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**MOVING TOWARDS THE SCIENCE-BASED FISHERIES MANAGEMENT (SBFM) IN CHINA**

By

Shu Su

B.A. Shanghai Ocean University, 2010

M.A. Shanghai Ocean University, 2014

A DISSERTATION

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

(in Ecology and Environmental Sciences)

The Graduate School

The University of Maine

August 2021

Advisory Committee:

Yong Chen, Professor, School of Marine Sciences, Advisor

Keith Evans, Associate Professor, School of Economics

Walter Golet, Assistant Professor, School of Marine Sciences

Jake Kritzer, Executive Director, Northeastern Regional Association of Coastal Ocean Observing  
Systems

Lisa Suatoni, Deputy Director, Natural Resources Defense Council

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# **MOVING TOWARDS THE SCIENCE-BASED FISHERIES MANAGEMENT (SBFM) IN CHINA**

By Shu Su

Dissertation Advisor: Dr. Yong Chen

An Abstract of the Dissertation Presented  
in Partial Fulfillment of the Requirements for the  
Degree of Doctor of Philosophy  
(in Ecology and Environmental Sciences)  
August 2021

Sustainable fisheries management requires decisions to be made based on sound science. To help ensure this, a Science-Based Fisheries Management (SBFM) system should be established to produce the best available science (BAS) and to ensure that the BAS forms the basis of decision-making. The goal of this dissertation is to look at how China, the world's largest marine fisheries country, might build an effective SBFM system to enable its marine fisheries to attain sustainability. Studies were conducted to answer the following guiding questions: 1) what is SBFM? 2) why is it necessary for China to deploy SBFM? 3) what are China's challenges, roadblocks, and opportunities in implementing SBFM?, and 4) how to overcome the obstacles by reforming China's fisheries system.

This dissertation is structured into four chapters. An extensive literature review was conducted in Chapter 1 to determine the concept and enablers of SBFM in the world. A framework that included a thorough set of criteria and a basic operational structure for SBFM was given. The evolution of China's marine fisheries management practices from 1949 to 2019 was examined in Chapter 2 based on a comprehensive literature review and the researcher's observations in meetings and conversations with Chinese fisheries experts. This Chapter provides materials to help people better understand the features and trends of China's marine fisheries policies, as well as the characteristics of its marine capture fisheries. The study indicated that China's sustainable marine fisheries management faces numerous challenges and hurdles, the majority of which are associated with SBFM - inefficient science-policy interactions and data shortages. The checklist of SBFM criteria defined in Chapter 1 was used in Chapter 3 to analyze China's marine fisheries management system from a system engineering perspective. The benefits and drawbacks

of the system for implementing SBFM were examined. Finally, in Chapter 4, the advantages and disadvantages of China's marine fisheries management system were summarized, and recommendations for China's marine fisheries reform with the goal of constructing a more successful SBFM were provided.

This dissertation concluded that 1) China's sustainable marine fisheries management cannot succeed without institutional reforms to support stronger science and its integration into fisheries policymaking; 2) reforming the fisheries management system from the perspective of system engineering can be an effective way to promote the production of better BAS and its use in policies; and, 3) use of the SBFM framework developed in this study can help China evaluate and reform its marine fisheries legal and institutional framework, and at the same time leverage the localized TAC pilot programs to develop and test a structured approach for SBFM. With the expansion of TAC pilots, the approach can be revised accordingly and finally inform the development and implementation of SBFM at large.

## **DEDICATION**

I am grateful to my mother for always believing in me, understanding me, and being supportive of my decisions. I would like to thank my family and friends in Maine and China for their endless support and happy memories throughout my time at the University of Maine.

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## **CHAPTER 1**

### **A COMPREHENSIVE FRAMEWORK FOR OPERATING SCIENCE-BASED FISHERIES MANAGEMENT: A CHECKLIST FOR USING THE BEST AVAILABLE SCIENCE**

#### **1.1. Abstract**

Developing fisheries policies based on the best available science (BAS) has been generally required in international agreements and national legal documents in many countries. However, it is difficult to comply with BAS when lacking a uniformly agreed-upon operational framework. In this chapter, we conducted an exhaustive literature review and developed a framework that includes a comprehensive set of criteria and a basic operational structure for science-based fisheries management (SBFM) to better integrate BAS in fisheries policies. We proposed that SBFM consists of four components: objective-setting, data input (implementation and enforcement process), data production (scientific research process), and data use (management strategy development). The capacity of a fisheries system to produce and use BAS is mainly reflected in the following areas: a) efficient informational feedback among these components; b) collecting a good range of quality-assured data that meet the needs of scientific research and fishery policy formulation; c) analyzing the collected data through a well-designed scientific research process; and d) selecting and using the best data from different sources. The framework developed can inform the creation, evaluation, and improvement of management systems rooted in SBFM and strengthen SBFM-related research, communication, and cooperation.

#### **1.2. Introduction**

Science-based fisheries management (SBFM), also called evidence-based fisheries has been proven to be significant and necessary for the sustainability of fisheries (Cooke et al., 2017). With the expanded role of collaboration and the participation of increasingly diverse stakeholders in fisheries management, there arises a new urge to make relevant decisions based on the integration of natural and social sciences as well as stakeholder concerns (Karl et al., 2007). Fisheries policy- and decision-makers are expected to

collect a broader range of information and knowledge, weigh the interests and values of all parties, and ultimately make decisions based on the best available scientific information (Ryder et al., 2010; Charnley et al., 2017; Stephenson et al., 2017). Meanwhile, the “science” on which fisheries management is based now includes not only natural science information but also social science information, interdisciplinary and multidisciplinary research results, as well as traditional ecological knowledge and local fishers’ knowledge (Martin et al., 2007; Bonney et al., 2009).

On the legislative side, best available science (BAS) based policies are generally required in many international agreements relating to fisheries. For example, the 1995 UN Fish Stocks Agreement requires coastal states and states fishing on the high sea to adopt measures that are based on the best scientific evidence available to maintain or restore stocks at levels capable of producing maximum sustainable yield (Article 5(b), A/CONF.164/37, UN, 1995). Furthermore, many jurisdictions including the United States, New Zealand, Australia, and the European Union have included corresponding provisions in their national or regional legislation for BAS-based fishery policies. For instance, in the US, the Magnuson-Stevens Fishery Conservation and Management Act of 2007 (MSA) stipulates that “conservation and management measures shall be based upon the best scientific information available” (§.301(a)(2), MSA, USA, 2007). European Union (EU) requests the management of its Common Fisheries Policy (CFP) to be guided by the principle that the establishment of measures in accordance with the best available scientific advice (Regulation (EU) NO 1380/2013, 2013).

Previous studies have outlined essential attributes of BAS (e.g., NRC, 2004; Sullivan et al., 2006; Esch et al., 2018, Ryder et al., 2010; Nosek et al., 2015; Stephenson et al., 2017). For example, some suggested that BAS is the product of a rigorous scientific research process that follows a series of scientific guidelines (Sullivan et al. 2006, Charnley et al. 2017). Cash et al. (2002) proposed that the effective scientific information supporting decision-making should be credible, legitimate, and salient. In addition, the National Resources Council of the United States proposed a set of criteria for ensuring the use of BAS in fisheries management, including relevance, inclusiveness, objectivity, transparency and openness, timeliness, and peer review (NRC, 2004). However, when it comes to solving specific problems in practice,

these general guidelines of BAS are somewhat vague and there is a lack of an operational framework with detailed standards to ensure the production and use of BAS in fisheries management. Specifically, lacking an operational framework could hinder the reform and evaluation of fisheries institutions to comply with BAS mandates. Although the processes of implementing SBFM in jurisdictions differ depending on various factors such as legal and institutional framework, cultural, political, and social systems, and the situation of data availability, developing a set of expected agreed-upon and widely applicable operational standards is still pursuable and meaningful. It will help facilitate compliance with the BAS mandates and assist in avoiding unnecessary communication difficulties due to mismatched understanding of SBFM among stakeholders. For example, it is much easier for government agencies to claim they are implementing SBFM when they are not being held to agreed-upon standards between peers and/or stakeholders (ICSP13, 2018). Furthermore, the BAS mandates may become the “evidence” to protect agencies from having to generate scientific information when none is available (Charnley et al., 2017; Esch et al., 2018).

The purpose of this study was to develop a comprehensive operational framework for SBFM from a perspective of system engineering and to integrate BAS into management strategies. The framework developed can be used as a guideline to establish, improve and/or evaluate SBFM in jurisdictions. The study was designed to answer the following questions: 1) To effectively produce and use BAS, what are the expectations for the different processes embedded in the fisheries management system?; 2) what criteria or enablers are needed to achieve these expectations?; and, 3) what potential methods can be used to meet these criteria?

It is worth noting that different studies and documents might use different terms to describe the BAS. For example, in the 18 documents included in the “Selection of International Fisheries Treaties and Documents”, the term “best scientific information available” was used 13 times, and “best scientific evidence available” was used 14 times (Cui & Huang, 2015). In this dissertation, the researcher(s) use the term BAS to represent all of them as the purpose is not to discuss which term is better nor the difference between them, let alone to discuss the potentially different legal and political meanings behind these terms.

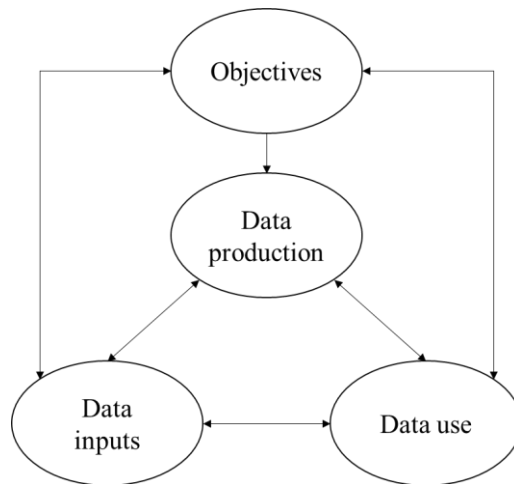


### **1.3. Materials and methods**

#### **1.3.1. Developing the basic framework for SBFM**

The effectiveness of the production and use of BAS in fisheries systems does not depend on a single component or process such as developing management strategies, or policy-making, but instead depends on components that make up the entire system and the information flow connecting these components (Soomai & MacDonald, 2019). Thus, Systems Thinking was used in this research as the theoretical basis for the development of the basic framework for SBFM. The theory emphasizes holistic analysis that focuses on the ways in which the components of the system are interconnected and how the system works over time (Meadows, 2006). It has been widely used in or supported by many natural resources management research to emphasize the importance of links between system components to the success of the entire system (e.g., Degnbol & McCay, 2007; Nutley & Davies, 2007; Hipel et al., 2008; McGuire & Harris, 2011; Glaser & Glaeser, 2014), although their focuses were not optimizing the production and use of BAS in fisheries management.

In this study, according to the operational process of fisheries management in the real world (Cochrane, 2002), we proposed that SBFM in its most straight-forward form is a conceptual model formed by a set of objectives and a subsystem consisting of three interactive components (information nodes) of data inputs, data production, and data use. These three components correspond to three practical processes including implement and enforcement, scientific research process, and management strategy development (Figure 1.1). The objectives guide the operation of the subsystem, and the latter in turn can lead to the revision of the former. This model consists of iterative processes where information flows in a continuum leading to system action.



Note: The arrows depict the flow of information. Objectives - management objective-setting; data production - scientific research process; data use - management strategy formulation; data inputs - implementation and law enforcement (providing a “data pool” for objective-setting, scientific research, and strategy formulation)

Figure 1.1. A conceptual model of science-based fisheries management.

We found that the ICES (2000) had proposed a similar conceptual model for fisheries system which consist of four subsystems including knowledge production, management decision-making, enforcement/ implementation, and adaptation. In their model, the four subsystems are connected end to end with information flows in a one-way cycle. The conceptual model of SBFM provided in this chapter can be considered a modification of the model of ICES: The formulation processes of objectives and strategies within the management decision-making subsystem are divided into two separated components of the system; and the implementation, enforcement, and adaptation are merged into one component. We believe the modified model is more applicable to operations and more in line with the perspective of policymakers and managers. In addition, the modified model emphasizes the two-way information exchange between the components that make up the system.

Specifically, the SBFM conceptual model developed in this research focuses on the production and use of BAS to formulate management strategies for already assigned management objectives; the management measures are specified. Management strategies here refer to adaptive regulations for fisheries management according to specified objectives. For example, if an objective is to use the total allowable

catch (TAC) as the management measure and to maintain the fisheries resources at the maximum sustainable yield (MSY) level, then the subsystem (data inputs, data production, and data use) will be run to develop and implement appropriate TAC-based regulations. The TAC regulations will be revised to adapt to the changing situation over time and the subsystem provide feedback information that may cause the objective to be revised, such as pursuing maximum economic yield (MEY) instead of MSY. An explanation of each process for SBFM will be provided in section 1.4.

### **1.3.2. Identifying the criteria**

An exhaustive review of research reports written in English was conducted to identify the expectations for each process in SBFM, the criteria, and the specific methods to achieve these expectations. Google Scholar and Web of Science were used to search for the keyword “fisheries” in combination with each of the following phrases: Best available science, best scientific information available, science (or evidence and knowledge), and policy (or decision). In this way, 50 research reports focusing on BAS and science-policy interactions in fisheries were selected for the first stage of the review. 43 additional reports relating to these topics were further selected from the bibliography of previously reviewed reports for the second stage of the review. Thus, a total of 93 reports were reviewed. These reports cover the study areas of management and conservation of natural resources, ecological environment resources, and endangered species. Table 1.1, Table 1.2, and Figure 1.2 present the number of reports reviewed by geographic coverage, focus areas, and year of publication, respectively. A list of reports reviewed is presented in the Supplementary Materials ([Appendix A](#)).

Table 1.1. Research reports by jurisdiction.

Jurisdiction	Count
Australia	4
Brazil	3
Canada	6
Cuba	1
EU	12
Fiji	1
Global	31
Mexico	2
Netherlands	5
New Zealand	1
Norway	1
Philippines	2
South African	1
UK	1
USA	23

Table 1.2. Research reports by study area.

Study area	Count
Fisheries management and conservation	50
Natural resource management conservation	12
Environmental (ecological) management and conservation	26
Endangered Species management	5
Total	93

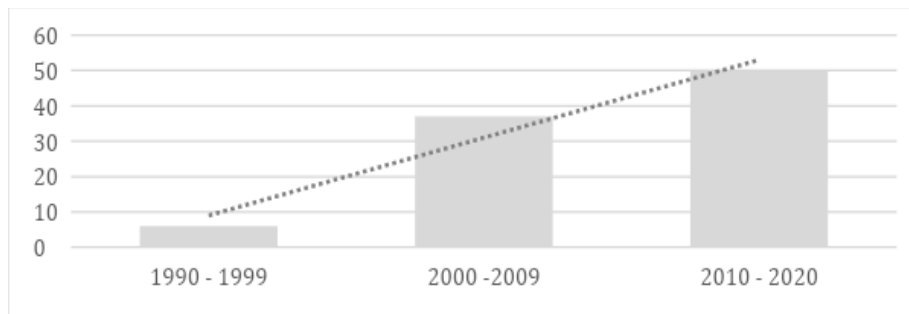


Figure 1.2. Research reports by publication year.

We reviewed the reports through a substantive coding process (Miles & Huberman, 1984). We first engaged in pattern coding to identify broad themes and contexts that related to enhancing the production and use of BAS according to in particular the abstracts, results/findings, and conclusions of the reports. Then we open-coded the identified contexts to sort expectations, facilitators/enablers, and methods in detail, line by line. After that, we cluster-coded the detailed codes and reconstitute them into more general expressions of expectations and enablers that emerged through the open coding process. Finally, we rewrote the identified facilitators/enablers as expected criteria in a restrictive tone and divided them into five categories (see Table 1.3). The methods identified are discussed in the text and some of them are presented in Table 1.4. Table 1.3 was then used to determine the key elements of each management process to develop the operational structure of the SBFM (Figure 1.3). We described the criteria and the structure respectively in sections 1.4 and 1.5.

Table 1.3. A comprehensive list of criteria that enable the production and use of the best available science in SFBM.

<b>General</b>
Best available science-based fisheries management and conservation is required by law (4, 42, 50, 60, 71, 72, 73, 80, 83, 85, 92)
Institutional structure is well designed for the involvement and collaboration of multidisciplinary stakeholders (13, 14, 17, 19, 25, 31, 34, 36, 37, 44, 50, 54, 60, 74, 75, 76, 81, 84, 87)
Standards and mechanisms regarding data collection, storage, and verification, including the fisheries monitoring plan, are developed and are in line with management objectives and the research plan (10, 23, 42, 58, 64, 66, 85, 88)
Division of responsibilities is clear; responsibilities for making policies and conducting scientific research are separated (9, 22, 23, 59, 67, 78)
<b>Process 1: Management objective-setting</b>
<b>Expectation: Objectives are achievable</b>
Objectives are measurable and time-bounded and performance indicators are identified over biological, social, and economic dimensions (10, 21, 22, 24, 37, 48, 56, 67, 88)
Management unit and boundaries are identified and informed by the biological feature of the fish stock or ecosystem function (3, 56, 81, 84)
Mechanisms for value-based debate among stakeholders are in place (13, 14, 17, 50, 19, 25, 31, 60, 75)
Fisheries monitoring programs are used to evaluate whether the objective is being met (2, 22, 23, 65, 75)
<b>Process 2. Scientific research process (data production)</b>
<b>Expectation: Scientific advice relevant to the policy demands and the fishery being managed</b>
A research plan is developed based on management objectives (4, 9, 10, 54, 78, 81, 82, 83, 91)
Data used to generate scientific advice are relevant to the specific fishery being managed (54, 60, 81, 83, 85, 84, 88)
External review of scientific advice based on user needs and other knowledge is conducted (57, 81)
<b>Expectation: Scientific advice is objective and credible</b>
Scientific advice is produced through a well-established scientific research process with:
i) a clear statement of objectives (10, 33, 88);
ii) conceptual models for predicting and testing hypotheses under different scenarios (10, 45, 71, 81, 93);
iii) well-established protocols to collect data (10, 42, 71, 80, 88, 93);
iv) rigorous statistical analysis and logical interpretation (10, 42, 71, 81, 85, 88, 93);
v) clearly documented methods, results, and conclusions (10, 88);
vi) independent peer review of research methods, results and conclusions (10, 35, 39, 42, 45, 68, 71, 72, 73, 81, 85, 88).
Skilled and reputable scientists are hired to do research including stock assessment (3, 60, 78)
Limitation of data and knowledge gaps are acknowledged and documented (5, 10, 45, 79, 80, 81, 86, 88)
<b>Expectation: Scientific advice is inclusive</b>
Social science research, multidisciplinary and interdisciplinary research are conducted (4, 12, 37, 39, 44, 47, 52, 55, 57, 80, 81, 88)
Methods are taken to incorporate stakeholders' knowledge in research (15, 18, 20, 33, 34, 36, 40, 43, 44, 51, 58, 61, 63, 65, 67, 71, 80, 81, 84, 91)
<b>Process 3. Development of management strategies (data use)</b>
<b>Expectation: Strategies developed based on legitimate scientific advice</b>
Decisions are based on the scientific advice produced following a well-designed scientific research process (10, 8, 88, 89)
Rules for using the scientific information account for divergences (4, 6, 11, 14, 15, 19, 29, 42, 57, 59, 71, 74, 80)
Approaches for communicating and understanding scientific advice and other knowledge are in place (2, 4, 5, 8, 9, 16, 17, 19, 30, 31, 33, 45, 46, 49, 57, 58, 59, 62, 61, 70, 74, 80, 81, 88, 90, 91)
<b>Expectation: Uncertainties are acknowledged, and decisions are capable of being adapted to environmental changes</b>
Rules for using the scientific information account for uncertainty and are formalized and repeatable (19, 36, 59, 60, 80, 81, 82, 84, 90)
Monitoring programs are in place to inform adaptive updating of management strategies (2, 22, 23, 64, 65)
Performance of management strategies are evaluated and learned from accordingly (3, 5, 21, 25, 34, 49, 69, 81)
Decisions are recurrent (23, 39, 60, 79, 81, 88, 91, 92)
Precautionary approaches are taken to reduce potential risks (3, 28, 60, 67)
<b>Process 4. Implementation (data inputs)</b>
<b>Expectation: Feedback is knowable; regulations are well implemented and complied with</b>

Table 1.3. continued

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Monitoring programs are in place to provide a means for supervision and collecting fisheries data (23, 60, 64, 66)  
Outreach programs and education courses for both managers and fishers are in place (18, 19, 57, 62, 74)

---

Note: The number in brackets represents the code of the report that proposes, reiterates, or demonstrates the corresponding criterion. Please use the code to find the corresponding report in Appendix A.

Table 1.4. Approaches that facilitate the communication and understanding of science.

- 
- Hiring interpreters or knowledge brokers (4, 46, 49)
  - Hiring social scientists as translators, mediators, and/or facilitators (57).
  - Establishing formal processes for iterative communication between scientific and policy communities (8, 9, 16, 30, 31, 59)
  - Establishing boundary or hybrid organizations; co-management (5, 6, 15, 27, 53, 74, 76, 84, 86)
  - Conducting workshops, conferences, and/or meetings that involve a diverse set of stakeholders (4, 6, 11, 14, 15, 19, 42, 53, 76)
  - Educating and training scientists in communication, translation, and mediation (57)
  - Scientists presenting scientific results in publicly accessible and understandable/simple texts (5, 70)
  - Government sharing and communicating data with disparate audiences/stakeholders via media (19, 33, 70, 77)
- 

Note: The number in brackets represents the code of the report that proposes, reiterates, or demonstrates the corresponding criterion. Please use the code to find the corresponding report in Appendix A.

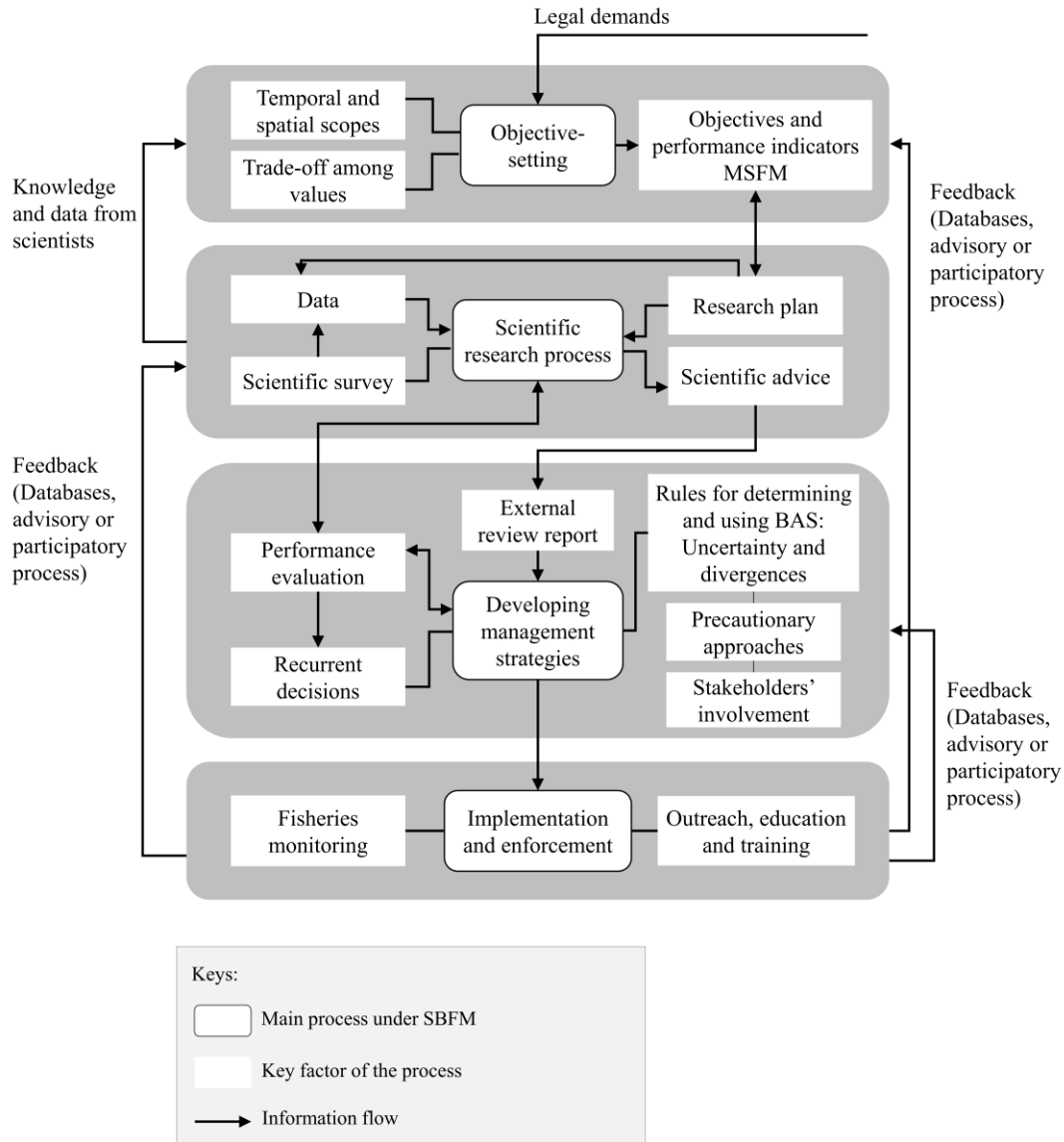


Figure 1.3. An illustrative diagram of the SBFM framework.

The coding process aimed to ensure the identification of the major expectations, criteria, and methods that were proposed, reiterated, and/or demonstrated in the reports. Thus, if a report is not a major source for a certain element, it will not be listed in Table. Additionally, although we intended to include all the important reports regarding BAS and science-policy interactions in relation to fisheries, we admit that this study cannot cover all of these reports, and the selection of reports was influenced by the authors' expert judgment. However, the list of criteria for SBFM can still be comprehensive, because representative



reports were included with wide geographical coverage, including those developed countries that are considered to be more mature in implementing SBFM and those developing countries where SBFM is in its infancy.

#### **1.4. SBFM criteria**

A total of 32 expected criteria for the production and use of BAS in SBFM were identified based on the findings of the extensive literature review and the results were presented in Table 1.3. The criteria were divided into five categories: Those related to the foundation of the system, including legislation and institutional structure, were classified as “general”; others are related to the four processes (objective, scientific research process, strategy formulation, and implementation). In the following sections, we described the role of each management process in producing and using BAS in SBFM and the corresponding expected criteria and methods. Some representative reports reviewed were quoted to support certain criteria in the text and more evidence can be found in Table 1.3.

##### **1.4.1. General**

The development of fisheries policies based on BAS should be required in domestic legal documents. Having a clear legal authorization undoubtedly means a higher possibility for BAS’s production and use (Domínguez-Tejo & Metternicht, 2018). The BAS-based policy mandates should be accompanied by a well-designed institutional structure to establish rigorous and easily repeatable mechanisms that allow for the integration of scientific information into policies and stakeholders’ involvement and collaboration (Garcia, 2008; Ramirez-Monsalve et al., 2016; Soomai, 2017). Jasanoff (1990) proposed that the boundaries around the scientific process are a prerequisite for maintaining the politically acceptable independence and objectivity of the advice. Although the objectivity of science in environmental management is still controversial (Rykiel, 2001), defending the “strict boundaries” around the scientific process is necessary for SBFM. To be precise, the institutional structure should ensure a clear division of responsibilities, especially separating and assigning the tasks of research and policymaking to different organizations or bodies (De Santo, 2010; Dankel et al., 2016; Soomai, 2017; MacDonald & Soomai, 2019).

The mechanisms for the integration of science and stakeholders' involvement are expected to be a statutory and long-term advisory framework guided by the principles of pluralistic participation, transparency, and openness (Fritz, 2010). Clear accountability should exist within the legal framework and include coherence as to the roles of participants (Fritz, 2010). The purpose of enabling stakeholders' participation and collaboration in the SBFM, although it varies in different processes, is ensuring appropriate collection, communication, and consideration of the broad spectra of data that are required for decision-making.

SBFM requires the availability of a wide range of quality-assured data (Chen et al., 2003) and there must be clear provisions in the law to ensure data collection, transparency, sharing, and accessibility. A clear set of data collection, storage, and verification standards is a prerequisite for ensuring the coordinated operation (continuity) of the various processes in the SBFM system. In general, fisheries monitoring programs, advisory and participatory processes embedded in the decision-making process, and investigations conducted through scientific research are the major ways to collect necessary data over biological, economic, social, and ecological dimensions. Among them, fisheries monitoring plays a vital role in connecting the divided processes in the fisheries systems: the data collected are used in the scientific research process and aid in the development and evaluation of management objectives and strategies (Kritzer, 2020). To ensure that the fisheries monitoring system is capable of providing accurate services for decision-making, formulating the fisheries monitoring plan should be part of the overarching plan of SBFM (Conroy & Peterson, 2013). The focus and design of a monitoring plan should be consistent with management objectives and meet the specific data inputs demands of scientific research and management performance evaluation (Lindenmayer & Linkens, 2010).

Additionally, allowing stakeholders to co-develop data collection, storage, and verification standards, including the fisheries monitoring plan, will improve the legitimacy, compliance, and cohesiveness of the entire SBFM system (Cullen, 1990; Byder et al., 2010; Karr et al., 2017). The stakeholders here include data end-users, i.e., policymakers, and data providers, e.g., scientists and representatives from the industry and NGOs.

### **1.4.2. Objectives**

A set of achievable management objectives is key to identifying necessary scientific information and thereby guiding data collection as well as the entire scientific research process (Sullivan et al., 2006; Conroy & Peterson, 2013). Fisheries management objectives should clearly state reference points, be measurable within a certain time frame, and be employed with clear management units and boundaries (Conroy & Peterson, 2013). For example, the EU's fisheries management plan requires that by 2020 all the important economic stocks managed at the EU supranational level must be managed by TAC and be maintained at a level capable of producing MSY.

Sullivan et al (2006) pointed out that the essence of objective-setting is the value game among stakeholders. Stakeholders' recognition of the overall management objectives is positively related to their future compliance with management interventions (Gray & Jordan, 2012). Thus, mechanisms allowing value-based debates among stakeholders should be in place (Sullivan et al., 2006, Failing et al., 2013). Meanwhile, objectives are expected to specify the trade-offs along biological, economic, social, and political (institutional) dimensions so that they can be used to determine the weight of potentially contrary information at the stage of strategy formulation in the future (Hilborn, 2007; Stephenson et al., 2017). Garcia (2005) proposed that using indicators will increase the transparency of the decision-making process and contribute to performance assessment and effective communication.

### **1.4.3. Data production - Scientific research process**

“Data production” in the SBFM refers to the generation of scientific advice through a scientific research process. The scientific research process includes collecting, evaluating, and analyzing the data in other processes of the system, especially amid implementation, and converting them into understandable language and scientific advice for the formulation of management strategies.

The first expectation for this process is that scientific advice is relevant to policy demands and the fishery being managed. Two criteria need to be met for this expectation. First, scientific research objectives must be consistent with management objectives (Sullivan et al., 2006). Second, the data used in scientific

research must be related to the fishery being managed (NRC, 2004). To ensure these two criteria are in place, it is necessary to establish an external review process to allow a group of experts to collectively assess and interpret the relevance and legitimacy of the scientific research process, including the research plan, methods, results, and findings (Bisbal, 2002; Van den Hove, 2007; Raymond-Yakoubian et al., 2017). A review conducted at a more local level, particularly at the fishery level, will contribute more to the link between the science employed and the fishery managed. The external review will not only examine the scientific research process to ensure their consistency with management objectives concerning economic, social, and political priorities but also increase the scope and diversity of the scientific information on which the development of management strategies is based. A hybrid group of experts consisting of a pool of leading non-advocate scientists, experienced agency managers, and industry and NGOs' representatives often lead to a more quality-assured and convincing external review process (Cullen, 1990; Guston, 2001; Cash et al., 2002; Webb et al., 2010).

At the core of the scientific research process is the principle of minimizing the impact of subjectivities to ensure the credibility and objectivity of scientific advice (Dietz & Stern, 1998; Rykiel, 2001). Generally, scientific research adhering to a well-designed process will contribute to credibility and objectivity (Bradshaw & Borchers, 2000; Doremus, 2004; Sullivan et al., 2006; Murphy & Weiland, 2016) as well as largely reduce the uncertainties of scientific research and increase the accuracy of predictions (Charnley et al., 2017). A well-designed process should include objectives, a conceptual framework, hypothesis testing, standard methods of data collection, statistical analysis methods, documented methods and conclusions, and independent scientific review (Sullivan et al., 2006). Particularly in developed countries, it is common to hire a group of skilled and reputable scientists, usually independent, to conduct stock assessments and generate scientific advice. This can increase the persuasiveness of scientific advice and ensure its credibility (NRC, 2004; Shelton, 2007). In the meantime, acknowledging and documenting the limitation of data and knowledge gaps is conducive to the credibility of scientific advice (Gleick, 2010; Webb et al., 2010).

Another expectation for the scientific research process is that the set of data used to generate scientific advice be inclusive. Where fisheries policies are developed based on stock assessment, it has been demonstrated in numerous case studies that ignoring the connections between a fish stock and the larger ecosystem or failing to include social science and local knowledge may lead to a failure in sustainability (Degnbol and McCay, 2007; McGuire & Harris, 2011). Many research reports indicated that establishing mechanisms that allow for multidisciplinary and interdisciplinary research, especially collaboration between social and natural scientists, and the consideration and use of fishers' local knowledge are vital for increasing the inclusiveness of scientific advice (Stead et al., 2006; Wesselink et al., 2013; Raymond-Yakoubian et al., 2017). Furthermore, allowing stakeholders, especially fishers to directly participate in scientific research will increase the trust between scientists and industry, increase the legitimacy of science, and increase stakeholders' compliance with management strategies (Jasanoff, 1990; Karr et al., 2017; Stephenson et al., 2017). To achieve quality assurance and quality control, rules about who can participate in this process and how to incorporate their opinions into scientific advice should be created in advance. Fishers' knowledge can be added to traditional assessment with appropriate analysis via social research methods or/and received as supplementary information through advisory or participatory processes (Jasanoff, 1990; Karr et al., 2017; Stephenson et al., 2017).

#### **1.4.4. Using the best science - Development of management strategies**

“Data use” is understood in SBFM as the sum of all procedures performed to formulate management strategies, including the activities taken to communicate and adopt the information available to develop measures and regulations. This information includes scientific advice generated through the scientific research process and knowledge brought directly by stakeholders.

At the stage of strategy development, the decision-makers use a set of formal, repeatable procedures and standards to determine the priority of information from a variety of sources and ultimately adopt the optimal combination of information (Bisbal, 2002). Generally, scientific advice generated through rigorous scientific research and that has passed peer review and external review is considered the best evidence for

decision-making (Sullivan et al., 2006). However, they can never be deemed absolutely robust when being used in decision-making (Jasanoff, 1990). This is significant to SBFM as it is rooted in a wider social environment in which views of scientific “reality” are always colored by contextual characteristics such as the educational, institutional, political, and cultural affiliations of scientists (Jasanoff, 1990). To this end, the knowledge and opinions of a broader range of stakeholders other than policymakers and scientists should be considered when adopting scientific advice in decision-making. Lipsman (2019) proposed that failure to legitimately include local communities in environmental decision-making leads to a lack of confidence in social institutions and a deterioration in coordination, thereby resulting in governance inefficiency. Thus, allowing decision-makers and stakeholders to jointly develop the procedures and standards of determining and using the best science can be conducive to not only addressing potential divergences among stakeholders but also the legitimacy of stakeholders’ participation and the use of stakeholders’ knowledge in decision-making (Cash et al., 2002; Stead et al., 2006, Gray & Jordon, 2012; Karr et al., 2017). Such procedures and standards should be established in advance and mandated by law.

Communication is another way to address the potential conflicts among stakeholders and to facilitate the legitimacy of scientific information that is used for decision-making. A transparent participatory process that allows dialogue, debate, and/or voting can be used to address potential disagreement or divergences on the interpretations of scientific advice among stakeholders (Christie et al., 2007; Runhaar & Van Nieuwaal, 2010; Wesselink et al., 2013). Other approaches for promoting communication are presented in Table 1.4. These approaches help to enhance mutual understanding and build trust between the science, policy, and industry communities, thereby contributing to the interaction of science and policy in decision-making, as well as the implementation, enforcement, and compliance of management measures.

Rules for using scientific information must account for uncertainty and must be formalized and repeatable (Bradshaw & Borchers, 2000; Fulton et al., 2011; Failing et al., 2013). Management strategies must be evaluated and revised periodically to adapt to the changing environment (Conroy & Peterson, 2013). When the development of management strategies is recurrent (e.g., annual harvest rules), research methods

and rules for adopting scientific information are updated by comparing predicted feedback to observed future conditions (Conroy & Peterson, 2013). The adjusted methods and rules for producing and using scientific information are then used to predict future conditions and generate better decisions for the following time period. This adaptive feedback loop provides the management system with a greater learning capacity. In addition, when determining management reference points (e.g., TAC levels), a precautionary approach is often used to account for uncertainties in the understanding of fisheries population dynamics. Finally, the aforementioned review processes and the mechanisms allowing for communication and interpretation of scientific information is conducive to recognizing and addressing the risks, costs, and trade-off of different types of management error (Rice, 2011).

#### **1.4.5. Data inputs - The implementation and enforcement**

The implementation of management strategies provides a “data pool” to be used for other processes constituting the SBFM. Although the definition of the “implementation” does not necessarily involve enforcement, compliance, and adaptation, the implementation process here refers to: Actions taken by agencies and organizations related to implementation, monitoring, and enforcement; actions taken by fishers in response to external constraints, including management interventions and variations of the social, economic, ecological and political environment within which the fishery is located; and the environmental changes themselves. The performance of these factors will be translated into quantitative or qualitative data through observation methods. These data are fisheries-dependent data and fisheries-independent data that include a broad spectrum of biological, ecological, social, and economic information and knowledge collected or provided by fisheries monitoring programs, scientific surveys, and stakeholders such as fishers and managers. These observation data will be transfer to other processes (objective-setting, scientific research, and strategy formulation) via the data storage system and/or partnership and participatory procedures.

Collecting reliable data amid implementation is an essential precondition for an effective and functioning SBFM (Chen et al., 2003). Hardware support is important, such as a well-established standard

for data collection, addressing, and verifying and a well-designed fisheries monitoring system (Kritzer, 2020). In addition, education, training, communication, and participatory processes can significantly promote the compliance of managers and law enforcers at the grassroots level and the industries in providing quality-assured data (Bremer & Glavovic, 2013; Hernandez & Kempton, 2003; Gray & Jordan, 2012).

### **1.5. SBFM operational framework**

The comprehensive list of SBFM criteria developed was further used to determine the basic elements that consist of SBFM. Subsequently, a basic operational SBFM framework was developed according to the conceptual model described in section 1.3.1 (Figure 1.3) and fisheries management in the real world. Although different countries or organizations have different institutional structures for performing fisheries management, we argue that the elements contained in this framework should be regarded as a minimum set of criteria that should be satisfied before one can say that SBFM is successful, that is using the presence of these elements as bottom-line requirements.

In SBFM, science research is driven by management purposes. A set of achievable and measurable management objectives is therefore required. The objective-setting process should clarify the operational objectives and performance indicators with temporal and spatial scopes, as well as the optional management approaches. Objective-setting is about trade-offs among values (Sullivan, 2006); thus, key stakeholders' involvement needs to be guaranteed. The process is influenced by at least three information streams. One is outside political demands or intervention such as international and national initiatives and policies (Soomai, 2017). This information is usually claimed by and reveals the position of government officials or NGOs. The second is the data collected in the implementation and enforcement process and conveyed through a database or by stakeholders such as grassroots fisheries managers and industry representatives and through participatory processes. The third is scientific knowledge provided by scientists to inform society about the potential consequences of its management objectives, whereas scientists are messengers rather than players in this objective-setting process (Sullivan, 2006).



The basis of scientific research is data that are two-folds: Fisheries-independent data collected through scientific surveys organized by scientists and fisheries-dependent data collected during the implementation process transferred by database and participatory processes. Research plans should clarify what data need to be collected for management purposes.

The output of the scientific research process is scientific advice, which should be externally reviewed by experts for relevance and then be used as the basis to develop management strategies. The rules for identifying BAS and using BAS in policymaking should take into account uncertainties and divergences and be pre-established. The rules should ensure the use of precautionary approaches to cope with the inevitable knowledge limitation. In addition, mechanisms for stakeholders' involvement should be in place to ensure the extensiveness of data considered in this process and the legitimacy of the BAS used. Considering adaptive, management strategy developed should be evaluated timely and the corresponding results will be used in and/or initiate a new round of scientific research and strategy revision.

The basic elements of the implementation and enforcement process are fisheries monitoring used for data collection and supervision, and other outreach activities such as training and educating fishers and fisheries managers and law enforcers, to improve their compliance with regulations especially those relating to data report and collection, their understanding and recognition of science-based policies, and their capacity to participate in and coordinate decision-making and scientific research.

## **1.6. Discussion**

### **1.6.1. Considering data availability**

SBFM is viable for data-poor situations with minimum information, to data-rich situations with extensive data and complex analyses, as well as everything in between. In the scenario that sufficient data are available for traditional stock assessments, the challenges for performing SBFM may be the limited capacity in conducting assessments based on more inclusive data, ensuring the integration of the scientific advice into policies, and dealing with scientific timelines, disagreement, and uncertainty (Esch et al., 2018).

In this case, the organization and agencies can use Table 1.3 as a checklist to improve their capacity and take the following factors as their primary considerations:

- 1) ensuring that the scientific advice based on assessments is being used for decision-making;
  - 2) applying more integrated stock assessments with consideration to the connections between the stock being managed and the broader environmental factors;
  - 3) expanding the breadth of information sources used for decision-making through a wider range of partnerships with stakeholders;
  - 4) ensuring sufficient communication on scientific advice and other information and employing a rigorous process for addressing disagreements among stakeholders;
  - 5) adhering to a time-bounded decision-making process to adopt BAS, allowing recurrent decisions;
- and,
- 6) adhering to a set of formal rules to address uncertainties.

In the scenario that data are limited for traditional stock assessment, it would be advantageous for scientists to have the flexibility and capacity to use alternative methods for analyzing limited available information (Newman et al, 2015), especially in the case of time-sensitive policy formulation scenarios where gathering substantial data may not be practical. Additionally, in the case of poor data exchange due to external forces such as politics or culture, which cannot be addressed in the short term, a fisheries metadatabase (e.g., ICES, 2017) could be a viable alternative for promoting data transparency, sharing and accessibility.

When problems associated with poor or limited data hampered the use of traditional stock assessment methods (Vasconcellos et al., 2005), yet even in these cases, decision-making may still be based on BAS. Although it might be impossible to meet the criteria regarding the “well-established scientific research process” listed in Table 1.3, the scientific research, whether robust or not, and other elements included in the basic SBFM operational framework (Figure 1.3) must be in place. In the extreme case that quantitative management cannot be carried out due to the absence of data, the keys to successfully implementing SBFM are as follows:

- 1) insisting on using a formal, rigorous, and repeatable process for data collection, communication, and consideration;
- 2) adhering to rules developed based on the principle of relevance, credibility, and legitimacy to use available data;
- 3) appropriately and sufficiently using the knowledge of stakeholders;
- 4) acknowledging, recording, and disclosing limitations in data or gaps in knowledge;
- 5) having already in place a well-designed institutional structure, which includes fisheries monitoring programs and decision-making processes for the acquisition, processing, and use of new information; and,
- 6) ensuring the transparency of management objectives and strategy formulation processes.

#### **1.6.2. Mode 1 or Mode 2 science?**

The key to the development of the SBFM framework is to understand our expectations of science and the relationship between science and policy in governance, which involves the topic of the differences between the paradigms of normal science (Mode 1) and post-normal science (Mode 2) (Merton, 1996; Ravetz, 2006; Ziman, 2000; Msomphora, 2016). Wouters et al. (2008) stated that fisheries science, used for management purposes, is moving away from traditional Mode 1 science and turning to Mode 2 science. Many scholars criticize Model 2 science for deviating from the “ethos of science”, including communism, universalism, interestedness, skepticism, and originality (Wouters et al., 2008; Hessels & Van Lente, 2008). They criticized Mode 2 science, as commissioned research, tends to be private and exclusive, and lack of transparency and peer review, which would weaken the quality of science and ultimately erode the legitimacy of science for decision-making (Wouters et al., 2008; Hessels & Van Lente, 2008). Msomphora (2016) further pointed out that failure to establish an effective new support structure for these changes would bring huge risks to the research enterprise.

The SBFM framework presented in the chapter provides a new support structure for the so-called post-normal problem-oriented fishery science. In general, the relationship between science and policy in

SBFM conforms to the philosophy of Mode 2, as described in Figure 2 of Msomphora 2016. However, seeing from the criteria developed based on the review of 94 reports, the science in SBFM neither fully satisfies the ideals of Mode 1 nor Mode 2 but is somewhere in between. First of all, although fisheries science is in nature commissioned and regulatory, it does not run counter to the institutional norms of interestedness and skepticism of Mode 1 science. Recognizing that scientists inevitably inject their political value into science, under SBFM, mechanisms are asked to be in place to ensure the objectivity and credibility of science. These mechanisms include a clear division of responsibility of science and policymaking, a well-established scientific research process, and independent peer review. Second, commissioned science does not mean privatization. As Msomphora (2016) suggested that scientific research in SBFM should be funded by the entire society at large, that is, the government, which provides a good reason for making the science public. Social concerns, such as complaints from NGOs, also require the disclosure of scientific methods and results used for decision-making. Communism is still a key norm: SBFM asks for mechanisms allowing stakeholders' participation in each management process and recording and disclosure of the methods and results of scientific research, thereby ensuring sufficient collaboration and communication and promoting the legitimacy of science. What is more consistent with the Mode 2 idea is that SBFM asks for using fishers' knowledge and allowing them to participate in scientific research since many reports we reviewed have shown that it is no longer feasible to use a "technocratic approach" to control the use of science in fisheries management, especially when facing highly localized problems. However, this does not mean abandoning the "technocratic approach". It is still vital to ensure that scientists play an important role in decision-making, including prioritizing peer-reviewed scientific advice provided by skilled and prestigious scientists in decision-making, appointing them to conduct management performance evaluation, and communicating and explaining science to the non-scientist community.

## 1.7. Conclusion

In this chapter, we propose an operational SBFM model consisting of four main processes: objective-setting, scientific research process, management strategy formulation, and implementation. These four processes are contained within the same system and thus mutually influence each other via information flow. The interaction process within the system is not linear, but multi-dimensional and intricate. Only when this multi-dimensional interaction is satisfied can the application of BAS in decision-making be guaranteed. Each process should meet a series of criteria to ensure the generation and use of BAS and the effective operation of the whole system. The capacity of the system to produce and use BAS is mainly reflected in the following areas: a) collecting a good range of quality-assured data that meets the needs of scientific research and fishery policy formulation; b) analyzing the collected data through a well-designed scientific research process including analyzing the performance of previous management strategies; c) selecting and using the best data from different sources; and d) efficient informational feedback among various components and stages of the SBFM.

Following the guiding questions of this study and according to literature review findings, we identified the expectations of each process of the SBFM system and the corresponding criteria for fulfilling these expectations in operations. Overall, an effective SBFM requires achievable management objectives and a set of inclusive processes to ensure the integration of diversified relevant information, the assessment of the credibility of this information, and the evaluation and update of decision-making based on this information. Fisheries-related databases and stakeholders' involvement serve as a vehicle to realize and tighten the information feedback loops between objective-setting, scientific research, strategy formulation, and implementation and enforcement. These results are consistent with the principles of models proposed by previous studies focusing on the application of science in decision-making, such as structured decision-making (SDM) (Gregory & Long, 2009, Irwin et al., 2011). However, compared to SDM, the SBFM framework we propose in this chapter includes a comprehensive list of criteria for those principles (expectations) and the criteria are divided into the four processes of fisheries management systems. The

framework can provide stakeholders, especially the policymakers with an operational standard to establish or reform their legal and institutional framework to satisfy SBFM. It will also help promote the role of science in fisheries management, govern the use of the post-normal problem-oriented fisheries science in management, avoid inconsistencies in the understanding of SBFM among stakeholders, and promote the compliance of relevant agencies with BAS responsibilities.

It should be noted that we do not assume that it is only when all the criteria presented in Table 1.3 are met that they can claim that SBFM has been implemented. In fact, it might be impossible that all the criteria will be met within a single fisheries management system and the extent to which the criteria will apply will depend on the social, economic, and cultural context. However, we believe that the comprehensive list of criteria presented in Table 1.3 provides a checklist for those jurisdictions or fisheries agencies that are committed to implementing SBFM to assess the capacity of their current management system and to facilitate capacity building for the production and use of BAS in fisheries management.

As aforementioned, SBFM may perform differently in different jurisdictions or fisheries due to data availability. We have discussed the primary considerations of implementing SBFM in data-rich and data-poor scenarios, respectively. We insist that the elements included in the basic SBFM operational framework presented in Figure 1.3 should be seen as a minimum set of criteria for SBFM. However, further case-based research on how to effectively use this framework and the comprehensive set of criteria developed to improve science-policy interactions in different scenarios, especially in data-poor fisheries is vital and necessary. In addition, concerning the nuances of the mandates for the production and use of BAS in fisheries management in different jurisdictions, research on relevant legislation is significant, such as systematically collating and comparing their requirements on the types and formats of scientific information for fisheries decision-making. Finally, since the reports reviewed in this research cover fields beyond just fisheries, the results of this study can also inform the production and use of BAS in other natural resources management.

## CHAPTER 2

### EVOLUTION OF MARINE FISHERIES MANAGEMENT IN CHINA FROM 1949-2019: HOW DID CHINA GET HERE AND WHERE DOES CHINA GO NEXT?

#### 2.1. Abstract

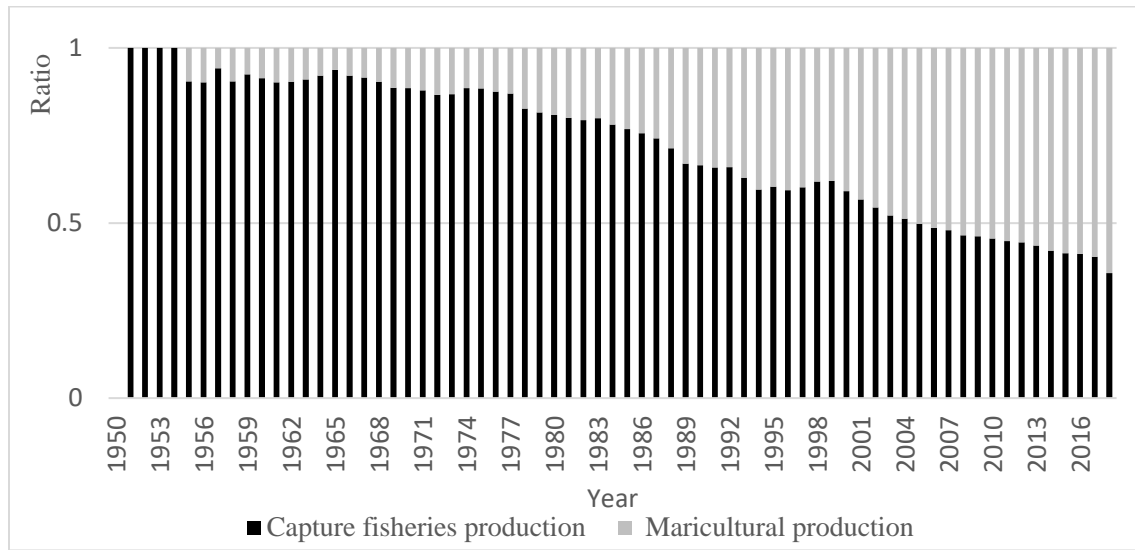
This chapter presents the evolution of China's marine fisheries industry and management policies, providing a comprehensive background for the follow-up study of this dissertation. In this study, we reviewed the evolving marine fisheries management practices in China to delineate changes in fisheries policies and their performances from 1949 to 2019. The study revealed that China's marine fisheries management has shifted from pursuing maximized landings to prioritizing conservation. This transformation is accompanied by the central government's increasing requirements for sustainable fisheries management and institutional innovation. However, the development and implementation of China's marine fisheries management are hindered by several outstanding issues, including the large size of the fishing fleet, large and poorly-organized fishing community, the "hidden" fishing capacity, uniform management approaches that sometimes fail to account for local conditions, lack of clearly defined and allocated fishing rights, limited data quality and availability, insufficient fisheries monitoring programs, and inadequate integration of scientific information in policymaking.

## **2.2. Introduction**

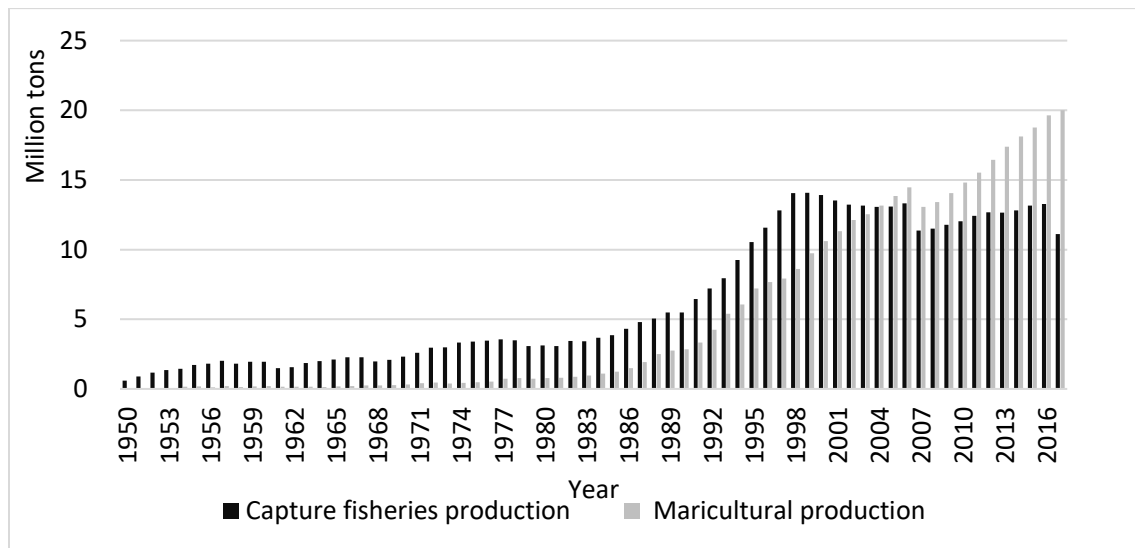
China is the largest producer and exporter of marine fish and fishery products in the world. Despite the fact that in recent decades in China, mariculture productions account for most of the increased seafood productions (Figure 2.1), a more sustainable marine capture fisheries industry in China is still critical to the global seafood supply, food security, and seafood trade (e.g., Smith et al., 2010; Blomeyer et al., 2012). Today, the production of China's domestic marine capture fisheries still accounted for 18% of the world's total (FAO, 2018), furthermore, many signs suggest that fish farming in China is reaching its limits: narrow species diversity cannot satisfy the whole spectrum of diet needs; a sharp increase in aquaculture production is impossible due to environmental caps (e.g. habitat destructions, pollution, climate change, feed scarcity) (e.g., Zou et al., 2011; Tacon & Metian., 2015; Luo., Feb 2019, Wang et al., 2013).



(A)



(B)



Note: Data on maricultural production before 1954 are unavailable. Inconsistency in production statistics before and after 2006 due to changes in statistical methods.

Figure 2.1. (A) ratio and (B) amount of total domestic marine capture fisheries landings and maricultural production in China from 1950 to 2017.

However, China's wild marine fisheries resources have been declining since the late 1970s. A recent research paper by Cao et al. (2017) suggested that China's steady and large volume of marine fishing

landings in the past decades is supported by a relatively small number of highly abundant fish stocks, whereas the majority of the other wild fish stocks are in decline or have already collapsed. More evidence points to the decline, such as the falling average trophic levels of marine catches (Du et al., 2014), the decreasing proportion of economically valuable (usually high-trophic level) species (Bian, Wan, & Jin, 2018), the diminishing fish sizes at maturity and at capture (Lin, Chen, & Lin, 2007), and declining marine biodiversity (Fu et al., 2018). These environmental challenges in China's oceans have only become more prominent in recent years (Jiao et al., 2015). Today, the Chinese government is faced with an urgent need to re-evaluate the ideal balance between marine resources conservation and socio-economic indicators (Ma et al, 2013; Lu et al., 2019).

In 2012, China's central government proposed the concept of "Ecological Civilization" and, for the first time since the founding of PRC, resources conservation and environmental protection became a guiding principle in policymaking. In 2015, the CPC Central Committee and the State Council issued the "Opinion on Accelerating the Ecological Civilization Construction" and then the "Overall Plan of Ecological Civilization System Reform" (which we will refer to as "The Overall Plan"). The Overall Plan proposed a framework for institutional reform in the natural resources management sector; there is a section specifically describing the exploitation and protection of marine resources. The proposals have been reiterated by the 13<sup>th</sup> Five-Year Plan for the National Economic and Social Development of the PRC (2016-2020).

In this context, the Chinese central fisheries authority launched the 13<sup>th</sup> Five-Year Plan for National Fisheries Development of the PRC (Referred to as 13FYP hereafter) in December 2016, which acts as the guidance for fisheries management throughout the country in the period from 2016 to 2020. The 13FYP echoes the call for "prioritizing ecosystem and promoting green development", breaking from the earlier balancing act of "paying equal attention to the development of production and ecological conservation" stated in the 12FYP. The 13FYP introduced concrete objectives: by 2020, [China] will decommission 20,000 motorized marine fishing vessels accounting for at least a total of 1.5 million kilowatts of main engine power (Double Control Target (DCT)) and reduce the total domestic fishing production to less than

10 million tons (from ~13 million tons in 2015). This is the first time that China has issued a quantifiable target on fishing yield (referred to as Total Yield Limit (TYL) below) (MOA, 2016). To meet these targets, the Chinese government has invested extensive efforts into reviewing and reforming its legislation, institutional arrangements, and mechanisms of the governance of marine capture fisheries (MOA, 2017).

Presently, the 13FYP period is coming to a close and the 14FYP (2021-2025) is in the pipeline. This offers an excellent opportunity to reevaluate China's marine fisheries management design, especially the initiatives since 2016, and identify important challenges, core issues, and possible areas for improvement going forward.

In this chapter, we trace the Chinese government objectives of marine fisheries management and the basic indicators and methods used to control domestic fishing capacity and conserve marine fisheries resources, as well as the corresponding performance from 1949 to early 2019. We would like to explore how the evolution of policy helps us understand and possibly predict the direction of changes in China's fisheries management policy. By doing so, we put forward six considerations that should be taken seriously in future fisheries reform in China.

In their paper, Cao et al (2017) pointed out that China needs serious institutional reforms to realize a true paradigm shift in marine fisheries management. More studies have reviewed the history of China's marine fisheries management, especially focusing on the evolution after 1978 when China pushed economic reforms and opened up the domestic market (e.g., Yu & Yu, 2008; Shen & Heino, 2014). Their results are also important references for this study. However, this study ventures further to capture a broader policy evolution perspective. This chapter traces the motivations behind the changes in marine fisheries policy and highlights new initiatives in China's fisheries reforms after 2016. We focus on the core issues of Chinese national marine fisheries management and decision-making mechanisms, as well as the management tools used. We believe our findings will be conducive to more targeted, confident reform measures in China, in terms of both legislative and institutional reforms.

### 2.3. Materials and methods

We traced historical fisheries practices by reviewing government documentation, white papers, and peer-reviewed journal articles and then inquired experts to supplement and confirm our findings (see section 2.5). We used official statistics data to observe changes in fisheries production; these data were the best available temporal and spatial information for our study. The data for 1949-1988 were obtained from the *Forty Years of China's Fisheries Statistic* (MOA, 1989). Data after 1988 were obtained from China's Fisheries Statistical Yearbooks (CFSYs) (Note that there is an inconsistency in production statistics before and after 2006 due to changed statistical methods. We recognize that there are potential biases and inaccuracies ingrained in these datasets, which previous studies have pointed out (e.g., Watson & Pauly, 2001; Pauly, 2008; Pauly & Froese, 2012), and also exposed by our research - by comparing the relationship between the statistics and the policies (see section 2.6.1).

Our keystone dialogues with the experts took place during two workshops on the Total Allowable Catch (TAC) system for marine fisheries management and a study tour organized by the University of Maine Marine Fisheries Partnership (MFP) (<https://umaine.edu/mfp/>). The two workshops took place on September 9, 2016, and April 28, 2018, in China, respectively; government officials, scientists, and other stakeholders from NGOs were invited to discuss the development and implementation of TAC programs in China. The study tour took place from July 29, 2018, to August 3, 2018, in New England, United States. Fisheries policy-makers, managers, and scientists from China and the US were invited for an academic and experience exchange on marine fisheries management. Participants from China taking part in the study tour are highly involved in China's post-2016 fisheries reforms. All in all, all three events provided the researcher with excellent opportunities to engage in in-depth conversations with the key figures in developing fisheries management policies in China. A total of 21 experts participated in a one-on-one discussion with the researcher, Shu Su; they are six fisheries policymakers and managers from Chinese fisheries administrative departments at national and provincial levels; nine scientists working for Chinese fisheries research institutions and public universities; four fisheries stakeholders from NGOs; and two

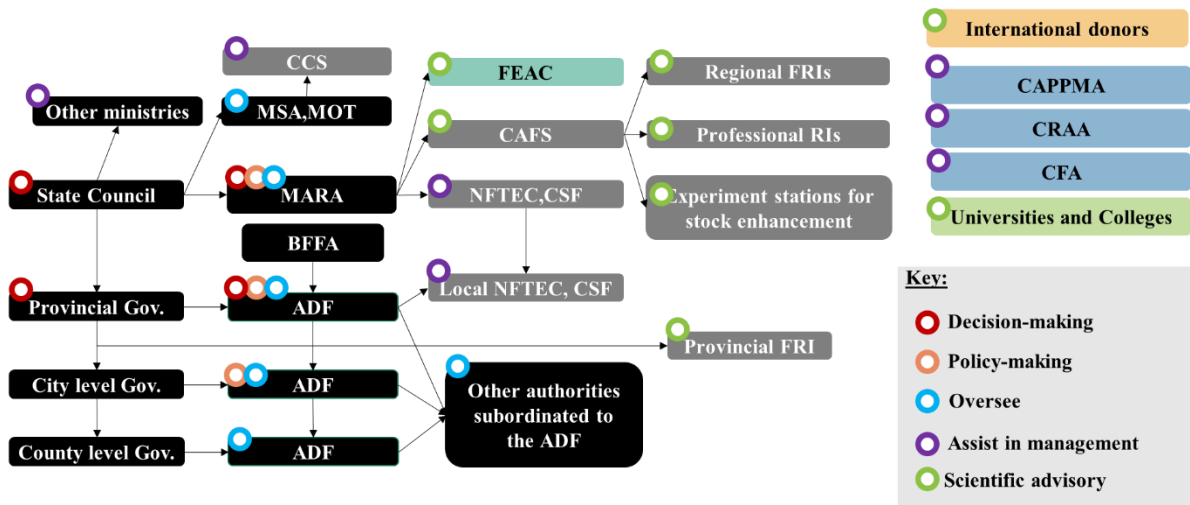
Ph.D. students engaged in fisheries policy and regulations research in China. The researcher inquired the experts for information relating to policy evolution and asked them to confirm the findings which were previously drawn from public sources. A list of the core questions/conversation topics with experts is presented in Appendix B. To protect the privacy of the respondents, their personal information is confidential.

## **2.4. Background**

Here, we present the necessary background information to help a better understanding of our findings stated in this chapter.

### **2.4.1. China's marine fisheries management**

Chinese marine fisheries management is typically top-down and reliant on a command-and-control approach (Shen & Heino, 2014). Management policies are passed down in order from national, provincial, municipal, and county levels. The Ministry of Agriculture and Rural Affairs (MARA) (known as the Ministry of Agriculture (MOA) before the State Council's institutional reform in March 2018 (Liu, 2018)), under the State Council, is the national administrative department for fisheries (ADF) in charge of fisheries affairs throughout the country. MARA's counterparts at the provincial level are responsible for issuing specific management policies and regulations for their respective administrative regions; fisheries policies at the provincial level mirror the national policies. Lastly, administrators at municipal and county levels are mainly responsible for enforcing policies and regulations on the ground. We outlined the various agencies and organizations that participate in marine fisheries management in China and their responsibilities. The results are presented in Figure 2.2. The feature of China's marine fisheries management system will be further illustrated in Chapter 3.



Note: Arrows indicate affiliations (upper-level points to lower-level). Colored circles indicate different functions listed in the diagram key. “Decision-making” specifically refers to the final review and adoption; “policy-making” refers to the development of policies and regulations; “Overseeing” refers to supervision and law enforcement; “assisting management” includes data collection duties, academic or industrial exchange organizing, and so on. Blocks in black represent government departments, blocks in gray represent non-profit organizations affiliated with the government, and the blue blocks represent industry associations (only examples are listed).

Acronyms: ADF- Administrative Department for Fisheries; BFFA-Bureau of Fisheries and Fisheries Administration; CAFS-Chinese Academy of Fishery Sciences; CAPPMA-China Aquatic Products Processing and Marketing Alliance; CCS-China Classification Society; CFA-China Fisheries Association; CSF-China Society of Fisheries; CRAA-China Recreational Angling Association; FEAC-Fisheries Experts Advisory Committee; FRI-Fisheries Research Institute; MARA-Ministry of Agriculture and Rural Affairs; MOT-Ministry of Transportation; MSA-Maritime Safety Administration; NFTEC-National Fisheries Technology Extend Center; RI-Research Institute.

Figure 2.2. Agencies and organizations participating in marine fisheries management in China.

#### 2.4.2. China’s marine fishery industry

China’s mainland is surrounded by the Bohai Sea (BS), the Yellow Sea (YS), the East China Sea (ECS), and the South China Sea (SCC) from north to south. Currently, there are more than 22,000 species discovered in China’s seas (Liu et al., 2011). Among them, more than 3,000 are fish species, about 1000 kinds distribute in the north of the SCS, mainly in the GOT, near 700 in the ECS, and about 290 in the YS and BS (Fu et al., 2008, Liu et al., 2011). Due to the geographic features, species stocks in the four sea areas

are relatively independent, especially in the BS and the Gulf of Tonkin (GOT), which are located in the north of the SCS (Liu, 2013).

According to the statistics of the Food and Agriculture Organization of the United Nations (FAO), China has been the largest producer of aquatic products in the world since 1989. The absolute volume of marine capture fisheries production in China peaked at more than 14 million tons in 1999 but has since then decreased and stabilized at a lower level of 11-13 million tons (Figure 2.1(B)). However, according to the Vice Minister of the MARA, the total volume still significantly exceeds the estimated maximum sustainable yield (MSY) for China's marine fisheries at eight to ten million tons (MARA: [http://www.moa.gov.cn/xw/zwdt/201701/t20170120\\_5461152.htm](http://www.moa.gov.cn/xw/zwdt/201701/t20170120_5461152.htm)).

In 2016, the total amount of landings of marine capture fisheries in China was over 13.28 million tons with fish species accounted for 69.15% of the total, followed by shrimp, crabs, shellfish, and squid (Table 2.1). Landings in ECS were generally the highest, followed by those in SCS, YS, and BS (Table 2.2). Most landings were captured by fishing gears with low selectivity (Table 2.3).

Table 2.1. China's marine capture production (million tons).

Categories	Fish	Crustaceans	Shellfish	Algae	Cephalopods			Others		
Subcategories		Shrimp	Crabs			Cuttlefish	Squid	Octopus	Jellyfish	Others
Production	9.19	1.59	0.81	0.56	0.02	0.14	0.39	0.14	0.21	0.44
Percentage	69.2%	12.0%	6.1%	4.2%	0.2%	1.1%	2.9%	1.0%	1.6%	3.3%

Note: Data is obtained from the 2016 Chinese Fisheries Statistical Yearbook published by the MARA.

Table 2.2. China's marine capture production (million tons) by sea area in 2016.

Sea areas	Bohai Sea	Yellow Sea	East China Sea	South China Sea
Production	1.02	3.32	5.18	3.77
Percentage	7.6%	25.0%	39.0%	28.4%

Note: Data is obtained from the 2016 Chinese Fisheries Statistical Yearbook published by the MARA.

Table 2.3. China's marine capture production (million tons) by fishing gear in 2016.

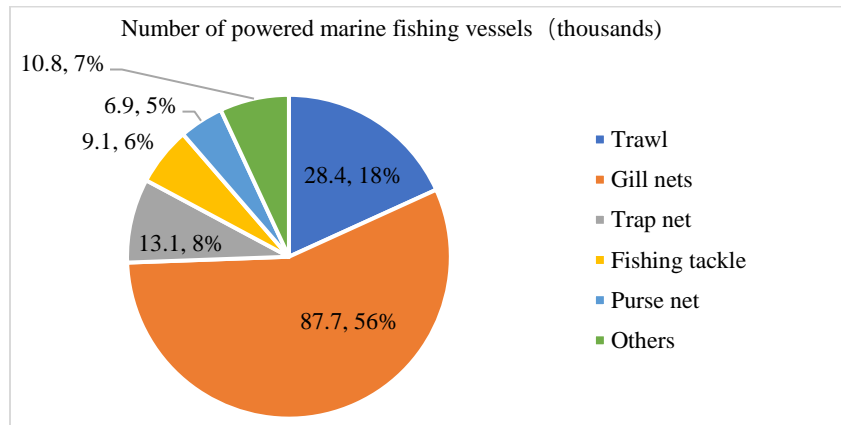
Categories of fishing gears	Trawl	Purse Seine	Gillnet	Trap Net	Line and Hook	Others
Production	6.23	1.10	3.04	1.55	0.40	0.96
Percentage	52.22%	9.26%	25.51%	13.00%	3.40%	8.01%

Note: Data is obtained from the 2016 Chinese Fisheries Statistical Yearbook published by the MARA.

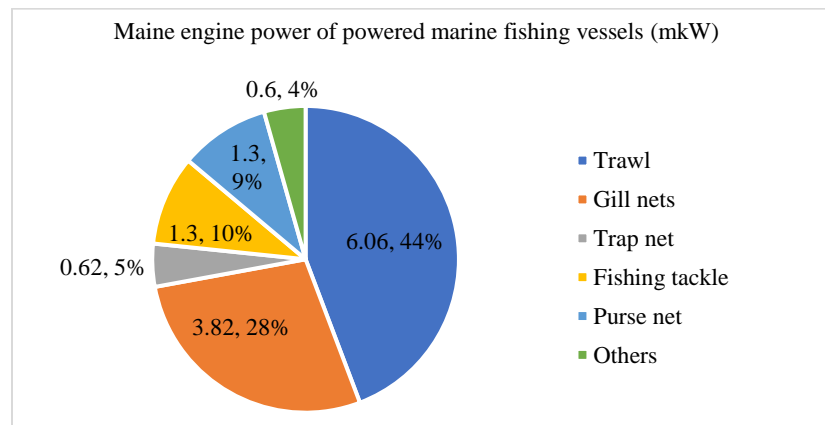
China has the world's largest marine fishing fleet; the fishing vessel number accounted for 19 percent of the world's total (FAO, 2018); making China's nearshore and offshore waters the busiest fishing area in the world (Kroodsma et al., 2018). However, the fleet operates with poor fishing selectivity (Figure 2.3) and a relatively low level of per capita productivity; the production per fisher in China was 1.89 tons in 2014, compared to 24.2 tons in Europe, 19.7 tons in North America, 10.4 tons in Oceania, and 2.47 tons for the global average (FAO, 2016). Additionally, a large proportion of the vessels are small-sized and concentrated in China's nearshore waters (Figures 2.4 and 2.5).



(A)



(B)



(C)

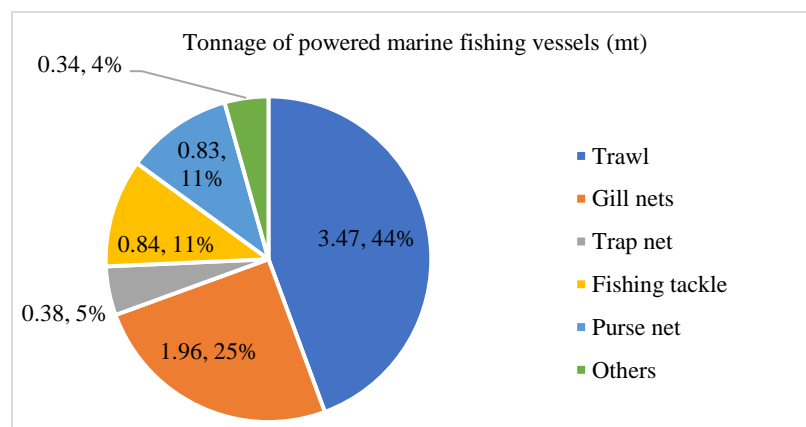
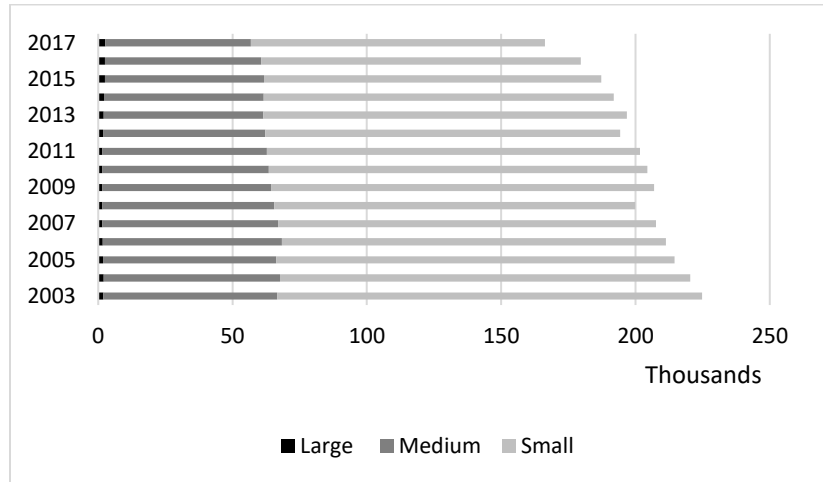
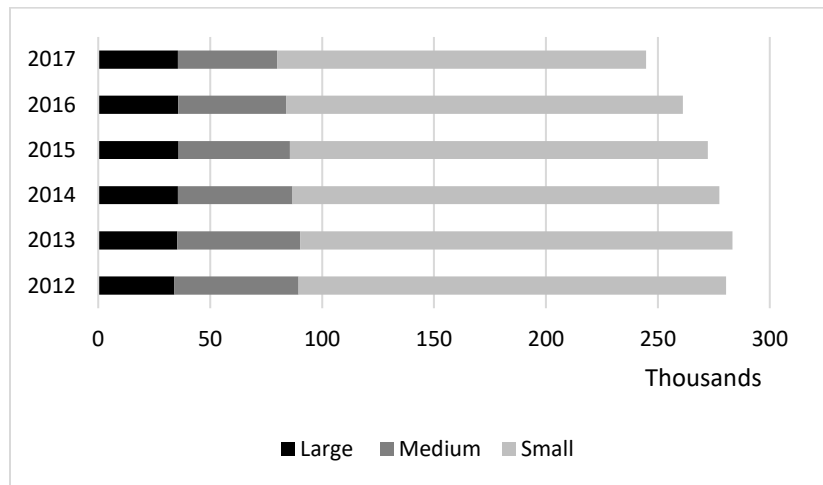


Figure 2.3. (A) number, (B) total engine power, and (C) total tonnage of China's marine motorized fishing vessels in 2018 by different types of fishing gears.

(A)



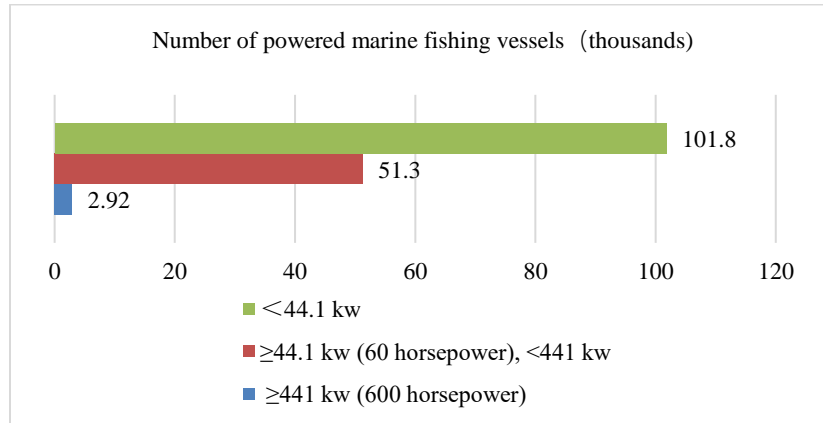
(B)



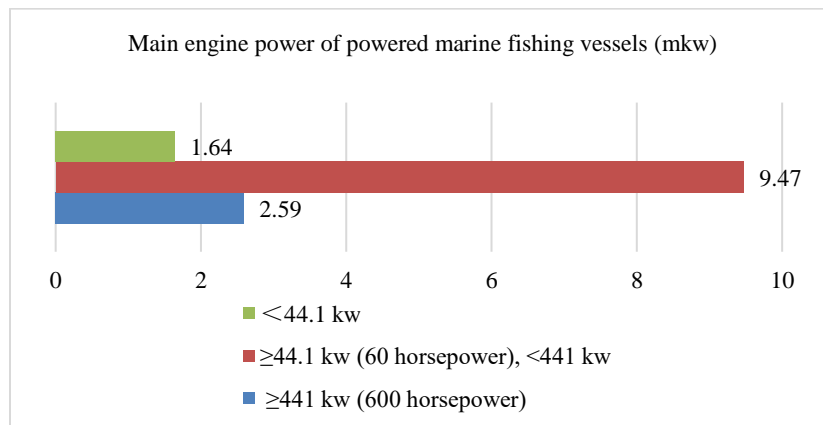
Note: Small: < 12 m; medium:  $\geq 12$  m and < 24 m; large:  $\geq 24$  m. Data are obtained from the CFSYs.

Figure 2.4. China's marine motorized fishing vessel number by (A) main engine power.

(A)



(B)



(C)

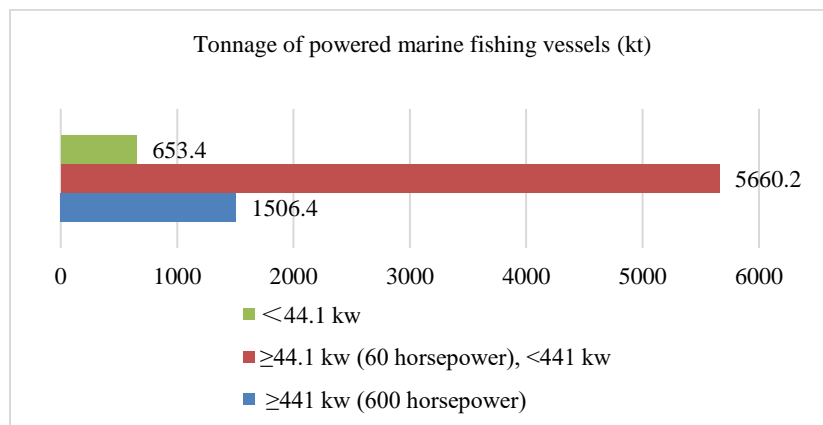


Figure 2.5. (A) number, (B) total main engine power, and (C) total tonnage of China's marine motorized fishing vessels in 2018 by categories of main engine power.

The marine fishing industry is critical for the economic development, income, and employment of the coastal communities in China. There were at least 3.9 million people directly engaged in marine fishing in 2017; about 75% of them are traditional fishers who have been fishing for generations, living in remote rural areas with low education levels, and highly dependent on fisheries income (MARA, 2017).

Any future fisheries reform in China must pay attention to these conditions. Next, we review China's historical fisheries management practices and provide suggestions for the improvement of China's sustainable fisheries management.

## **2.5. Results**

### **2.5.1. History of management practices**

China has increasingly displayed concerns for the protection and conservation of wild fisheries resources since 1949. The management priorities, once solely focused on optimizing economic values, now emphasize ecological values (Xiao & Zhao, 2017). We can better capture this broad-scale shift by dividing the history of China's fisheries management into four phases. Table 2.4 lists the significant national fisheries policies in different phases that drove the changes in both the fishing industry and management framework in China. Table 2.5 demonstrates the responses to said policy changes: specific changes in management targets and corresponding results. We can observe how the fisheries statistics (i.e., motorized marine fishing vessel number and horsepower, marine capture production) respond to the changing management priorities and fisheries policies in Figure 2.6.

Table 2.4. Significant national fisheries policies listed in chronological order of implementation date.

Government Documents
Phase One (1949-1978): driving for economic growth
1951 - Directives on fishery production (National ADF) - Maximize catch volume by devoting effort to developing fishery production.
1952 - Directives on fishers' work (National ADF) - Require local governments to work to increase the number of fishers.
1953 - Resolution on agricultural production cooperatives (CPC Central Committee) - Encourage the establishment of agricultural production cooperatives.
1960 - Outlines of the national agricultural development (1956-1967) (The 2nd NPC) - Advocate for the consolidation of the agricultural cooperation system and innovation in fishing technology.
Phase Two (1979-1999): awaking to fisheries resources conservation needs
1979a - Decisions on accelerating agricultural development (CPC Central Committee) - Introduce household contract responsibility system; rationally use fisheries resources and promote fishery production.
1979b - Regulations on the protection of aquatic resources reproduction (State Council) - Focus on the protection of economically valuable aquatic animals and plants.
1979c - Interim provisions on certain issues concerning fisheries licensing (National ADF) - Introduce the fishing license system.
1980 - Implementation plan of national fisheries resources survey and fisheries zoning research (National ADF) - Mark the beginning of China's fisheries scientific research.
1981 - Decision of the State Council on the establishment of juvenile fish reserves - Launch the first two juvenile fish reserves.
1983 - Report on several issues concerning the development of marine fisheries (National ADF) - Propose to establish a marine fisheries resource protection and proliferation fund.
1985 - Directives on relaxing the policy and accelerating the development of the fishery and aquaculture industry (No.5 Central Document) (CPC Central Committee & State Council) - Emphasize the protection, enhancement, and rational employment of fish stocks; require innovation in the "household contract responsibility system" to mobilize fishers' fishing enthusiasm; proposes to offset capture fisheries depletion with the development of aquaculture and distant-water fishing.
1986 - Fisheries Law of PRC (Revised and reacted in 2000, 2004, 2009, 2013)
1987 - Opinions on control indicators for nearshore and offshore motorized fishing vessels (National ADF) - Require the local government to control the amount of horsepower of MMFVs (Single-control).
1989 - Measures for the management of fishing licenses (National ADF) - Improve the fishing license system.

Table 2.4. continued

<p>1992 - Opinions on controlling the growth indicators of marine fishing intensity during the 8<sup>th</sup> FYP period (National ADF)</p> <ul style="list-style-type: none"> <li>- Emphasize the importance of controlling the blind growth fishing intensity; use fishing vessel number as another indicator for fishing intensity.</li> </ul> <p>1996 - China ocean agenda 21 (China oceanic administration)</p> <ul style="list-style-type: none"> <li>- Call for sustainable fisheries management.</li> </ul> <p>1997a - Opinions on further accelerating fisheries development (National ADF)</p> <ul style="list-style-type: none"> <li>- Emphasize the development of legislation on fisheries administrative management.</li> </ul> <p>1997b- Opinions on the implementation of controlling indicators of marine fishing intensity during the 9<sup>th</sup> FYP period (National ADF)</p> <p>1999 - “Zero-growth” policy for national annual marine fishing yield (National ADF)</p> <ul style="list-style-type: none"> <li>- The first policy considering output (landings) control.</li> </ul>
<p>Phase Three (2000 -2015): balancing economic, social, and conservation goals</p>
<p>2000a - Revised Fisheries Law of PRC</p> <ul style="list-style-type: none"> <li>- TAC has been mandated.</li> </ul> <p>2000b - “Negative growth” policy for annual fishing yield (National ADF)</p> <p>2001 - The 10<sup>th</sup> FYP for national fisheries development (National ADF)</p> <ul style="list-style-type: none"> <li>- Ensure an increase in fisheries economy, optimize the structure of the fishing industry, reduce fishing intensity.</li> </ul> <p>2002a - Important decisions on fishers’ retirement and relocation (State Council)</p> <ul style="list-style-type: none"> <li>- Mark the introduction of marine fishers’ resettlement program.</li> </ul> <p>2002b - Notice on promoting stock enhancement programs (National ADF)</p> <ul style="list-style-type: none"> <li>- Mark the beginning of the popularization of fish stock enhancement programs.</li> </ul> <p>2002c - Provisions on the administration of fishery licensing (Revised and reacted in 2004, 2007, 2013, and 2019)</p> <p>2003 - Opinions on the implementation of MMFVs control system in 2003-2010 (National ADF)</p> <ul style="list-style-type: none"> <li>- Issue the first national measurable management target; the DCT.</li> </ul> <p>2006a - An action plan for the conservation of aquatic living resources (State Council)</p> <ul style="list-style-type: none"> <li>- Identify measurable management objectives for both short-term and long-term; provide a management framework for fisheries resources protection and enhancement.</li> </ul> <p>2006b - The 11<sup>th</sup> FYP for national fisheries development (National ADF)</p> <ul style="list-style-type: none"> <li>- Ensure the continuous increase in the income of the fishers; promote fisheries sustainable development; advance harmonious social development in rural fishing areas.</li> </ul> <p>2007 - Plan for medium and long-term fishery science and technology development (2006-2020) (National ADF)</p>

Table 2.4. continued

<p>- Form a complete high-efficient fisheries science and technology system by 2020, realizing the transformation of traditional fisheries into modern fisheries.</p> <p>2009 - Notice on the investigation of fishing gears and methods in the national fishing industry</p> <p>- Provide a basis for the development of the fishing gear assessment system.</p> <p>2011 - The 12<sup>th</sup> FYP for national fisheries development (National ADF)</p> <p>- Further improve fisheries economy and industry structure and the protection of fishers' livelihood and fisheries resources.</p> <p>2013 - Notice on soliciting opinions on the improvement of the minimum mesh size system and the fishing gear access system for marine fishing (National ADF)</p> <p>2015 - Overall plan for the reform of eco-civilization system (CCP; State Council)</p> <p>- Provide a framework for institutional reform of natural resource management. There is a section specifically emphasizing the need to regulate marine resources' exploitation and implement protections.</p>
<p>Phase Four (2016- ): prioritizing ecological conservations</p>
<p>2016 - 13<sup>th</sup> FYP for national fisheries development (National ADF)</p> <p>- Promote green development of fisheries; issues DCT and TYL for 2016-2020; increase the level of fisheries modernization.</p> <p>2017 - Notice on further strengthening domestic fishing vessel management and implementing the system for managing total marine fisheries resources (National ADF)</p> <p>- Improve MMFVs double-control system; implement total marine fishery resources management system; improve the organization level of fisheries resources management; improve governance capacity.</p> <p>2017 - Notice on further regulating the proliferation and release of aquatic organisms (National ADF)</p> <p>2018 - Notice on further clarifying issues related to the protection and compensation of aquatic biological resources in fishery-related engineering project</p> <p>2019 - Key work points for fisheries administrative management in 2019</p> <p>- Further promote the conservation and restoration of aquatic biological resources; deepen reform in the comprehensive management of fishing vessels and ports.</p>

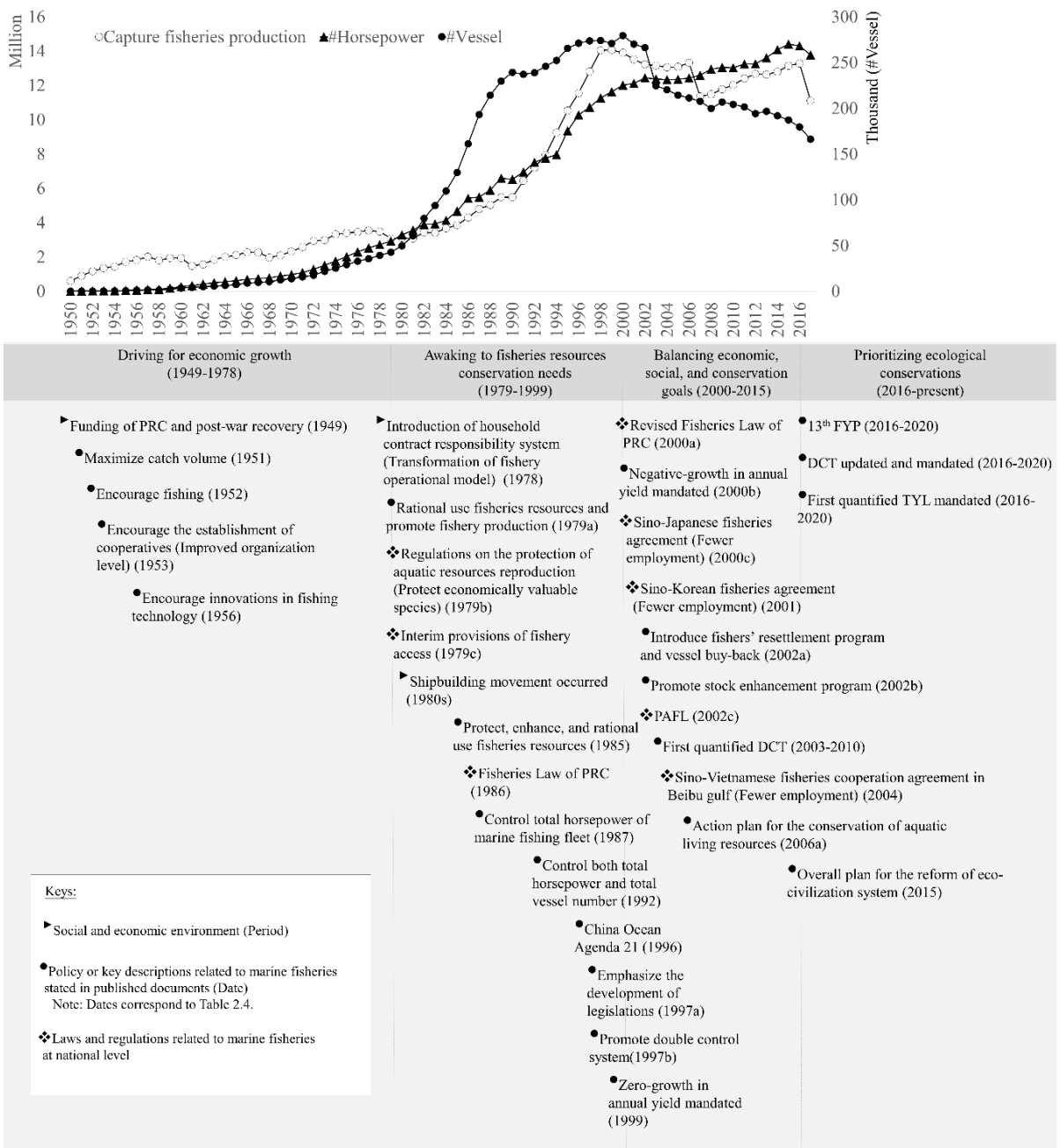
Format: Issued Date - Title of the document (The entity issued the document); description related to marine fisheries in the document, or the role of the document in the history of China's marine fisheries management. Acronyms: ADF - Administrative Department for Fisheries; CPC - Communist Party of China; DCT - Double Control Target; FYP - Five Year Plan; MMFV - Marine Motorized Fishing Vessel; NPC - National People's Congress; TYL - Total Yield Limit.

Table 2.5. Evolution of input-based targets and output-based targets of Chinese marine fisheries management, with corresponding results. Information and data are acquired from relative documentation and China’s fisheries statistical yearbooks.

Time	Targets/Limit	Results (Total changes in the period)
Input control indicators (Total number of MMFV (V) and total combined horsepower of all MMFVs (CHP))		
1987-1992	“Single control” policy	CHP + 19.7%
1992-1996	“Double control” policy	CHP + 36.9%; V + 13.5%
1996-2000	“Double control” policy	CHP + 16.8%; V + 3.1%
2003-2010	DCT: CHP - 10%; V - 13%	CHP + 8.5%; V - 23.8%
2016-2020	DCT: CHP - 10%; V - 10%	Preliminary results until 2018: CHP - 4.2%; V - 13.2%
Output control indicators (Amount of marine capture fisheries production (P))		
1999-2000	“Zero-growth”	P - 1.2%
2000-2015	“Negative-growth”	P - 5.5%
2016-2020	TYL: P - 23.6%	Preliminary results until 2018: P - 21.4%

Acronyms: MMFV - Marine Motorized Fishing Vessel; DCT - Double Control Target; TYL - Total Yield Limit; P – Production; “-” – decrease by; “+” – increase by.





Note: The top line chart shows the evolution of production, the number, and the total horsepower of motorized fishing vessels of China's marine capture fisheries. The lower part indicates the key elements of the social and economic environment and the changes in fisheries policies at the national level.

Figure 2.6. Relationship between management objectives, policies, and the dynamic of the fishing industry.

Table 2.6 lists the significant, still-active fisheries resources conservation and protection management measures. We can see how conservation methods became more sophisticated and diverse over the years. The management evolved from a sole reliance on simple technical regulations to employing a combination of input (effort) controls and technical measures, and finally towards a regime that combines a diverse array of effort controls, technical measures, and output (catch) controls (The terms are explained in Table 2.6). In the following section, we extract the key events in history that shaped today's Chinese fisheries management system.

Table 2.6. China's significant marine fisheries management and conservation measures listed in chronological order of national implementation date.

Time	Management Measures	Mandated Management Scope (current)
1955	Coastal zones closed to motorized bottom trawling	Bottom trawling in certain areas (Figure 2.7)
1958	Stock enhancement programs	Some economically valuable species
1962	Banned fishing methods †	Fishing by the explosion, with poison or with electricity, etc
1979	Fishing license system ‡	All fisheries
1981	Fisheries resources protected reserves †	Designated areas
1989	Fisheries resources proliferation protection fees ¶	All fisheries
1992	“Double control” system ‡	All fisheries
1995	Summer fishing moratorium †	Designated fisheries
2002	Fishing Logs ¶	All fisheries
2002	Fishers exiting and relocation system	Traditional fishers
2003	Fishing vessel buyback and scrapping system	Certain types of vessels
2004+	Minimum mesh size of fishing gears	45 types of fishing gears
2007	Aquatic germplasm resources reserves	51 certain areas (Marine)
2014	Fishing gear access system	All fisheries
2017	Limiting system for total marine capture fisheries production	All fisheries
2017	TACs	Selected fisheries (Pilot)
2017	On-board observers	At least 2 fisheries (Pilot)
2018	Minimum catchable-size	15 species
2018	Maximum proportion of undersized catch	15 species
2019	Designated port for landing	Taizhou City (Pilot)

Note: The mandated management scope includes the fisheries, fishers, and fishing equipment that the measures currently (in 2019) covered or targeted. Acronym: TAC - Total Allowable Catch.

Keys:

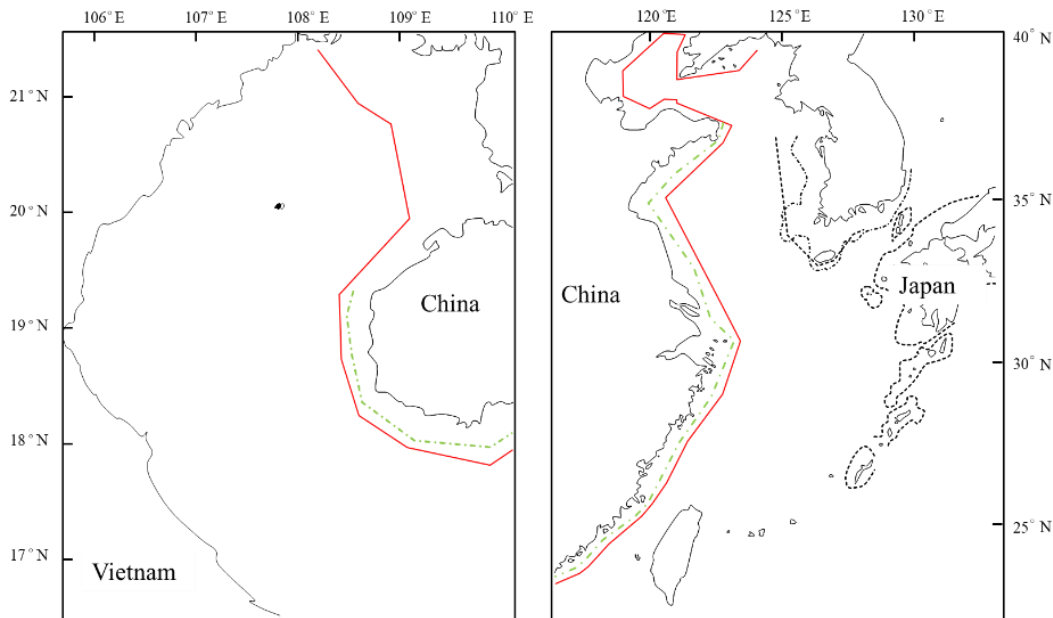
Technical measures: control on the types of fishing gears allowed and restrictions on times and areas of harvest.
Input controls: restrictions put on the intensity of use of gear or boat that fishers use to catch fish.
Output controls: controls are direct limits on the amount of fish coming out of a fishery.
Fisheries monitoring methods
Others

### **2.5.1.1. Phase One: driving for economic growth (1949-1978)**

After the founding of the PRC in 1949, China entered a period of post-war reconstruction. All industrial sectors in the country set forth the goal of maximizing economic outputs, and the fisheries sector was no exception (Zhou & Li, 2009; Muscolino, 2009). In 1953, the central government passed a document named “Resolution on Agricultural Production Cooperatives”, encouraging fishers to establish fisheries cooperatives, for the sake of enhancing fishing efficiency, increasing production, and reducing operational risks. To heed this call, hitherto independent fishers began to organize. An organization-based fisheries operation and management system was subsequently formulated; the ownership of fishing vessels, gears, and other tools passed from individual fishers to the cooperatives; cooperatives took charge of the fishery operations, and even managed and distributed income from fishing in a centralized way (Li, 2017). By 1956, these cooperatives expanded into different regions and covered almost all coastal communities in China (Hu, 2007). In the 1960s, cooperatives continued to consolidate, forming even larger groups called communes (Zhao, Sun, Zheng, & Geng, 2016). However, the unionization of fishers played a limited role in driving production growth, in light of the large fisheries economic increase at the next historic period when the organizations were disbanded.

Depletion has been observed in some fisheries at a local level, which is caused by not only the Chinese state’s intervention after 1949 (i.e., policies advocated for maximizing catch volume to increase economic returns) but also other multiple factors. In particular, Japanese motorized fishing fleets entered waters off Zhejiang after exhausting fisheries stocks in the ECS, which overrode the institutions that used to regulate fisheries by Chinese fishers and accelerated the resources decline (Muscolino, 2006). This prompted the Chinese government to demarcate the coastal no-fishing zone to prohibit motorized bottom trawling operations in 1995 (Figure 2.7). The coastal zone for motorized bottom trawling became the first significant marine fisheries resources conservation approach in China. It was initially implemented in the Bohai Sea, Yellow Sea, and the East China Sea in the 1950s, and then expanded into the South China Sea in 1980. Today, the operation of motorized fishing vessels using bottom trawl is prohibited all year round

in this area. The outer boundary of this area has become the basis for distinguishing marine fisheries waters in China's marine fisheries administrative management.



Note: The red line, straight with 40 designated points (with specific latitude and longitude), represents the outer boundary of the closed zone. These points vary in distance from the sea baseline (represented by the green dotted line).

Figure 2.7. A simplified schematic map for coastal zones closed to motorized bottom trawling.

### 2.5.1.2. Phase Two: awaking to fisheries resources conservation needs (1979-1999)

After China began its economic reforms in 1978, the communes gradually disintegrated. Fishing vessels and equipment, owned by the collectives, were contracted out or sold to individuals (Qian, 2000). Fishers began to operate independently and retained all incomes from fishing (except for a small portion paid to the collectives according to the contracts and for taxes) (Shen, 2006; Wang, 2011). During this phase, fishing capacity increased rapidly, propelled by a massive influx of new fishers and a new wave of shipbuilding (Guo & Huang, 2001). According to the fisheries statistics, the number of full-time and part-time fishers swell by one million and 440,000, respectively, between 1979 and 1999. During the same period, the number of motorized marine fishing vessels increased by 533.7 % and the annual catch increased by 357.4%.

Still, optimizing economic output remained the priority amidst China's drive for development during this phase, but concerns about the protection and enhancement of coastal fisheries resources began to emerge in the national fisheries-related government documentation (Ferraro & Brans, 2012). A fishing license system, introduced in 1979 to control fishing efforts, ended the era of pure open access fisheries in China (Mu et al., 2007; Huang & He, 2019). The Summer Fishing Moratorium (SFM) was first introduced and tested in Zhejiang Province to prohibit trawlers from fishing from August to October 1979. It has been officially implemented since 1995, and its temporal and spatial scale and the fisheries being covered have been extended. Today, SFM is considered to be the most extensive (in terms of coverage) and the most intensive (in terms of enforcement) conservation measure for marine fisheries resources in China.

These aforementioned fisheries management measures were officially authorized by the *Fisheries Law of the People's Republic of China* (referred to as "*Fisheries Law*" in this dissertation) promulgated in 1986. This law formed the legal basis of China's marine fisheries management (Huang & Tang, 2010). Soon afterward, the central government called for limiting the total horsepower of the marine fishing fleet in 1987, and then further mandated a limitation on both the total horsepower and number of motorized marine fishing vessels in 1992 (known as the "Double Control" system) (Zhang et al., 2016). Meanwhile, China began to boost mariculture and distant-water fishing, attempting to offset pressure on coastal fisheries resources by adjusting the industrial structure, indicated by the No.5 Central Document published in 1985. More fisheries subsidies have been issued to encourage and support fishers to fish farther from the Chinese shores (Mallory, 2016).

During this phase, the implementation of those conservation methods was not satisfactory. Recognition of the need to conserve coastal marine fisheries resources was overshadowed by the national drive for economic growth (Palmer, 1998). Local authorities, pressured to meet economic growth objectives (e.g. development and employment), favored short-term socio-economic gains rather than long-term conservation needs.

### 2.5.1.3. Phase Three: balancing economic, social, and conservation goals (2000-2015)

The “Ocean Agenda 21” set the tone for China’s marine fisheries management going into the 21<sup>st</sup> century, signaling a shift towards more environmentally responsible and sustainability-focused management practices (Shi, 2002; Zhao, Hynes & He, 2014). However, various bilateral fisheries agreements signed by China with its neighboring countries, including ones signed with Japan, South Korea, and Vietnam, came into force around the year 2000, which complicated China’s domestic marine fisheries management (Rosenberg, 2005; Ou & Tseng, 2010). Many Chinese fishers lost access to their historic fishing grounds located in more distant fishing grounds. The situation dwindled employment opportunities for fisheries communities, and at the same time further increased coastal fishing pressure; as most of those fishers returned to operate in China’s domestic offshore waters (Zhang, Cui, & Rong, 2004). In this context, the national government had to reconsider the trade-offs between socio-economic and conservation goals (MOA, 2006).

On the one hand, the government issued a directive on “zero growth” in marine fishery production in 1999, and then another directive requested “negative growth” in 2000. Besides, they issued the first quantitative target on reducing the total number of marine motorized fishing vessels and the total horsepower for 2003-2010 nationwide (Double control target, DCT) (MOA, 2003). On the other hand, the government began to carry out fishing vessel buyback programs and developed training programs (coupled with monetary incentives) to help traditional fishers to withdraw from capture fisheries and find alternative employment (MOF & MOA, 2003). In response to these policy measures, fishing yields and fleet size both decreased. However, the total amount of horsepower kept increasing (Figure 2.6).

Legally, China made a major revision to the two primary legislations for fisheries administrative management during this phase. *The Fisheries Law* was reenacted in 2000 and the *Provisions of Administration of Fishing Licenses* (PAFL) was reenacted in 2002. A maturing legal framework for fisheries resource protection and conservation was then in the works. Later in 2006, China issued the *Outline of Action Plan for the Conservation of Aquatic Living Resources*. This document guides the development of subsequent fisheries resources conservation policies in China.

Remarkably, the 2000 *Fisheries Law* mandated the use of TAC for the first time in China, despite the management still being reliant on input controls and technical methods. An expert group was set up in 2003 to study the implementation of TACs. However, it turned out that the TAC cannot be implemented unless major reforms are made to the fisheries systems (Tang & Tang, 2003).

#### **2.5.1.4. Phase Four: prioritizing ecological conservations (2016-present)**

Domestically, China's national development philosophy has gradually shifted from emphasizing economic growth to emphasizing ecological protection in recent years. Internationally, there is a growing global call-to-action to protect the marine environment. In this context, fisheries resource conservation has become a top priority of marine fisheries management in China. After 13FYP proposed the updated DCTs and the first TYL, the MOA issued the *Notice on Further Strengthening the Management of Domestic Fishing Vessels and Implementing the System for Managing Total Marine Fisheries Resources* in February 2017, which outlined China's central agenda for fisheries reforms. Soon afterward, the national government reauthorized the PAFL which has entered into force on January 1, 2019; the *Fisheries Law* is currently being revised.

A series of initiatives have been taken since 2016 to improve the mechanisms and methods for marine fisheries management. Here, five major initiatives were identified and elaborated on; these initiatives may shed light on the future directions of Chinese fisheries reforms. Other initiatives were presented in Box 2.1.

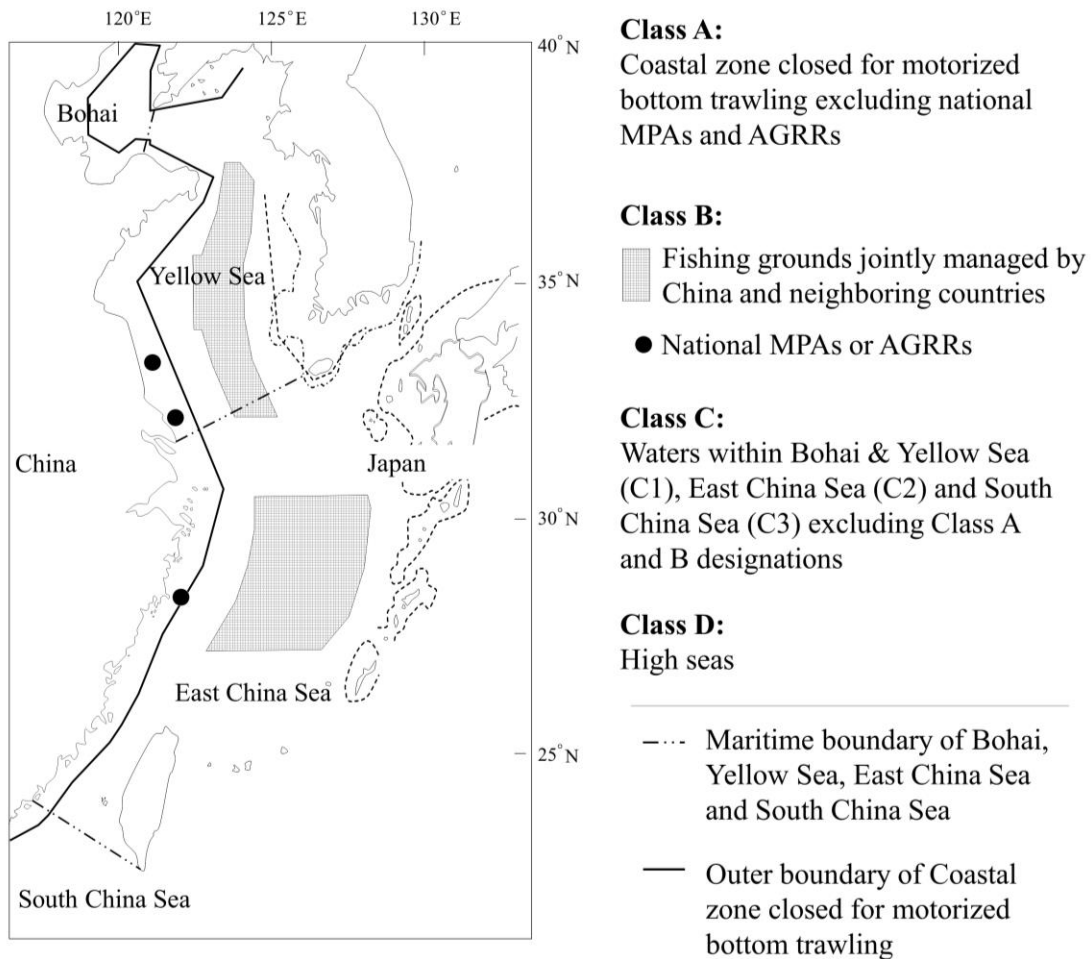
### **2.5.2. Fisheries reform actions**

#### **2.5.2.1. Fishing vessel classification system**

The MARA has re-defined marine fishing vessels into three size-classes according to their length overall (LOA) (large, medium, and small) and further divided the permissible fishing areas for the three size-classes of vessels (Figure 2.8). The new system indicates a decentralization in fisheries management; DCTs for small-sized fishing vessels with LOA less than 12m - previously determined by the national ADF and allocated to each coastal province according to a pre-determined ratio - are now determined by

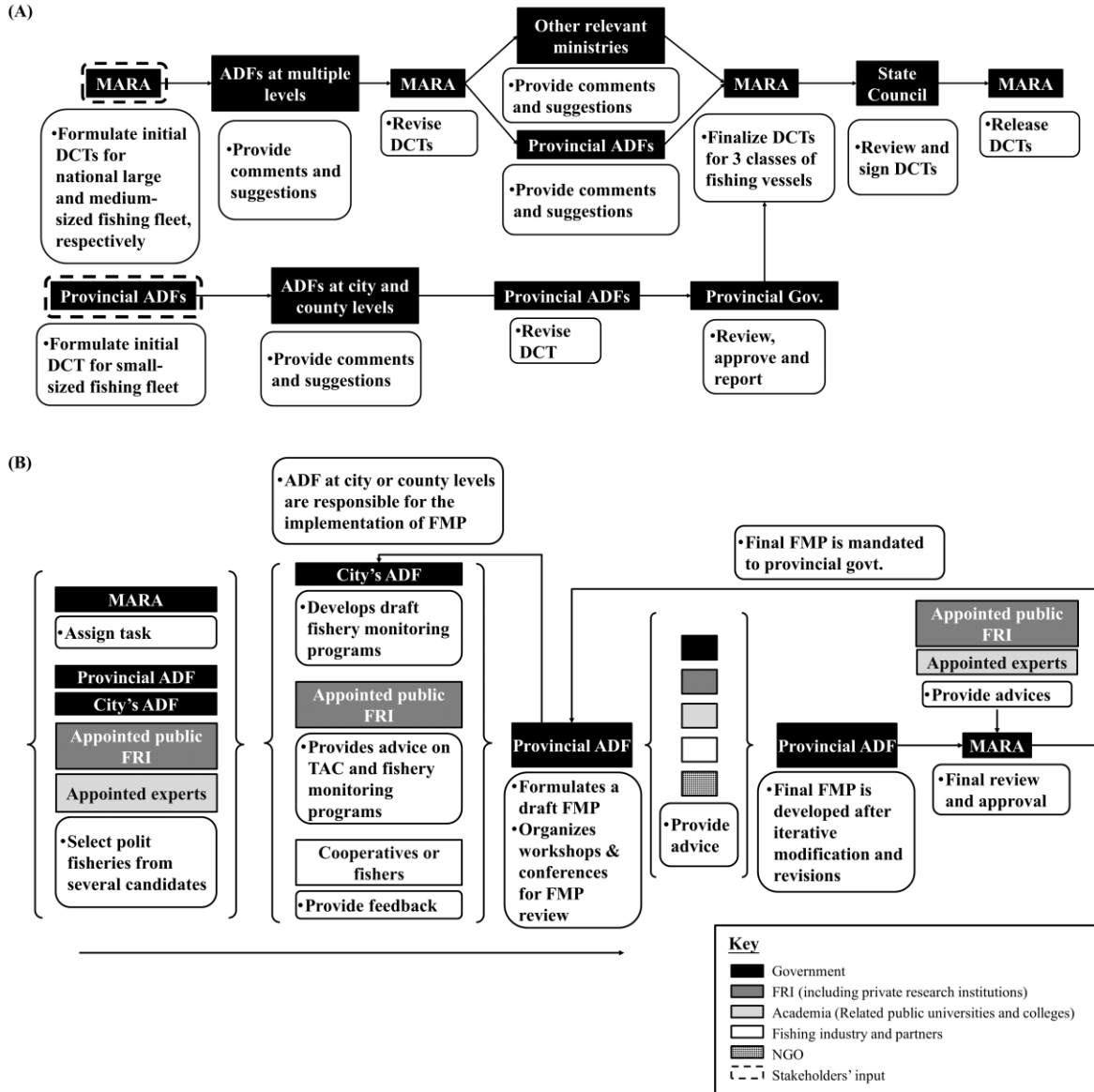


provincial authorities (Figure 2.9). Combined with regulations on prescribed fishing areas, whereby small-sized fishing vessels can only operate in the provincial waters to which they belong, the new management scheme greatly bolstered local autonomy.



Note: The number of dots representing national marine protected areas (MPAs), or aquatic germplasm resources reserves (AGRRs) does not reflect the actual number. Since 2017, large and medium-sized fishing vessels (Length overall (LOA)  $\geq 12$  m) are no longer allowed to enter Class A waters without a special permit; vessels approved for operations in Class B or C cannot operate across sea areas (which refer to C1, C2, and C3); small fishing vessels (LOA  $< 12$  m) can only operate in Class A waters and cannot operate across provincial boundaries.

Figure 2.8. Schematic diagram of the spatial division of China's marine fisheries areas.



Note: The processes for TAC pilots in Liaoning, Shandong, Zhejiang, Fujian, Guangzhou are different. The flowchart (B) represents their general practice. Arrows indicate the direction of the process. The brackets imply sub-processes. Flowcharts were developed based on related documentations and then reviewed by experts involved in the processes.

Figure 2.9. Decision-making processes for (A) double control targets (DCTs) and (B) fisheries management plan (FMP) of total allowable catch (TAC) pilot programs.

### **2.5.2.2. Reorganizing fisheries communities**

The changed fisheries operation model emerged after China adopting economic reform ushered in an era of rapid economic growth in the fishing sector. Fisheries productions previously coordinated by the communes came to independently operate by individual households. This transformation has the downside of making monitoring, control, and surveillance more difficult (Chen, 2009). Also, the loss of the fisheries cooperatives to act as intermediaries between the government and fishers reduced fishers' voice in management (Gao & Gao, 2008).

Currently, reinventing fisheries community organizations is becoming a concern in China. The 2019 PAFL has indicated that fishers should be associated with one of the local corporate or unincorporated organizations, such as fisheries cooperatives, fisheries associations, village collective economic organizations, and village committees.

The primary purpose of the re-organization of fisheries communities is to aid the implementation and enforcement of fisheries policies and regulations. The government views this initiative as a way to reestablish the severed channels of communications with local stakeholders as well as a potential first step to foster an environment of compliance with management regulations within the communities.

### **2.5.2.3. Output controls - TAC pilot programs**

China uses fisheries pilot programs to incubate innovations and integrate bottom-up initiatives and local knowledge into the national policy process. From 2017 to 2018, the TAC-based management approach was piloted in six selected fisheries located in provincial jurisdictional waters. In 2019, the approach was further used in the fisheries where were exempted by the SFM regulations; those fisheries are also located in provincial waters. Thus, so far, TACs management plans were all developed at the provincial level and reported to the MARA for approval (Figure 2.9 (B) shows the general decision-making process). TACs were calculated based on historical fisheries statistical data in 2017 due to insufficient conditions for stock assessment especially in terms of data limitation. TACs quotas were then allocated to individual fisheries cooperatives or vessel sectors. Because of the inadequate monitoring and enforcement capacities in China

today, provincial managers regard the pilots as “test runs” primarily for refining methods and building social acceptance, rather than a measure to produce immediate conservation effects.

#### **2.5.2.4. Co-management approach**

China also introduced co-management ideas in its fisheries management with the launch of TAC pilot programs (Jentoft, McCay & Wilson, 1998). Comparing the decision-making processes of the DCTs with that of the TACs, we can observe that scientists, the fishing industry and the partners, and NGOs are receiving more opportunities to be involved in the decision-making process for the latter (Figure 2.9). In fact, fisheries cooperatives played an especially important role in those programs; for example, in the pilot swimming crab (*Portunus trituberculatus*, Portunidae) TAC program in Zhejiang province, the cooperatives, composed of fisher representatives, assumed the responsibilities for quota allocations within the organization. Besides, they were responsible for fisheries-dependent data collection and helped in supervision. From these trends, we are optimistic that a more adaptive and more transparent management regime is taking shape.

#### **2.5.2.5. Fisheries monitoring**

In the past, in addition to the fisheries statistic system, only the fishing logbook program was used to obtain production data of fisheries using medium and large boats. Since 2019, fisheries using small-size vessels have been first included in this program. In addition, China has investigated and tested a number of alternative fisheries monitoring and reporting programs. For example, on-board observers, hail-out and hail-in systems, and electronic logbooks have been used in various TAC pilots. Local governments have gradually begun to designate ports for unloading catches to improve landings-control and catch-reporting (MARA, 2018; MARA 2019). These attempts could improve the quality and availability of data and as well as promote seafood traceability in the future.

### **Box 2.1. Other initiatives since 2016**

Various other initiatives in addition to the five elaborated in the main text have also been taken in China to optimize sustainable marine fisheries management. They are:

1) A brand-new fishing gear access system has been introduced; rather than relying solely on banning certain types of fishing methods and restricting minimum mesh size for a limited number of types of fishing gears, all types and standards of fishing gears allowed will be clearly specified under this new system.

3) Fishing boats using trawl nets, standing nets with single anchors, or large deep-water purse seines nets are no longer allowed to be built, and existing vessels will be phased out due to their destructive impact on the ecological environment.

4) Non-local residents or enterprises applying for local marine fishing licenses are no longer allowed. Thus, the inland residents will be not able to obtain a marine fishing license and the mobility of fishers in coastal communities will be reduced.

5) Fishing licenses for recreational fisheries are now mandated, which filled the gap of recreational fisheries management in China.

6) Rules of some existing management measures have been revised and become severer, such as the SFM.

7) A reallocation of fishery subsidies is unfolding. Fuel subsidies have been decreased in some provinces.

## **2.6. Considerations in China's fisheries management**

China's marine fisheries management has come to a historical turning point, that is, the conservation of fisheries resources, instead of economic growth, has become the primary management objective of central leadership. The same is true at local levels; for the first time, the quality of the ecology and environment has been used as one of the indicators for the working evaluation of local government leaders. Meanwhile, ensuring the livelihoods of fishers, especially those who are highly dependent on fisheries, is also seen as a significant management objective (Cao et al, 2017). Here, we conclude five issues that may impede the realization of these goals based on Chinese historical management practices. We believe that China's future fisheries reform should first consider these six issues.

### **2.6.1. Remarkable efficiency or misleading data?**

There is, at first glance, an encouraging response in the dataset to policies: in 1999, just as the “zero-growth policy” was issued, the total fisheries production stopped growing and remained at a relatively stable level in the following years. The 2016 observation reflected similar incidents, where fisheries productions decreased right away after the release of TYL (Figure. 2.6). The immediacy of the statistical response to policy shifts inspires skepticism: Were these positive responses realistic situations? Did they reflect real policy success or were they merely a result of data manipulation?

The reliability of China’s statistical data was questioned by previous studies. Some argued that the data may be “trimmed” by government agencies at successive administrative levels as they are reported from the ground up, due to political incentives (e.g., Guan & Yu, 2004; Sun & Huang, 2009; Pauly et al., 2014). Watson and Pauly (2001) pointed out that China over-reported its domestic marine fishing output in the 1980s and 1990s because the state entities monitoring the economy were given the task of increasing output. Fortunately, conserving natural resources and restoring the ecosystem instead of increasing output has become a state priority since 2016. Such a transformation, although cannot totally eliminate concerns in terms of political influence in data reporting, does inspire more confidence in providing a better environment for reporting more reliable fisheries statistics. Even so, the ability of the Chinese statistical system to provide accurate data deserves reasonable doubt since the data collection scheme in place in China is not immune to quality loopholes (Gao, 2005). The data quality issue should be further investigated in future studies.

### **2.6.2. The “hidden” fishing capacity**

Since 1979, input controls have been the cornerstone of China’s fisheries management to limit the fishing intensity and conserve fisheries resources (Yu & Yu, 2006; Tang & Zou, 2010). However, success has been limited, as the total marine fishing capacity in China remains high (Yang et al., 2016). One reason for this is the government’s lack of control over other factors in determining fishing capacity except for

horsepower and vessel numbers, such as vessel tonnage, storage capacity, auxiliary vessels, time of operations, gear deployment, and the number of fishers (Tang, Zou, & Hu, 2009).

Besides, the underestimated horsepower clouds over the veracity of national fisheries statistics and lead to input controls' failure. Zhang et al. (2018) pointed out that since almost all taxes, fees, and/or fines levied on fishing vessels are calculated based on the vessel's horsepower, fishers tend to under-report the horsepower of their vessels (or otherwise only report the lowest possible diesel engine power rating, which does not reflect reality). Zhang et al (2018) also observed that even diesel engine manufacturers participate in this increasingly elaborate deception by mislabeling the engines that they produce to suit the market preference. All of these factors contribute to the hidden fishing capacity in China, which remains unfathomable due to inadequate surveys and ground-truthing in management (only 6,500 certified surveyors are assigned to meet the annual inspection needs for more than 1.09 million fishing vessels, including about 300,000 marine fishing vessels).

Unregistered fishing vessels are another contributor to the “hidden capacity”, presenting yet another obstacle to China's fisheries effort reductions and input controls objectives (e.g., Shen & Heino, 2014; Buszynski, 2012; Mills et al., 2011). Since the 1990s, China has sought to fight illegal fishing boats by introducing a series of normative documents. However, coming short of a formal and higher-level legal mandate, success has been limited (e.g., Hua, 2005; Zhu & Pei, 2015; Pei & Xie, 2018).

### **2.6.3. Different fisheries vs Consistent management approaches**

In addition to the pilot programs, other fisheries management approaches in China exhibit a certain degree of uniformity across different regions (Schwartz, 2003). However, uniform management measures are placed at odds with the diverse environmental, ecological, and social characteristics in China's fisheries and fishing communities across different regions (Shen & Heino, 2014; Huang & Tang, 2019; Li et al., 2019; Liu & Tao, 2016; Tang, 2017).

In particular, the situation of fisheries using small-sized fishing vessels located in China's coastal waters is greatly different from other fisheries. These fisheries share similar characteristics with small-scale



fisheries around the world, such as involving highly mixed species; hiring a large number of temporary seasonal workers, many of whom are migrants; exhibiting low community and environmental resilience and in a weak and disorganized market (e.g., Andrew et al., 2007; Su, 2016;). Some common problems are more prominent in these fisheries (Chen & Tang, 2013), such as overexploitation, lack of data, complex social issues (e.g., low coverage of insurance (Liu & Ping, 2010)), and enormous scale (the number of small-sized fishing vessels in China is about twice that of large and medium-sized fishing vessels).

China's diverse fisheries urgently need diversified, devolved policy and management measures that are not only feasible but also responsive to the specific needs of a particular fishery or fishing community (Wilson et al., 1994; Chen & Tang, 2014). To elaborate this point, the current SFM closes all Chinese coastal and offshore waters regulated with consistent rules - with only a limited number of fisheries were exempted and managed by separate regulations during the closure (MARA, 2019). This clear-cut approach creates a hard time for some groups of fishers whose fishery is more reliant on the summer season; when the optimal fishing season overlaps with the closure in a particular fishery, fishers are incentivized to fish during the closure, resulting in more illegal fishing and higher costs of law enforcement.

Furthermore, the knowledge asymmetry between policymakers at the national level and those working locally could impede management success (Jasanoff, 1996, Cash et al., 2002). The decentralization of the fishing vessel classification management system provides opportunities to address this issue. However, the challenge to devolve responsibilities remains formidable, considering China's top-down, command and control management framework. Today, the TYL is developed and allocated by the MARA (central government) to the eleven coastal provinces at a fixed proportion determined by historical catch. In addition, local governments have less capacity to develop fisheries policies and regulations due to the lack of experience and knowledge. The lack of policy solutions rooted on the ground may lead to significant management failure.

#### **2.6.4. Participatory policymaking**

Failure to integrate stakeholders' knowledge and opinions in decision-making might be the vital reason for the past poor compliance and low efficacy of fisheries management in China. As Figure 2.9 (A) indicated, the government is the dominant player in the decision-making process of DCTs, in which the mechanism for stakeholders' involvement is severely inadequate. However, Figure 2.9 (B) indicates that the science, policy, and fishery communities have been better bridged in the decision-making process of TACs. This might be another valuable gain from piloting TACs, and such a model is worthy to be learned and used in the development of other fisheries management measures.

#### **2.6.5. Poorly designed rights-based fisheries management system**

Rights-based fisheries management is another perspective of management (Townsend & Charles, 1997; Charles, 2001). In China, with the demise of fishing communes at the start of the second policy phase (1979-1999), the privatization of fishing equipment was not accompanied by the privatization of fisheries resources, leading to "Olympic" competition and sharply increased fishing capacity (Ostrom et al., 1994); the failure to distribute the use rights led to governance failure in conservation (Hu & Xue, 2003; Tang & Su, 2017).

Paying more attention to perfecting the rights-based fisheries management system, rather than being limited by the traditional management idea (i.e., improving input controls, output controls, technology measures, etc.) could improve China's fisheries management system.

### **2.7. Moving forward: recommendations for China's fisheries reform**

Overall, China's fisheries management is moving in the direction of becoming more refined, diversified, and modernized. The transformation of China's national development agenda has provided a great opportunity for fisheries institutional reform.

We suggested that the reform should take into account the previously identified issues in this chapter. Implementing and creating more property-rights approaches will resolve the problem of the poorly

developed rights-based fisheries management system. This is an important research subject for people studying Chinese fisheries management, whereas it does not fall within the scope of this dissertation.

With regard to the four remaining considerations described above, while they involve various aspects of fisheries management, we recognized that they fall under the umbrella of science-based fisheries management (SBFM) and relate to a significant problem: how can scientific information and knowledge be better generated and used during fisheries management? To be more precise, the uncertainty associated with the fisheries statistical system and the “hidden” fishing capacity result in untrustworthy data inputs for the management system, especially unreliable fisheries-dependent data. The use of highly unified fisheries management approaches throughout the country comes at the cost of failing to account for local variations, which indicates a lack of integration of local fisheries knowledge in fisheries research and policymaking. Similarly, the lack of a formal mechanism for multiple stakeholders to participate in decision-making indicates insufficient use of available information. In this light, we argue that improving the production and use of science in fisheries management, and thus developing the SBFM scheme, is critical to China’s fisheries reform. The following chapters of this dissertation will address further analysis and a reform plan.

## CHAPTER 3

### DIAGNOSE AND ADVISE ON CHINA'S MARINE FISHERIES MANAGEMENT USING SYSTEM THINKING

#### 3.1. Abstract

Ensuring that fisheries decision-making is based on the best available science (BAS) is critical to sustainable fisheries management and science-based fisheries management (SBFM) is thereby widely advocated worldwide. China is the largest marine fishing country in the world, but its marine fisheries management system's ability to implement SBFM has yet to be analyzed. In this study, I reviewed China's marine fisheries management system and used a pre-developed SBFM framework as a guide to diagnosing the system from the perspective of system thinking. The system's advantages and disadvantages in terms of BAS development and usage were identified and evaluated.

#### 3.2. Introduction

Sustainable fisheries management requires decisions based on sound science. To help ensure this, fisheries policies should establish institutions to conduct the best available science (BAS) and processes to ensure that it forms the basis of decision-making (Cooke et al., 2017). Science-Based Fisheries Management (SBFM) is committed to completing satisfactory integration and consideration of all available information across multiple dimensions provided by various stakeholders through effective processes and procedures, thereby ensuring the timely production and use of BAS in the development of management strategies (Bisbal, 2002; NRC, 2003; Sullivan et al., 2006; Su et al., 2021). Due to variations in the legal and institutional structure and data availability, SBFM can be operated in a variety of ways in different jurisdictions or fisheries (Ryder et al., 2010). However, there are still a set of criteria that need to be met to ensure that SBFM is implemented and to facilitate the operation of SBFM (Su et al., 2021). Failure to meet these criteria will not achieve successful SBFM, which may weaken the effectiveness of SBFM in collecting,

addressing, and considering information (Su et al., 2021). This may lead to biased decision-making and unsustainable fisheries management.

China is a major player in worldwide seafood production, consumption, and trade (FAO, 2020). Its government has initiated an ambitious fisheries reform effort and elevated the goal of sustainability since 2017, which needs a well-designed legal and institutional framework to support strong science and its integration into decision making (Cao et al., 2017; Su et al., 2020). However, no assessment of China's marine fisheries management system's capacity to produce and use BAS has been undertaken to date. This study was conducted to fill this gap and to evaluate the Chinese marine fisheries management system to better understand its performance and progress in implementing SBFM. We believe this study will help people better understand China's marine fisheries management and inform China's fisheries reform moving towards more sustainable and science-based management. Meanwhile, this study provides a reproducible method for evaluating the capacity of a fisheries management system in terms of producing and using BAS in decision-making from a perspective of system thinking.

The rationality of this study is based on a hypothetical premise that China would need to implement SBFM. An important argument is that the United Nations Convention on the Law of the Sea (UNCLOS) has entered into force in China since 1996 and the UNCLOS stipulates that “the coastal State, taking into account the best scientific evidence available to it, shall ensure through proper conservation and management measures that the maintenance of the living resources in the exclusive economic zone (EEZ) is not endangered by overexploitation (§61, UN, 1982). Furthermore, China's domestic policies call for structured, democratic, pluralistic, and scientific decision-making, which is consistent with the principle of SBFM (Zhou, 2012). The regulatory document of “Implementation outlines for comprehensive promotion of law-based administration 全面推进依法行政实施纲要”, released by China's State Council in 2004, introduced a ten-year goal of developing a framework to ensure structured, democratic, and scientific administrative decision-making in any area (GOSC, 2004). This goal was reiterated and updated in the document “Implementation outlines for building a government ruled by law 法治政府建设实施纲要

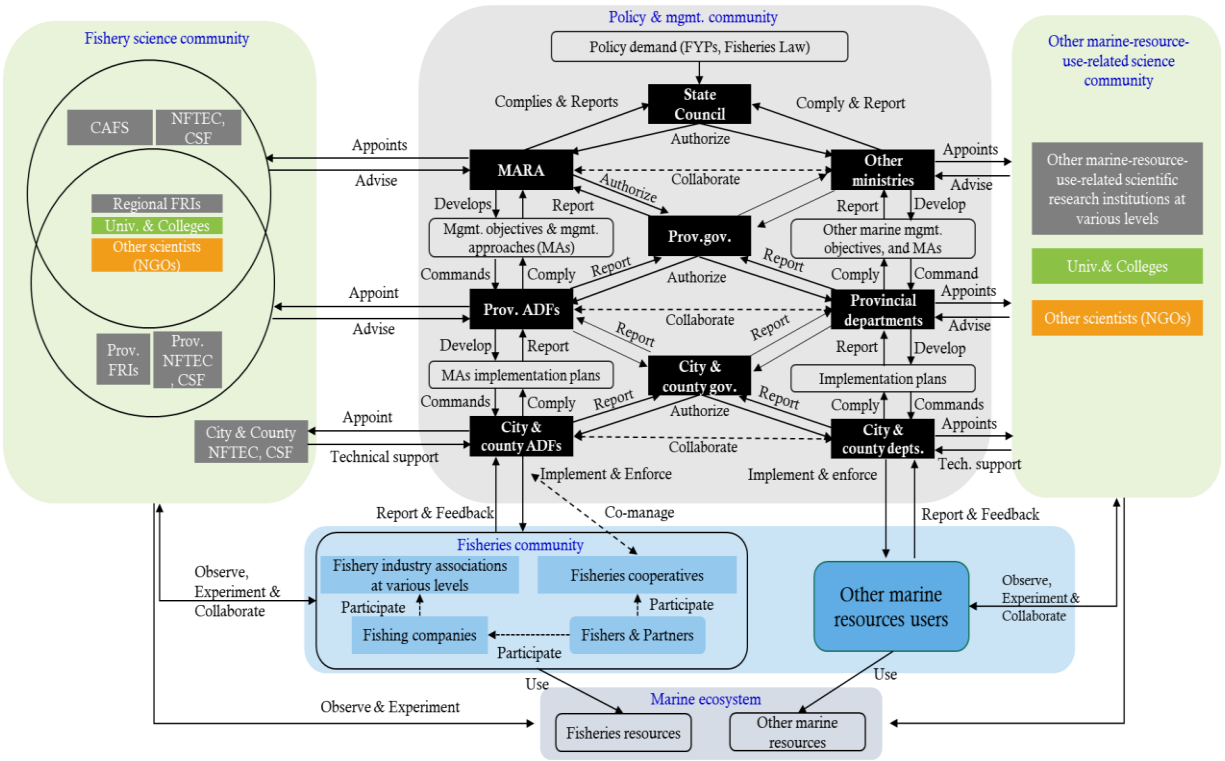
(2015-2020)”. It calls for the establishment of statutory mechanisms to allow expert demonstration, risk assessment, legitimacy review, public participation, and to enhance their role in decision-making (GOSC, 2015). The “Implementation Outline for the Establishment of a Rule of Law-Based Society 法治社会建设实施纲要 (2020-2025)” further elaborates the following development goals: (i) improving the social governance system to be supported by science and technology; ii) allowing democratic consultation, social coordination, and public participation in decision-making; iii) creating a social governance pattern of co-construction, co-governance, and sharing; and (iv) promoting the role of citizen’s and social organizations in industrial self-regulation (GOSC, 2020). Additionally, China’s historical management practices point to a shift towards more science-based sustainable marine fisheries management (Su et al., 2020). Therefore, the results of this study can provide a reference for China’s future fisheries reforms to better meet the needs of international obligations and domestic policy development on making BAS-based decisions.

### **3.3. Materials and methods**

In this study, we use system thinking to assess China’s marine fisheries management system. The System Thinking theory stresses holistic analysis that focuses on how the system’s components are interconnected and how the system works through time (Meadows, 2006). Based on a detailed review of the relevant laws and regulations, management objectives, institutional structure, and decision-making process, we diagnosed the interconnections between the many components that comprise China’s marine fisheries management system to determine if sufficient circumstances are in place in the system for SBFM to be successful. The information used to describe China’s marine fisheries management system was obtained from the most widely available resources, including those provided by organizations’ official websites, regulatory documents, grey reports, and peer-reviewed articles, and it was cross-verified by the authors of this paper.

### **3.4. An overview of China's marine fisheries management system**

To visualize the components of China's marine fisheries management system, as well as their relations and interactions, I sketched a map of the country's current marine fisheries management system, from national policies through operations on the water and underlying ecosystem, using the most widely available resources (Figure 3.1). Note that Figure 2.2 also showed several sections of this map concerning the organizational structure for management within the fisheries sector.



Acronyms: CAFS – China’s Academy of Fishery Science; MARA - Ministry of Agriculture and Rural Affairs; FYP – Five-Year Plan for the National Economic and Social Development of the People’s Republic of China; ADF - Administrative Department for Fisheries; MA – Management Approach; CFA-China Fisheries Association; CSF - China Society of Fisheries; NFTEC-National Fisheries Technology Extend Center; FRI-Fisheries Research Institute; NGO – Non-Government Organization

Figure 3.1. A system map of China’s current fishery management system.

Like most jurisdictions in the world, China’s marine fisheries management involves the policy and management community, the science community, and the industrial community. The players or components in these three communities are connected based on legal obligations, policy demand, and/or their natural attributes and hence form an intricate network.

In the following sections, I will diagnose the system using system thinking to identify and describe both important and missing links and feedback loops critical to the production and use of BAS in fisheries policy and decision-making. Before moving on to the diagnosis, I’ll first highlight some key aspects of the system, even though some of this information was briefly mentioned before in Chapter 2.



To begin, China's marine fisheries management highly relies on a top-down command-and-control system using input controls and technical measures (Su et al., 2020). This situation has been partly changed after China launched a new round of fisheries reforms in 2017 (Cao et al., 2017). The most relevant initiative is the introduction of Total Allowable Catch (TAC). Currently, China is implementing a single Total Catch Limit (TCL) for the overall marine fisheries and at the same time is also testing single-species-based TACs in some selected fisheries (Su et al., 2020; Tang & Zhao, 2020).

In terms of bureaucratic structure, China runs a hierarchical administration (Shen & Heino, 2014). From top to bottom, the administrative levels are national, provincial, municipal, and county. Horizontally, governments at various levels divide the management functions into different units according to the legislation and assign the administrative functions to different functional departments. The functional divisions are responsible for implementing management and accountable to the government to which they are subordinated at the same level. Vertically, governments at different levels administer their territories in a top-down manner: lower-level government is directed and supervised by higher-level units.

Marine fisheries management is governed by a series of laws that regulate activities related to the use of marine resources (Huang & Tang, 2019), among which the Fisheries Law is the basic law of fisheries management. At the same time, the management is guided by the Five-Year Plan for the National Fisheries Development of the People's Republic of China. The Ministry of Agriculture and Rural Affairs (MARA), which is the National Administrative Department for fisheries (ADF) under the State Council, oversees fisheries affairs throughout the country. And there are other departments involving in marine fisheries administration, including the Ministry of Transportation (MOT), which is in charge of fishing vessel inspection, the Ministry of Ecology and Environment (MEE), which is responsible for marine conservation and pollution control, and the Ministry of Natural Resources (MNR), which is responsible for planning and managing the use of sea areas and rebuilding damaged ecosystems.

Within the policy and management community, fisheries management objectives, plans, measures, and regulations are mainly formulated by the national and provincial governments and their ADFs. MARA is responsible for drafting and proposing national fisheries management goals and policies, formulating

specific fisheries development plans and management measures, and organizing scientific research and demonstrations on the reform and improvement of fisheries policies. Those policies that involve the functions of other departments of the State Council or the distribution of major interests and responsibilities (such as the allocation of “double control” indicators) require the approval of the State Council.

There are 11 provincial-level administrative regions along the coast of mainland China. Provincial fisheries policies are demonstrated and proposed by the provincial ADFs based on national fisheries policies, and then be reviewed and approved (or declined) by the provincial governments. Policies that involve the unified arrangement of the country are required to be submitted by the provincial government to MARA for review and approval. ADFs under the provincial level are responsible for implementing and enforcing fisheries management regulations within their jurisdictions.

Regarding the interaction between policy and science communities, policymakers usually appoint experts from various organizations for scientific inputs based on the expertise needs for the development of fisheries policies. Early knowledge accumulation is often used as a basis for selecting and nominating experts, which means that experts with extensive experience engaging in fisheries decision-making and demonstrating persuasive abilities, as well as experts who have made significant contributions and have a strong reputation in their research areas, are more likely to be chosen.

For those initiatives that require expertise in new areas, investigations and discussions will be conducted to select experts with matching capabilities for the scientific consultation. For example, the decision-making departments will first choose the widest possible selection of potential candidates based on experts’ experience and expertise, as well as findings from literature review, and then convening candidates to participate in seminars to discuss the nominees. Another approach is that the ADFs will identify certain research topics and programs based on potential policy needs and recruit applicants from the general public as a reserve of expert nominees.

The experts being nominated for providing scientific consulting services are primarily from governments’ in-house research institutions, including the Chinese Academy of Fishery Science (CAFS) and its branches (especially its regional FRIs), provincial fisheries research institutions (FRIs), and the

National Fisheries Technology Extend Center (NFTEC) and its branches at local levels, as well as fisheries-related public universities and colleges. In addition to experts from governments' in-house institutions and public universities, several non-governmental organizations (NGOs) have signed a memorandum of cooperation with governments and may act as scientific advisors for the development of fisheries policies (Su et al., 2020).

Furthermore, the research-oriented societies including the Chinese Fisheries Society (CFS), and its branches involving different specific fields related to fisheries at various levels also play a role in providing scientific references for policymaking. The CFS, in particular, has been entrusted by MARA with compiling China's Fisheries Statistical Yearbooks (CFSYs). These research-oriented societies are composed of members from science and industrial communities, with some also having members from the management community; and they hold conferences and seminars for fisheries academic exchange both nationally and internationally on a regular or irregular basis, which, at the same time, offer platforms for the academic communication among multiple stakeholders.

In recent years, the increasing practices in establishing expert tanks have offered an additional contributor to the interactions between science, policy, and industrial communities in China's fisheries management. The expert tanks are MARA-led advisory committees (see Table 3.1) that were formed to conduct management-needs-oriented research, produce scientific advice for policymaking, and provide technical support for fisheries management implementation. These committees are hybrid organizations composed of senior government officials, senior scientists, senior employees from related state-owned enterprises, and sometimes fishers' representatives.

Table 3.1. A list of fisheries-related expert advisory committees.

Fisheries Expert Advisory Committee (FEAC)
National Marine Fisheries Resources Assessment Expert Committee (NCEMFRA)
Marine Ranch Construction Expert Advisory Committee (MRCEAC)
National Fishing Port Management Experts Committee (NFPMEC)
National Committee of Experts on Fishing Vessel Management (NCEFVM)
National Recreational Fisheries Expert Think-tank (NRFET)

As for the interactions between policy and industrial circles, the industry’s responses on policy interventions, including fisheries data and the opinions of fisheries communities, are typically fed back to the policy and management community through a bottom-up process (Pan, 2015). Meanwhile, associations composed of industry representatives and their partners have long been critical in collecting and supplying fisheries data for management, as well as conducting research and providing consulting reports. In addition, co-management between local government and fisheries cooperatives is being implemented in some areas (Tang & Zhao, 2020).

There are additional ways for involving fishers and their partners in policymaking. First, the national and provincial ADFs can directly solicit their input on pertinent decisions through surveys, interviews, and hearings. Second, governments at all levels are required to initiate procedures for soliciting public opinion on proposed policies, and the public can submit comments and suggestions through specified channels, such as email. Additionally, scientists and industry may cooperate on research to inform policymaking; industry participation and insight into the research may eventually influence management decisions.

### **3.5. A diagnosis of China’s marine fisheries management system**

At a glance, the system map of China’s marine fisheries management (Figure 3.1) shows that data from different components can all be passed through the current feedback loops to the system’s primary fisheries policy- and decision-making bodies - MARA and provincial ADFs. That is, in principle, this

system is capable of ensuring that fisheries policymakers collect usable data from all corners of the system for the purpose of crafting policies.

However, it is worthwhile to consider whether these existing feedback loops are productive and efficient in conveying available data; whether there are sufficient mechanisms or methods to ensure the collection and transformation of quantity- and quality-assured data; and, most importantly, whether there are legal mandates and consistent protocols that could ensure that the data are adequately considered and integrated into decisions. From another angle, it's worth analyzing whether the established connections are capable of ensuring or promoting trust among various components and communities, thereby contributing to the legitimacy of the scientific basis for policymaking.

Indeed, the ability of the existing feedback loops in the system to communicate accurate data varies significantly. It appears that a feedback loop with more components has a higher chance of data loss and inaccuracy, and that when two components are only weakly coupled, the extent of data exchange between them decreases. Some components of the system are loosely connected for a variety of reasons, including a lack of a clear legal mandate, a failure to resolve multi-party interests and disputes, the absence of collaboration plans, and insufficient capacity for implementation in terms of monitoring, supervision, and education, as we demonstrate in greater detail below. These frayed or even missing connections may intensify distrust and misunderstanding between the various components and communities, further eroding the already frayed connections.

### **3.5.1. Legal demand for science-based policymaking**

Providing specific legislative requirements for science-based decision-making is crucial to ensuring the integration of science into the development of management measures (Su et al., 2021). China has enacted a number of laws and regulations governing marine fisheries management (Xue, 2005). Six of these legal documents include clauses referring to the use of science in fisheries-related decision-making. Table 3.2 presents the names of these documents and the most relevant statement(s). These statements involve several management approaches and four of them are mandated to be formulated and implemented by ADFs,

including TACs, Fishing Quota System (FQS), Fishing Vessel, and Gear Index System (FVGIS), and Fishing Licensing System (FLS). Overall, the legislation stipulates that the creation of these approaches must be based on or consider the state of fisheries resources and the surrounding environment. TACs and the FQS, in particular, require stock assessments. However, TACs and the FQS were not implemented until 2017 and those legal statements relating to the FVGIS and the FLS were only added in 2018. Therefore, for those widely used management measures in China's marine fisheries management, the integration of science into policymaking was not required by legislation before 2017.

Table 3.2. The legislation mandating the use of science in fisheries policymaking in China’s marine sector.

<b>Name (Laws and regulations) and the corresponding description concerning “science”</b>
<b>Fisheries Law</b>
§22. The ADF of the State Council shall be responsible for organizing the investigation and assessment of fisheries resources and providing the scientific basis for the implementation of the Fishing Quota System.
<b>Provisions of Administration of Fishing Licenses</b>
§3. The state shall, according to the change of fisheries resources and the state of the environment, determine the control indexes for fishing vessels and gear, total fishing capacity, and the number of fishing licenses.
<b>Action Outlines for Conservation of Aquatic Living Resources</b>
Part III, §3.1. To establish and improve the fisheries resources investigation and assessment system, the quota allocation system, and the supervision and management system, distribute quota indicators fairly, justly, and openly, and actively explore effective mechanisms and approaches for quota transfer. Part VI, §5. Increase scientific research investment in the conservation of aquatic resources, strengthen infrastructure building, integrate current scientific research and educational resources, and enhance their technological advantages.
<b>Wildlife Conservation Law</b>
§8. The national key protected wild animals list shall be formulated after scientific evaluation organized by the wildlife protection department of the State Council, and the list shall be adjusted according to the evaluation every five years.
<b>Marine Environmental Protection Law</b>
§6. The coastal local government shall use the sea areas scientifically and rationally according to the local marine functional zoning.
<b>Nature Reserves Ordinance</b>
§17. The environmental protection administrative department of the State Council shall, in conjunction with the relevant nature reserve administrative department of the State Council, formulate a national nature reserve development plan based on the investigation and evaluation of the national natural environment and natural resource status.

At present, although China’s domestic legislative requirements indicate that the development of certain fisheries management measures should be based on scientific information, the laws do not expressly authorize BAS (i.e., best available scientific evidence or best available scientific information).

Regarding the legislative statements per se, they at the very least fail to reflect a significant attribute of BAS on which fisheries decision-making should be based under SBFM, namely, inclusiveness (NRC, 2004). The legislative statements in Table 3.2 rarely address the consideration and use of alternative types of data in addition to the evidence obtained by scientific study, such as local fisheries knowledge (Stead et al., 2006; Stephenson et al., 2016). They also do not show much potential in dealing with issues concerning data limitation and the trade-offs of different types of data offered by various stakeholders. At present, most

Chinese fisheries are data-poor or data-limited. This is one of the most serious issues confronting China's sustainable fisheries management. TACs, for example, were mandated by China's Fisheries Law in 2000 but never implemented due primarily to a lack of data (Tang & Tang, 2003), and they are still only tested in a few fisheries today in China. If legislation could mandate the consideration, evaluation, and integration of anecdotal information, including experiential, narrative, and local information in decision-making, it could contribute to timely decision-making and promote the implementation of certain management measures when available data is scarce or limited for satisfactory scientific research (NRC, 2004; Su et al., 2020).

Second, there is a misalignment between China's marine fisheries management objectives and its legislative requirements for science-based decisions. The existing legislative statements emphasize that the development of certain fisheries management measures should consider the state of natural resources, including wildlife and the aquatic environment, implying the need for natural science research while overlooking the need for social science research. China's 13th FYP, on the other hand, specifies the country's fisheries management objectives, which encompass social, economic, and biological aspects (Table 3.3). Natural science knowledge alone will not be sufficient to assist the development of fisheries management measures to achieve multi-dimensional objectives. To effectively manage the complex fisheries system under such multi-dimensional management objectives, a suitable combination of biological analyses with social and economic concerns is important (Heck et al., 2015; Stephenson et al., 2017; Charnley et al., 2017).



Table 3.3. Management objectives of China’s marine fisheries management in 2016 to 2020.

<b>General objective</b>	<b>Mean objective (management measure)</b>
<b>Conservation</b>	
Effectively addressing overcapacity	Removing a certain number of fishing vessels and a certain amount of horsepower of the national marine fishing fleet (Double control system)
Fishing production is less than the growth amount of fisheries resources	Controlling landings to a certain level (Total yield limit and Total allowable catch)
Initially curbing the declining trend of fisheries resources Effectively protecting important fishing areas Gradually restoring ecological functions of key fishing grounds Making progress in protecting endangered aquatic wildlife and some economically important fish species	Establishing a certain number of a) National demonstrative marine ranching area; b) National Aquatic Germplasm Resources Reserve; c) National and provincial aquatic biological nature reserve
<b>Socio-economic</b>	
Lifting out of poverty	Increasing per capita disposable income of fishers and farmers in poverty areas
Improving income	Increasing per capita net income of fishers and farmers
Expanding coverage of insurance	Increasing the coverage of insurance of fishery communities (including aquaculture)
Improving safety	N/A

### 3.5.2. Linkage between fisheries policy and science communities

The key to a good system for integrating BAS in decision-making is to establish a clear boundary between those who use scientific advice (policymakers) and those who provide scientific advice (scientists) (Jasanoff, 1990; Rykiel, 2001). At the same time, well-designed mechanisms and methods should be in place to facilitate communication and collaboration between policymakers and scientists, ensuring mutual understanding and trust between the two parties (Briggs, 2006; Soomai, 2017).

These two criteria are theoretically met by China’s institutional framework in the fishery sector. MARA and provincial ADFs in charge of fisheries policymaking entrust FRIs or universities with specific fisheries research, and methods are in place to enable their collaboration and communication. However, marine fisheries management in China involves not only the fishery sector but also other sectors in charge

of marine resources, as aforementioned. The inadequacy of inter-departmental cooperation mechanisms has significantly hampered interaction between policymakers from the fishery sector and scientists from other related sectors. This will be explained later.

Another major concern about the connection between fisheries policy and science communities is that although scientists are consulted and their advice is passed on to policymakers, it is unclear whether and how the advice is considered and used in policymaking. The process's lack of transparency can be blamed, but the more underlying explanation is that there is a lack of statutory, unified, and explicit protocols in place to authorize and regulate the consultations. This problem can also be observed in the interaction between policymakers and other data providers such as industry associations. The lack of statutory unified protocols for considering and using available data in decision-making may lead to more subjective decisions that rely on the personal experiences and intentions of the policy- and decision-makers. This issue exists in many areas of management in China and was recognized by previous studies (Ren, 2018).

### **3.5.3. Connections within science communities**

In China's highly top-down system, the marine fisheries across the country are treated as a single management unit when formulating national management strategies and measures (Su et al., 2020). By contrast, the fisheries research institutions focusing on different sea areas around China's mainland are only loosely linked in the map via surveys and research, and their collaboration affects only the resources but not management or industry. The links between the in-house research institutions of MARA and other departments are even weaker due to the disconnect between departments. The disconnections within the overall scientific enterprises limit the availability, sharing, and accessibility of fisheries data, and hinders interdisciplinary research (Haapasaari et al., 2012), which remains an enduring obstacle to the implementation of SBFM in China.

The direct driver for the low level of scientific collaboration in the realm of China's marine fisheries is the lack of mandatory scientific research cooperation programs for the purpose of providing the scientific

basis for fisheries decision-making. Meanwhile, scientists' potential competition for financing, study topic selection, and personal career advancement impedes spontaneous collaboration between scientists or different scientific research institutions. The appointment procedure for scientific consultation in the decision-making process further stimulated this competition. Being appointed means that the ability and reputation of scientists are recognized by the political community and may be accompanied by some advantages such as in applying for research funding.

The initiative – the establishment of a series of advisory committees since 2017 – can partly solve the issues described above, at least in theory. The advisory committees have developed charters specifying the responsibilities of different groups of committee members (which are mainly scientists) and the ways of cooperation among the groups.

Taking NCEMFRA as an example, it was founded to be responsible for conducting stock assessments, generating suggested TACs for national marine fisheries, reviewing species-based TAC management plans, and providing technical guidance for fisheries resources surveys (MARA, 2019a). The committee's members are recommended by the organization to which they belong, with a five-year recruitment duration. The committee currently consists of 44 scientists, one MARA official, and one manager from China Agricultural Development Group Co., Ltd. (CADG), and the annual committee meeting is required. Scientists are from governmental scientific institutions affiliated with the fisheries department (N=33), universities and colleges related to marine fisheries (N=28), and other governmental scientific institutions outside of the fisheries system (N=3). They are divided into three groups to assess fisheries resources of the three Chinese sea areas and collaborate on developing proposed TACs for the national marine fishery. Members from MARA and CADG are responsible for reviewing the proposed TACs to ensure that TACs meet policy requirements and adapt to industry conditions (MARA, 2019a).

Therefore, a formal and regular process has been formed allowing scientists to collaborate and develop scientist advice for decision-making through a structured method. Scientists being recommended by their peers appears to be a more convincing approach than being nominated by decision-makers. Meanwhile, since they are from different institutions and different fields related to marine fisheries, the

connection within the overall marine science enterprise can be promoted, and this provides conditions for making fisheries decisions that consider the ecosystem (Ramirez-Monsalve et al., 2016). Furthermore, the review conducted by the members from MARA and the fishing industry increases the relevance and legitimacy of the scientific advice (Cash et al., 2002), as well as facilitating direct conversation among stakeholders from the three communities, namely science, policy, and industry.

Despite these improvements, the committees are still in the early stages of development. Some important criteria concerning the production of scientific research results in SBFM remain absent, including a detailed and comprehensive collaboration research plan, independent scientific review process, and rules to address uncertainties and divergences (Su et al., 2021). Furthermore, according to the NCEMFRA regulations, only the responsibility of producing and reviewing scientific advice within the committee is explained, whereas it is still unclear how the scientific advice provided by the committee is used by policymakers. Mandatory and consistent protocols for integrating scientific advice into decision-making are still absent.

#### **3.5.4. Linkage between fisheries department and the industry**

Different levels of fisheries agencies in the fisheries unit transmit information through a feedback loop of “commands” from top to bottom and “reporting and feedback” from bottom to top (see Figure 3.1) (Liu et al., 2009). However, some scholars pointed out that the quantitative fisheries data collected at the grassroots level may be tampered with for political purposes in the process of upward transmission (Gao, 2005; Sun & Huang, 2009). This issue may have been avoided if a method for cross-verifying data from various sources had been established. However, China has not yet developed such a method, and it appears that the quantitative data obtained from different sources at present have their own set of limitations, which we will discuss in section 3.5.6.

In the shortage of quantitative data that can reliably characterize industry behavior, qualitative data, such as industry and partner views and comments on policies, become increasingly relevant (Lipsman, 2019). The interactions between grassroots managers and the industry are the main means to bring industrial

perspectives into the policy and management community in China. For example, when revising the rules of Summer Fishing Moratorium (SFM), ADFs at the coastal city and county level collected opinions and suggestions from local fisheries communities on the revised rules through various methods, including public hearings, and reported the feedback to the higher-level government. However, this could also be hindered by inefficient bureaucracy and inadequate transparency (Mol & Carter, 2006). For example, Xiao and Bai (2019) complained that the comments of the local fisheries communities in Zhanjiang City on modifying the SFM regulations to fit local features had not been adopted by the higher-level government after being reported many times by the local government (Xiao & Bai, 2019). Moreover, the top-down command and control regime leads to local policies that are destined to be highly aligned with national policies, which may reduce the motivation of grassroots fisheries agencies and the fisheries industry to participate in policymaking due to the limited negotiation space (Pan, 2015).

The industry's opinions and suggestions can also be directly passed on to the national and provincial ADFs through other channels that were described earlier in section 3. Among these channels, industry representatives participating in the advisory committees could secure two-way information exchange between the representatives and policymakers under a structured method. Other approaches, such as fishers engaging in policymaker-organized surveys and opinion consultation sessions, are more one-way information delivery, and the degree to which the information is considered by policymakers and incorporated into decisions is unclear due to missing explanations (Pan, 2015).

Another feedback loop contributing to the policy-industry interface relies on the implementation of co-management. The co-management approach benefits the implementation of SBFM in many ways, including its potential capabilities in facilitating the integration of local fisheries knowledge into decision-making, promoting the localization of fisheries management, and improving compliance (Bremer & Glavovic, 2013). In China, this approach has been used in some TAC pilot fisheries (Tang & Zhao, 2020). However, the widespread usage is hampered by the lack of cohesive community organization (Su et al., 2020). China's vast marine fishing communities - with over 5.5 million fishers engaged - appear largely unstructured; in particular in small-scale fisheries, most fishing activities are operated based on household

(Chen & Tang, 2014). However, thanks to China's recent efforts to empower fishing communities, more extensive use of co-management is anticipated: the MARA agenda has placed a strong focus on promoting the formation of local fisheries cooperatives and their engagement in management since 2017 (MOA, 2017). Fishers engaging in marine fisheries are now mandated to join a fisheries organization according to the revised Provisions of Administration of Fishing Licenses (PAFL) enacted in 2019 (§11, China, PAFL).

### **3.5.5. Inter-departmental information transfer**

By design, the responsibilities regarding fisheries management and marine conservation are divided and held by the MARA and other departments including MOT, MEE, and MNR. Collaboration between these departments is important in not only science-based decision-making but also in implementation and enforcement. However, compared with the strengths of vertical communication and coordination within an individual department, the horizontal interactions between departments are relatively loose in China. This is due to various reasons, among which the widely recognized ones are the issues related to departmentalism (Linden, 1994) and lacking inter-department collaboration mechanisms (Xu, 2008; Liu, 2013, Fu, 2013).

In the marine fisheries sector, a data-sharing mechanism between departments is missing. MARA has limited access to data collected by other departments and even by their in-house scientific research institutions. Insufficient data sharing between departments on the one hand causes a waste of resources, on the other hand, it may lead to duplication of investment in monitoring and scientific research.

### **3.5.6. Databases serving as a vehicle for interactions**

In addition to the institutional structure, databases serve as the vehicle to connect different communities (Su et al., 2021). In China, the Fisheries Statistical Yearbooks (CFSYs) providing fisheries production data serve as the primary resources for fisheries decision-making and scientific research (Gao, 2005). They involve 361 indicators including fishing production, economic output, the number and horsepower of fishing boats, and fishers' income. The corresponding data are collected through the National Fisheries Statistical Surveys (NFSS), which is conducted annually by fisheries agencies and statistical units to monitor the dynamic changes of the national fisheries industries (MARA & NBS, 2019). Data are

gathered by the grassroots agencies, reported from the bottom to the top, and are compiled and published in CFSYs (MARA & NBS, 2019).

Previous studies have criticized the CFSYs for their poor quality, blaming obsolete survey methodology, flawed data audit systems, insufficient data collection efforts, and insufficient inter-departmental collaboration (Guan & Yu, 2004; Gao, 2005; Sun & Huang, 2009; Wang & Yin, 2012; Pauly et al., 2014). Furthermore, it is suspected that the fisheries data provided by CFSYs may be manipulated by handlers for various reasons while being transmitted upwards (Gao, 2005). This concern can be addressed by comparing and confirming CFSYs with data acquired by other fisheries monitoring programs. Furthermore, at-sea monitoring of fishing activity and total catch could influence the performance of the processes that make up the fisheries management system significantly; they collect data on the spatial and temporal dimensions of effort and total catch, as well as the taxonomic and life stage composition of catch to facilitate the science underlying management decisions (Kritzer, 2020). However, China's at-sea fisheries monitoring is imperfect and lagging behind. The fishing logbook, which is the only fisheries monitoring method authorized by the Fisheries Law in China so far, has great uncertainties and limitations: the quality of data is poor due to low level of compliance (Sun & Huang, 2009); and the small-sized fishing vessels which currently account for 64% of China's marine fishing fleet have only been required to fill in the fishing logs since 2019 (§50, China, PAFL, 2019). Lack of reliable fisheries data can be the Achilles' heel of SBFM, especially in a highly top-down context like China, where policymakers at high levels can be misinformed and make incorrect conclusions.

Fortunately, enhancing data quality and limitation has been at the forefront of China's fisheries reform agenda since 2017 (MOA, 2017). Monitoring methods including e-logbook, dockside landing checking, hail-in, and hail-out reporting, product labeling, on-board observers, telephone interviews, Fishing Vessel Identification Management (FVIM), and Vessel Monitoring System (VMS) are now tested in selected areas or fisheries, especially in the fisheries piloting single species TAC-based management (Shandong ADF, 2019; Tang & Zhao, 2020).

Another drawback of CFSYs, China's primary database utilized for fisheries management, is a mismatch between the data composition they supply and the data needs of fisheries scientific research. Scientists complained about the limited usability of CFSYs in scientific research due to the inappropriately designed methods or missing survey indicators of the NFSS (Liu, 2011; Zhang et al., 2017). For example, Zhang et al. (2017) proposed that the surveys failed to provide fisheries production data required by traditional single-species-based stock assessment models. China's historical fisheries management has been heavily reliant on the top-down system using input controls but not stock-based. In this case, the CFSYs classify the production of the national marine fishing fleet by species categories (including finfish, shrimp and crab, shellfish, algae, and others), sea areas (including Bohai, Yellow Sea, East China Sea, and the South China Sea), and fishing gear types. The production data of some fish species with high economic value are in place but not being recorded by regions or places (MARA, 2019b). The lack of connection between the NFSS and scientific research might be the most relevant contributor to the data shortage in fisheries science research, especially stock assessment in China.

### **3.6. Discussion and Conclusion**

China's marine fisheries management system is composed of a variety of elements embedded in the management and policy community, science community, and industrial community through a series of feedback loops. MARA and provincial ADFs are major policymakers in developing fisheries management strategies. Governmental fisheries research institutions and public universities play a major role in providing policymakers with scientific support. The fisheries industry also plays a role in decision-making via advisory committees and other relatively less structured methods. Overall, fisheries policymakers can obtain feedback from the fisheries science community and the industry through various exiting feedback loops. However, the system still has critical deficiencies that could hinder the production and use of BAS and the implementation of SBFM. Here, we conclude that the following points need to be improved:

We propose that the scope of application of such mandate should be extended to cover other fisheries management measures. Meanwhile, we believe that it is necessary for China to explicitly authorize



BAS-based fisheries decision-making through its domestic fisheries legislation, so as to be in line with the requirements of related international legal documents (such as UNCLOS). Even if it does not, to achieve a successful SBFM, China's current fisheries-related legislation should be improved to address the specific issue relating to the use of science. The critical questions that may be considered to be addressed by the legislation include what kinds of scientific information are required for the decision-making, how to address uncertainties and the trade-offs between information provided by different groups of stakeholders and in different dimensions, as well as how to use best available scientific information to make timely decisions. Inadequate legislative mandates for the use of science in decision-making may be the most important factor contributing to the paper's findings of loose relations between various players in the system.

We reiterate that it would be helpful for China to include clear legal requirements for socioeconomic evidence in addition to natural science as a decision-making basis, which will not only promote the consistency between legislation and its multi-dimensional management objectives but also promote cooperation among different disciplines and more systematic scientific advice for fisheries decision-making. In addition, adopting legal provisions to consider broader information beyond scientific research results in fisheries decision-making, while clarifying the priority of data from diverse sources for consideration, will facilitate timely and unbiased decisions.

Second, the connection between the many scientific institutions within the fisheries science community is insufficient, let alone the even more weakly related communities of fisheries science and other marine-resources-use science. The establishment of advisory committees may be able to assist alleviate this disconnect. However, incentives and mandatory scientific research cooperation plans aiming to inform fisheries decision-making are still required to stimulate collaboration and data-sharing within the overall scientific enterprise.

Thirdly, the inter-departmental collaboration mechanisms between MARA and other departments are absent. China's administrative regime is heavily reliant on vertical contact and collaboration between agencies within individual departments, however, the horizontal interaction between different departments

is relatively weak. Disconnection between departments not only impedes data exchange, but also the implementation and supervision of fisheries management policies.

Last but not least, as for the current state of the system, the quality and amount of relevant fisheries-related data cannot be guaranteed, which results in poor availability and high uncertainty of the science underlying management decisions. Many factors contribute to this, including a lack of a data audit process, insufficient fisheries monitoring programs, limited enforcement capacity, and low compliance. The ultimate cause could be insufficient policy mandates for the production and use of BAS in policymaking.

Aside from a lack of data quality and quantity, it appears that the use of available data in fisheries research and decision-making is insufficient. This is owing to poor data sharing among organizations, as well as a misalignment between the design of the data collection method (NFSS) and the needs of scientific research (especially stock assessments). Standards and protocols for data collection, storage, and verification should be developed, and they must be defined in accordance with fisheries management objectives and research agendas (Su et al., 2021).

Despite the flaws discussed above, China has made great progress toward SBFM since 2017, when a new phase of fisheries reform was initiated. First, the establishment of a series of advisory committees has created a formal and stable framework for multidisciplinary stakeholders to participate and collaborate in decision-making, especially scientists from different organizations and disciplines. Furthermore, the single-species TAC pilot programs have aided in the production and use of BAS in a variety of ways by introducing multiple new fisheries monitoring programs and the co-management approach. In fact, in some of the TAC pilot programs, a more structured decision-making process with mechanisms allowing the integration of scientific information and the participation and collaboration of multiple stakeholders has been developed (Su et al., 2020). To step forward, China certainly needs more practical and proactive reforms in its legislation, institutional structure, decision-making process, and data collection, storage, and verification systems. We propose that the two best strategies could be to optimize the mechanisms related to the advisory committees and to improve and promote the TAC-based management model of single species at scale.

## CHAPTER 4

### MOVING TOWARDS SCIENCE-BASED FISHERIES MANAGEMENT: A PROPOSAL FOR FISHERIES REFORM

#### 4.1. A summary of challenges, obstacles, and opportunities

In the study presented in Chapter 1, a comprehensive checklist for operating SBFM was developed, which lists a series of elements that enable or promote the production and use of BAS in fisheries management. The checklist was then used as a reference when evaluating China's marine fisheries management; challenges, obstacles, and opportunities to implement SBFM in China's marine sector have been identified and described through a study of China's historical marine fisheries management practices and an evaluation of China's current marine fisheries management system (Chapters 2, 3 and 4). A summary of the evaluation results is presented in Table 4.1. Note that some minor changes were made to the checklist to clarify the results. For example, I added adjectives describing the degree to some of the criteria. In the following sections, I will synthesize and wrap up the important disadvantages and advantages of China's fisheries management system for the implementation of SBFM, summarize the opportunities, and then propose suggestions for China to move towards a more successful SBFM.

Table 4.1. China's national marine fisheries management system's performance over SBFM criteria.

<b>General</b>	<b>Yes or No</b>
Best available science-based fisheries management and conservation is required by law	No
Institutional structure is well designed for ensuring science-policy interaction and the involvement and collaboration of multidisciplinary stakeholders	No
Standards and mechanisms regarding data collection, storage, and verification, including the fisheries monitoring plan, should be developed and be in line with management objectives and the research plan	No
Division of responsibilities is clear; responsibilities for making policies and conducting scientific research should be separated	Yes
<b>Process 1: Management objective-setting</b>	
Objectives are measurable and time-bounded	Yes
Objectives have performance indicators over biological, social, and economic dimensions	Yes
Management unit and boundaries are identified and informed by the biological feature of the fish stock or ecosystem function	No
Mechanisms for value-based debate among stakeholders are in place	Unknown
Fisheries monitoring programs are used to evaluate whether the objective is being met	Yes
<b>Process 2. Scientific research process (data production)</b>	
A research plan is developed based on management objectives	Unknown
Data used to generate scientific advice are relevant to the specific fishery being managed	Yes
External review of scientific advice based on user needs and other knowledge is conducted	Yes
Scientific advice is produced through a well-established scientific research process with:	
a clear statement of objectives;	Unknown
conceptual models for predicting and testing hypotheses under different scenarios;	Unknown
well-established protocols to collect data;	Unknown
rigorous statistical analysis and logical interpretation;	Unknown
clearly documented methods, results, and conclusions;	No
independent peer review of research methods, results, and conclusions.	Unknown
Skilled and reputable scientists are hired to do research	Yes
Limitation of data and knowledge gaps are acknowledged and documented	Unknown
Social science research, multidisciplinary and interdisciplinary research are conducted	Unknown
Methods are taken to incorporate stakeholders' knowledge in research	Yes
<b>Process 3. Development of management strategies (data use)</b>	
Rules for identifying the "best science" must be developed and are formalized and repeatable	No
Rules for using the scientific information must account for divergences	No
Approaches for communicating and understanding scientific advice and other knowledge are in place	Yes
Rules for using the scientific information must account for uncertainty	No
Monitoring programs are in place to inform adaptive updating of management strategies	Yes
Performance of management strategies are evaluated and learned from accordingly	Unknown
Decisions are recurrent	Yes
<b>Process 4. Implementation (data inputs)</b>	
Sufficient monitoring programs are in place to provide a means for supervision and collecting fisheries data	No
Sufficient outreach programs and education courses for both managers and fishers should be in place	No

#### **4.1.1. Challenges and obstacles**

Inadequate science-policy relations in decision-making may be a significant barrier to SBFM implementation in China. This was discovered during the review of China's historical fisheries management practices, and it was reinforced by the subsequent studies of China's current marine fisheries management system and the perspectives of stakeholders. The most compelling evidence for this conclusion is the lack of a statute, systematic, and routine protocols and mechanisms that allows for the processing, consideration, and integration of BAS during the development of management measures (Chapters 3). There are no consistent guidelines for defining BAS, dealing with divergences and complexities, or incorporating BAS into policies (Chapters 2 and 3). The decision-making process for objectives-setting was not investigated due to a lack of available material, while it is likely a higher-level process with less transparency and stakeholders' involvement than the policymaking process for specific management measures.

Regarding the institutional framework, although it has established various mechanisms that allow multiple players to provide their knowledge, data, and information to policymakers, it is unknown how their inputs are considered and used by policymakers in decision-making, let alone to say that the institutional framework per se is imperfect due to insufficient and missing connections set for certain players (or system components) that lead to insufficient collaboration and data exchange between different departments and organizations (Chapter 3).

Another evidence indicating the isolation of science and policy in China's marine fisheries management is that there is a lack of management-problem-oriented fisheries scientific research. No fisheries science research plan or report (except those established in the single-species TAC pilot programs) that aimed to support or advise the implementation of a specific fisheries management measure or to assess fisheries management success was found. Although such a plan or report may exist, the lack of transparency is self-evident. This can be linked to the finding in Chapter 3 that existing Chinese national fisheries management priorities fail to make clear demands (such as MSY) for directing scientific research.

Furthermore, China's capacity to conduct fisheries scientific research is constrained, owing to a lack of adequate fisheries data, technology, and talent, as well as a lack of collaboration between scientists from different organizations or disciplines (Chapter 3). Additionally, since China's fisheries management objectives are set for the national marine fisheries as a whole rather than by fishery, the serious mismatch between management and biological units makes fisheries scientific research far more difficult to provide useful advice for decision-making (Chapter 3).

A lack of availability of quality-assured fisheries data is another major impediment to China's SBFM (Chapters 2 and 3). The National Fisheries Statistical Survey (NFSS), which is China's primary tool for collecting fisheries-related data, is thought to be incapable of providing sufficient quality-assured data for scientific research and decision-making. The accuracy of data collected is questionable due to factors such as the contradiction between the comprehensive statistical survey approach and the limited survey capability, and the numerous potential issues that occur in the data reporting process (Chapters 2 and 3). The disconnection between the old NFSS design and the new policy and scientific research requirements further reduces the data's usability in scientific research and decision-making, especially in fisheries where single-species TACs are tested (Chapter 3). The fishing logbook, in addition to the NFSS, is another tool used in China to collect fisheries-dependent data. However, the data gathered are limited in scope - its application in small-sized fishing fleets was not mandated until 2019 - and could be less accurate due to poor compliance (Chapters 2 and 3). Additionally, the quality of fishery data (fishing vessel parameters) provided by the fishing vessel inspection department has also been questioned due to limited inspection capabilities and hidden fishing capabilities (Chapter 2). Worse, the IUU fishing further exacerbates the uncertainty of the data collection system and data collected via NFSS, fishing logbooks, vessel inspections are stored separately and are not used for cross-validation (Chapter 2 and 3).

Issues such as an insufficient fisheries monitoring and supervision system, a lack of legitimacy in fisheries decision-making processes, the contradiction between uniform national fisheries policies and local fisheries, and a low level of awareness within the fishing industry about the importance of science-based

fisheries management provide conditions or motivations for the fishing industry to fail to comply with regulations, which further exacerbate the unreliability of reported fisheries data (Chapters 2, and 3).

The above-mentioned issues can all hinder the implementation of SBFM in China, and there may be a causal relationship between them. One of the fundamental explanations for these issues can be the absence of a legal and specific mandate for BAS-based policymaking in China's domestic fisheries-related laws (Chapter 3). A specific legal requirement for BAS-based policymaking can provide the legislative basis and incentives for SBFM implementation and the data exchanges between the different processes and components that comprise the fishery system as a whole.

Last but not least, the conflict between the conservation of fisheries resources and the social security and welfare of fishing communities may weaken the effectiveness of China's implementation of SBFM. Despite the fact that China has prioritized conservation objectives in its national marine fisheries management agenda, concerns about social security, especially the livelihood security of small-scale fishing communities, will prevent grassroots managers from pursuing conservation goals. This problem has historically hampered the implementation of conservation practices in China's marine fisheries management in recent decades (Chapters 2).

#### **4.1.2. Advantages and opportunities**

There are advantages and opportunities that can benefit China's SBFM implementation, including the criteria in place (marked as Yes in Table 4.1) and the following points:

First, the transformed national environmental protection policy elevates the requirements for using science to assist in developing more environmentally stabilizable fisheries management measures and making more refined and quantitative decisions (Chapter 2). The growing policy demand made by China's central government for the establishment of decision-making processes that enable scientific demonstration and stakeholder participation is consistent with the SBFM principle (Chapter 3). Thus, with stronger political wills, China is reforming its fisheries institutions, and moving towards a more successful SBFM could be the reforming goal.

Second, multiple methods and channels are in place in China for fisheries policymakers to solicit inputs from and communicate with fisheries scientists for decision-making and a satisfactory relationship of mutual trust between fisheries policymakers and scientists is established (Chapter 3).

Third, a more robust fisheries data collection system will benefit from China's increased investment and efforts in improving its fisheries monitoring system. In the draft statute of Fisheries Law amendment published in 2019, more additional fisheries monitoring methods were mandated. In some places, early practices such as using an electronic logbook, dockside monitoring, hail-in and hail-out reporting, and designating landing ports are conducted accompanying the implementation of TACs (Chapter 3).

Fourth, the single-species TAC pilot programs, as the product of fisheries reform after 2016, provide enhanced circumstances for implementing SBFM locally: more structured fisheries decision-making processes with clear management objectives, specific scientific research plans, and closer partnerships between a broader range of stakeholders have been established; more robust data collection systems are developed with the introduction of multiple new fisheries monitoring methods; and, some of these programs have implemented co-management approaches (Chapters 2 and 3). These pilot programs provide a model of decentralization, localization, and collaboration of fisheries management in China's top-down regime, which enable the production of a better BAS by improving data limitation for scientific research and decision-making, increasing the relevance between science being used in decisions, the decisions per se, and the fisheries being managed, and enhancing the compliance of the industry.

Fifth, the newly established hybrid expert advisory committees provide an opportunity for the establishment of a statutorily mandated, structured, and routine fisheries decision-making process for the development of national management measures at large (Chapter 3). They provide formal platforms for collaboration among stakeholders from different circles, including policy and management, science, and the industry, which aids in promoting communication among stakeholders, addressing their divergences, and controlling uncertainties. More importantly, the establishment of these committees mandates cooperation between scientists from different institutions and different disciplines, which tightens the connections within the entire marine fisheries-related scientific enterprise.



## 4.2. Steps moving forward

In general, I suggest that China use the SBFM operating framework and the criteria checklist given in Chapter 1 to evaluate and reform its national marine fisheries management system. Here I am proposing suggestions on key reforms and approaches that should be taken into account.

### 1) Reform legal framework

I propose that China's domestic fisheries legislation provide a provision for BAS-based policymaking. At the least, the nature, type, and scope of the evidence that should be considered in developing fisheries management strategies, as well as the guidelines for the identification of "the best science" should be clarified. The legislation also should contain provisions explicitly created to enable collaboration and sharing of data between various marine fisheries agencies, organizations, and disciplines. Furthermore, management reference (MSY, MEY, OY, and etc.) guiding fisheries scientific research should be mandated.

### 2) Improve the fisheries data collection and verification system

First, I propose developing unified standards for collecting and storing fisheries data. Second, in terms of data collection methods, the NFSS should be reformed to align with policy and research needs, and more fisheries monitoring methods with greater coverage should be implemented. It is worthwhile to research to create the most cost-effective fisheries monitoring system. Third, as soon as possible, methods enable cross-validation of data obtained using various methods. This can be aided by electronically storing data. Given that the draft statute of revised Fisheries Law released in 2019 requires legality labeling of seafood, I propose that China develop a thorough fisheries traceability system that integrates the fishing, refining, and trading processes to further strengthen the fisheries data verification system.

### 3) Establish separate fisheries management regimes for small-scale fisheries and industrial fisheries

Given the distinction between small-scale and industrial fisheries, I propose that China create two separate management systems for fisheries that use small-scale fishing vessels (small-scale fisheries) and fisheries that use medium- and large-scale fishing vessels (industrial fisheries). The national and provincial

governments should devise management priorities, plans, and measures for these two fisheries, respectively. Doing this will promote the relevance between policies, scientific research, and the fisheries being managed, as well as enhance the involvement of local stakeholders in decision-making. The TAC pilot programs and the reformed fishing vessel management system have created favorable conditions for the establishment of the two different regimes (Chapter 2).

#### 4) Establish structured methods for developing fisheries management strategies

I suggest that China establish structured decision-making methods for the development of management strategies, whether for industrial fisheries (at the national level) or for small-scale fisheries (at the provincial level). Clear and unified processes, procedures, and standards for data collection (fishery monitoring, statistics, and surveys), processing (scientific research process and independent peer-review), communication (stakeholder participation and external review), and use (rules to consider and incorporate multi-source data and to address uncertainties and divergences) should be established.

In the decision-making process, the distribution of roles should be clear. The already formed hybrid expert advisory committees, in particular, may play an important role in the national process (for commercial fisheries). Scientist groups are in charge of conducting scientific research, while other members (management circle representatives or fishing industry representatives) are in charge of external review. At the provincial level, I propose that each province's FRI be designated as the permanent body responsible for scientific research. Meanwhile, the government should empower and educate fisheries cooperatives to play a larger role, such as participating in external reviewing advice provided by FRIs. Furthermore, I propose to allow the scientists from the expert advisory committees and the provincial FRIs to cross-review (independent peer review) each other's research plan, results, and conclusion. In addition, the factors that trigger the decision-making process should be clarified, that is, under what circumstances should consider evaluating and updating management strategies.

#### 5) Leverage the localized TAC pilot program to develop SBFM at large

Many favorable conditions for the implementation of SBFM are provided by the TACs pilot programs, including those relating to the decision-making process and fisheries monitoring, which are not

available or are lacking in China's national marine fisheries management system. As a result, I propose that China combine SBFM development with TAC pilot programs. In this case, China can use the SBFM operating framework described in Chapter 1 of this dissertation to review and reform the management framework of its current single-species TAC pilot programs, and then further improve the framework as the scope of TAC implementation expands.

I propose that the TAC pilots be extended in two ways simultaneously. The first is to develop TAC approaches for multi-species fisheries while keeping the pilot in a relatively limited sea area (i.e., coastal sea areas within provincial jurisdictions). Since provincial jurisdictional waters are targeted by small-sized fishing vessels involving in capturing multiple species. The other is to continue concentrating on a single species but to explore the TACs of economically important fish species with a wider distribution and migration range in offshore water managed by the national government. Regardless of the expansion of the dimension, the fisheries management framework should be improved with the goal of implementing SBFM, and the pilots will ultimately provide experience and lessen for building the SBFM framework nationwide.

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## APPENDICES

### APPENDIX A. CHAPTER 1. A LIST OF REPORTS REVIEWED FOR IDENTIFICATION OF SBFM CRITERIA.

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## **APPENDIX B. CHAPTER 2. CORE QUESTIONS/CONVERSATION TOPICS WITH EXPERTS.**

1. How did China's national fisheries management objectives evolve (maximizing economic and social benefits vs ecological benefits)? We divided China's fisheries management history into four phases according to the management objectives, which are 1949-1978, 1979-1999, 2000-2015 and post-2016. Do you agree with us on this? how do you evaluate China's fisheries management in each policy phase?
2. What important government documents or meetings, as well as other events that guided or influenced the development of China's national fisheries management policies in history?
3. Which of China's reform initiatives since 2016 are the most noteworthy? In other words, what are the major changes?
4. Do you think China has come to a critical period of fisheries reform and why?

## **BIOGRAPHY OF THE AUTHOR**

Shu Su was born in Zhejiang, China in 1992. She earned a B.S. in Marine Management with honors from Shanghai Ocean University in 2014. She then was recommended for and enrolled in the School of Marine Sciences at Shanghai Ocean University in Dr. Yi Tang's lab. In 2017, she earned a Master's degree in Fisheries Management with a focus on Fisheries Policy and Regulations with honors. She then received financing from both Shanghai Ocean University and the University of Maine, allowing her to pursue a Ph.D. at the latter. She then moved to the United States and enrolled in Ecology and Environmental Sciences program at the University of Maine in the fall of 2017 in Dr. Yong Chen's lab. Shu is a candidate for the Ph.D. degree in Ecology and Environmental Sciences from the University of Maine in August 2021.