch accounting and TAC enforcement—and enabling conditions for TAC management should be gradually improved, and step-by-step goals and an action roadmap for the implementation of TAC management in China should be formulated.
- There should be improved TAC management training, which will promote the translation of concepts into actions. Educational opportunities should be provided to scientists and fishery managers to learn from TAC experience in other countries. Priority areas for fisherman training should be identified through discussions with cooperatives, enforcement officers, and government officials. Opportunities for international and domestic exchanges—such as international workshops, study tours, and TAC-themed training—should be promoted.

Recommendation 2: Set TACs on a scientific basis and make the status of fishery resources publicly available.

- There should be a national fishery resources assessment system, with support for national and provincial research institutions to conduct regular fishery resource surveys and stock assessments, the results of which should be published regularly.
- There should be national funding to support long-term, regular stock abundance surveys, especially for fish species and stocks managed by TAC.
- Scientific data collection should include fishery-dependent data, such as those collected from paper or electronic logbooks and checked against independent verification tools and dockside samples. For such purposes, analyses regarding the status of a fishery or fishery complex can be enhanced even further with CPUE, biological sampling (e.g., age and weight of fish catch), and bycatch data collected from human at-sea observers.

- TAC should be set scientifically, based on the estimated abundance and productivity of the relevant stocks, for purposes of ensuring fisheries' sustainability. Such analyses are reliant on fishery resource surveys, catch data collected at sea or port, and biological sampling data.
- Science-based harvest strategies and control rules should be developed to adapt TACs and other management measures as fishery conditions change.

Recommendation 3: Increase investment in improving catch monitoring and accounting.

- Establishing an effective catch-monitoring scheme should be considered a top priority for building a national TAC system and a key indicator for evaluating pilot progress.
- The requirement to maintain accurate logbooks should be strictly enforced. The value of keeping and reporting accurate catch records should be widely disseminated through training and public awareness campaigns.
- The continued development and application of the electronic logbook system should be promoted, so as to eliminate delayed catch and transshipment data collection and to ensure the timely transmission of key information to national centralized databases for recording, reporting, analyzing, and sharing catch, landing, sales, and transshipment data.
- Transshipment vessels should be required to provide accurate daily reports of the quantity and type of catch received.
- The establishment of designated ports for landing throughout the country and the development of a port-based catch monitoring and traceability system should be accelerated.
- An electronic monitoring (EM) data analysis system should be developed and machine learning techniques should be used to promote the application of EM.
- A coordinated monitoring system should be developed—incorporating logbooks, hail-in/hail-out, designated port landing, port-based inspection, and VMS monitoring, including cross-comparison of data—in order to enhance the reliability of catch information.

Recommendation 4: Build on China's current fishery management policy and establish fishery management plans that are consistent with China's characteristics.

- China should design a fishery management system that conforms to national conditions and combines input and output controls.
- Economically important fisheries should have a coordinated and agreed-upon fishery management plan, with clear objectives that comply with legal requirements, promote rebuilding and protection of fish stocks and habitats, and address the needs of different stakeholders.
- Fishery management plans should be easily accessible to participants and updated periodically as fishery conditions and community priorities change.

Recommendation 5: Strengthen regulations and enforcement.

- As part of an amended Chinese Fisheries Law and subsequent regulations, a legal regime for comprehensively implementing a TAC system should be established, including requirements for at-sea observers, VMS, designated ports for landing, a catch certificate and traceability system, enforcement mechanisms, a limited entry system, and a green subsidy system.
- Enforcement of proper maintenance of accurate catch records, including logbooks, should be strengthened as one of the priorities for at-sea and port inspection. Penalties for failing to submit logbooks or submitting inaccurate logbooks should be further enhanced. Technical guidance and implementation rules on the inspection and verification of logbooks should be compiled to guide law enforcement officers.
- Regulations on transshipment management should be strengthened, and penalties for violations should be clearly defined and properly enforced.
- Big data and scientific and technological methods should be used to enhance the flow of information to law enforcement departments and to increase efficiency.
- A fishery law enforcement information system should be established, encompassing elements ranging from evidence collection to punishment. Efficient information sharing between authorities and the establishment of an "intelligent law enforcement" model should be promoted. Information on best practices for using evidence generated from electronic tools (e.g., VMS and electronic monitoring) should be compiled and distributed.
- In order to address management of the large number of commercially important, highly migratory fish stocks, cross-regional and cross-sectoral supervision and management should be strengthened and multiparty participation and cross-regional management mechanisms established under the leadership of the Chinese Central Government.

Recommendation 6: Elevate the importance of TAC management and integrate it with current input-control-management measures.

- It should be widely recognized that developing a science-based TAC system is an opportunity to fundamentally improve fisheries' management capacity and is key to achieving scientific, sustainable management.
- China's current input control measures play an important role in fishery management. Development of the TAC system should be coordinated and integrated with the further implementation of traditional input control measures—such as fishing capacity reduction; cracking down on illegal, unreported, and unregulated fishing; selective gear; minimum catch size; and mesh size—to maximize the conservation impact.
- The central and provincial governments should provide sustained institutional, financial, and technical support to improve the TAC management system.

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1. Introduction

1.1 Introduction to Total Allowable Catch Management

Total Allowable Catch (TAC) is a key feature of marine fishery management in many countries, including the United States, Australia, Chile, New Zealand, the member states of the European Union. Of the 24 major fishing countries listed by the Food and Agriculture Organization,[a] only two countries, Malaysia and Myanmar, have not introduced any form of TAC-based management. The principal aim of TAC management is to conserve resources and maintain sustainable, long-term yield. TAC is one of the principal forms of output control (management that prescribes what is allowed to be harvested), and it may be used in conjunction with a range of other measures as part of an overall system of sustainable fishery management. Other measures may include input control tools such as limited access, effort controls, gear restrictions, and area management, depending on the fishery and policy objectives.

A TAC is an upper limit on the amount of fish—usually expressed in weight, but possibly numbers—that can be landed during a year or specified fishing season. Related terms include catch limit or catch quota. A TAC is typically set for a fish stock or fish stock complex and may be allocated as quotas to separate gear sectors (e.g., trawl and trap sectors) or to different user groups (e.g., commercial and recreational fishing and subsistence fishing). Quotas may be further allocated to individual fishing businesses or associations. In most cases, uptake of a TAC is monitored through the amount of fish landed in a period of time, not the amount of fish that is actually killed by fishing. An additional allowance may therefore be needed to account for all the fishing mortality in a stock, including any discard, bycatch, or incidental mortality.

There are several key elements of administering a TAC program. First, the TAC must be set on some reasonable basis. A TAC is ideally based on scientific assessments of fish stock abundance and productivity. In the absence of sufficient data, it could be based on recent catch levels, provided there is some evidence that these levels are likely to be sustainable. If enforced and routinely updated (e.g., in response to changes in stock size), a scientifically informed TAC should optimize a fish stock's sustainable production over time. Second, the uptake of a TAC must be monitored on a scale appropriate to its effective implementation. This can be accomplished through logbooks and verified using a number of independent data sources, such as buyers' trip tickets, random dockside catch inspections, at-sea observer monitoring, and camera-based electronic catch monitoring. These tools enable the cessation of fishing, when necessary, to help ensure that the total catch does not exceed the TAC. Finally, fishing rules in a TAC system must be effectively enforced to ensure accountability to legal requirements and fishing communities. The supporting regulatory infrastructure for TACs includes laws, regulations, and sufficient resources for implementation, all of which should be adapted as fishery conditions change.

[a] China, Indonesia, United States, Russian Federation, Peru, India, Japan, Vietnam, Norway, Philippines, Malaysia, Chile, Morocco, Republic of Korea, Thailand, Mexico, Myanmar, Iceland, Spain, Canada, Argentina, Ecuador, United Kingdom, Denmark.

1.2 Total Allowable Catch Management in China

1.2.1 Policy background

Since the amended Chinese Fisheries Law in 2000 first prescribed a TAC system, the State Council and the Ministry of Agriculture and Rural Affairs (MARA) of China (formerly the Ministry of Agriculture) have issued a series of policies, notices, and opinions calling for gradually establishing and implementing a TAC system and selecting appropriate species and areas to carry out TAC pilots.

Below is a list of relevant excerpts from those documents.

- 2000, Chinese Fisheries Law
    - Article 22: "Following the principle of keeping the allowable catch lower than the increase of the fishery resources, the State determines the total allowable catch of the fishery resources and applies a quota system for fishing."
- 2006, *Circular of the State Council on the Printing and Distribution of the Action Program for Conservation of Aquatic Living Resources of China*
    - "Determine the total allowable catch level of fisheries resources, gradually implement total allowable catch system."
- 2013, several opinions of the State Council of the People's Republic of China on promoting the sustainable and healthy development of marine fisheries
    - "Study and initiate the total allowable catch system, select appropriate species and areas to carry out total allowable catch pilots, and promote scientific and refined management of capture fisheries."
- 2015, Integrated Reform Plan for Promoting Ecological Progress
    - "24. Improve the system for managing total marine fishery resources, strictly enforce fishing moratorium and fishing bans, and promote domestic total allowable catch management."
- 2016, guidelines of the Ministry of Agriculture on accelerating development transformation and structural adjustment of fisheries
    - "Change the mode of domestic fishing production, improve the access system for capture fisheries, promote the organized management of fishing vessels and fishermen, and carry out total allowable catch pilots."
- 2016, China's No.1 Central Document of 2016 (Several Opinions of the Central Committee of the Communist Party of China and the State Council on Carrying Out New Concept of Development and Speeding Up Agricultural Modernization to Realize the Goal of Moderately Prosperous Society)
    - "Improve the system for managing total marine fishery resources, strictly enforce fishing moratorium and fishing bans, and carry out domestic total allowable catch management pilots."
- 2017, opinions of the Ministry of Agriculture on advancing agricultural supply-side structural reform
    - "Implement the system for managing the total amount of marine fishery resources and the 'dual control' system for fishing vessels, launch total allowable catch pilots, strengthen regional coordinated protection, and

reasonably control offshore fishing."

- 2017, *Circular of the Ministry of Agriculture on Strengthening Domestic Fishing Vessel Control and Implementing Total Amount Control Over Marine Fishery Resources*
    - "Explore total allowable system for individual species. Actively explore new models of marine fishery resource utilization management, select some specific fishery species to carry out total allowable catch management, explore the experience, and gradually extend the model. Since 2017, Liaoning, Shandong, Zhejiang, Fujian, Guangdong need to determine a city or sea area and selected fishing species to carry out TAC management. The related provincial department of fishery administration shall be responsible for formulating the implementation plan and shall organize the implementation after the approval of the Ministry of Agriculture. By 2020, all coastal provinces should choose at least one more mature area to carry out TAC management. The specific measures shall be formulated and implemented by the department of fishery administration at the provincial level."
- 2017, Letter of the General Office of the Ministry of Agriculture and Rural Affairs on Implementing Marine Fisheries Total Allowable Catch Pilot
    - "Organizing to carry out the total allowable catch pilots of marine fishery resources is an important measure to improve the ability of marine fishery management and realize the total amount control system of marine fishery resources."

1.2.2 Chinese TAC pilots

The 2017 circular is an important milestone because it set a time-bound agenda for all coastal provinces and municipalities directly under the Central Government to initiate pilots for individual species. In response, Zhejiang province and Shandong province initiated the first two TAC pilots in 2017, and by the end of 2020 almost all coastal provinces or municipalities had established at least one pilot project. Because of the requirement to set catch limits for fisheries specially permitted to operate during the marine summer fishing moratorium, many provinces or municipalities have taken those fisheries as a TAC pilot.

As of November 2020, there were 15 TAC pilot projects, of which nine were specially permitted fisheries operated during the marine summer fishing moratorium.[b] The criteria for the pilots included fisheries with a single species of short life span (e.g., crabs, shrimps, jellyfish, and clams), a small geographical distribution (e.g., all provincial waters), and a limited number of fishing vessels (less than 100).

The primary objectives of these pilots for the scientists, fishermen, and government officials focused on familiarity with TAC concepts. They would also test the key elements and procedures of TAC system, such as catch limits, quota allocation, and, most importantly,

[b] See Appendix 1, which lists the first pilot of each coastal province or municipality directly under the Central Government, except two of Zhejiang's pilots.

catch monitoring and accounting. Therefore, a variety of data collection tools and processes were tested. All pilots required vessel monitoring systems (VMS) or automatic identification systems (AIS) and paper logbooks, while some developed e-logbooks or used at-sea observers or port observers. Additionally, some pilots used designated transshipment vessels or ports to facilitate monitoring and inspection.

2. Research Goal, Objectives, and Methodology

2.1 Goal

Four years after the launch of the first pilot in 2017, it is necessary to conduct a periodic review of the design and implementation of the coastal TAC pilots. The goal of this study is to systematically analyze the experience gained and problems encountered so far, and to put forward practical recommendations for both the improvement of these pilots and the promotion of a TAC system at the broader regional or national level. We hope that this study can provide both a reference for Chinese decision-makers and a window for international scholars who are concerned about the process of fishery reform in China.

2.2 Scope and Objectives

2.2.1 Rationale for studying the Zhejiang and Fujian pilots

The three TAC pilots of Zhejiang and Fujian province were selected for the study. Besides being among the highest producers of wild-caught seafood in China, they were selected based on two criteria: the pilots' representativeness and diversity.

Unlike most other fishery TAC pilot projects in China—which lasted about 10 days during the summer fishing moratorium, with few other fisheries operating simultaneously—the swimming crab pilots in Zhejiang and Fujian lasted several months during the regular fishing season when other fisheries were operating. This added significant complications, including the need to share regulatory resources and, in the case of the Fujian pilot, multispecies fisheries operating in overlapping geographic fishing areas. In addition, the Zhejiang and Fujian pilots involved comparatively larger industrial fishing vessels (greater than 20 to 30 meters), which are more typical of those under TAC management worldwide compared with the small-scale subsistence fishing vessels (less than 12 meters) involved in many other pilots. Moreover, transshipment vessels were heavily used in these pilots. In summary, these pilots were representative of the common challenges facing China's domestic fisheries, and their program design is more complex, thereby better serving the purpose of piloting.

While the juvenile anchovy pilot is unique in many aspects, it still provides a valuable example of the role of incentives in the fishing industry. In 2018, one year after the implementation of the first (gazami crab) TAC pilot, Zhejiang province decided to advance the exploration of the TAC system by testing it in a different type of fishery: an at-sea processing fishery. The specific objectives of this pilot were to (1) explore a model of industry-led TAC and quota management; (2) build monitoring standards for China's

emerging at-sea processing fisheries; (3) further improve at-sea scientific observer systems and understand more about their role in supporting the management of the fishery; and (4) test the feasibility of opening and managing a species-specific fishery during the national "one-size-fits-all" summer fishing moratorium.

2.2.2 Objectives

For each pilot, we selected the time frame when rules and regulations at each locality were most developed. After preliminary investigation, it was 2017-2018 for the Zhejiang gazami crab pilot, 2020 for the Zhejiang juvenile anchovy pilot, and 2018 for the Fujian multispecies swimming crab pilot (see Table 1).

Because the pilot projects are in the preliminary exploration stage, they will not have a tangible impact on the resource abundance or economic performance of fishermen in the short term. Instead, we evaluate the performance of these pilots against their objectives. Therefore, the research scope of this study is focused on the catch reporting and monitoring system, the enforcement of laws and regulations, and stakeholders' familiarity with TAC elements and procedures. Secondary considerations are stakeholder participation and quota setting and allocation. The specific objectives are:

1) To analyze the design and performance of the catch-monitoring tools adopted in the pilot project—including fishing logbooks, scientific observers, and electronic monitoring (EM)—and summarize the experience and challenges.
2) To analyze the factors related to successful pilot implementation through the comparison of the three pilot projects.
3) To analyze the method for developing a science-based TAC based on the catch-monitoring system combined with the resource-abundance survey.
4) To examine the participation of stakeholders and the awareness-raising effect brought about by pilot training and project practice.
5) Through the above analysis, to develop specific recommendations for further improvement of the three pilot projects and for the establishment of a national TAC system.

Table 1. Overview of three TAC pilots (at the year for the study)[c]

		Zhejiang gazami crab	Zhejiang juvenile anchovy	Fujian multispecies swimming crab
Pilot staring year		2017	2018	2018
Year of the study		2017-2018	2020	2018
Fishery characteristics	Gear	Set gill net	Purse seine	Pot
	Period	September 16-March 31	May 1-June 15	August 1-April 30
	Access	Exclusive access during pilot season	The only fishery of this kind during summer fishing moratorium	Open access to other fisheries as well
TAC setting		Six years' historical catch	Within 10 percent of three years' anchovy historical catch	Three years' historical catch
Catch monitoring and data collection		• Paper and electronic logbook • At-sea scientific observers • VMS	• Paper and electronic logbook • At-sea scientific observers • Onboard camera (EM) • VMS	• Paper and electronic logbook • AIS
Enforcement		• Spot-checking at sea • Designated transshipment	• Onboard enforcement observers • Spot-checking at sea	• Spot-checking at sea
TAC (metric tons)		3,200	4,000	400
% quota update		38	57.5	49

[c] Please see Appendices 2-4 for a detailed plan of each pilot.

2.3 Methodology

In order to get a comprehensive picture of the design and implementation of the pilots, this study conducted a multi-stakeholder field survey of the three pilots from October 2019 to July 2020. The subjects are generally divided into five groups—namely, fishermen, cooperative managers, at-sea scientific observers, scientific directors, and fisheries officials or law enforcement officers. In this study, a questionnaire was used with fishermen, and open-ended questions were used for semi-structured interviews[d] with scientists, managers, and other groups (see Table 2). For detailed questionnaire and interview questions, please refer to Appendix 5.

In the surveys, we asked fishermen about their experiences in catch recording overall, their experiences in recording catch during the TAC pilot, and their perceptions of any training they had completed with the Ocean and Fisheries Bureau before the pilot. We also asked fishermen about the perceived accuracy of paper and electronic logbooks, their views on observers on the boat, their recommendations for changes in the logbook format, and their views on the effectiveness of fisheries enforcement. In the survey we delivered to fishing cooperatives, we asked the managers about the role of cooperatives in fishermen's daily life and in the new pilots.

In the scientific observer survey, we asked about their roles on the boat, their perception about fishermen's paper and electronic logbooks, the challenges encountered, and their recommendation for improving observer training. The science survey was an interview conducted with the science directors of Zhejiang Marine Fishery Research Institute (ZMFRI) and the Fujian Marine Fishery Research Institute (FFRI). In this survey, we asked questions about the design and utilization of logbook systems, their findings from quantitative analysis of the logbook data, their experiences managing the observer programs, the administrative challenges in the TAC pilot program, and how the catch data feed into scientific assessment of pilot species' resource abundance.

In the enforcement officer survey, we asked about the enforcement actions taken during the pilot, the nature of infractions reported during the pilots, and their assessment of the level of fisherman preparation for new regulations under the pilot. We also asked about the efficacy of the penalty and reward system, about the difficulty of monitoring and enforcing compliance for any catch offloaded to transshipment vessels at sea, and how different levels of government (city and provincial) cooperate in fisheries enforcement.

The main survey findings for each pilot and recommendations for improving the provincial TAC pilots are summarized in Section 3. Based on our survey findings and our own experience with fishery monitoring systems, in Section 4 we offer several policy recommendations for promoting future science-based TAC management at the regional

[d] A semi-structured interview is one where there is a list of predetermined questions, but it is not necessarily strictly followed and questions are open-ended. Interviewees are encouraged to fully express themselves.

and/or national level.

It should be pointed out that the sample size was limited by the inability to convene all fishermen and the data are influenced by the differences in the fishermen's understanding of the questionnaire. Therefore, a certain degree of uncertainty and subjectivity exists in the analysis and conclusions of this study.

Fisherman survey in Zhejiang swimming crab pilot (left) and juvenile anchovy pilot (right)
Credit: Zhou Haichao

Table 2. Overview of the stakeholder survey

(a) Zhejiang gazami crab pilot

Stakeholders	Approach	Number of representatives
Vessel operators	Questionnaire	11
Cooperative managers	Semi-structured interview	2
Scientific observers	Semi-structured interview	6
Science director	Semi-structured interview	1
Fishery managers and enforcement officers	Semi-structured interview	3

(b) Zhejiang juvenile anchovy pilot

Stakeholders	Approach	Number of representatives
Vessel operators	Questionnaire	11

Cooperative managers	Semi-structured interview	2
Scientific observers	Semi-structured interview	6
Science director	Semi-structured interview	1
Fishery managers and enforcement officers	Semi-structured interview	2

(c) Fujian multi-species swimming crab pilot

Stakeholders	Approach	Number of representatives
Vessel operators	Questionnaire	9
Cooperative managers	Semi-structured interview	1
Science directors	Semi-structured interview	2
Fishery managers and enforcement officers	Semi-structured interview	2

3. Results and Discussion

3.1 Zhejiang Gazami Crab Pilot

3.1.1 Results

Fishermen characteristics

General survey questions were asked of the 11 fishing captains (Appendix 5, section 1). Eight of 11 captains surveyed have a fishing history of more than 20 years. Ten of 11 have an education in junior and primary school, and one from high school. All captains go out to sea for 8 to 8.5 months a year, with a crew of 10 to 16, mostly 12 to 15. The captains came from the Tuichuangou Co-op (seven of 11) and the Fanshen Co-op (four of 11). Outside crab season, they mainly catch pomfret in coastal waters.

Captains' and observers' feedback on the trainings

TAC trainings had 100 percent participation from vessel captains. When interviewed, most recalled the key topics covered: logbooks, hail-in/hail-out, and the laws and regulations. Most captains were aware that TAC management systems are adopted to protect marine resources, and all captains were aware of the quota limits for their boats during the pilot. However, most expressed uncertainty about why logbooks should be filled out, indicating that they did so to comply with the pilot project rules. Nearly every captain expressed the desire for further training on e-logbooks. For the e-logbook training, the captains preferred "teaching by observers" and a "training class." Only one captain choses to "look at the material by myself."

Fishermen training class for the Zhejiang gazami crab pilot (left) and observers teaching how to use the e-logbook at port (right)
Credit: (left) Li Wei and (right) Zhu Wenbin's PPT in 2017 on Zhejiang gazami crab TAC pilot

Most of the observers recalled what was covered in their training: data collection requirements such as technical protocols, routine reporting practices, and safety issues. However, they shared mixed reviews about the adequacy of their training. Two of the five respondents found the training "adequate," largely because they already had a good foundation in fisheries science, and three observers found the training inadequate for various reasons. These observers generally felt that two half days were insufficient to learn everything, particularly for observers lacking a degree in fisheries science. Student observers who had limited experience coped by learning from institute scientists when they were also on board the vessel. The lack of data standardization was emphasized by many interviewees, due to its importance for data comparability. Most observers recommended a more in-depth treatment of fish species identification and data standardization methodologies.

Receptivity, accuracy, and timeliness of fishing logbooks

Prior to the TAC pilot, all 11 vessel captains kept their own fishing records outside the logbooks, mostly recording catch weight (ten of 11). About half of them also recorded fishing locations and unit price, and a few recorded transshipment volume (two of 11).

To evaluate fishermen's receptivity to paper and electronic logbooks, we asked participants to score the difficulty of both types of logbook and to identify their preferred reporting method (Appendix 5, section 1). We also interviewed observers for their perceptions of fishermen's receptivity to logbooks in general and to e-logbooks in particular (Appendix 5, section 3).

Receptivity. All captains said they had little or no difficulty using paper logbooks. This finding was reinforced by Zhu et al. (2021),[e] when they found a relatively high return rate for paper logbooks (50 out of 56, or 89.2 percent) compared to electronic logbooks (76.8

[e] Wenbin Zhu et al., "Transition to Timely and Accurate Reporting: An Evaluation of Monitoring Programs for China's First Total Allowable Catch (TAC) Pilot Fishery," *Marine Policy* 129 (2021), https://doi.org/10.1016/j.marpol.2021.104503.

percent). The average reporting frequency of paper logbooks was nearly twice that of e-logbooks, and the total catch reported was also higher in paper logbooks. The number of fishermen using e-logbooks decreased with time, and no one has used them since January 2018. In contrast to the paper logbooks, all respondents scored the difficulty of e-logbooks as high (four or five on a scale of one to five). When asked why they did not fill out the e-logbooks, nearly all captains identified "system failures." A common failure was not being able to open the app. Two captains also reported not knowing how to use an electronic logbook. Incidents of system failure with e-logbooks were confirmed by observers.

Observers provided an additional perspective regarding the vessel captains' willingness to fill out logbooks, which, in their view, was generally low. The primary reason offered by the observers is that sea captains are very busy on board the ship. The captains do not view completing the logbooks as their job, and they do not fully understand the value of catch accounting overall. Ultimately, vessel captains completed their paper logbooks because it was mandated by the Fisheries Law and the pilot program. However, according to the observers interviewed, the technical challenges of the e-logbooks were too overwhelming for the captains' limited incentive. A primary challenge was the electronic literacy of fishermen. It was found that most captains have been fishing for more than 20 years and have only a primary school education. It is notable that the percentage of e-logbook reporting decreased over the months, reaching zero in January 2018.

Completeness and accuracy. Despite the fact that paper logbooks are much easier for fishermen, Zhu et al. found that e-logbooks outperform paper logbooks in data completeness. The biggest issue with paper logbooks was omissions in entries and illegible handwriting. Supported by built-in quality-control features, an e-logbook effectively prevents omissions and ambiguities in date and location.

Typically, the accuracy and reliability of fishermen's logbook data is evaluated by comparing their logbooks to similar independent data streams such as observer catch records or transshipment purchase records. This was not a possibility in this pilot, however, due to limited coverage of at-sea observers and the unreliable transshipment vessel reports. Accordingly, we asked pilot participants to estimate the accuracy of their logbook entries. Most fishing captains rated their estimates of the number of rows of gill net pieces, production weight, and transshipment weight as being highly accurate. Only two captains rated the records as medium accuracy. This self-assessment was consistent with impressions provided by the other pilot participants. Observers and science directors communicated that they also believed the data provided by fishermen in the paper logbooks were largely reliable, and that fishermen do not intentionally report false information. They speculated that this was because the total catch limit was set very high.

As further evidence of reliable paper logbook entries, Zhu et al. found no significant discrepancies in the catch weight, number of gill net rows, CPUE, and transshipment volume recorded by observers and their vessel captains when observers were on board. Furthermore, there were no significant differences between logbook entries from vessels that had observers on board during the pilot versus vessels that never had an observer on board.

Despite this optimistic result, participants did identify several factors that made accurate data logging more challenging. One major source of error was the speed with which things happen on board the vessel. Observers explained that crab baskets—the method of estimating the landed weight of catch—were quickly moved into storage once filled, making it difficult for operators and observers to count them accurately. Observers noted, however, that counting the total number of baskets during the transshipment process may allow for higher accuracy because the transfer is more orderly and occurs at a slower speed. Additional sources of error included counting volume (the number of baskets) instead of catch weight and the tendency to assume all baskets were equally full.

Timeliness. To examine the timeliness of fishing captains' logbook data entry, we asked observers how quickly captains completed their logbooks and any causes for delay (Appendix 5, section 3). Observers said that when they were on board, they noticed that the logbooks were filled out by the captain in a relatively timely manner, at least once a day or even two or three times a day. However, when they were not on board the vessels, observers and the science director believed there were significant delays in reporting (by one to two days, or even longer). This was believed to be the case for the e-logbook app as well, as it can accept data for any time over the past seven days. In this case, it is difficult to tell whether fishermen reported in real time or within seven days.

Science directors and observers pointed out that late reporting is a significant problem for accuracy because it is easy for fishermen to forget their catch volume while busy working. The science director also found that fishermen have their own definition of a working day, which is different from the day cycle provided on the logbook (12:00 p.m. to 12:00 p.m. the next day). This may explain why certain data in observers' and captains' logbooks are very close but recorded on neighboring days.

Electronic monitoring

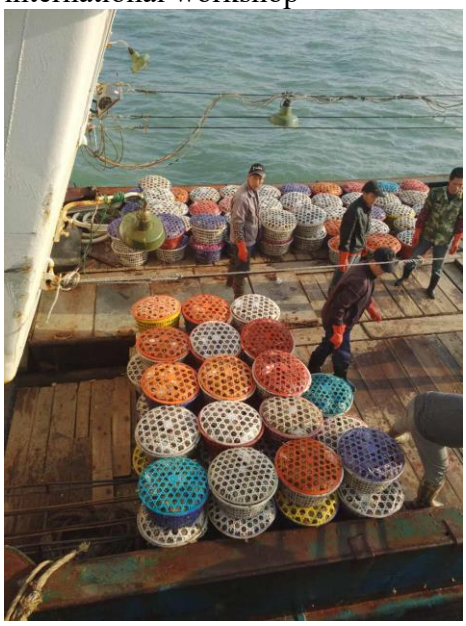
Most fishermen's vessels (eight of 11) are equipped with cameras on board for the purposes of "safety" and "direct production." The running cost is about 6,000 to 8,000 yuan per year, which the industry bears, not the government. Communication on board the ship has improved considerably over the last two years, with 100 percent of captains saying they now have offshore Wi-Fi. That enables them to use WeChat at sea to send messages and pictures to the cooperative and to their family at any time.

Monitoring catch via onboard cameras
Credit: Li Wei

Transshipment

All surveyed fishermen reported selling catch to transshipment vessels at sea. Although the pilot project declared that fishing vessels were to interact with a designated group of 15 transshipment vessels, logbook data and interviews (with observers and enforcement officers) revealed that fishing vessels typically did not comply with the rule. The survey showed these transactions were based on personal relationships or high purchase price rather than proximity to fishing grounds. Of 44 vessels that provided transshipment records (contained in paper logbooks), 10 vessels recorded only using designated transshipment vessels, while the other 34 recorded using transshipment vessels that were not designated. This finding was contradictory to what was communicated by the interviewed vessel captains, as 100 percent of them reported that they only transshipped to designated vessels. There was considerable mismatch between the records of fishing and transshipment vessels. Specifically, fishing vessels recorded dealing with a total of eight designated transshipment vessels, while 14 designated transshipment vessels recorded dealing with fishing vessels in the pilot. None of the transshipment vessels' data can be matched with the correspondent fishing vessels. Their catch recordings differed significantly.

Gazami crab transshipment vessels
Credit: Zhu Wenbin's PPT in 2018 on multispecies TAC fisheries management international workshop



At-sea observers

To evaluate the role and experience of the observers in the pilot, we asked them about their duties on board, how they experienced the working environment, and their major challenges. We also interviewed the science director and captains about their experience of observers.

The observer program was deployed using a mixture of researchers from ZMFRI and students from Zhejiang Ocean University. We found that observers executed roles beyond the tasks described in the pilot design. In addition to collecting data, they taught fishermen how to use fishing logbooks and communicated with the captain and crew about daily operations. Observers also used the opportunity to better understand the experience and perceptions of the fishermen. All observers valued their importance to the fishery operations in terms of generating essential data for fishery assessments, understanding the entire fishing operation from direct observation, and explaining to fishermen the importance of conservation policies. Each observer communicated the hope that the coverage of observers will increase.

Scientific observers on gazami crab fishing vessels
Credit: Zhu Wenbin's PPT in 2017 on Zhejiang gazami crab TAC pilot



All observers felt safe on the vessels and the fishermen were very friendly. This is consistent with captains' feedback from the survey. Nine captains out of 11 thought "observers were helpful for them and they feel good about observers." Observers identified that the key reason for this receptivity was the communication in advance about sending observers to specific vessels. Because this was the very first observer pilot for domestic fisheries, the fishing boats that carried observers were not randomly selected. The personnel of the institute communicated with the local fisheries administration, and the fisheries administration communicated with the captains to coordinate whether they would be willing to carry the observers. Fishing captains who were easy to communicate with and had a good temperament were selected.

The science director was generally satisfied with the observers' performance and found that they did very well in core tasks and that the quality of their data was very high. The science director determined the only weakness of the observer program to be the lack of recording standards for each data entry, resulting in gaps in observers' logbooks. This is consistent with observers' own feedback on their training.

Maintaining observer programs is one of the biggest challenges, in particular the lack of available trained observers. Relying on institute researchers is not sustainable. A limited number of observers were deployed only on fishing vessels, not on transshipment vessels and landing sites. Their coverage on fishing vessels was too low to provide an independent data stream to evaluate the accuracy of logbook entries. No at-sea observers were deployed for the second and third year of the pilot (2018-2020). According to the science director, the biggest challenge in maintaining an observer program is the lack of professional, trained observers.

Law enforcement

To evaluate the role of enforcement in the pilot project, we surveyed fishermen and enforcement officers. Interviews focused on (1) the frequency and nature of enforcement actions taken during the pilot project; (2) fishermen's compliance with pilot project procedures; and (3) challenges of enforcing the pilot rules.

All fishermen interviewed observed provincial, city, and county law enforcement vessels in the TAC fishing waters. However, the frequency of sightings was rare throughout the pilot project: an average of 3.72 times per season in 2017-2018, 3.52 times per season in 2018-2019, and 4.27 times per season in 2019-2020. This was generally consistent with the three instances per season of TAC-targeted enforcement activities reported in the enforcement officers' interviews. When enforcement checks occurred, each captain had their license, safety facilities, and fishing gear checked, and eight (out of 11) had their logbooks checked.

Linhai fishery enforcement officer inspecting gazami crab fishing vessels
Credit: Zhu Yupeng

Enforcement during the pilot period was mainly carried out by county-level (Linhai) and city-level (Taizhou) enforcement officers. When enforcement agents stopped boats, they usually checked safety issues first. Issues relating to the TAC pilot were secondary. Law enforcement officers' primary concerns also included whether the vessel was fishing within the area specified by its special fishing permit. Enforcement officers used VMS to assist with this evaluation, because they are very familiar with the VMS tracks of gill net fishing operations. Secondarily, enforcement officers checked the captain's paper logbook. Inspection officers have no way of inspecting e-logbook entries at sea (because they cannot contact land-based data managers). The most common problems found by enforcement officers, with respect to the pilot project rules, were that fishermen were not completing their logbooks in a timely manner and that fishermen did not identify the transshipment vessels with which they were dealing. However, no penalties have been issued. Four general challenges were highlighted by the enforcement agent's interviews:

(1) Lack of detailed rules or guidance for penalties on logbooks

Imposing penalties for absent or inaccurate logbook entries posed a challenge during the pilot. While the recently revised fishing-permit-management regulation mentions a penalty for failing to submit logbooks or for providing false information, there are few precedents nationwide and no guidance on how to assess the penalty for delayed, incomplete, or incorrect logbook entries. Enforcement of logbooks had not been a priority prior to the TAC pilots. Additionally, there is no legal support to penalize the sale of catch to non-designated transshipment vessels. The plan to lower the quota and deduct pilot subsidies for violations during the pilot project had little impact on fishermen, as the quota was set at a very high level and the subsidy is low.

(2) Lack of incentive to enforce transshipment rules

Among all the rules, the designated transshipment scheme was most difficult to implement, facing resistance from captains from the beginning, since each captain already had a long-term relationship with a handful of transshipment vessels. Captains also worried that the 15 designated transshipment vessels would form a monopoly, leading to the acquisition of their gazami crabs at a low price. While fully aware that the transshipment rules were established to help validate fishing captains' logbook data, officers felt that strict enforcement of the rules was a bit futile, given other loopholes such as the lack of dock monitoring. For these reasons, the transshipment vessel scheme was discontinued in the third year of the pilot project (2019-2020).

(3) Lack of legal support to implement rules for transshipment vessels

There are currently very few laws and regulations for transshipment vessels. Existing rules focus on safety regulations. They no rules about who can purchase from whom. Also, because there is no fuel subsidy for transshipment vessels, there is less incentive to comply with any regulations, since the consequences are not as great as if they were risking the loss of a subsidy.

(4) Lack of coordination among different governance levels

As the TAC pilot project began, county-level enforcement agents were given the primary responsibility for implementation and enforcement. However, after the pilot was initiated, there seemed to be a lack of close coordination between the province and the county-level agencies on priorities and logistics with respect to implementation and enforcement. This lack of interaction may have stalled the county-level enforcement practices, which decreased each year of the pilot. At present, there appears to be less long-term planning and emphasis on the work at the provincial level.

Thoughts for the future

All surveyed fishermen believed gazami crab abundance has decreased in recent years. They reported usually putting back egg-holding females and undersize crabs to protect the resource. They were concerned about their future prospects: two of them were thinking about leaving the industry, and others reported seeing no good prospects but lacked ideas

for a different livelihood.

3.1.2 Discussion and recommendations

As the first TAC pilot in China, Zhejiang's gazami program was perhaps the most multifaceted TAC pilot project among the provinces, and the experiences gained have provided valuable knowledge to help advance catch monitoring and TAC management systems in other Chinese domestic fisheries. This evaluation demonstrates that the objective of testing various catch-data collection and monitoring tools was fulfilled and confirms the value of pilot projects in developing sustainable management practices in China's domestic fisheries. We found the participants in this pilot to be highly engaged in its objectives and willing to share their experiences and insights. Overarching lessons learned and recommendations for advancing the pilot project are discussed below by topic and in Table 5.

1. Goals

The goals of a pilot project are central to its design, implementation, and evaluation. While the goals were initially clearly defined by the Bureau of Ocean and Fisheries of Zhejiang province (ZBOF)[f] in 2017, it would be prudent to reexamine the pilot's objectives prior to each iteration.

To foster a mutual understanding of the pilot's goals and enhance buy-in among participants, ZBOF should include key representatives of pilot participants in a goal-setting exercise. Modifications to the design of the pilot should be guided by those objectives and a general workplan distributed to participants prior to its implementation. It is important that everyone involved in the pilot has a clear and unified understanding of what the pilot aims to accomplish and how.

2. TAC setting

Currently, the pilot TAC is based on average recent catch levels. The TAC was set relatively high to avoid triggering a fishery shutdown during the course of the pilot; it was believed that constraining fishermen's catch would reduce their incentive to record catch accurately. Ultimately, however, the goal of TAC management is to identify science-based catch levels that will yield maximum sustainable catch over the long term. Given fishermen's concerns about the health of Zhoushan's gazami crab fishery, we recommend establishing a scientific program that will support stock assessment and the development of a science-based TAC recommendation.

To build toward this goal, we recommend assembling a scientific team to develop a monitoring and research program that will enable a data-limited stock assessment of the gazami fishery. In time, implementing a science-based approach to TAC determination could help incentivize fishermen to keep more accurate logbooks, due to their role in maintaining a healthy long-term fishery.

3. Logbook recording

Recording catch via paper logbooks on fishing vessels was a central component of this

[f] The name of the organization in 2017

pilot project and one of its most successful elements. There was a high return rate of paper logbooks during the pilot season, and all participants reported some level of confidence in the recorded catch data. Importantly, the science director and observers felt that fishermen did not knowingly misrepresent their catch levels.

Although compliance was high, many fishermen reported not understanding the utility of catch reporting. The value of setting TACs to achieve sustainable fishery resources over the long term was not fully evident to most fishermen, potentially undermining their incentive to accurately record catch. In addition, common sources of error were identified by observers and the science director, including rapid transfer of fish catch to the hold, estimating fish catch by counting baskets (not weight), and, most importantly, delays in logbook reporting. These obstacles should be the focal points for improvements to logbook accuracy in future iterations of the pilot.

To build on fishermen's general acceptance of paper logbooks and to improve the accuracy of their catch accounting, we recommend engaging with the fishing vessel captains to better understand their challenges and motivations for keeping catch records. Some effort should be made to design a paper logbook that is both convenient to complete and helpful to the captains' business practices. In addition, compulsory training for captains should contain a curriculum about the importance of catch accounting to maintaining sustainable fisheries.

Pilot participants identified more problems using e-logbooks compared to paper ones (see Tables 3 and 4). The primary challenges stemmed from technical difficulties with the e-logbook and lack of electronic literacy among fishermen. There are numerous reasons, however, to overcome these challenges and accelerate the adoption of electronic record keeping. Because of the existence of transshipment and the need for more complete data sets—as well as the need to process and validate huge amounts of monitoring data with highly constrained professional personnel—we must turn to electronic logs in the future.

Generally, electronic logbooks should be designed according to the characteristics of the fishery, be highly convenient to fishermen, and provide fishermen with some utility in managing their business. The highest priority in developing a widely adopted system is to ensure the stability of the reporting platform, allowing fishermen to store their data even when the cellular signal is not good. System malfunctions should be carefully noted, since they are not only dampening the efforts of scientists to collect reliable and timely data but are also making fishermen feel frustrated and negative about catch reporting. Additionally, effort should be made to create a system that is simple to use. The difficulty of electronic reporting is very real to fishermen, including the use of mobile phones. Contracting with fishing cooperatives to develop an easy-to-use reporting system would likely be a fruitful partnership.

The training of fishing captains and observers prior to the initiation of the pilot was regarded as an important element of its success. In fact, we recommended an expanded role for these trainings in future pilots, with two principal modifications. First, it may be easier to conduct the training through the fishing cooperatives, which are familiar and trusted places of support and information exchange. Doing so could enable more frequent trainings

and help to eliminate communication barriers. Second, the training of fishing captains should include information about the multiple values of accurate catch accounting, including its role in protecting the long-term health of the fishery and its value in managing the business. This could help incentivize accurate logbook record keeping.

Table 3. SWOT analysis for the e-logbooks

Strengths • Timely reporting • Automatic upload of spatial-temporal data • Built-in quality-control features prevent omissions • Data are easier to organize and analyze	Opportunities • Preferred by operators who are good at smartphones • Draft Fisheries Law amendments have new articles that specifically mention electronic monitoring
Weaknesses • Frequent malfunctions • Not easy to work with • Difficult to handle under terrible sea conditions • Repetition of filling paper logbooks • Costly installation and maintenance • Data cannot be validated on-site	Threats • Not mandated by any current laws or regulations • Low fishermen acceptance • Fishermen's literacy is inadequate to handle smartphones

Table 4. SWOT analysis for the paper logbooks

Strengths • Easy to work with • Easy to handle under terrible sea conditions • Running cost is low	Opportunities • Mandated by the current Fisheries Law • High fishermen acceptance • Users have more experience • Training is easy
Weaknesses • Low timeliness • Data need to be filtered and sorted manually • Omission and mistakes in recording • Illegible handwriting	Threats • Delays in fishermen's recording

4. Verification

To be effective, catch-monitoring programs must have a mechanism for verification. The government must be able to assess the accuracy of fishermen's logbooks and to identify noncompliant actors. Verification is often accomplished by establishing a second, independent catch accounting record. In Zhoushan's gazami fishery, such a record could be achieved by transshipment captains or dockside monitoring.

Transshipment presents challenges and opportunities for validating fishermen's catch records. During this pilot, participants reported low compliance in both transshipment

requirements: working exclusively with designated fishing vessels and catch recording. While transshipment captains used paper logbooks, they had low return rates and incomplete records.

In future iterations of the pilot, effort should be made to invigorate the capacity of transshipment captains to conduct an accurate accounting of purchased product. Feedback from observers identified the point of sale with transshipment captains as a good opportunity to accurately count catch, due to its slow and orderly transfer. It is recommended that transshipment vessels be required to keep a daily log of all purchases specifying relevant data such as fishing vessel ID, biomass of fish purchases, and time and location. In an effort to move toward real-time electronic monitoring, the pilot should continue to test and improve e-logbooks with transshipment captains. Using WeChat as a transitionary electronic reporting tool could also be explored.

Relatively slow and orderly transfer of gazami crab baskets
Credit: Zhang Yazhou

An alternative method of logbook verification is dockside monitoring. This method has many advantages and should be incorporated into the next iteration of the pilot program. A first step in developing a dockside monitoring program would be to conduct a study examining port habits of transshipment vessels. This could be facilitated by accessing VMS data from transshipment vessels and establishing a hail-in/hail-out requirement for them.

Zhoushan International Aquatic Product City port, the biggest port for gazami crab in

Zhejiang
Credit: Li Wei

5. Observer program

The Zhejiang gazami pilot project provided a unique opportunity to test the first at-sea observer program in a Chinese domestic fishery. Overall, the program was highly successful and demonstrated the value of observer programs in advancing TAC management in China.

Survey findings revealed three successful elements in the design of the pilot program: the selection of qualified observers, their preparation, and the decision to consult fishing captains prior to placing observers on vessels. Responses by all participants showed that the observers played an important educational role in training fishing captains on logbook entries and in collecting biological information that could be used in developing TAC recommendations.

Because of limited space and the lack of sleeping quarters for the observers, we recommend transferring the primary observer program from fishing vessels to transshipment vessels. There, observers will be able to assist in transshipment reporting and conduct supplemental biological research. The pilot directors may still want to place observers on fishing vessels on occasion to assist in logbook training.

Implementation of the observer program was conducted by the ZMFRI utilizing researchers and students from Zhejiang Ocean University. However, limited resources and staffing strongly restricted the scale and sustainability of the observer program. Moving forward, pilot project leaders should consider establishing a fully funded third-party organization to lead the observer program. Finally, observer programs currently lack legal status in domestic fishery law, and therefore lack important protections for the observers. This omission should be addressed in future amendments of the Fisheries Law.

6. Enforcement and incentives

While a detailed and sound enforcement plan was developed for the gazami pilot project, it was not fully implemented. Enforcement officers communicated that the monitoring rules laid out for the pilot participants were difficult to enforce due to a lack of underlying legal support from the existing Fisheries Law. Given the circumstances, enforcement officers felt that they could only seek captains' cooperation through positive incentives. This is probably a challenge facing all of China's domestic fisheries. The ongoing fishery law amendment process offers an opportunity to reinforce pilot program goals by articulating requirements for complying with various catch-monitoring tools and penalties that can be imposed for violation. Of particular importance is the need to formulate regulations for transshipment vessels and develop guidance for the enforcement of logbooks. In the meantime, enforcement officers should increase inspection frequencies, make logbook checks compulsory, and impose stricter penalties when fishing captains violate catch accounting rules.

Table 5. Summary of findings and recommendations from Zhejiang gazami crab TAC pilot

	Findings	Recommendations
TAC setting	1. Catch limit was set as the average catch of 2011-2016, as calculated from value records kept by local cooperatives. It was set above the average catch and is possibly too high.	1. Maintain regular fisheries resource survey and sampling and continue to improve data quality. 2. Assemble a scientific team to evaluate the status of the data and develop a plan to work toward a science-based TAC. 3. Conduct data-limited stock assessment and possibly use a management strategy evaluation as a future goal to guide management.
Logbook (fishing vessels)	1. Paper logbooks had a relatively high return rate. 2. Most groups (science director, observers, and captains themselves) agreed captains do not willfully misreport catch, but the accuracy of logbook data is undermined by incompleteness of data entries and multiple sources of errors, such as lack of attention to detail, the method of catch estimation, and high speed of operation. 3. Due to their low coverage, observers' records are not	1. Concentrate on the paper logbooks for now as the primary means of colleting catch data from the fishing vessels. 2. Improve the paper logbook's design to increase its convenience and usability by the vessel captains.

	Findings	Recommendations
	sufficient to objectively verify captains' catch records. 4. The design of paper logbooks is relatively complicated for captains, requiring much time and frequent interruptions to their busy operation.	
	1. E-logbooks have a lower user rate than paper logbooks, due to inconveniences (system failures such as not being able to log into the app, unfamiliarity with the new tool and with the smartphone itself, and the sea environment) and the voluntary nature of e-logbooks. 2. The data set for each e-logbook is a bit more complete than the corresponding paper logbook, due to the e-logbook's automatically generated time and location information. 3. All captains prefer to use WeChat to report.	1. Continue to develop the e-logbook to improve reliability and utility, reduce inconvenience, and increase the value of record keeping for captains. Adding a messaging option for captains to receive the co-op's messages would be useful. 2. Explore using WeChat as an alternative or transitionary electronic reporting tool (especially for captains who strongly resist the e-logbook), since the system is stable, the utility familiar, and most fishermen have access to it at sea and already use it frequently.
Logbook (transshipment vessels)	1. Only used paper logbook and ignored e-logbook. 2. Very low return rate, and very low completeness of paper logbook. 3. Highly unreliable data because transshipment vessels did not follow the requirement to differentiate the catch received from pilot vessels and non-pilot vessels. 4. Both fishing vessel captains and transshipment vessel captains failed to record a full list of their trading partners.	1. Require catch recording on transshipment vessels. 2. Put observers on transshipment vessels (see recommendations made for Observers). 3. Explore the feasibility of requiring daily reporting of all transshipment vessels using WeChat or radios. This ensures real-time, daily completion of logbooks and enables at-sea checking of logbooks against WeChat or radio reports.

	Findings	Recommendations
Designated transshipment	1. The compliance with designated transshipment was low. Fishing vessels often sold their catch to non-designated transshipment vessels, and some designated vessels never entered the pilot water. 2. Designated transshipment was considered by all interviewees as not practical. This requirement was discontinued in the second year.	1. Monitoring programs that constrain or disrupt the natural course of the commercial fishery usually do not work. Allow fishing vessels to work with any transshipment vessels but require transshipment vessel to obtain a TAC permit and report catch.
Dockside monitoring	1. There was no requirement for designated dockside landing. 2. Landings are mostly made by transshipment vessels and rarely by fishing vessels themselves. 3. Monitoring dockside landing was not conducted.	1. Set up dockside monitoring as a priority for the pilot's next step. 2. Require transshipment vessels and fishing vessels to hail-in ahead of port arrival and gradually learn how many and which ports are used. 3. Find out whether there is a need to require designated ports for landing. 4. Officers or observers conduct dockside monitoring of transshipment vessels and check and collect the transaction proof, such as the transaction tickets currently being used. Keep dockside monitoring records for later data comparison.
Observers	1. Observers on fishing vessels played essential roles in regular scientific work, logbook assistance, and training of fishermen. They also provided valuable evaluations of the monitoring program design and implementation to allow for improvements. 2. Onboard cameras are not a	1. Maintain observer programs. 2. If human capacity is limited, put the focus on observing transshipment vessels and docks, instead of expanding the number of fishing vessel observers.

	Findings	Recommendations
	suitable substitute for human observers at this point in time, given the observers' many roles. 3. The onboard conditions during the pilot were as ideal as they could be (as local enforcement officers picked the right vessels), but the conditions for observing were still very difficult due to the size of the vessels and mode of operation.	
	1. There are no observers on the transshipment vessels or at the landing site.	1. Deploy observers on transshipment vessels, observing transshipment activities, collecting independent data, and teaching the use of logbooks. 2. Deploy observers on the landing site of transshipment vessels and fishing vessels upon hailing in.
	1. Observer program is difficult to maintain due to lack of human capacity, funding, and safety concerns.	1. Establish a third-party observer agency or increase the staff size and funding for the research agency to carry out the long-term observer program. 2. Strengthen the legal status of observers and empower enforcement to provide better protection for them.
Electronic monitoring	1. Long and continuous hours for observers are challenging. EM may help. 2. High onboard camera coverage to document safety issues (used daily by fishermen). 3. All vessels are required to use functioning VMS.	1. Develop a feasibility study to experiment with the use of cameras for EM with a few selected vessel operators. 2. Use VMS to monitor transshipment vessels and fishing vessels in pilot area and landing sites, as well as their interactions. 3. Continue to observe VMS effort data.

	Findings	Recommendations
Data verification and management	1. Observer logbooks can be an indicator of fishermen's logbook accuracy, but they are limited because of observers' low time coverage and low vessel coverage. 2. A "two ticket" system (fishermen's and buyers' data comparison) was designed for data verification in this pilot, but weak compliance with the logbook scheme make it difficult to compare. 3. Dockside catch data was not collected. 4. Data entry and analysis of paper logbooks is very labor intensive and time consuming.	1. Collect value (selling price of the catch) data from fishermen as another source to verify data reliability. 2. Collect dockside catch data to compare with fishing vessels' and transshipment vessels' logbook data. 3. Develop a procedure and data structures for cross-checking data from various sources—e.g., logbooks, at-sea observers, and landing data—to verify catch data accuracy. 4. Establish a data analysis and management team with strong technical capacity. 5. Accelerate the transition from paper logbooks to electronic logbooks to reduce human cost.
Enforcement	1. At-sea spot-checking is only two to three times per year. The pilot did not attract much additional enforcement effort. 2. Before the pilot, logbook checking was neglected by enforcement agents compared to safety issues, gear, and license violations. 3. During pilot enforcement, paper logbooks were checked and problems found, but penalties were not issued. National regulation on misreporting was only established in 2019. 4. There is a penalty of a quota reduction for violating logbook requirements, but it is ineffective because the quota had been set too high for fishermen to reach.	1. Increase involvement of enforcement officials from provincial enforcement team and Shengsi county enforcement officers. 2. Require law enforcement agents to check logbooks during every onboard inspection. 3. Develop guidelines for enforcement officers to check major errors in logbook keeping. 4. Impose more severe penalties for repeated misreporting offenses.

	Findings	Recommendations
	1. Regulating transshipment vessels is rated the most difficult part of fishery management. Enforcement is very challenging due to lack of relevant laws.	1. Routinely check transshipment logbooks during every onboard inspection. 2. Strengthen national laws and regulations for the management of transshipment vessels.
Quota allocation	1. Quota was allocated to individual fishing vessels.	1. Maintain this approach this year.
Cooperatives	1. Local cooperatives of this pilot mainly played a service role, lacking management rights. Nevertheless, they generally play a critical role in delivering policies and regulations from the government to the fishing industry and helping fishermen to comply.	1. Local cooperatives remind fishermen to fill out logbooks daily through WeChat. 2. Collaborate with local cooperatives to help understand the economic and social factors of the fishery, including the activities of transshipment vessels, to inform the design of the monitoring program. 3. Provide training to the cooperatives so that they can teach fishermen whenever needed. 4. Collect catch value data from cooperatives.
Training	1. Taizhou Bureau of Fisheries and Zhejiang Marine Fisheries Research Institute organized several training meetings for fishermen. They were also trained at port and at sea on the use of e-logbooks, but fishermen still found them difficult and desired more training on how to use them. 2. Fishermen understood the TAC and their quota but still had very limited understanding of why they should fill out logbooks and how to use e-logbooks.	1. Provide trainings on e-logbooks and laws, regulations, and policies for fishermen through collective meetings, observers, and cooperatives. However, incentive is still the key for fishers' future performance. 2. Collect feedback from fishers, cooperatives, observers, and enforcement officers to constantly improve the training design.

	Findings	Recommendations
	1. Training for observers (only two half days) was inadequate, although sampling technique was considered by observers as adequate. 2. The institute that designed and organized the training lacked experience in developing observer training programs.	1. Bring in international resources to help the institute develop observer training programs, especially in identifying any missing parts. 2. Develop detailed protocols to help standardize observer information collection and documentation.
	1. There were no special trainings for fishery managers and enforcement officers, even though they play a key role in designing and implementing the pilot.	1. Make sure fishery managers and enforcement officers participate in the trainings and workshops on TAC and catch monitoring. In short, training is needed for all stakeholders, so everyone feels part of the project and understands the priorities. 2. Promote cross-province and cross-country exchanges on experiences and lessons, especially on how to promote compliance with logbooks.
Institutional arrangement	1. Provincial coordination and local fishery bureaus' incentives are considered the most important institutional factors for the success of the pilot. 2. Current management measures for the pilot are dispersed in several government documents: one observer program document, one enforcement program document, one monitoring program document, and so on.	1. Appoint a provincial official as TAC coordinator to make sure different cities and counties and different departments work collaboratively. 2. Combine all existing management schemes (several separate documents on management measures) into a single management plan with clear short-term and long-term objectives. The plan can make sure everyone is on the same page. 3. Highlight TAC and catch monitoring in high-level national policy documents, such as the 14th Five Year Plan, to win more provincial-level institutional, financial, and human capacity support.

	Findings	Recommendations

3.2 Zhejiang Juvenile Anchovy Pilot

3.2.1 Results

Fishermen characteristics

Five of the six captains of catcher and processing vessels surveyed had fished more than 10 years, and four of five transshipment captains have operated for about five years. Nine of 11 captains only completed their primary school education. Outside of the anchovy season, catcher vessels mainly fish octopus, cuttlefish, pomfret, and hairtail by trawling. For anchovy fishery, catcher vessels and transshipment vessels carry a crew of four to six people, and the processing vessel carries a crew of 27.

Captains' and observers' feedback on the training

Training sessions had 100 percent participation from all three groups of captains interviewed. Most reported learning about the key topics covered: paper and electronic logbooks, the laws and regulations, and safety issues; one captain could not recall the content of the training. About two-thirds of all captains were aware that TAC management systems are adopted to protect marine resources, though mainly because they had heard it from the owner of the at-sea processing vessels and the cooperative (not from the training). Only one catcher vessel captain was not aware that the fishery has a catch limit. All captains agreed that keeping logbooks helps conserve the resource, and three of them agreed it helps to record every year's production level. Captains had an interest in safety, e-logbooks, and paper logbooks. However, safety issues ranked highest (for seven out of 11 captains) among all issues. For trainings on e-logbooks, observer teaching and training classes were equally preferred.

There were no land-based training classes for juvenile anchovy observers. Student observers learned by observing and assisting the institute's observers directly on board, acquiring the required skills, and familiarizing themselves with procedures. Gradually, they were able to undertake observation tasks independently. Observers and the science director agreed that this form of in situ training was the most efficient for this fishery. The identification of other juvenile species while classifying percent bycatch was the only challenge mentioned by observers, as it required expertise in species identification and there were no existing guidelines.

Receptivity, accuracy, and timeliness of fishing logbooks

Receptivity. According to the science director, the return rates were 100 percent for paper logbooks. For e-logbooks, the return rates were more variable: the two processing vessels

returned them, but four of the eight transshipment vessels did not submit their e-logbooks. We asked captains to score the convenience and difficulty of both logbooks and to elaborate on the major reasons for not using e-logbooks, in those instances where they did not return them. Half of the captains thought e-logbooks were more difficult and less convenient, while the other half thought e-logbooks were less difficult and more convenient, citing the automatically generated data entries as the reason (Figure 7). In contrast to the gazami crab captains, who consistently identified paper logbooks as easiest (a score of one) and e-logbooks as hardest (a score of five), anchovy captains scored both paper and electronic logbooks within the two-to-four range; only the processing captain had a strong preference for the e-logbook over the paper logbook. All captains identified the frequently unstable Internet connection as the primary reason that discouraged the use of e-logbooks. The second reason was that they were "too busy," as they had already filled out paper logbooks. When asked what additional functions the captains wanted the e-logbook to have, most transshipment vessel captains selected "help calculate accumulated catch" and "receive cooperative messages," closely followed by "inform me of accumulated catch with the cooperative" and "weather warnings." The processing vessel captain only wanted reminders of timely reporting. Even if these functions were provided and there was no problem with Wi-Fi, most captains would still prefer WeChat reporting and paper logbooks—but, again, the processing vessel captain had a strong preference for e-logbooks.

In observers' views, fishermen had relatively high receptivity to filling out and submitting paper logbooks, as it was an order from the cooperative and requested by the processing-industry leader, and captains normally try their best to cooperate with such requests. Also, the fishermen were aware that any violation to the rules set by the pilot project might disqualify them from the fishery. At-sea observers believed some captains' cell-phone illiteracy and at-sea Wi-Fi connection still posed significant challenges to completing e-logbooks. The observers saw that a few captains still use old cell phones that can only call and text and had no previous experience of using smartphones. Observers also confirmed that the app itself worked well but that Wi-Fi connections were not stable.

Accuracy and timeliness. In the self-assessment of the accuracy of the logbook entries (time, location, and catch volume), most captains assessed that e-logbook information was more accurate or at least as accurate as the paper logbook data. All e-logbook items were scored at highest accuracy of five, with the exception that two captains scored the "time" entry at three. Relatively more captains scored paper logbook entries at three. The average score for the e-logbook was 4.67, 4.67, and 5—for time, location, and catch volume, respectively—and for the paper logbook was 3.83, 4.3, and 4.3. The science observer, after comparing captains' paper and electronic logbooks, found that catch records between the two logbook methods were similar. Furthermore, observers commented that the two processing vessel captains and two of the four transshipment vessel captains did exceptionally well in e-logbook entries.

In our interviews, scientific observers believed that catcher and processing vessels had no incentive for false reporting, since their data can be quickly compared and cross-checked by either themselves or the enforcement officer. The observers were also monitoring the process of loading catch from transshipment vessels to the processing vessel. It was

consistent with our survey findings that—unlike the gazami crab captains, who all kept records private—most transshipment vessel captains used the logbooks as trading records with the processing vessels, which gave them an incentive to record as accurately as possible. The difference between the paper logbook and the electronic logbook was only that the former used the number of standard baskets and the latter used kilograms to measure the catch. According to the science director, there is a conversion commonly used by fishermen from baskets to kilograms.

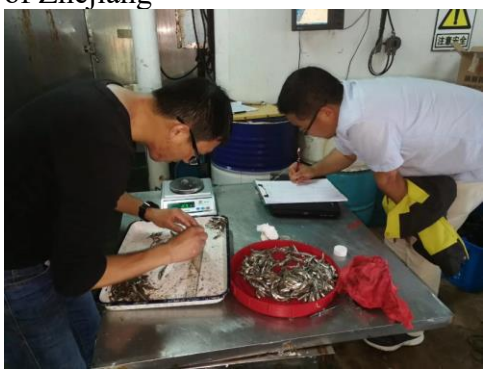
Fishing vessels, transshipment vessels and processing vessels
Credit: Zhu Wenbin's PPT in 2019 on the observer program for juvenile anchovy fishery of Zhejiang

Our survey showed that the transshipment vessels transferred five to fifteen times per day. Most captains completed both the paper and electronic logbooks each time after the transfer. Only one captain used the paper logbook once a day and the e-logbook once every few days. Processing vessels received catch 30 to 60 times per day and recorded each time after receiving the transfer in paper logbooks and e-logbooks. Observers noticed that the paper logbooks were filled out by the captain in a timely manner. Unlike the gazami crab fishermen, who only rest for three hours a day, anchovy fishermen follow a natural sunrise-to-sunset working pattern and did not think filling the logbook was too much of a burden.

<u>At-sea observers</u>
Observers interviewed found that the anchovy processing vessels provided favorable conditions for them to perform all tasks. The living conditions were very comfortable, the workspace was big enough, and fishermen were very supportive. Because observers had adequate working space, they were able to perform more complicated biological sampling

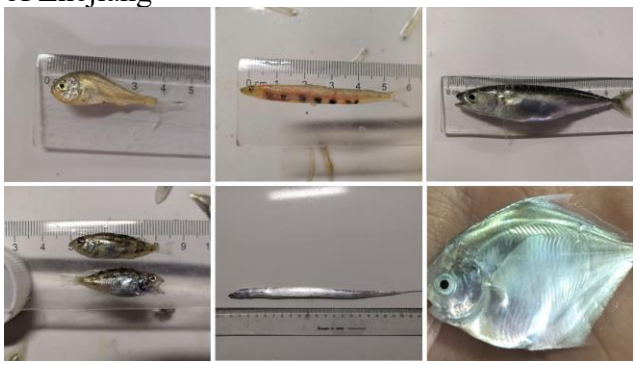
tasks and additional scientific projects, such as fishing gear selectivity testing.

Observers doing biological sampling onboard
Credit: Zhu Wenbin's PPT in 2018 on the observer program for juvenile anchovy fishery of Zhejiang



The science director was satisfied with the work of the observers, especially for the year 2020, during which one experienced institute observer covered the entire fishing season, which helped ensure high-quality and consistent data. Considering the difficulty of identifying juvenile economic fish species, observers had begun to prepare a guidebook by taking clear photographs of all types of juvenile fish caught and bringing their samples back to the laboratory for genetic sequencing.

Photographs of bycatch juvenile fish
Credit: Zhu Wenbin's PPT in 2018 on the observer program for juvenile anchovy fishery of Zhejiang



In addition, industry funding has enabled the observer project to last for three years since its inception in 2018, resulting in an increasingly rich accumulation of data. Although longer monitoring time is needed to obtain sufficient scientific data for stock assessment, observers have already played an essential role in ensuring that the fishermen change fishing grounds quickly to avoid catching too much of other economically important fish species.

Electronic Monitoring

The video monitoring system installed on both transshipment and processing vessels worked well. Videos were collected from the camera system on board and brought back to land. We checked a few videos and found the footage to be very clear and complete. No incidents of bycatch of protected species were reported by fishermen during the pilot season. Observers believed the use of cameras will make fishermen less likely to violate the rules on protected species such as sea turtles, especially considering the videos will be able to be used as direct evidence for penalties in the near future. However, interviews with the local fishery bureau indicated there is not yet a detailed plan on how to make use of the enormous amount of data generated by EM.

Electronic monitoring tools on juvenile anchovy at-sea processing vessels
Credit: Zhu Wenbin's report in 2019 on MSC preassessment of Zhejiang juvenile anchovy fishery

Enforcement

The enforcement level in this pilot was high. Enforcement observers covered the entire fishing season. Our interviews with them showed that no violations had been detected in the fishery. The crew's certificates, gear, and safety equipment were checked at the port before departure. When the proportion of bycatch was beyond the allowable 2 percent threshold, under close monitoring by science observers and the order from the enforcement observer, fishing vessels changed fishing grounds in time. Enforcement observers directly checked the logbook of the processing vessel and compared it through talks (over ordinary maritime radios) with the captains of transshipment vessels. The official who monitored the fleet's daily VMS tracks found that there were no cases in which vessels broke away from the fleet or entered waters outside the permitted or protected areas. Both port officials and the science observers mentioned that the dry product transshipment vessel only landed at the designated port, as determined by VMS tracks and hail-in records. The cooperative director added that, so far, there have not been any significant challenges in implementing pilot rules among fishermen, and the cooperative maintained close communication with them and provided reminders when necessary.

All captains who were interviewed observed provincial, city, and county law enforcement vessels in the TAC fishing waters. The frequency of sightings for catcher vessels and processing vessels was about one to three times every year, but most transshipment vessels reported over 10 times per year. During the pilot project, all captains had their licenses, safety facilities, fishing location, and fishing gear checked; all but one had his logbook checked. Enforcement observers on the processing vessels also described several occasions when the vessels were inspected by law enforcement officers from other cities.

Thoughts for the future

All surveyed captains believed that juvenile anchovy abundance has increased in recent years and that the fishery has good prospects. They saw their future of continuing with this fishery.

3.2.2 Discussion and recommendations

The Zhejiang juvenile anchovy TAC pilot tested many key elements of a sophisticated fishery catch monitoring system and yielded important results for advancing catch monitoring in China. Overall, our evaluation showed that the program had extensive stakeholder engagement, and all stakeholders were satisfied with the pilot implementation, especially the monitoring schemes, which have been improved every year since 2018 and have achieved the set objectives (see Table 6).

1. Incentives

Industry investment and positive incentives among stakeholders are believed to be critical factors to the success of this pilot project.

The incentives to obtain accurate catch monitoring and to achieve overall sustainability are high in this unique fishery. It is a big privilege to be able to fish during the summer fishing moratorium. Due to the closure, Huacheng has become the only fleet permitted by MARA to access the fishery. Whether it can maintain this permit next year depends on its degree of compliance with the regulations during the current year. As fishermen and law enforcement agents from surrounding counties and cities are paying close attention, Huacheng has a strong desire to prove that it strictly complies with the management regulations and carries out responsible fishing. Similarly, the Ruian Fisheries Department has a strong incentive to establish a national model for the management of the at-sea processing industry, and therefore is willing to allocate adequate human capacity and resources for the successful execution of this pilot. In short, comanagement is exemplified in this fishery by the way that fishermen, managers, and scientists work together to achieve the same goal.

In addition, strong leadership from principals in the industry has bolstered investment by participants. Interviews with different stakeholders in this fishery helped us identify one singular leader, the owner of the processing vessels and the Huasheng company, Mr. Chen, who was regarded as the critical element for the successful pilot. A face-to-face interview with Mr. Chen revealed that he held a deep understanding of the sustainable use of marine resources, the TAC system, science-based management, and the “two ticket” catch

accounting system, thanks to his prior work experience in Japan's fishing industry. He has been highly motivated to build a world-renowned juvenile anchovy industry. As the only buyer of juvenile anchovy that can offer a high purchase price to catcher vessels, Mr. Chen has been using this power as leverage to train and educate fishermen since 2007. He works closely with fishermen in his operation, sets many detailed rules for daily activities on board, strictly ensures implementation, and discontinues cooperation with any catcher vessels that do not following the rules. After all these years, the captains take his words seriously. Mr. Chen helped translate the pilot requirements to the captains in his own way, similar to orders issued within the fleet. The Ruian Fisheries Department believes that anchovy captains are among the highest quality and most compliant captains in Ruian.

2. Logbook accuracy and catch accounting

The accuracy, completeness, and timeliness of paper logbooks was high in this pilot project. The e-logbooks were not similarly received among captains in the first year, even at the request of the cooperative and Mr. Chen. This was likely the result of the instability of at-sea Wi-Fi and the lack of familiarity with electronic tools among the fishermen. These are significant obstacles for fishermen and should receive targeted attention. One promising example of such a program is provided by the Ruian Fisheries Department. At present, fishermen are required to use mobile phones to hail-in and hail-out, despite the fact that many fishermen are not used to smartphones. So, the department has hired local cooperatives to fill in for fishermen during an interim period. This solution gives fishermen time to adapt to the new tools and helps them discover the value of e-logbooks through training. On the other hand, compared with the swimming crab pilot, fishermen seemed less resistant to the e-logbook and were more likely to try to undertake the exercise and see some of its benefits. From the e-logbook sample in Figure 2, we can see that most of the entries can be automatically obtained or selected to fill in, saving the trouble of writing.

In contrast to Zhejiang's gazami crab pilot, there are no obvious gaps in the catch accounting in the anchovy pilot. Overall, the existence of transshipment vessels in this fishery does not introduce a complication in the catch-accounting process. These vessels only serve this fishery and work in a synchronized way with catcher vessels and processing vessels. They are like a focal point that helps gather catch from catcher vessels, and the fact that there is only one dry transshipment vessel makes it easier to inspect at port. All transshipment vessels installed cameras, and the dry transshipment vessel strictly complied with the designated landing in Dongshan port, where fishery law enforcement personnel are stationed. This provided good conditions for cross-checking catch data from different sources. At present, the catch data of transshipment vessels and processing vessels match well. In the future, more efforts are needed to explore how to use camera data and port monitoring to further verify catch data.

3. At-sea scientific observers

There was significant buy-in to the observer program because the industry, the Ruian Fisheries Department, and the research institute all have the same need for the scientific information gathered by the observers. First, the volume and composition of bycatch species identified by observers can help the processing company, Huasheng, prove that it has not caused unacceptable damage to other species during the summer fishing

moratorium. Second, the observations of the oceanographic environment and species' distribution will help the industry identify fishing grounds, improve fishing efficiency, reduce production costs, shorten operating time, and further reduce the impact on other resources. Moreover, the data collected continuously for many years will help the fisheries institute develop an anchovy stock assessment and establish a more scientific TAC limit. As a result, fishermen are very receptive to observers and the newly installed camera system. On the other hand, it must be realized that not every at-sea processing industry has leadership that understands and emphasizes responsible fishing practices. An at-sea processing fleet can be potentially very destructive if not monitored well, due to its great fishing capacity, close relationship between catchers and buyers, and the fact that most of its production activities are carried out at sea. One lesson that the pilot generated for China's emerging at-sea processing industry is the necessity of deploying at-sea observers and video cameras. Relevant laws and regulations should be formulated to mandate it.

4. Limited entry scheme

The processing ship owned by Huasheng is one of the first such ships in China. In recent years, various localities have also begun to invest in the construction of offshore processing ships. However, the fishing capacity of processing ships is huge, and if their number increases too fast, it will soon lead to overcapacity. It is necessary to manage the target fishery with a TAC and a limited access system to ensure that the number of offshore processing vessels matches the catchable resources from the beginning, rather than allowing open access and blindly encouraging investment, resulting in overfishing. One of the experiences that other fisheries can take from the anchovy pilot is setting strict conditions for entry. For example, Hucheng obtained the permit based on its long record of good compliance with management regulations, and catcher vessels were selected from captains who have juvenile anchovy fishing experience and have no violation records for the past three years.

Contrary to the swimming crab fishermen, who said that the future was not good, all the anchovy fishermen interviewed said that they were full of hope for the future and would continue to work.

Table 6. Summary of findings and recommendations from Zhejiang juvenile anchovy TAC pilot

Issues	**Findings**	**Recommendations**
TAC setting	1. Catch limit was set as about 10 percent of the average anchovy production level of Zhejiang in the last 12 years.	1. Maintain regular fisheries resource survey and sampling and continue to improve data quality. 2. Conduct data-limited stock assessment and plan for management strategy evaluation in the future.
Logbook (all vessels)	1. 100 percent return rate of paper logbooks. 2. High accuracy, completeness, and timeliness of logbook data	1. Make no change to the format of both paper logbook and e-logbook system.

	entries due to strong incentives. 3. Captains have sufficient time to complete paper logbook.	
	1. E-logbook has a lower user rate, due to the new mobile-phone-based tool and unstable at-sea Wi-Fi, which reduce willingness. 2. Captains think the e-logbook is more accurate than paper logbook. 3. WeChat is a preferred reporting tool.	1. Continue to develop the e-logbook to improve reliability and utility so as to reduce inconvenience and increase value to captains.
Designated landing	1. Hail-in and hail-out is required for all vessels. 2. Designated port landing is strictly followed. 3. Spot-checking for landings was conducted.	1. Maintain designated port landing requirement. 2. Improve dockside monitoring and inspection and keep dockside monitoring record for later data comparison.
Observers	1. The observer covered the entire fishing season and generated high-quality data. 2. Observers played an important role in the fishery's bycatch control 3. Observer program is paid by the industry.	1. Maintain observer programs. 2. Strengthen laws and regulations for the observer system for at-sea processing vessels.
Electronic monitoring	1. Onboard cameras for catch-monitoring purposes were installed and tested. 2. All vessels are required to use functioning VMS, and VMS tracks were monitored daily.	1. Develop a plan for making use of EM information.
Data verification and management	1. A "two ticket" system (transshipment vessels and processing vessels) is used in data verification in this pilot. 2. EM and designated landing created good conditions for data verification.	1. Maintain current system and develop a procedure and data structures for cross-checking data from various sources—e.g., logbooks, landing data, EM—in order to verify catch data accuracy.

Enforcement	1. Enforcement level is high, including at-sea enforcement observers, VMS staff, port officials, and other counties' agents. Logbook check is receiving similar emphasis as other traditional items. 2. No significant violations were detected.	1. Maintain current enforcement observer scheme. 2. Make checking of logbooks compulsory during every onboard inspection by law enforcement officers.
	1. Transshipment vessels does not cause complications in catch accounting.	1. Routinely check transshipment logbooks during onboard inspection. 2. Strengthen national laws and regulations for the management of transshipment vessels.
Quota allocation	1. Quota was allocated to five vessel groups.	1. Make no change to the allocation approach.
Cooperatives	1. Local cooperatives of this pilot played an essential role in organizing all vessel captains to implement TAC schemes.	1. Provide training to the cooperatives so that they can teach fishermen.
Training	1. The cooperative and local fishery department offers one training per year to captains. Captains have training interests in various topics, including e-logbooks. 2. Bycatch species identification is difficult for science observers due to the diversity of the fish species and because most of the observers are early in their careers.	1. Continue to provide trainings on e-logbooks, highlighting their benefits and convenience to captains.
Institutional arrangement	1. The ministry, provincial government, and local fishery department attached great important to this pilot fishery. 2. The local fishery department allocated adequate management resources and human capacity for the design and	1. Combine all existing management schemes (several separate documents on management measures) into a single management plan. The plan can work to make sure everyone is on the same page.

	supervision of the pilot performance.	

3.3 Fujian Multispecies Swimming Crab Pilot

3.3.1 Results

Fishermen and vessel characteristics

Seven of nine fishermen surveyed had been fishing for more than 10 years. Seven of nine completed only primary school education, and most could not read or write. All vessels were over 24 meters long, typically fished with seven crew for an eight-month season. The primary target species was crab, but they also reported catching and selling other local fish, such as silver croaker and sea snail.

Fujian TAC pilot crab pot vessels
Credit: Fujian Fisheries Research Institute

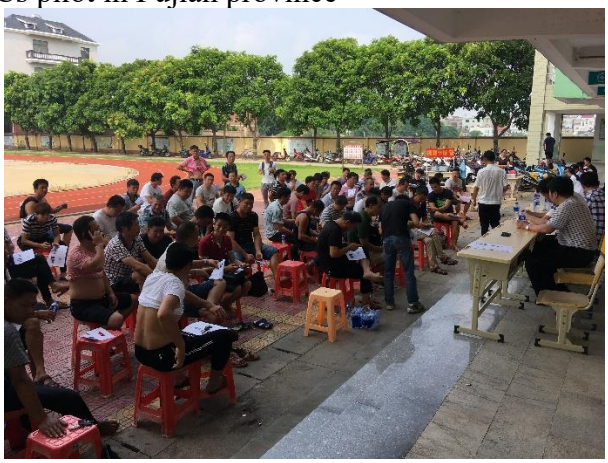
Catch recording and logbooks

According to the science director, while the 106 special licenses were conveyed only to crab trap vessels, many of these did not fish within the designated pilot area during the TAC pilot. After the pilot was underway, FFRI started collecting landing data from crab gill net vessels as well. In total, 368 monthly logbooks were distributed to vessels and 168 were returned, reporting trip-level landings from 20 trap vessels and 20 gill net vessels. No electronic logbooks were completed during the pilot due to lack of necessary 4G wireless connectivity at sea.

Prior to the TAC pilot, seven of nine fishermen recorded their catch data independently, including records of total landing weight, unit price, and in some cases fishing times and locations. All surveyed fishermen reported participating in TAC pilot trainings, but reactions to the training were mixed: some found it useful, others found it inadequate, and some reported not understanding the training materials or why logbooks are useful. Most believed it difficult to complete the paper logbooks and would prefer to report catch data

using WeChat. The enforcement officer believed trainings did not focus enough on TAC-related regulations and enforcement and that trainings should extend to all fishery enforcement officers.

Fishermen training class of Fujian swimming crab pilot
Credit: Shen Changchun's PPT in 2018 on status of marine fishery and tentative plan of the TACs pilot in Fujian province



At-sea observers

No at-sea human observers were used during the Fujian crab TAC pilot. Two surveyed fishermen believed that the role of observers is to supervise their fishing operations. Others had a positive attitude about observers' role in protecting ocean resources and would accept observers aboard their vessels.

Electronic monitoring

All fishermen operated AIS on their vessels. Eight of nine fishermen installed at least one camera on board to supervise crew activities for safety, productivity, and maintenance. Some fishermen installed at-sea Wi-Fi, although they reported it is very expensive to maintain, and two fishermen reported suitable mobile phone signals on board their vessels.

Transshipment

All surveyed fishermen reported selling catch to transshipment vessels at sea. The amount sold to transshipment vessels ranged from 30 to 50 percent, and transaction tickets were issued. These transactions were based on personal relationships or proximity to fishing grounds.

Law enforcement

The area's crab fishery is patrolled by Fujian provincial and Longhai and Zhangzhou municipal enforcement vessels. During the pilot, these vessels would inspect logbooks, permits, and safety features dockside and at sea.

Thoughts for the future

All surveyed fishermen believed that crab abundance has decreased in recent years. They reported usually discarding undersize crabs. They were concerned about their future prospects, but otherwise they reported lacking ideas for a different approach.

3.3.2 Discussion and recommendations

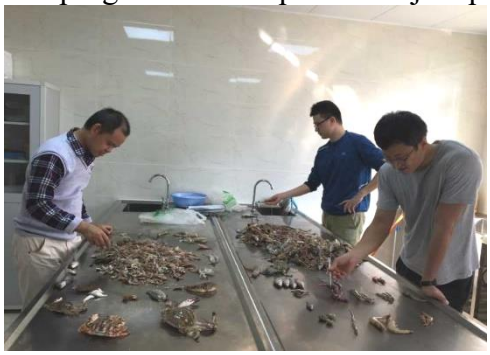
Key findings from our surveys and related policy recommendations are summarized in Table 7. Below, our findings and recommendations are grouped into three broad categories: TAC setting and allocation, effectiveness of logbook systems, and monitoring and enforcement challenges.

1. TAC setting and allocation

The multispecies crab TAC for the pilot was based on average catch in the pilot area between 2015 and 2017. We have not verified which of the crab fishing gear sectors' catch was counted in the historical catch or what the sampling protocol was in the absence of a logbook system. The aggregate TAC was specified for all four species combined, without suballocations linked with individual species' abundance or historical catch. Looking ahead, we recommend piloting allocations for separate crab species, supported by appropriate science-based TACs for each, as well as allocations to individual vessels or groups of fishing vessels (e.g., gear sectors, cooperatives) such that allocations can be tailored to the fishing activity and the needs of individual users.

To help determine scientifically appropriate future TACs to allocate, we recommend developing funding streams to support expanded stock abundance surveys and routine sampling of other biological information necessary to conduct ongoing stock assessments. This should include fishery-dependent data collection and dockside samples from trap, gill net, and trawl vessels involved in crab fishing near Fujian. Then, future TACs can be better linked with abundance in the species or species complex, and science-based harvest control rules can be used to determine appropriate TACs as fishery conditions change.

Portside crab sampling in Longhai City
Credit: Shen Changchun's PPT in 2019 on progress of TAC pilot in Fujian province



2. Effectiveness of logbook systems

Overall, the completion rate and accuracy of paper logbooks during the pilot was relatively low. Of 378 paper logbooks distributed, 168 were returned—a 46 percent response rate. An additional challenge is that returned logbooks were not timely. While logs for each fishing

trip were due at the end of each month, most arrived in a batch in late December, with inconsistent reporting in later months. Surveyed fishermen reported mixed views on the accuracy of trip logbooks generally, though only one of the fishermen we surveyed completed either type of logbook during the pilot.

Electronic logbooks were not used by any pilot participants due to lack of 4G connectivity, necessary to submit the logs. Network connectivity is an obvious priority for the fishery to obtain timely and accurate logbooks with minimal paperwork and data entry. We recommend that the fishery department and appropriate coordinating agencies develop a standardized electronic logbook system that is suitable for different fishing operations. Such a system is already in use among China's distant water fishing vessels.

Prior to pilot implementation, FFRI conducted several trainings for fishermen on both paper and electronic logbooks. The training covered how to complete logs, how to submit them, and planned enforcement activities. As described, while participation in trainings was high, the fishermen's reactions to training materials were mixed and some found them not useful.

A clear lesson learned from the TAC pilot experience is that, although FFRI conducted outreach rallies to promote the pilot and training sessions prior to implementation, fishermen and enforcement officers alike lacked adequate understanding and capacity to effectively participate in TAC management. First, completion of logbooks and timely submission should be a mandatory component of the annual inspection of fishing vessels. That is, a successful compliance record should be required for a vessel to be permitted for fishing. Simple, concise logs could make them easier for fishermen to complete. Second, the frequency and content of trainings should be enhanced. We recommend soliciting input from fishermen, enforcement officers, and other relevant stakeholders to reconsider priority areas for training (e.g., regulations, timely log submission, enforcement) and the necessary level of outreach and training detail. Other organizations can support FFRI trainings using existing resources, such as the fisheries training toolkit from the Environmental Defense Fund (EDF), or other training resources tailored to the specific needs of Fujian fisheries. Beyond creating a foundation for important data collection and adherence to catch limits, more preparation and understanding for logbook systems will increase fishermen's sense of participation in the fishery science and management process and promote strong incentives for compliance.

3. Monitoring and enforcement challenges

There was significant leakage in catch accounting during the pilot. Reported catch in the logbook system does not approach the likely level of total crab catch in this time and area. All fishermen and the science director believed that enforcement is weak generally, particularly with respect to tracking and enforcing illegal fishing. Reasons cited for weak enforcement included lack of funding, relatively few enforcement officers, and lack of government leadership and coordination. With that context, it is reasonable to expect enforcement of trip-level catch within a TAC pilot area to fall short.

According to the enforcement officer surveyed, the primary enforcement actions taken

during the pilot were increased at-sea patrols and port inspections, along with more community outreach to solicit fishermen's advice and strengthen their awareness of fishing regulations. The most common illegal activities reported were vessels fishing without the appropriate permits.

There were no designated ports to land and offload crab catch during the pilot. This means that enforcement agents could be unaware of places and times where crab catch was offloaded. We recommend designating suitable landing sites for catch in TAC pilots and future TAC programs. This will enable improved dockside validation of reported logbook catch.

However, this will improve monitoring of only the catch offloaded at dock. The enforcement officer we surveyed believed that most crab catch in Fujian waters is sold and offloaded to transshipment vessels at sea. These transshipment vessels are an important part of total crab catch accounting, yet with the current system it is significantly more difficult to count and validate reported catch offloaded to transshipment vessels compared with dockside landings. Transshipment vessels should be registered as legal fishing operations, with their own logbook system for at-sea catch receipts. An electronic trip ticket system—where all agents in the supply chain (fishermen, transshipment vessels, and buyers) use a unique record to report all catch—should be developed and implemented to enable validation of catch along the supply chain.

A consistent theme from the surveys was conflict created by multiple gear sectors fishing for crabs in the same area. The Fujian TAC pilot area was not reserved specifically for crab trap vessels. Trap fishermen had the perception that any benefits to crab trap vessels in the TAC pilot area would be canceled out by fishing from gill net and trawl vessels, reducing the trap fishermen's incentives to participate fully in the pilot. We recommend developing laws and regulations to define appropriate rights for fishing within pilot areas, such as defining allowable participants, gear sectors, or fishing areas. These rights should be exclusive and enforceable. Certain fishing areas could have allowable fishing gear, for example, and fishermen could gain access to special fishing areas by converting to permitted gear, with compensation for costs incurred. Vessels not meeting access criteria should be monitored and directed to fishing areas outside of pilot areas. These measures will promote TAC program participation and more complete catch accounting, but they will require significantly enhanced monitoring from a combination of enforcement officers, at-sea human observers, and electronic monitoring tools.

The Fujian crab TAC pilot did not use human at-sea fishery observers. One fisherman surveyed said he was unwilling to accept observers due to safety concerns. A second said he was open to having observers on board but had reservations about observers disturbing the crew's fishing operations. Looking ahead, observers are an important tool to validate reported catch and even assist fishermen with completing their logbooks. We recommend allocating at least one observer to all fishing trips in the pilot area, and ideally two observers on all transshipment vessels. Observers should be knowledgeable about local fisheries and appropriately trained for at-sea catch monitoring.

If it is determined that human observers are prohibitively expensive or fishermen are strongly opposed to carrying them aboard, then camera-based EM is a potential cost-effective and accurate alternative. Onboard cameras are not a new concept for many fishermen. Two fishermen respondents had installed multiple cameras on their vessels voluntarily. These were used to monitor crew activities and safety, not for catch monitoring. In cases where cameras are already installed, it may be possible to reposition existing equipment for catch monitoring if camera resolution is good enough to allow auditing and data can be stored.

Similarly, VMS was not used during the pilot to monitor the spatial distribution of vessels, but many Fujian fishermen have experience with AIS, which is installed to track vessels and help avoid collisions among them. Making full use of VMS systems would allow enforcement officers to monitor entry of non-TAC pilot crab fishing vessels into the pilot area, protecting pilot participants' security in their fishing area, reducing gear conflict, and strengthening their incentives to participate in management.

Table 7. Summary of findings and recommendations from Fujian multispecies swimming crab TAC pilot

Issues	**Findings**	**Recommendations**
TAC setting	1. Catch limit is currently set as the average catch from 2015 to 2017, as reported by fishermen.	1. Develop funding streams for ongoing stock assessment activities, supported by demonstration of the economic and ecological benefits of science-based management. 2. Increase stock surveys and data collection to improve inputs into stock assessments. 3. Develop and apply science-based harvest control rules to set TACs and more clearly link science to management.
Logbook	1. Relatively low return rate and low accuracy of paper logbook.	1. Formulate relevant regulations, including mandatory measures. In particular, completed logbooks should be a mandatory component of annual inspection of fishing vessels. 2. Make the paper logbook smaller and streamline the content to make it easier for fishermen to use. 3. Increase the frequency of training during the summer moratorium to enhance fishermen's understanding of the importance of completing logbooks and increase their sense of participation in fishery management.

		4. Conduct random sampling of catch against logbook contents and sales records to cross-check the accuracy of logbook information.
	1. No fishermen use electric logbooks due to poor cell reception, expensiveness, difficulties in using them at sea, etc.	1. MARA should develop a standardized electronic logbook system that is suitable for different fishing operations. The standard distant water fishing logbook reporting system could be a useful model. 2. The fishery departments should establish a national logbook database of information from the standardized logbook. Provincial fishery research institutes should have primary responsibility for data processing and analysis. 3. Cultivate the habit of using e-logbooks early in fishing careers by targeting training at young fishermen.
	1. Transshipment vessels are not required to fill in logbooks.	1. Require transshipment vessels to be registered in order to be considered as legal operations. 2. Design logbooks tailored to transshipment vessels and require that they be completed as soon as possible. 3. Develop an electronic trip ticket system so that fishermen, middlemen (transshipment vessels), and buyers use a unique record to report all catch, enabling cross-validation along the supply chain.
Designated catch landing	1. The TAC pilot does not include a designated landing site, making it difficult to monitor participation and catch.	1. Design a designated catch landing site pilot by choosing a suitable port. 2. Arrange for dockside monitoring at the designated catch landing port.
Observers	1. Observers have not yet been deployed in the pilot.	1. Provide at least one onboard observer on all fishing trips in the pilot area and ideally two onboard observers on all transshipment vessels, with observers serving to monitor catch and assist in completing logbooks. 2. Ensure that observers are suitably trained and knowledgeable about biology and fisheries, especially by drawing from local universities.

Enforcement	1. Enforcement is insufficient due to a shortage of enforcement officials, inadequate budgets, and leniency for relatives and acquaintances of officials.	1. Integrate at-sea and dockside law enforcement, including deployment of fishing port supervisors to strengthen the supervision of fishing ports and dockside operations. 2. Adopt VMS or other advanced technologies to support enforcement activities. 3. Establish mechanisms by which fishermen themselves can contribute to enforcement while ensuring confidentiality. 4. Increase budgets for local enforcement officials by demonstrating the need for and value of effective enforcement.
Monitoring	1. Most fishermen have installed at least one camera on their boat voluntarily for ensuring the safety of fishing activities, but they do not yet store data.	1. Select several vessels with cameras currently installed and provide them with a hard drive to pilot data-storage systems, with technical support for maintenance of equipment and data storage and retrieval.
	1. The pilot area is not exclusively for trap fishing, and conflicts with gill net and trawl vessels reduce the motivation of the trap fishermen to participate in the pilot.	1. Formulate local laws and regulations to define the fishing rights for pilot areas, including eligible participants and gear. Allow vessels using other fishing gear to convert to allowable gear in pilot areas and provide some compensation for the conversion, or guide them to shift their fishing effort outside the pilot areas. 2. Establish regulations that delimit an exclusive area for trap fishing and prohibit gill nets and trawling, with strict and enforceable penalties. 3. Make full use of VMS to monitor entry of non-TAC-pilot vessels into the pilot area.
Quota allocation	1. The pilot adopts derby fishing without allocation of quota to individual fishing vessels.	1. Pilot allocation of quotas to individual fishing vessels, supported by communication and training on the rationale, advantages, and operational changes involved with fishing an allocation (e.g., reporting). 2. Evaluate the potential for expanding quota allocation to the whole fishery as a mechanism to promote capacity

		reduction and enable fishermen to profitably exit the fishery at the end of their careers.
Cooperatives	1. The cooperative has played a critical role in fishery management but lacks real rights and has limited experiences. As a result, some fishermen feel the cooperative is not yet useful, but that it could help solve conflicts among fishermen and convey information from higher levels of government.	1. Conduct a scoping analysis of the current role of Chinese fishery cooperatives, summarize the regulations, and recommend ways that cooperatives can play a real and active role in managing the fishery. 2. Strengthen exchanges among Chinese and international cooperatives, enabling leaders in the Chinese government and cooperatives to learn about the role and operations of cooperatives in other countries.
Training	1. FFRI has conducted training for fishermen on multiple occasions, but understanding of regulations and capacity to effectively participate in management remains inadequate.	1. Other organizations should step in to support FFRI's training efforts, using existing resources, such as EDF's fisheries training toolkit, and new resources tailored to the specific needs and context in Fujian. 2. Identify priority areas for training (regulations, enforcement, etc.) through discussions with fishermen, officials, enforcement officers, and other actors, to guide the development of training strategies and materials.

4. Summary

4.1 Major Findings

Finding 1: Zhejiang and Fujian have made breakthroughs in a number of TAC elements and accumulated valuable experience at the institutional and technical levels.

We found that both Fujian and Zhejiang provinces demonstrated ambition and hard work in experimenting with TAC management. The two provinces took the opportunity to actively participate in international exchanges, learn from international experience, and substantially promote international cooperation in sustainable fisheries. Fishery managers and scientists from Zhejiang and Fujian provinces attended several international study tours to the United States and European Union countries—with the support of NRDC, EDF, and Shanghai Ocean University—to learn from other professionals' experience in TAC management. They have also organized or participated in a number of international workshops on TAC, catch monitoring, multispecies fisheries management, and territorial

use rights in fisheries. They are open to sharing their own experience and lessons learned, and the scientists of the two provinces have established long-term cooperation with the University of Maine, the University of California, Santa Barbara, and the University of Washington. The primary goals of the pilots were to learn about TAC concepts and test ways of improving catch monitoring and accounting, and by these measures all three pilots were successful.

International workshops (left) and study tours (right) on TAC
Credit: EDF and NRDC

After becoming familiar with the international practice, the two provinces have made breakthrough explorations of several TAC elements, especially creating, implementing, and seeking to improve entirely new catch-monitoring and enforcement systems. All pilots have involved coordination across fishery departments at the provincial, city, and county levels, as well as with scientific research institutes and fishing cooperatives. Scientists, policy makers, and enforcement officers are learning about the various moving parts needed to make TACs work and identifying priorities. For example, at the beginning, it was not a goal to set science-based TACs for all species and fully account for catch. Instead, by experimenting with new catch-monitoring systems, the provinces significantly improved the quality of fishery-dependent data, which can be used to set scientific TACs in the future. Following this strategy, Zhejiang and Fujian took the lead among coastal provinces in testing catch-monitoring tools—such as logbooks, at-sea observer systems, and onboard cameras—based on the characteristics of the fisheries. Many of these are the first such attempts in China's domestic fisheries. Through the pilots, the provinces also recognized the importance of limited access, industry engagement, and fishery management plans. These lessons are a measure of success.

Finding 2: The pilots created a path toward scientific TACs.

The TACs in all pilot programs were based on recent historical catch, not a scientific assessment of stock status and productivity. The Fujian multispecies crab TAC was set based on the previous three years' catch history for all four crab species combined, without suballocations linked with individual species' abundance or historical catch. The Zhejiang gazami crab pilot TAC was based on the previous six years' catch history, and the juvenile

anchovy pilot TAC was set conservatively to 10 percent of the entire fishery's recent ten-year annual catch.

In the absence of scientific information on fish stock abundance, catch history provided provincial policy makers with the most reasonable index of recent fishery trends. At the time of pilot implementation, the understanding of pilot species' abundance was too limited to set science-based catch limits. Given the experimental nature of the pilots, it was prudent to set catch limits in line with fishermen's recent experiences. Otherwise, participation could have seemed too constraining, there could have been a perception that fishing might close mid-season, and the incentives for cooperation in a voluntary program would have been diminished.

Our surveys revealed that many fishermen participating in the TAC pilots were concerned about the future health of their fisheries. Looking ahead, we find that fishery-dependent and fishery-independent data collected during the pilots is already providing information that contributes to some preliminary scientific stock assessments on which to base sustainable TACs.

The enhanced system for catch reporting and the science programs developed during the pilot programs allowed researchers to collect the data needed to make an estimation of maximum sustainable yield and to set science-based TACs. This is already happening in Fujian, where red-swimming-crab-length frequency data sampled at port during the TAC pilot have supported estimation of a length-based Bayesian stock assessment model and established a scientific basis for TACs and harvest control rules in future fishing seasons. In Zhejiang's swimming crab and juvenile anchovy pilot, data collected by ZMFRI in resource survey trips and independent sampling, as well as biological data collected by human observers on board fishing vessels, could support similar crab stock assessment models and scientific TACs.

Collecting information to support science-based TACs can be accomplished at a reasonable cost and would be a significant improvement over the status quo. Over time, as monitoring systems evolve during continued and future TAC pilots, data collection and stock assessment systems can be upgraded as scientific information and administrative capacity improves.

Finding 3: Fishing logbooks proved to be a viable method to monitor catch on participating fishing vessels.

Given the focus on catch-accounting tools, the use of paper and electronic logbooks was central to the design of each TAC pilot project. While this review found areas for improvement in fishermen's receptivity, accuracy, and timeliness, there were many successful elements of logbook keeping in each of the three pilots, illustrating the potential value of this tool.

All three pilots developed new paper and electronic logbooks. The paper logbook turned out to be the primary tool for collecting catch data in the three pilot projects. It was the most well received by the fishermen because it was familiar to them and clearly prescribed

in the Fisheries Law. Zhejiang fishermen felt the training was adequate for paper logbooks, while most Fujian fishermen found it inadequate. The return rate in Zhejiang's juvenile anchovy pilot was the highest and most complete (100 percent), followed by Zhejiang gazami crab pilot (79 percent), and Fujian pilot (46 percent).

The popularity of the electronic logbooks tested in all three pilot projects was lower than that of the paper logbooks. For example, in Fujian, no electronic logbooks were completed during the pilot due to lack of the necessary 4G wireless connectivity at sea. In the Zhejiang gazami crab pilot, although 76 percent of pilot vessels have a record of e-reporting, the average reporting rate per vessel and total catch reported by e-logbooks was about half those of the paper logbooks. Similar to Fujian, in the two Zhejiang pilot projects, system failures (e.g., unstable electronic connections and software problems) were the main reason fishermen found the e-logbooks inconvenient to use. Low levels of literacy in electronic tools was also a common challenge, but nearly all fishermen preferred WeChat reporting to using the e-logbooks. Several meetings and field trainings on e-logbooks appear to have been inadequate, because most fishermen communicated the desire for expanded training with e-logbooks, and they frequently consulted observers on how to use them at sea. Additionally, despite the training, fishermen generally lacked knowledge of the various benefits of accurate catch accounting and its importance to sustainable fisheries, potentially reducing their motivation to report promptly and accurately. Future training should incorporate this important contextual information.

Analysis of the data from both types of logbooks showed that e-logbooks have obvious advantages over paper logbooks for scientists and fishery managers, such as machine readability, timely and relatively complete information, and the ability to be conveniently processed and cross-checked with large amounts of data from other sources, saving time and human resources. Data reported electronically in real time also provide a mechanism for monitoring quota uptake and warning of potential quota overage early. These are all desirable features to support TAC management. However, in order to increase fishermen's acceptance of e-logbooks, it is necessary to secure the stability of the electronic platform, increase the value to fishermen by integrating business rules into the reporting process, and simplify the use of the e-logbook by incorporating advanced features such as automatic data entry or pull-down menus. Some of these enhancements have already been identified by captains in the juvenile anchovy and Fujian swimming crab pilots, who communicated a preference for e-logbooks if those improvements could be realized. Improving both paper and electronic logbook functionality and exploring the transition from paper to electronic logbooks should be a priority in future pilot projects.

With the exception of the juvenile anchovy pilot, project science directors were unable to routinely evaluate the accuracy of logbook entries because they rarely collected multiple independent data streams on fishing vessel catch (e.g., fishery observer data, camera-based electronic monitoring, or buyers' trip tickets). Nonetheless, fishing vessel captains rated their logbook accuracy as medium to high. This self-evaluation was largely confirmed by data from at-sea observers when such data were collected. Common sources of error that require improvements included delays in data reporting due to the busyness of sea captains and the estimation methods of the volume of catch. TAC pilot officials should work with

fishermen to minimize obstacles in catch accounting. This might be addressed in part through more careful logbook design. Survey results also showed that fishermen would benefit from further education about the value of accurate catch accounting for long-term fishery sustainability. Future pilots should also work with them to identify positive business-related incentives for good logbook keeping.

Finding 4: Verification of reported catch is needed.

Self-reporting catch data using logbooks and hail-in/hail-out can provide important fishery-dependent information such as catch species, time, location, gear, CPUE, and bycatch. The accuracy of these data and stakeholder confidence in them can be improved significantly through independent catch verification. Fishery managers typically collect one or more of the following independent data streams: at-sea human observer records, camera-based electronic monitoring, buyers' trip tickets, or dockside monitoring. In our review of the three TAC pilots, we found that the use of catch verification varied considerably.

The Fujian multispecies crab TAC pilot planned but did not implement dockside verification of catch and did not use at-sea human observers or buyers' trip tickets to verify catch reported by vessels. Moreover, the Fujian pilot left out logbooks and verification for catch offloaded on transshipment vessels entirely. The Zhejiang crab TAC pilot deployed at-sea observers on some trips, but their coverage was low. The pilot did not include dockside verification, and while it did require vessels to offload at designated transshipment vessels so paper logbooks could be cross-checked, this requirement was mostly ignored. The Zhejiang juvenile anchovy TAC pilot included observers, buyers' trip tickets, and onboard cameras, but the fishery had only one buyer so catch data verification was relatively easy.

Overall, the lack of independent catch verification introduced significant gaps in catch monitoring and concerns about the accuracy of catch reported. The amount of verification needed and resources available to produce it vary across different fisheries with different management and scientific goals. While the provinces cannot be expected to achieve full verification of catch during experimental pilots, provincial governments can work toward improved accuracy and confidence in catch-monitoring systems. This can be accomplished by selecting appropriate independent data streams and starting to test and develop a verification system.

Finding 5: Transshipment poses challenges and opportunities to effective catch monitoring.

Transshipment vessels, which collect fish from fishing vessels and transport it to shore or to offshore processing vessels, play a key role in China's domestic fisheries. On the one hand, the transshipment process can introduce significant loopholes in catch monitoring and verification. On the other hand, this process can contribute to catch management and monitoring systems if transshipment vessels and amounts are recorded, thus providing a cross-check on the accuracy of the catches recorded in fishing vessels' logbooks. In addition, transshipment vessels can help provide information via hail or VMS data regarding the ports where the catch is being landed, which in turn can support a system of

dockside monitoring.

The fishing vessels in the three pilots mainly relied on transshipment vessels to bring their catch either directly to port or, in the case of the juvenile anchovy fishery, to an at-sea processing vessel. The juvenile anchovy pilot had a good system in place for data gathering by the transshipment and processing vessels; the other pilots did not.

In the Fujian swimming crab pilot, approximately 30 to 50 percent of the catch was sold to transshipment vessels, and private transaction tickets were issued. The rest of the catch was brought to port directly by the catcher vessels. The transshipment vessels were not required to fill out logbooks.

In the Zhejiang gazami crab pilot, between 80 percent and 100 percent of the catch was sold to transshipment vessels. The pilot designed a scheme in which the fishing vessels were required to utilize only designated transshipment vessels and all vessels were expected to keep paper logbooks. However, logbook recording by those designated transshipment vessels was spotty and, for the records that were kept, the catch amounts recorded differed significantly between the fishing vessels and the transshipment vessels. Most importantly, most of the fishing vessels in the pilot did not use the designated transshipment vessels, and detailed records regarding transactions between fishing vessels and these other transshipment vessels were not kept. The designated transshipment scheme was discontinued from the second year of the pilot. In both Fujian and Zhejiang's pilots, fishermen chose transshipment vessels based on price and personal relationships. Therefore, without considering the impact on fishermen's business operations, the transshipment monitoring scheme may be difficult to implement.

In the special juvenile anchovy fishery, it was the transshipment vessels, rather than the catcher vessels, that actually hauled the nets; consequently, they were the vessels that kept paper and electronic logbook records of the catch during the pilot. Transshipment vessels transferred the catch to processing vessels, which were also required to maintain logbooks during the pilot. The fishing vessels, transshipment vessels, and processing vessels operated in a highly synchronized way and no vessel could detach from the team during operations. This organizational level enabled the collection of logbooks from all vessels easily, as well as the cross-checking verification by the scientific observers and enforcement observers aboard one of the only two transshipment vessels in real time. At present, the catch data of transshipment vessels and processing vessels match well.

The experience of the three pilots shows the importance of monitoring transshipment vessels. More information about transshipment activities is needed before a practical transshipment reporting scheme can be designed, including participating transshipment vessels, landing ports, and trading habits. This gap can be filled by requiring application for transshipment permits in particular fisheries, the use of observers on transshipment vessels, VMS tracking, and learning from local cooperatives' knowledge. Ideally, catch recording would be required on all transshipment vessels and they could electronically report the catch information to shore daily. Requiring transshipment vessels to hail-in ahead of port arrival would also help identify where the catch is being offloaded and permit

dockside monitoring.

Finding 6: TAC pilot projects pioneered the very first at-sea observer programs in Chinese domestic fisheries, with a high degree of success.

The two Zhejiang pilot projects included deployment of at-sea observers. While small in size, the programs demonstrated the feasibility and value of training and deploying at-sea observers to support TAC management systems.

In both Zhejiang pilots, observers reported high receptiveness among the captains of the fishing and processing vessels. They felt safe on board the vessels and reported having a collaborative relationship with the captains. This was partly due to the voluntary nature of the observer program. Fishing captains who were willing to take observers and who were easy to communicate with were identified prior to the start of the pilot.

Observers' roles were tailored to the objectives of each pilot. In Zhejiang's gazami pilot, observers helped to train fishermen on logbook keeping and conducted important biological sampling for future evaluation of stock health and status to help inform sustainable TACs. In the juvenile anchovy pilot, in addition to doing similar work to the gazami pilot, observers played an essential role in monitoring bycatch, warning enforcement officers when they exceeded acceptable bycatch levels and needed to shift fishing grounds, and conducting additional scientific research. They also observed the entire fishing operation on the vessels, learning more about the fishery and providing insights regarding improvement of the pilot.

Although observers proved to be of great value, there were a number of challenges. Key challenges for maintaining observer programs are a lack of qualified personnel, insufficient funding, and the observers' lack of legal protection. Safety is a big concern before clear legal protections for observers are in place. These combined factors resulted in a low coverage of observers and removal of the program from the second year of the gazami crab pilot. The juvenile anchovy observer program was improved and maintained for three years. Thanks to industrial investment and good working conditions, the observers in that pilot collected rich and consistent data.

Investment in targeted observer programs, including training, should continue for several reasons, including the need for improved knowledge regarding the operation of domestic fisheries and catch composition, the value of independent data for catch verification, and the opportunity to train fishermen in catch monitoring. For fisheries that could not have adequate coverage at sea, our findings suggest that future pilots should experiment with putting observers on transshipment vessels and dockside for logistical reasons.

Finding 7: Effective enforcement is necessary to ensure compliance.

All three pilots' work plans included targeted enforcement activities to ensure pilot rules were being followed. The three pilots had mixed experiences with enforcement.

In the Fujian swimming crab pilot, there was some increased inspection of logbooks,

permits, and safety features, dockside and at sea, by inspectors on provincial and municipal enforcement vessels. The most common violation was fishing without carrying a fishing permit, but no enforcement actions were taken. Despite fishermen being offered cash incentives to complete and submit logbooks each month, there was also a relatively low rate of logbook returns and low accuracy of those that were returned. Additionally, there was no penalty for noncompliance. Transshipment vessels were not required to keep logbooks, but enforcement officers still expressed their concerns over the difficulty of regulating transshipment vessels.

For the gazami crab pilot, only two to three enforcement trips per fishing season were arranged in waters covered by the pilot. Sightings of at-sea enforcement vessels by fishing vessel captains occurred about four times. During onboard inspections of both fishing vessels and transshipment vessels, logbooks were not an enforcement priority; instead, the focus was on permits, gear, and safety violations. For the fishing vessels, law enforcement officers did document some problems: catch-recording inconsistencies, paper logbooks not being completed in a timely manner, and not identifying the transshipment vessels with which they were dealing. However, no penalties were imposed. The plan to deduct quota for violations provided no incentive for compliance since the quota was set so high. In addition, most fishing vessels did not use designated transshipment vessels as originally planned and, as a result, there were not detailed records of the transactions between the fishing vessels and the transshipment vessels. This made cross-checking logbook entries between catcher vessels and transshipment vessels virtually impossible. This loophole also discouraged enforcement officers from strictly enforcing transshipment vessel logbook requirements.

Enforcement officers reported a lack of legal support for imposing penalties for not completing logbooks in a timely manner and little guidance on how to penalize incorrect logbook entries. Cases that can be referred to are very rare nationwide. There was also no legal support for penalizing the sale of catch to non-designated transshipment vessels. There were few regulations covering the operations of transshipment vessels and therefore no basis for enforcement. Finally, there was a reported lack of support at the provincial level for county-level law enforcement.

In contrast, substantial enforcement resources were deployed during the juvenile anchovy pilot. The local fisheries department has a strong incentive to establish a national model for managing the at-sea processing fishery during the summer fishing moratorium and therefore has been willing to allocate adequate enforcement resources. Enforcement observers were present throughout the 1.5-month fishing season. These observers checked logbook entries of the processing vessels and compared them with those of the transshipment vessels, which are the vessels that haul the catch in this fishery. They also worked closely with science observers to make sure fishing vessels changed fishing grounds when the allowable threshold for bycatch (2 percent) was exceeded. Unlike the two swimming crab pilots that required VMS but did not use it for enforcement, VMS tracks in this pilot were monitored daily to determine whether vessels fished only within the permitted area and landed their catch only at designated ports. At the time of this writing, no violations had been detected in the fishery.

Given that most fishermen are expecting weak enforcement of the requirements on the timeliness and accuracy of their logbook entries, in the future, logbook inspection should be given similar priority to safety and permit issues. Enforcement officers should be encouraged to include logbook checks at every inspection. Also, there should be greater legal support for imposing penalties for failure to complete logbooks in an accurately and timely manner and guidance provided on how to recognize incorrect logbook entries. Finally, there should be stricter regulations on the operation of transshipment vessels.

Promoting fishermen logbooks in Taizhou city
Credit: Li Wei

Finding 8: The pilots demonstrated the importance of establishing incentives for compliance, including with the requirement for accurate catch accounting.

Among the pilot projects, Zhejiang's juvenile anchovy pilot performed best in terms of compliance with management rules, achievement of goals, and gradual improvement. For example, the return rate and completeness of the paper logbooks was 100 percent, and the completion of the electronic logbooks was better than in the other two pilots. The coverage and data quality of at-sea observers have improved year by year, and no violations have been found by enforcement officers. The comparative success of this pilot lies in the local leadership and good incentives that promote industry compliance, combined with support from local fisheries departments.

Using the privilege of fishing during the summer fishing moratorium as an incentive, the Zhejiang's juvenile anchovy pilot set very high access conditions from the beginning. All participating vessels must have no history of violations. Vessels must also provide clear, ongoing evidence that their fishing operation is sustainable and does not cause harm to

other fishery resources. Hence, accurate catch accounting is essential for maintaining access to this specialized fishery. Consequently, the industry is willing to pay for the observer program and supports its continuous development to obtain those data. The logbook is also integrated with the use of trading tickets. In contrast to the anchovy pilot, while there is limited access in the Zhejiang gazami crab pilot area, the maintenance of fishing permits is not much affected by compliance with the pilot rules. In the Fujian crab pilot, access is not limited, due to the fishing ground overlapping with other fisheries using different gear.

The level of organization within the Zhejiang juvenile anchovy fleet as a cooperative is very high, with the processing vessels as the only buyer. The owner of the processing vessels has a deep understanding of the TAC system and how catch accounting contributes to sustainable fisheries. The owner turned the pilot rules into an internal business arrangement, which was easily understood and accepted by fishermen. Any fishing vessels violating the terms of the pilot will not only be punished by regulators but will also be avoided by the buyer. The high level of organization and strong industry commitment, in turn, secured strong support for the pilot from local government. Government allocated significant enforcement resources and human capacity to working with the industry to build the pilot into a model for the national management of the at-sea processing industry. By comparison, the level of organization in the other two pilots is much lower. The cooperatives are not taking on a leadership role, leaving it up to enforcement to ensure that vessels participate properly, which is an unrealistic expectation.

In the two swimming crab pilots, fishermen were offered cash incentives to complete and submit logbooks. However, this approach was not effective because fishermen felt that the inconvenience of completing fishing logs far outweighed the monetary rewards on offer. Completion and timely submission of logbooks should be a mandatory component of the annual renewal process for fishing permits. That is, a successful compliance record should be required for a vessel to be permitted for fishing.

Appendix 1. Basic Information on the First TAC Pilots in the Marine Fisheries in China's Coastal Provinces or Municipalities

Starting year	Province	Species	Area	No. and type of vessels	Limited access	Time period	Quota allocation	Fishing logbooks	At-sea observers	Designated
2017	Zhejiang	Gazami crab	Provincial water	93, set gill net	Yes	9/16-3/31	Cooperatives and vessels	Paper and electronic	Yes	15 transshipment vessels
2018	Zhejiang	Anchovy	Provincial water	36, purse seine	Yes	5/1-6/15	Sector quota	Paper and electronic	Yes	8 transshipment vessels; 1 port
2017	Shandong	Jellyfish	Provincial water	231, gill net	Yes	7/20-7/31	Olympic	Paper	No	7 ports
2018	Liaoning	Shrimp	Provincial water	42, gill net and stow net	Yes	8/27-9/30	Individual Vessel Quota (IVQ)	Paper	Yes	1 port
2018	Fujian	Swimming crab (4 species)	Provincial water	106, pot	No	8/1-4/30	Olympic	Paper and electronic	No	No
2018	Guangdong	Clam (3 species)	Provincial water	181, trawling	Yes	2 months	IVQ	Paper and electronic	No	2 ports
2019	Tianjin	Jellyfish	Provincial water	21, gill net	Yes	10 days	___	Paper	No	___

Starting year	Province	Species	Area	No. and type of vessels	Limited access	Time period	Quota allocation	Fishing logbooks	At-sea observers	Designated
2019	Hebei	Jellyfish	Provincial water	268, gill net and stow net	Yes	10 days	IVQ	Paper	No	6 ports
2019	Shanghai	Jellyfish	Provincial water	21, stow net	Yes	7/15-7/25	IVQ	Paper	No	3 ports
2019	Jiangsu	Jellyfish	Provincial water	301, gill net and stow net	Yes	8/1-8/10	Olympic	Paper	No	11 ports
2020	Guangxi	Gazami crab	Provincial water	20, gill net	Yes	9/15-9/30	IVQ	Paper and electronic	No	1 port
2020	Hainan	Pomfret	Provincial water	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Appendix 2. Zhejiang Province Gazami Crab TAC Pilot Plan

1. Pilot Fishery Selection

Gazami crab (*Portunus trituberculatus*) is one of the most important crustacean fisheries in China (Lu 2018). Stocks are found in different regions, but most production is from the East China Sea, and Zhejiang accounts for more than one-third of total landings in the East China Sea (China Fishery Statistics Yearbook 2017). In Zhejiang, swimming crab is mainly caught by gill net and pot fisheries, and secondarily as a bycatch species in the bottom-trawl and beam-trawl shrimp fisheries. The fishery is yearlong with two peak seasons, spring-summer and autumn-winter. Because gazami crab carries out a short migration between coastal and offshore waters, the fishery utilizes drift gill nets in the warmer months (August and September) and set gill nets in deeper waters in the cooler months. Outside the TAC pilot, the primary gazami crab management measures in Zhejiang are minimum size limits (≥ 60 mm carapace length, or ≥ 125 g) and the prohibition on catching egg-bearing females.

Gazami crab was selected because it is an economically important species to the region and there is a limited-entry permit program in which a group of fishers from Taizhou city have exclusive access. In addition, the fishery is located in Zhejiang's provincial water, for which Zhejiang has full management rights. It was determined that having a limited and well-defined size and geographic scope would facilitate the implementation of the pilot in early trials.

Gazami crab
Credit: Zhejiang Marine Fisheries Research Institute

2. Administrative Details

To ensure input and cooperation at the provincial and local levels, numerous organizations were involved in the design and execution of the Zhejiang gazami crab pilot project, including the Bureau of Ocean and Fisheries of Zhejiang province (ZBOF), the Marine

Fisheries Research Institute of Zhejiang (ZMFRI), the Bureau of Ocean and Fisheries of Taizhou city (TBOF), the Bureau of Ocean and Fisheries of Linhai county (LBOF), the Bureau of Ocean and Fisheries of Sanmen county (SBOF), and the fishing cooperatives. ZBOF is responsible for leading and coordinating the design of the TAC pilot plan. TBOF and ZMFRI worked together in developing the pilot design and regulatory measures, which were then discussed among stakeholders and finally approved by the Ministry of Agriculture and Rural Affairs (MARA) in February of 2017. In August of the same year, ZBOF issued the official gazami crab TAC pilot plan to various city and county-level fishery bureaus. Each organization's specific roles are provided in Table 8.

Table 8. Roles of participating organizations in the 2017-2018 Zhejiang gazami crab TAC pilot program

Organizations	Roles in pilot implementation
ZBOF	• Develop the provincial TAC work plan • Coordinate data collection and catch reporting • Monitor and evaluate pilot progress • Conduct surveillance and law enforcement at sea
TBOF, LBOF, and SBOF	• Develop local work plan according to provincial work plan • Provide training for fishers • Collect logbooks from fishers • Conduct surveillance and law enforcement at sea
Co-ops	• Quota allocation within cooperatives
ZMFRI	• Develop implementation plan • Guide local implementation • Develop paper logbook and e-logbook system • Recruit and train observers • Conduct TAC setting and resource survey • Guide and evaluate pilot implementation

3. Pilot Vessels, Water, and Period

The first year (2017-2018) of the Zhejiang gazami crab pilot was built on a limited-entry permit program composed of 93 fishing vessels (≈ 30 meters, > 200 horsepower) from three cooperatives that fish with set gill nets in provincial waters off Zhoushan city in an area of approximately 2,300 square km (E 122°47′ - 123°00′, N 30°00'-31°00') (Figure 1). The mesh size of the gill net must be no smaller than 110 mm and the total length less than 20 km. The fishing ground is delineated by a grid, and each vessel is allocated a fishing area by lottery yearly. The pilot vessels also include 15 transshipment vessels designated by local cooperatives to serve those fishing vessels. The pilot fishing period is from September 16 to March 31 of the next year.

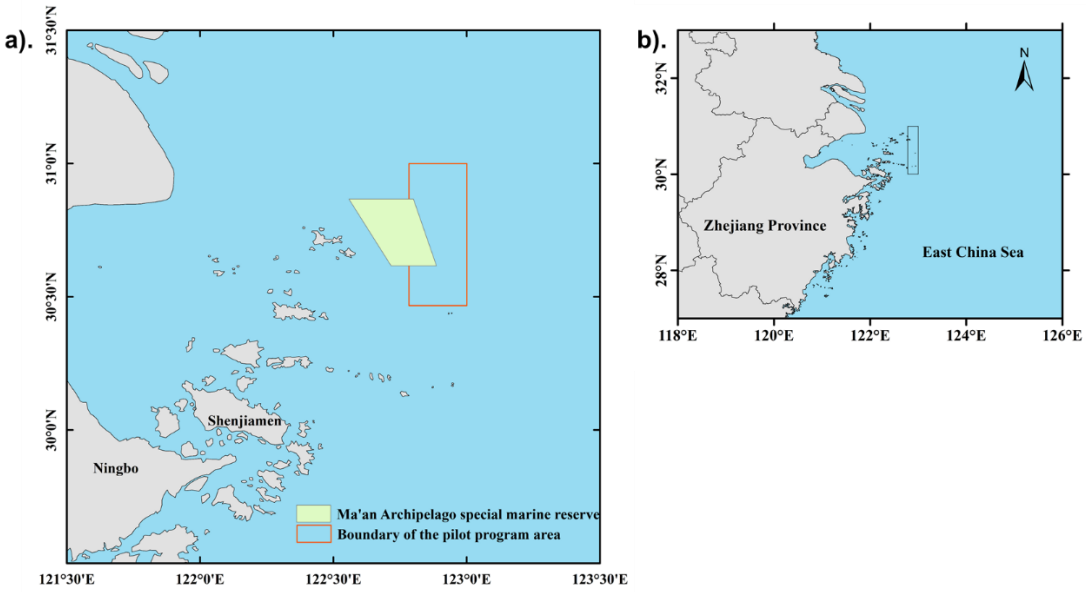


Figure 1. Zhejiang province gazami crab TAC pilot area

4. Pilot Overview

A total catch size of 3,200 metric tons was established for the first year of the pilot. This TAC was derived from the average catch between the years 2011 to 2016, as calculated by the transaction records provided by local fisherman cooperatives. The TAC was then allocated to three existing fishery cooperatives at 1,800 metric tons, 900 metric tons, and 500 metric tons, respectively. Each cooperative was responsible for further allocation to individual vessels; however, vessel quotas were not transferable.

Logbooks were the primary catch data collection tool that Zhejiang's crab TAC pilot aimed to test and develop. ZMFRI developed both paper and electronic logbooks (Figure 2). The paper logbook recorded the time and location of each setting and hauling of fishing gear, catch weight per haul and per day, and transshipment events (time, location, and weight). The electronic logbook collected number of gears and quantity of catch per haul. Date and location information were automatically generated. Fishermen were required to complete both paper and electronic logbooks within two hours of harvest. Transshipment vessels had a similar catch-recording requirement, though it was restricted to paper logbooks.

Paper logbooks were submitted at the end of each fishing term. Electronic logbooks were submitted the same day they were filled out. The e-logbook had a built-in feature that could count the accumulated catch against the vessel quota and give warnings when 95 percent of the TAC had been caught. Finally, all vessels were required to have a functioning VMS, and vessels were required to hail-in and hail-out upon leaving and returning to port.

Vessel name			Date		
	Net setting		Net hauling		
	Time	Location	Time	Location	No. of pieces
1		N E		N E	
2		N E		N E	
.....					
	Net setting		Net hauling	Catch (kg)	No. of Pieces
1		N E		N E	
2		N E		N E	
....					
Daily sum					

Transshipment				
Vessel name	Time	Location	Transshipped (kg)	Note

Figure 2. Examples of paper (Upper) and electronic (lower) logbook forms used during the Zhejiang gazami crab TAC pilot

A limited at-sea observer program was implemented in the first year of this pilot, with observers placed on two randomly selected vessels for one week. Throughout the pilot, a

total of 10 one-week fishing trips were observed. Observers were selected from a student and postgraduate pool from Zhejiang Ocean University and the ZMFRI and therefore had foundational knowledge of fisheries. While on board fishing boats, observers were asked to provide catch-reporting support for fishing vessel captains and to collect the following information themselves: catch weight, location, timing, transshipment vessel, fishing gear, bycatch, and biological sampling (see observer log).

Prior to the initiation of the pilot project, trainings were carried out for pilot fleet captains and at-sea observers. Three training meetings for fishermen were carried out through a collaboration among the Zhejiang Bureau of Fisheries, the Bureau of Ocean and Fisheries of Linhai County, and ZFMRI. Researchers from ZFMRI also provided training on e-logbooks at ports to captains. Two intensive half-day observer trainings were provided on shore prior to deployment.

Enforcement was provided by the provincial, city, and two county authorities. Law enforcement officers were able to do at-sea spot checks of logbooks to document problems with hail-in/hail-out entries, as well as catch-record inconsistencies and overages. Officers could also compare VMS tracks and reported catch records.

A punishment and reward system was designed for participating vessels. A subsidy was to be provided to all pilot vessels. In the case of misreporting or violation of transaction rules, the compensation would be canceled and the quota for that vessel reduced. Overage would also lead to a deduction from next year's quota. If the violation was severe, the fishing permit or transshipment permit may be revoked. Surveillance between fishers was encouraged. If one vessel involved in illegal behavior was confirmed, the violator's quota could be transferred to the whistleblower's vessel. Both the reward and punishment cases were to be recorded in an online system under the vessel's license number (Figure 3).

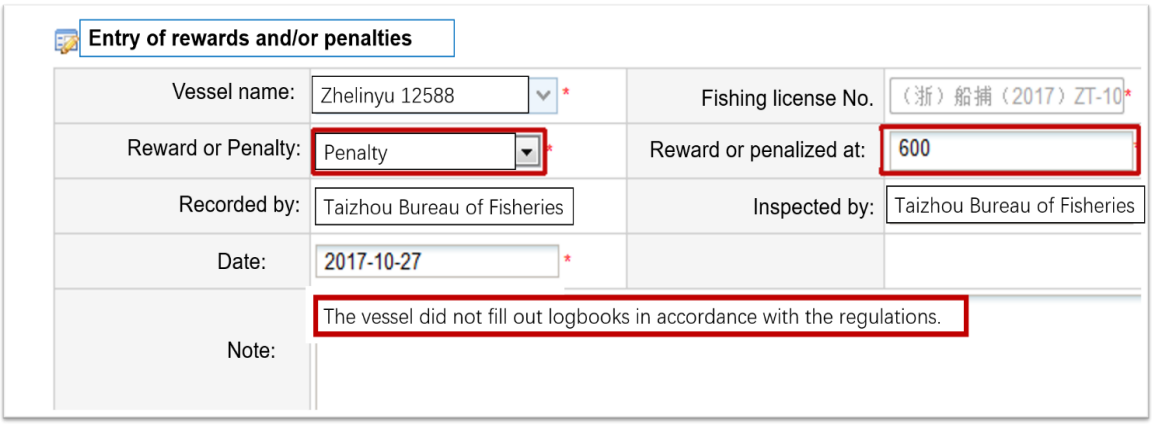


Figure 3. Example of reward and penalty form used during Zhejiang gazami crab TAC pilot

Appendix 3. Zhejiang Province Juvenile Anchovy TAC Pilot Plan

1. Pilot Fishery Selection

Anchovy (*Engraulis japonicus*) is a small-size pelagic fish that is widely distributed in China's East China Sea, Yellow Sea, and Bohai Sea. Adult anchovies measure 9 to 11 cm and 8 to 10 g. According to Zhejiang's fishery economic statistics, annual production of anchovy in Zhejiang ranged from 59 to 82 thousand metric tons over the past decade, and it is considered underfished (Marine Fisheries Research Institute 2018).

Unlike adult anchovy, which mostly goes to low-value fish oil/feed markets, juvenile anchovy (measuring 3 to 5 cm) can be dried and transformed into a tasty and nutritious traditional food referred to as "clove" fish and sold at a much higher market price. Every mid-April to mid-June, Zhejiang's coastal fishermen use lift nets, stow nets, and purse seines to catch juveniles. Because the product decays quickly, preservation before drying is important and challenging. Processing occurs directly at sea, reducing waste and producing the best quality and most profitable product.

Air dried juvenile anchovy product

Credit: Li Wei

When the start of the summer fishing moratorium was advanced to May 1 in 2017, the juvenile anchovy fishery was greatly affected, as its fishing season now fell during the closure period. In response, the provincial fishery department applied to establish the fishery as a specially permitted pilot program with limited entry. The department argued that the specialized fishery could be operated sustainably under scientific catch limits and only have minor impact on other species if managed well. The first pilot fleet was screened among Zhejiang's several coastal cities that have a tradition of anchovy fishing; Huacheng Juvenile Anchovy Cooperative in Ruian county under Wenzhou city was selected. The cooperative is composed of two at-sea processing vessels and a group of affiliated fishing fleets. The two at-sea processing vessels belong to a company named Ruian Huacheng. Among the reasons this fleet was selected are its good compliance record since its establishment in 2007, the fact that it is operated in an organized enterprise manner, and

that the fishing gear it uses—a type of non-light luring paired purse seine operated within six-meter depth—is highly selective to the catch. In 2018, after a feasibility discussion meeting, it was officially permitted by MARA as China's first and only juvenile anchovy TAC pilot, and it is also the only finfish fishery in the country that is allowed to operate during the summer fishing moratorium so far.

2. Administrative Details

The program design team consists of fisheries agencies, a scientific research institute, and the industry. The ministry and provincial fisheries department set the overall rules based on the requirements of the summer fishing moratorium and special permitted fisheries. ZMFRI cooperated with Wenzhou fisheries department to formulate the juvenile anchovy fishery management framework. Local fisheries authorities, the cooperatives, and the Huasheng company jointly formulated regulatory measures. ZMFRI also helped design the logbook and observer program. Roles of different participants are outlined in Table 9. (ZBAR is short for Zhejiang Bureau of Agriculture and Rural Affairs, and WBAR and RBAR are short for Wenzhou Bureau of Agriculture and Rural Affairs and Ruian Bureau of Agriculture and Rural Affairs.)

Table 9. Roles of participating organizations in the 2020 Zhejiang juvenile anchovy TAC pilot program

Organizations	Roles in pilot implementation
MARA	• Issue anchovy TAC fishing permit
ZBAR	• Plan, coordinate, and supervise
WBAR, RBAR	• Develop local work plan and management schemes • Conduct enforcement and monitor the implementation
ZMFRI	• Assist ZBOF to develop work plan and guide local implementation • Develop paper logbook and e-logbook systems • Conduct observer program • Conduct resource survey and TAC setting

3. Pilot Vessels, Water, and Season

Under the newly established limited-entry scheme, a total of 43 vessels obtained permits. These included 32 catcher vessels, 8 transshipment vessels, 2 at-sea processing vessels, and 1 dry product transshipment vessel (Figure 4). In this specialized fishery, the catcher vessels are only responsible for finding fish and setting the net. The transshipment vessels then will haul in the net, roughly examine the catch, and deliver the catch to the processing vessels. After the catch is processed to dry products, the dry product transshipment vessel will deliver product boxes to the Dongshan port for landing. The pilot fishing ground is between 27°20′N～30°20′N, 20 nm off the coast to the bottom-trawling forbidden line (Figure 5). The pilot fishing period is from May 1 to June 15.

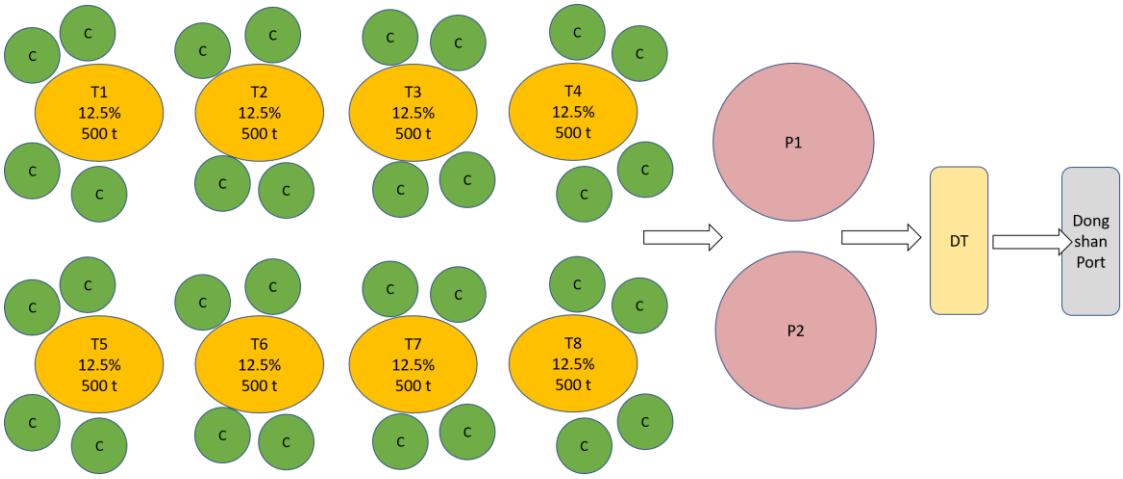
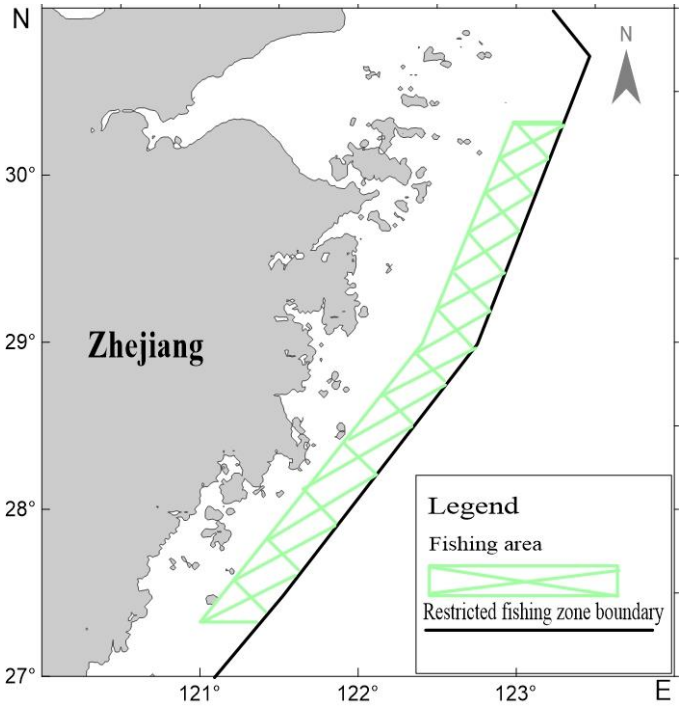


Figure 4. Fleet structure of Huacheng fishery cooperative: 32 catcher vessels (C), eight transshipment vessels (T), two processing vessels (P), and one dry transshipment vessel (DT)

Figure 5. Zhejiang province juvenile anchovy TAC pilot area



4. Pilot TAC Plan

A total catch limit of 4,000 metric tons was set for the pilot fishery. Because there is no stock assessment for anchovy, the TAC was based on records of historic catch and was set at no more than the 10 percent of the minimum yearly catch of anchovy from Zhejiang

province. The TAC was then allocated to eight groups at 500 metric tons per group, with each group consisting of four catcher vessels and one transshipment vessel (Figure 4). The 500 metric tons were not further allocated to individual catcher vessels. An additional requirement was the rule that juvenile anchovies must make up 98 percent or more of the total catch (i.e., bycatch of other species cannot exceed more than 2 percent of total catch volume). For the past three years, the catch was close to but did not reach the TAC.

The participating fleet was required to execute specific duties during the pilot. All vessels had to hail-in and hail-out of port. All transshipment vessels and processing vessels were required to keep both paper and electronic logbooks, and all transshipment vessels and one of the processing vessels were required to install video cameras. The dry product transshipment vessel was required to land at the Dongshan fishing port of Ruian city for spot-checking. All vessels were required to have a functioning VMS.

Every year, prior to the beginning of the fishing season, one training session was carried out for pilot fleet captains by Ruian enforcement officers, organized by the cooperative. The training was focusing on teaching paper and electronic logbooks (Figures 6 and 7) and introducing information on sustainable fishery.

Transshipment vessel Name			Permit No.			Date	
No.	Catcher vessel No.	Catcher vessel No.	Time	Location	Total delivering volume (basket)	Anchovy	others
1							
2							
3							

Processing vessel Name			Permit No.			Date	
No.	Catcher vessel No.	Catcher vessel No.	Time	Location	Total receiving volume (basket)	Anchovy	others
1							
2							
3							

Figure 6. Examples of paper logbook forms for transshipment vessels (top) and processing vessels (bottom) used during the Zhejiang juvenile anchovy TAC pilot

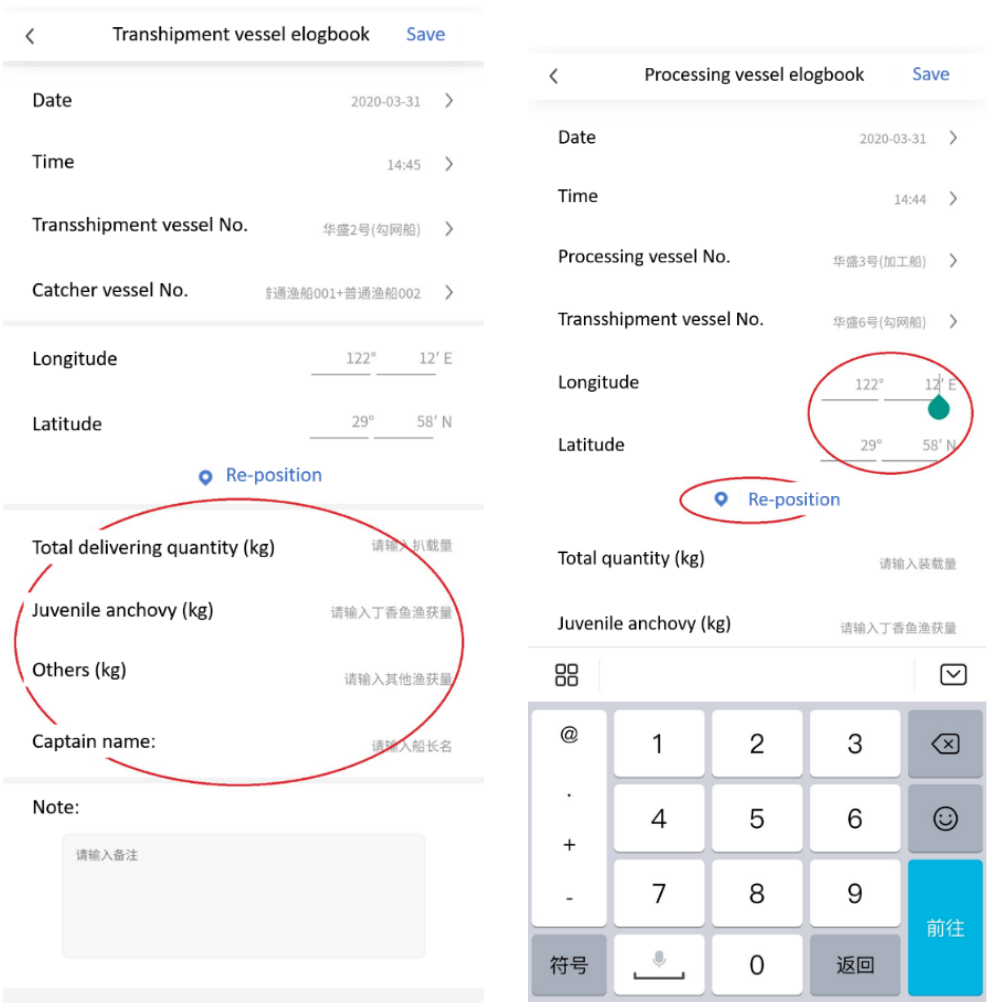


Figure 7. Examples of electronic logbook forms for transshipment vessels (left) and processing vessels (right) used during the Zhejiang juvenile anchovy TAC pilot

An at-sea observer program was deployed from the first year 2018, utilizing a mixture of institute researchers and students from Zhejiang Ocean University. In 2020, all observations were conducted by one institute observer covering the entire 1.5-month fishing season on one processing vessel, so the coverage rate was 50 percent for the processing vessels. Observers were required to assume similar scientific roles as in the gazami crab pilot, collecting biological data, recording production and CPUE, measuring environmental parameters, and reporting to the science director upon return. Observers could also check captains' logbooks. Because the fishing occurs during the summer fishing moratorium, one of the observer's key tasks was to monitor the bycatch. The observer would examine the catch transferred from transshipment vessels to the processing vessels, and if the proportion of bycatch is more than 2 percent, the observer would report to the enforcement observer to decide on the change of fishing ground. The order will be transmitted by the processing vessel to each vessel group (including catcher vessels and transshipment vessels).

The Ruian fishery department was responsible for daily supervision (see Table 10). Two enforcement officers took turns inspecting one of the two processing vessels as

"enforcement observers." In addition, landings of the dry product transshipment vessel would be spot-checked by port-based Ruian enforcement officers. Additionally, the Wenzhou fishery enforcement agents planned to conduct at-sea inspections no fewer than three times. As the fishing area crossed waters of several nearby counties, these counties also had the rights to patrol and inspect this fishery's operation. Violating the rules would disqualify captains from participating in the fishery the next year. If the case is serious, the pilot permit may be revoked for the entire cooperative.

Table 10. Overview of monitoring requirements for different vessels

Monitoring tools	Fishing vessels	Transshipment vessels	Processing vessels	Dry product transshipment vessels
Logbooks	✓	✓	✓	
Scientific observers			✓	
Enforcement observers			✓	
Video camera		✓	✓	
Port inspection				✓

Appendix 4. Fujian Province Multispecies Swimming Crab TAC Pilot Plan

1. Pilot Fishery Selection

During the 2018-2019 crab fishing season, the Ocean and Fisheries Bureau of Fujian province (FJBOF) tested TAC management for a complex of four swimming crab species commonly caught in the region: gazami crab (*Portunus trituberculatus*), blue swimming crab (*Portunus pelagicus*), red swimming crab (*Portunus haanii*), and three-spot swimming crab (*Portunus sanguinolentus*). These species were selected for the pilot because of their commercial importance and multispecies distribution, which frequently leads to combined harvest of any number of the four species together. This pilot program was the first experiment with TAC setting, catch accounting, and enforcement in Fujian province.

Four swimming crab species in Fujian TAC pilots
Gazami crab (upper left), credit: Ma Chao
Red swimming crab (upper right), credit: Liu Ming
Three-spot swimming crab (lower left), credit: Ma Chao
Blue swimming crab (lower right), credit: Ma Chao




Swimming crab catch in Fujian province accounts for 18 percent of all swimming crab

catch in China, after Zhejiang and Jiangsu provinces. In Fujian, crabs are caught with a combination of traps, bottom trawls, and gill net gears. After the annual summer fishing moratorium, the trap sector is the first to open on August 1, followed by trawl and gill net sectors on August 16. Fishing for each sector continues until the next moratorium, beginning May 1. Outside of the 2018-2019 TAC pilot, the primary crab fishing management measures in waters off Fujian have been minimum size limits (≥ 80 mm carapace width for red swimming crab, ≥ 120 mm carapace width for gazami crab and three-spot swimming crab, ≥ 100 mm carapace width for *Charybdis feriatus*) and minimum mesh sizes in crab traps (≥ 25mm), gill nets (≥ 110 mm), and crab trawl nets (≥ 54 mm).

2. Administrative Details

The FJBOF issued its multispecies crab TAC pilot plan in May 2018. In advance of the pilot, the bureau issued four documents detailing the overall TAC plan, authorized landings sites, and the monitoring and enforcement plan.

Pilot program administration was shared among four local government institutions, including the respective bureaus of ocean and fisheries from Fujian province (FJBOF), Zhangzhou city (ZZBOF), and Longhai city (LHBOF), and the Fujian Fisheries Research Institute (FJFRI). The administrative roles for each institution are itemized in Table 11.

Table 11. Roles of participating organizations in the 2020 Fujian multispecies swimming crab TAC pilot program

Institutions	Roles in pilot implementation
FJBOF	• Plan, coordinate, and provide guidance • Develop the provincial TAC work plan • Formulate and improve regulations for TAC pilot • Determine TAC
ZZBOF	• Conduct surveillance and law enforcement at sea
LHBOF	• Administer detailed TAC pilot • Determine allowable fishing vessels roster and fishing location • Issue special fishing license for TAC pilot • Designate and manage catch landing site • Manage logbooks • Monitor fishing vessels' position using BeiDou satellite system • Maintain early warning system for reaching catch limit • Develop local work plan according to provincial work plan
FJFRI	• Assist FJBOF to develop implementation plan and guide local implementation • Develop paper logbook and train fishermen • Conduct resource survey and advise TAC setting to FJBOF • Summarize pilot experiences and lessons

3. Pilot Vessels, Water, and Season

The pilot program formally began August 1, 2018, and continued through April 30, 2019. Fishermen participating in the pilot project applied to the bureau for a special license, ultimately conveyed to 106 crab trap vessels from Longhai city. The Fujian Fishery Research Institute (FFRI) conducted promotional meetings and trainings in the community between May and August 2018. (118°04′4.8″E 24°30′00″N, 119°00′00″E 24°30′00″N, 119°00′00″E 24°22′30″N, 118°30′00″E 24°00′00″N, 117°49′44″E 24°00′00″N).

FFRI conducted TAC trainings in the fishing community
Credit: FFRI

4. Pilot TAC Plan

During the TAC pilot, the catch limit was set and monitored for all four species and gear sectors combined. A combined annual TAC of 400 metric tons for the pilot season was based on 2015-2017 average catch data collected by FFRI. While it is believed these crabs exist and are caught far outside of the fishery pilot area, the TAC was assigned for a specific area covering approximately 4,300 square kilometers in the waters off Xiamen and Zhangzhou.

An important feature of the Fujian multispecies crab pilot was implementation of new paper and electronic logbook systems (see Figure 8). The logbooks were developed by FFRI, with support from the ZMFRI for electronic book system. Trip-level logbooks collected landings yield and revenue data for the four crab pilot species. In principle, participating fishermen could choose to submit paper or electronic logbooks for each trip and were required to cooperate with on-site validation from enforcement officers. Fishermen were offered cash incentives to complete and submit logbooks each month, and there was no penalty for noncompliance. The logbook pilot required one full-time

employee at FFRI to manage the logbook system. No VMS or human at-sea fishery observers were required or used during the pilot. Vessel positions were monitored with the BeiDou satellite system, and fishermen were required to keep these systems operable and running. Crab-length-frequency biological information was created through dockside sampling of landings from two trap vessel trips each month. To support pilot program administration costs, MARA allocated 600,000 RMB and the Fujian bureau allocated 400,000 RMB (approximately 141,000 USD).

Figure 8. Examples of paper (left) and electronic (right) logbook forms used during the Fujian multispecies crab TAC pilot

Appendix 5. Questionnaires and Interview Questions

1. Questionnaire for the Vessel Operators

Basic information

1. Which cooperative are you from? ☐ Tuichuangou; ☐ Fanshen; ☐ Yunsheng
2. How many years have you been a gazami crab captain? ☐ more than 20; ☐ 10-20; ☐ 5-10; ☐ less than 5 years
3. Education? ☐ primary school; ☐ middle class; ☐ high school;
4. How many crews on your boat? _____how many months at sea fishing per year? _____
5. Fishing gear? ☐ driftnet, how many months; ☐ fixed gill net (with anchor), how many months? _____; ☐ others _____
6. The main catch species other than crab? _____ how to deal with it? ☐ sell; ☐ eat; ☐ give away; ☐ throw it away.
7. Transshipment ratio ☐ >80%; ☐ 50% - 80%, ☐ 30% - 50%; ☐ no or occasionally
8. Co-ops mainly help with ☐ licensing; ☐ organizing training; ☐ insurance; ☐ finding crew members; ☐others_____; ☐ no help

Production records during non-limiting fishing season

9. Will you record the catch? ☐ do not record; ☐ record by yourself; ☐ not record by myself but by transshipment vessels
10. Record what: ☐ number of baskets; ☐ total weight; ☐ weight per basket; ☐ unit price; ☐ transshipment volume; ☐ fishing location/time; ☐ others_____
11. Record for what? ☐ for business; ☐ for annual production calculation; ☐ for marking good fishing locations; and ☐ others_____
12. Resources in different grid differ? ☐ big; ☐ small; resources in the same grid differ between years? ☐ big; ☐ small

Fishing logbooks

13. Understand why you should fill out (official) fishing logbooks? ☐ unclear, mandated; ☐ to protect resources; ☐ others_____

14. Understand why there are catch limits? ☐ unclear; ☐ to protect resources; ☐ others_____

15. Do you know there are limits on your boat?

☐ I don't know;

☐ I know it, from where: ☐ heard at the training session; ☐ the village posts; ☐ the cooperative notice; ☐ the observers; ☐ other fishermen; ☐ others_____

16. Have you attended TAC training? ☐ attended; ☐ not attended

17. The contents of the training: ☐ electronic logbook; ☐ paper logbook; ☐ notification; ☐ laws and policy; ☐ others_____

18. Wish to have more training on: ☐ electronic logbook; ☐ paper logbook; ☐ notification; ☐ laws and policy; ☐ others_____

19. Rate difficulty of fishing logbooks (1-5 points, 5 points is most difficult): paper ____, electronic ____, notifications,

20. The most useful training method for using e-logbooks: ☐ meeting/training class; ☐ read the manuals by himself; ☐ observers teaching on board; ☐ all training is useless

21. Identify the reasons why the e-logbooks is not filled in: ☐ forgotten; ☐ don't know how to; ☐ no time; ☐ program malfunction; ☐ not knowing what the benefits

22. Rate the frequency of e-logbook malfunction: ☐ often; ☐ occasionally; ☐ never used it

23. Describe the accuracy of the logbook information (1-5 points, 5 points is most accurate): catch volume ___; gill net pieces ___; transshipment vessel and volume____

24. What additional features do you want the e-logbooks to have?

☐ Help calculate how much I've caught myself this year

☐ Help calculate how much the cooperative has caught

☐ Monitor how much fish is caught within the quota;

☐ Record the transshipment vessels I traded with

☐ Real-time market prices

☐ Weather and safety warning

☐ Regularly remind me to submit logbooks

☐ Receive the message from the co-ops

☐ Help calculate fishing cost such as fuel cost

☐ Others

25. If all desired functions are available, and there is no e-logbook malfunction, which one will you choose for long-term use? ☐ paper logbooks; ☐ e-logbooks
26. Your favorite way to report data? ☐ phone calls; ☐ WeChat; ☐ paper/e-logbooks; ☐ transshipment vessels help report
27. Do you know the new hail-in/hail-out system? ☐ know; ☐ don't know
28. Do you know that hail-in/hail-out system requires reporting catch data? ☐ know; ☐ don't know

Observers

29. Are there any observers on board? ☐ yes; ☐ no, skip Q30 and Q 31
30. Do you know the reason for the observers? ☐ government pay attention to this fishery and want to know more; ☐ protect the resources; ☐ supervise us; ☐ others_____
31. Observers: ☐ teach how to use logbooks; ☐ introduce policies on resources and environment protection; ☐ others_____; ☐ no chatting with observers
32. How do you feel about the observers? ☐ helpful, have good feeling for them; ☐ bring trouble, but will accept; ☐ do not accept
33. No observers on my boat, but felt that observers were good: ☐yes; ☐no

Electronic monitoring (EM)

34. Is there a camera on board? ☐yes; ☐no
35. What is the purpose of the camera? ☐ for crew safety; ☐ for directing fishing activities; ☐ others; how much it costs _____
36. What type of communication do you have on board? ☐ mobile phone; ☐ at-sea Wi-Fi; ☐ satellite phone

Transshipment

37. Did you only sell to designated transshipment vessels? ☐ yes; ☐ no, because____

38. How do you choose transshipment vessels? ☐ by distance; ☐ best relationship; ☐ high price; ☐ others_____

39. Will the transshipment vessel give you a trading ticket? ☐ yes; ☐ no

Law enforcement

40. Before the pilot, have your logbooks been checked at sea? ☐ never; ☐ 1-2 times per year; ☐ more than 10 times a year

41. After the pilot, have you seen law enforcement vessels in the pilot water?

    ☐ No, I didn't.

    ☐ Yes; how many times: 2017-2018____ , 2018-2019_____, 2019-2020___

    Law enforcement vessels are mainly from: ☐ provinces; ☐ Taizhou; ☐ local city/county

42. During the pilot season, enforcement officers check: ☐ permits; ☐ safety facilities; ☐ fishing location; ☐ AIS/VMS; ☐ logbooks; ☐ fishing gears; ☐ juvenile fish; ☐ others_____

Prospects

43. Do you think fish resources have changed a lot over the years? ☐ more and more; ☐less and less; ☐no special feeling

44. How do you usually protect the resources? ☐ return egg-bearing female crabs; ☐ return small crabs; ☐ must leave enough stock at sea

45. Will you be in this fishery in the future?

    ☐ the prospect is good, will stay; ☐ the prospect is not good, but there are no other ideas now; ☐the prospect is not good, consider changing

2. Questions for Cooperative Managers

1. The structure of the cooperative.
2. What's the major role/function of fishery cooperatives?
3. Any internal requirement set up by the cooperative for the pilot? Or penalty and reward system? If yes, any difficulties in implementing these internal rules?
4. How do fishermen and cooperative interact and what do you communicate?

5. How did they feel the fishermen receive the catch reporting requirements?
6. How do the fishing vessels choose transshipment vessels?
7. How does the cooperative help with fishermen's compliance?
8. Are there any policies issued to support the development of cooperatives?
9. What's fishermen's perception about gazami crab resources?

3. Questions for Observers

1. What is your profession/training/level of education?
2. How many days/weeks did you act as an observer on a boat?
3. Was your training adequate? What would you recommend for improvements, if any?
4. What were your primary duties on the boat?
5. Were you treated well by the fishermen? Did you feel safe on the boat?
6. How do you regard the accuracy of the data (with and without observers on board?)
7. Was the training of the fishermen adequate? What would you recommend?
8. Were fishermen receptive to filling in logbook?
9. Did the paper logbook work well?
10. Do you think the electronic logbook would work better?
11. Was the catch recording real-time?
12. How was catch being measured?
13. What worked well for the fishermen? What didn't?
14. Discuss the role and complications of transshipment vehicles in quantifying catch. What might be solutions to those complications?
15. What were your largest challenges?

4. Questions for the Science Director

1. How many logbooks were distributed and how many were returned?
2. Were logbook entries paper, electronic, or both?
3. Were the logbooks returned on the designated schedule?
4. (For both paper and electronic logbooks) How consistent were the logbook entries? Are there temporal gaps in logbook entries? If so, describe. Are there information gaps in logbook entries? If so, describe.
5. Were there differences in the reliability/accuracy of data when comparing paper and electronic logbooks?
6. What was the variation of the reported catch between vessels and within a vessel (i.e., variation haul to haul or trip to trip by the same vessel)? Are there trends in

the variation over the fishing season (e.g., were vessels getting better at collecting data)?

7. Were there any boats that regularly reported outliers in the data (i.e., very high or very low values compared to the mean)? If so, what percentage of the boats returned these outliers—or unusual catch records—and how frequently? Were there any patterns in the occurrence of outlier data among vessels or in space or time? Were the outlier data used in analyses or discarded? How was the determination made whether to include or exclude?
8. How many observers were deployed? How many boats? What proportion of total boats in the pilot had observers?
9. How consistent were the observer data? Are there temporal gaps in logbook data? Are there information gaps in logbook data? Was there any evidence that some observers were performing their job better than others? Would you say that some observers generated more reliable data than others? If so, what was the indicator of this?
10. What's the difficulty of deploying observers and maintaining this program?
11. What landings data were gathered, if any?
12. What were the consistencies/inconsistencies among industry reported data, at-sea observer data, and landings data?
13. Qualitatively identify successes and concerns with the fishermen/fishing company reporting.
14. Qualitatively identify successes and concerns with the observer reporting.
15. Qualitatively identify successes and concerns with the landings reporting.
16. What kind of reporting was required of the transshipment vessels? And were there any observers onboard these vessels?
17. Discuss the role and complications of transshipment vehicles in quantifying catch.
18. How is designated transaction implemented (i.e., vessel can only sell their catch to designated transshipment vessels)?
19. Did the data collection methods change between pilot years? Is catch data monitoring improving? Is it staying the same?
20. Do you think electronic logbooks are preferable? Do you think it's reasonable to shift to fully electronic logbooks?
21. How did the reward and punishment system work? Any cases where this was implemented? Any whistleblowers happen?
22. How would you quantify the human resources required to execute these pilots projects each year? How much financial resources, if any, of this kind are provided to the pilot?
23. What are the major difficulties of coordination among different level of fishery managers and different divisions?

5. Questions for Law Enforcement Officers

1. What enforcement actions, if any, were taken during the pilot project?
2. What were the most common infractions? Do you have any recommendations for addressing them?
3. Do you use VMS for enforcement and how?
4. Have you checked the fishing logbooks? What problems were found?
5. How did you feel the fishermen received the pilot project?
6. How did different levels (provincial and city) of enforcement officers cooperate and share enforcement responsibility?
7. Discuss the role and complications of transshipment vehicles in quantifying catch.
8. Is the penalty and reward system of the pilot working?
9. Major challenges or success in the enforcement?
10. Did you have sufficient training in preparation of the pilot project?
11. What stories/thoughts would you like to share with us?

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