

Opportunity for marine fisheries reform in China

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China's 13th Five-Year Plan, launched in March 2016, provides a sound policy platform for the protection of marine ecosystems and the restoration of capture fisheries within China's exclusive economic zone. What distinguishes China among many other countries striving for marine fisheries reform is its size—accounting for almost one-fifth of global catch volume—and the unique cultural context of its economic and resource management. In this paper, we trace the history of Chinese government priorities, policies, and outcomes related to marine fisheries since the 1978 Economic Reform, and examine how the current leadership's agenda for “ecological civilization” could successfully transform marine resource management in the coming years. We show how China, like many other countries, has experienced a decline in the average trophic level of its capture fisheries during the past few decades, and how its policy design, implementation, and enforcement have influenced the status of its wild fish stocks. To reverse the trend in declining fish stocks, the government is introducing a series of new programs for sustainable fisheries and aquaculture, with greater traceability and accountability in marine resource management and area controls on coastal development. As impressive as these new plans are on paper, we conclude that serious institutional reforms will be needed to achieve a true paradigm shift in marine fisheries management in China. In particular, we recommend new institutions for science-based fisheries management, secure fishing access, policy consistency across provinces, educational programs for fisheries managers, and increasing public access to scientific data.

marine fisheries | institutional reforms | China | Chinese characteristics

China's 13th Five-Year Plan, launched in March 2016, maps a strategic vision for the country's socioeconomic and resource development for the period 2016–2020. For the first time since the Chinese Economic Reform in 1978, this new Five-Year Plan places social equity and environmental protection as priorities on par with economic development. It also includes marine ecosystem protection as a significant component of the central government's environmental agenda. The opportunities that the 13th Five-Year Plan

offers for the restoration and enhancement of wild fisheries, the protection of marine ecosystem services, and the amelioration of coastal pollution are momentous. Achieving the Plan's marine protection objectives will be challenging, however, and will require new approaches for state governance of marine resources, data sharing and use for policy implementation, and an expanded public appreciation of marine ecosystem services for sustained economic growth and environmental quality. Without serious institutional adjustments, even the most limited

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management strategy for conserving China's marine fisheries will be tenuous.

Here, we trace the history of Chinese government priorities, policies, and outcomes related to marine fisheries since the 1978 Economic Reform, and propose a set of institutional initiatives that could help China realize a true paradigm shift in fisheries management. China is not unique in its challenges to sustain marine fisheries. Over the past two decades, most countries have recognized the need to improve fisheries management (1). Efforts to rebuild stocks have been most successful for large, data-rich fisheries that have formal assessments (representing ~20% of global catch volume and ~1% of marine fish stocks), and less successful for small, data-poor fisheries (2, 3). China's marine catch, like that of other Asian countries, is composed largely of nontargeted and unassessed fisheries (or at least stocks for which public data are unavailable), and almost one-third of its total catch is classified as "nei" (not elsewhere identified or included) (3, 4). What distinguishes China among the many countries striving for fisheries reform is its size (accounting for almost one-fifth of global catch volume) (5) and the cultural context of its economic and resource management. China's centrally controlled economy combines strong incentives for state-owned enterprises with an open market system to promote industrial and social modernization. Its socialist market economy and its deep cultural traditions (often referred to as Chinese characteristics) provide major opportunities, but also potential impediments, for sustainable fisheries management.

China's opportunity for fisheries reform rests on the fact that its centralized government has the legitimacy and capability of commanding transformational change in economic and social outcomes according to its policy objectives. Such transformational power is evident by the country's success in reducing the incidence of poverty and food insecurity (as defined by calorie deficits) from over 50 to 8% of its total population within a single generation after the launch of the 1978 Economic Reform (6). Similarly, during the ensuing era of market-oriented growth and increased openness to the global economy in the 1990s and 2000s, China's real gross domestic product (GDP) grew, on average, at an astounding rate of around 10% per annum (*SI Appendix, Fig. S1*) (7). Overall, China experienced four decades of unprecedented economic expansion under centrally planned economic reforms, with the most significant growth occurring through urbanization and industrialization in its coastal provinces. The environmental repercussions of China's economic expansion have been substantial, however, as manifest by widespread pollution, ecosystem degradation, and biodiversity loss (8–12). The impediments to sustainable development in China are revealed in the unintended, and often poorly reported, consequences of economic growth on human health, welfare, and the environment.

In an effort to reconcile economic development with environmental quality and human well-being in recent years, the current leadership under President Xi has promoted an agenda of "ecocivilization," which aims to "build a resource-saving and environment-friendly society based on environmental carrying capacity of resources, the laws of nature, and sustainable development" (13). Emphasis on the concepts of land–sea coordination, green development, and social–ecological balance provides a platform for a paradigm shift in China's marine fisheries management. This paradigm shift will only be realized, however, if concepts are effectively translated into action, compliance, and enforcement at the local level. In the sections that follow, we discuss some of the key Chinese characteristics that

have shaped government objectives related to China's marine economy during the past 40 years, and show how fisheries management and catch have matched these objectives. We then address the critical question concerning China's 13th Five-Year Plan: How might institutions for fisheries management be reconfigured so that local incentives align with the central objective of ecocivilization?

The Cultural Context

One of the biggest challenges for international scientists working in China is understanding the deep cultural roots that influence policy and management practices. Without such knowledge, recommendations for institutional or policy reforms are likely to be inappropriate. A comprehensive analysis of Chinese culture and philosophy is beyond the scope of this paper, but we highlight a few traditional beliefs and modern economic practices that are likely to influence the transition in China's marine fisheries management.

Like many other countries, China developed its economy with agriculture as a foundation, but the symbolism of agriculture extends well beyond the cultivation of crops. Agriculture depicts China's naturalistic view of life, its traditional orientation toward terrestrial systems, and its cultural principles of simplicity and human centrality in the process of ecological change. Agriculture also reflects a preference for taming nature over preserving natural habitats and wild species, despite the benefits of ecosystem services and biodiversity to society—ideas that are gaining greater appreciation in China today (14). It is no surprise that aquaculture accounts for roughly three-quarters of China's fish supplies, and that the country's long history of land-based fish farming has been at the core of its dominance in global aquaculture production (15). The concept of food security in China is associated mainly with staple agricultural systems, but aquaculture plays a central role in meeting national targets for fish supplies.

Chinese characteristics also encompass the yin–yang ideal of harmony and balance that extends to all segments of society, including the marine economy. China's cultural ethic of conservatism permits minimal waste, which helps to explain the country's widespread practice of nonselective fishing, in which all catch is used for some purpose (e.g., food, feed, fertilizer, and other industrial uses). Although moderation is a traditional Chinese value, there is no delusion that humans and ecosystems are in a steady balance. Instead, there is a general acceptance of oscillation from excessive to conservative resource use, as reflected, for example, by President Xi's current attention toward ecocivilization following decades of unrivaled economic expansion.

The challenge of meeting human needs and desires for a population of over 1.3 billion while sustaining natural ecosystem functions is nontrivial. The Chinese desire for avoiding extremes (e.g., social inequality and environmental damage) has been difficult to maintain in a rapidly developing and globalized economy, especially where full impacts of various activities such as use of fossil fuels were not appreciated until recently. In an earlier era, guiding marine resource management in China with the ecological ethic of "nature and man in one" was easier to achieve (16).

The principles embedded in the 1978 Economic Reform—socialism with Chinese characteristics—were derived, at least in part, from the increasing tension between the growing material and cultural needs of the Chinese population and the underdeveloped nature of its production system (17, 18). The socialist

market economy emerged with strong central control over most sectors of society, but with openness to capitalist markets that allowed for growth in industry, nonfarm employment, and personal incomes. Despite the apparent rise in Western-style capitalism, the Chinese culture demonstrates a greater respect for top-down decision-making, mutual responsibility, and deference to leaders and elders. This philosophy, which has no direct translation in the English language, is generally accepted by Chinese citizens as a means of preserving social stability and cultural pride. Most analysts agree that the central government, with its top-down control, has been successful in meeting its broad economic goals.

Like other sectors of the economy, policy priorities for fisheries management are governed by central policy objectives, as outlined in Fig. 1. Three broad sets of policy goals have shaped the transition in China's marine ecosystem and fisheries management since 1978: (i) economic growth and food supply, (ii) development of the blue economy and the expansion of economic activities outside of China's borders ("going out strategy"), and (iii) environmental protection and ecological civilization (ecocivilization). These objectives are cumulative; that is, food production and economic growth have been major objectives since the economic reform of 1978 and remain so today, but environmental protection and ecocivilization are now added as essential elements of sustainable development.

The stakes for improving the economic-social-ecological balance in China's marine fisheries are high. China abuts four major seas—Bohai Sea, Yellow Sea, East China Sea, and South China Sea—and has a coastline of 11,200 miles (19, 20). Over 20,000 marine species are reported off its coasts, including 14% of the world's fish species, 43% of mangrove species, and 33% of the Indo-west Pacific's coral reef species (9). With such vast marine resources, China ranks as the world's leading fishing nation, supplying roughly 15 million metric tons (mmt) of marine catch in

2014 (13% of which came from distant water fleets; *SI Appendix, Fig. S2*) (21). Accordingly, China has the largest fishing fleet and the greatest number of people employed in the fishing sector. Sustaining its capture fisheries and fishing communities is no small feat and will require a long-run commitment to the health and resilience of marine ecosystems.

History of China's Marine Fisheries Management

Marine fisheries management in China reflects the yin-yang principle of unity of opposites—a shifting balance between anthropocentric and ecocentric paradigms. Fig. 1 displays the history of marine policy initiatives since the Economic Reform of 1978. At that time, the government launched a major effort to develop its fisheries and coastal economy in line with its market-oriented approach. A production contract of responsibility for fisheries was established under the household responsibility system (by which local managers are responsible for the profits and losses of an enterprise), and a fishery licensing system was put in place. Given China's extensive marine resources, low level of economic development, and bitter memories of famine, these measures were oriented mainly around the exploitation of fisheries resources and growth in the marine economy (19, 22).

China's annual marine catch, estimated at around 3 mmt in the mid-1970s, increased by only 2% each year through the mid-1980s to reach 3.7 mmt in 1985 (21). This catch level was less than one-half of the estimated maximum sustainable yield (MSY > 8 mmt) (3, 23) and fell far short of the country's self-sufficiency target for fish supplies. As a result, the Chinese government introduced the No. 5 Central Document in 1985, a policy directive that aimed to accelerate marine fisheries development within China's waters by promoting the privatization of fishing vessels and market circulation of seafood products (24). Acknowledging the common goods nature of marine fisheries, the government introduced its

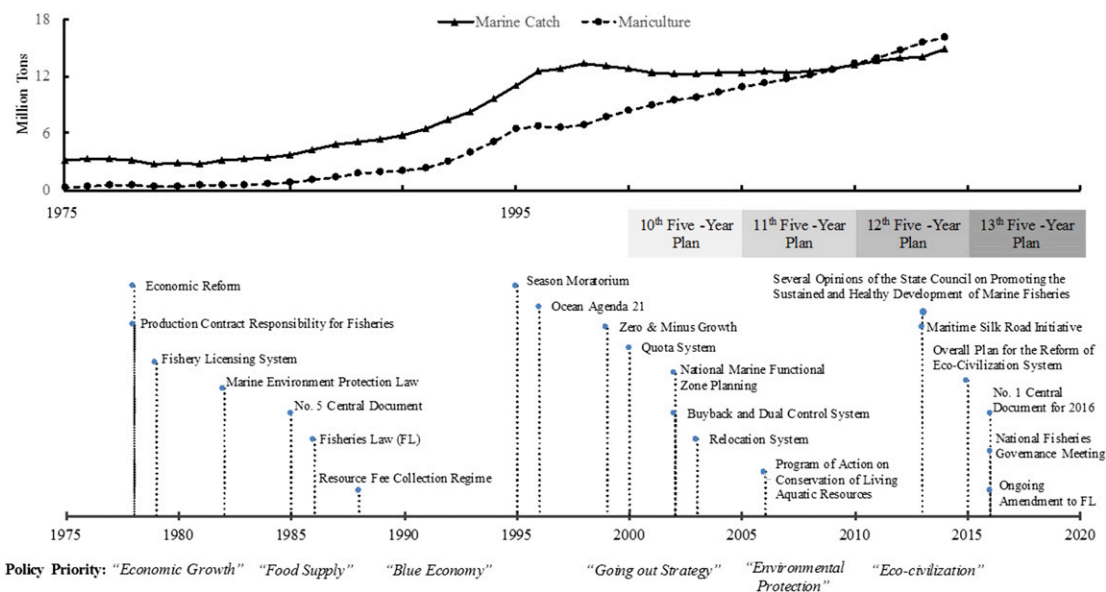


Fig. 1. Marine fish production and milestones in China's fisheries management. Top depicts China's reported marine catch and mariculture production (in million metric tons, excludes aquaplants) (5). The data include distant water fishing, which accounted for 9.2% of China's total marine catch on average between 2007 and 2014 (data on distant water fishing have been published only since 2007) (21). Middle indicates China's Five-Year Plans oriented toward marine fisheries, starting in 2001. Bottom shows timeline of the introduction of central government priorities and policies. These policy priorities are cumulative, meaning that economic growth and food supplies remain a high priority for China's leadership even as environmental protection and ecocivilization gain more attention.

first comprehensive Fisheries Law in 1986, setting specific rules for the utilization and protection of fisheries resources, as well as the protection of fishermen's lawful rights (19). The No. 5 Central Document also encouraged aquaculture and distant water fishing as important supplements to coastal fisheries. Although aquaculture has historically played a vital role in China's total fish production (15), the No. 5 Central Document extended the scope of aquaculture production from mainly land-based systems to marine-based systems with varying trophic scales, from seaweeds to carnivorous species and multitrophic systems. Investments in marine aquaculture and vessels for distant water fishing were further promoted in China's Five-Year Plans after the turn of the 21st century as part of its "going out" strategy (Fig. 1).

The No. 5 Central Document spurred innovation and improvements in fishing technology and operations, and generated remarkable growth in China's fisheries economy. Between 1986 and 1996, the volume of marine capture increased by 11.8% per year on average to reach a peak of 13.3 mmt in 1998 (21). China became the world's largest fishing nation in 1992, and by the mid-1990s, its marine fishing fleet had exceeded 250,000 registered vessels (*SI Appendix, Fig. S3*). Poor enforcement of measures designed to sustain wild fish populations [e.g., the Marine Environmental Protection Law (1982), the Fisheries Law (1986), and the Resource Fee Collection Scheme (1988) as indicated in Fig. 1], resulted in rising catch volume and the decline in numerous fish stocks. Peak fishing seasons for commercial fisheries, defined by times of the year when the catch rate is consistently high, disappeared in most fishing grounds due to stock depletion, as has been the case in many countries around the world.

Intense fishing pressure in the 1990s also corresponded with the increased focus by the central government on the "blue economy" (Fig. 1). In addition to marine fishing activities, other industries, such as offshore petroleum, tourism, transportation, and shipbuilding, were promoted. Between 1990 and 2010, China's marine economy grew to become one of the nation's fastest growing sectors, contributing ~10% of China's annual GDP (9). Coastal reclamation for urban and industrial growth also proceeded at a rapid pace. A 6,800-mile seawall, lining ~60% of China's total coastline and exceeding the length of the ancient Great Wall, was constructed to enclose coastal wetlands for agricultural, aquaculture, and industrial development (10). The cumulative reclaimed area rose from an estimated 0.8 million hectares (ha) in 1990 (9) to over 1.5 million ha in 2015, with roughly one-third of the total area devoted to mariculture (*SI Appendix, Fig. S4*). Together, marine-based industries and other industries in coastal provinces contribute 60% of China's GDP and 90% of its imports and exports (9, 10).

Not surprisingly, coastal conversion and the rapid development of China's marine economy have placed tremendous pressure on the country's marine ecosystems (10). China has lost over one-half of its coastal wetlands, 57% of mangroves, and 80% of coral reefs, most of which are critical spawning, nursing, or feeding grounds for fish (9, 25). Pollutants from agriculture, urbanization, and other land-based industries have further eroded marine ecosystems and many key habitats of wild fisheries, resulting in an estimated economic loss of more than half a billion US dollars annually to the country's marine fisheries (9). Some large marine ecosystems, most notably in the Bohai Sea, have been degraded to the point of becoming dead zones (26).

Table 1. China's major management instruments for marine fisheries (19, 22, 27)

Type	Key examples
Input control	Licensing system Vessel buyback program and dual control* Fishermen relocation program
Output control	Closed seasons and zones Total allowable catch system [†] Zero and minus growth targets
Technical instruments	Minimum mesh size of fishing nets Minimum catch size of fishing targets Ban of destructive fishing methods Proportion limit of undersized fish in catch
Ecological instruments	Enhancement programs Construction of artificial fish reefs Habitat restoration
Economic instruments	Fish stock damage compensation [‡] Resource fee collection regime Subsidies on fishing vessel construction and fuel

*Dual control of both the total number of marine motorized fishing vessels and their total engine power.

[†]In the amended Fisheries Law of 2000, the concept of a fishery quota system, or total allowable catch (TAC), was introduced and incorporated into bilateral fisheries agreements. However, TAC programs have not yet been applied species-specifically for fisheries in China seas, mainly because of inadequate data, monitoring constraints, lack of an appropriate institutional structure, insufficient enforcement, and the widespread indiscriminate fishing practices.

[‡]Ocean or coastal operations, if causing negative impacts to fish stocks, must compensate for the loss in fisheries, for example, by funding stock enhancement and artificial reef construction.

In response to overfishing and the steady degradation of coastal ecosystems, the Chinese government has introduced a series of management measures to rebuild marine fisheries (19, 22, 27). These measures, listed in Table 1, include input and output controls, technical limits such as gear specifications and restrictions, spatial and temporal closures, ecological instruments, and economic incentives. There has also been a symbolic shift in policy language surrounding the exploitation of China's ocean resources. Following the China Ocean Agenda 21, which declared the sustainable development of oceans and coasts as a basic development strategy, the government has introduced a series of Five-Year Plans with greater emphasis on resource conservation, environmental protection, and marine awareness (*SI Appendix, Table S1*).

One of the most notable reforms in fisheries management was the seasonal moratorium on marine fishing, introduced by the government in the mid-1990s. Seasonal closures, which prevent all vessels from fishing for a certain period each year, were established in 1995 for 2.5 mo/y in the Bohai and Yellow Seas, 3 mo/y in the East China Sea, and extended to 2 mo/y in the South China Sea in 1999. Seasonal closures have helped to protect several spawning stocks and juveniles with negligible implementation costs, but these improvements have been offset by heavier-than-usual fishing pressure in the postclosure months (27), and greater pressure on women in fishing communities to find alternative income during the closed seasons (28).

China has established a number of spatial regulations to protect coastal habitats and wild fish resources, but these measures have been fairly weak and have not been carefully evaluated. The country officially has 49 marine protected areas (MPAs), but they span only 0.5% of its total marine area. A mere fraction of this MPA

area—0.05% of China's oceans—is strongly protected in no-take zones (29). China also has 51 marine germplasm resource conservation zones, although monitoring and enforcement of these protected areas has been deficient (30).

In addition to seasonal and spatial closures, the Ministry of Agriculture (MOA) introduced a “zero-growth” strategy for total marine catch in 1999, and a “negative-growth” strategy in 2000. This regime shift, from targeting for high growth in the 1980s to negative growth at the turn of the century, meant that high catches were no longer encouraged—a sharp contrast to earlier periods when an achievement of local governments was measured with the annual increment of catch. As a result, the reported total marine catch leveled off between 2000 and 2009, and has risen only slightly since that time (Fig. 1). China's overall fish production increased by 20% during the 2000s and by threefold over the past two decades, but virtually all of this growth came from aquaculture (21).

China's seasonal closures, spatial regulations, and negative-growth targets have served as blunt regulatory measures in the past. Ecological characteristics of individual species have not been incorporated into these management practices, and

insufficient or erroneous catch monitoring has compromised their effectiveness, resulting in overexploitation or underexploitation of various fish stocks (9). China's agenda for marine resource management has traditionally been set by central authorities in a top-down fashion, yet the data required to regulate and enforce fisheries management and spatial closures must come from the bottom up. Adverse incentives for local officials to increase reported fish catch have often conflicted with sustainable fisheries goals. The absence of transparent data on stock status and ecosystem impacts has hampered central control over marine protection, and there have been few institutional mechanisms in place to incorporate scientific input into the process of fisheries management reforms.

Meanwhile, stock enhancement programs (releasing cultured juveniles for harvest at larger sizes) have been promoted in all coastal provinces. Large-scale implementation of stock enhancement began in 1984 with the landmark case of the Chinese prawn (*Fenneropenaeus chinensis*) in the Bohai Bay (31–33). By 2008, stock enhancement was practiced for over 100 species of finfish, crustaceans, and shellfish, and almost 20 billion juveniles were released annually (20, 33) (SI Appendix, Table S2). Monitoring has

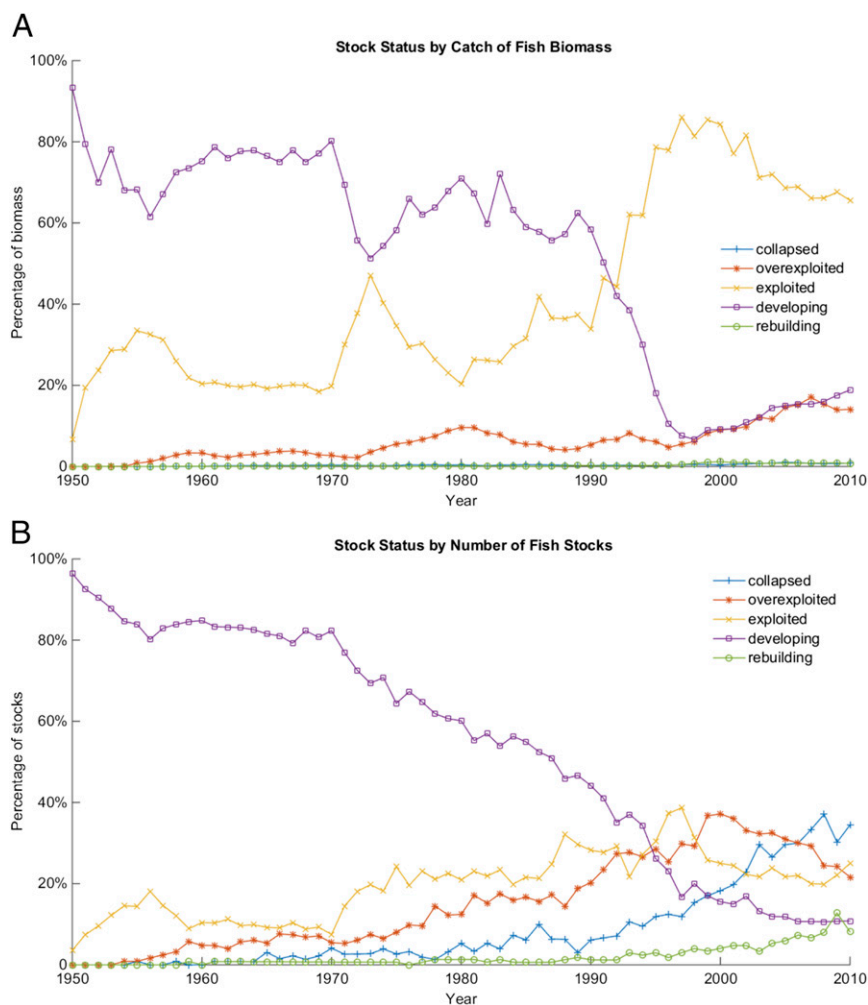


Fig. 2. Fish stock status by catch (A) and number of stocks (B) in China seas. Collapsed: after the peak year, catch/landing is below 10% of maximum landing; overexploited: after the peak year, landing is between 10 and 50% of maximum landing; exploited: landing is above 50% of maximum landing; developing: before the peak year, landing is less than or equal to 50% of maximum landing; rebuilding: after the year of post peak minimum (the minimum landing after the peak), landing is between 10 and 50% of maximum landing. Data source: refs. 38 and 50.

been weak, however, and scientific studies evaluating the economic and biological performance and impacts of enhancement programs have largely been lacking (34).

Various other policy instruments have also been introduced in China to reduce fishing pressure. A vessel buyback program was implemented in 2002, leading to a 31% contraction in the number of commercial fishing vessels between 2002 and 2014 (*SI Appendix, Fig. S3*). In addition, the program attempted to reduce the engine power of individual vessels, but this dual control initiative was largely unsuccessful. Vessel tonnage increased by 20% and the average horsepower of fishing vessels rose by 5%, offsetting the gains from the reduced fleet. Total marine catch actually increased slightly between 2002 and 2014 by 1.6% per annum. In a further effort to downsize the fishing industry, the government implemented the Fishermen Transfer and Fishery Transition Program in 2003, with the aim of moving fishermen to other industries such as fish processing, coastal tourism, and mariculture. Like the dual control program, however, the fisherman transfer program had limited success. From 2003 to 2014, the number of professionals used in marine fisheries fell by about 7% but still exceeded 1 million, whereas the number of traditional fishermen remained above 3 million (21). Overall, these programs have suffered from limited inspection by local governments, the continued presence of illegal fishing vessels, and new entrants into the industry despite the transfer program (27).

Further complicating the picture is a suite of government subsidies for marine fishing. These subsidies include, for example, direct funds for vessel purchases, fishing employment and vessel insurance, seasonal closure allocations, and various tax deductions. Fuel subsidies have also been provided to fishermen to improve their incomes, augment domestic fish supplies, and raise foreign exchange through exports. The fuel subsidy has been politically difficult to remove, but in July 2015, the Ministry of Finance and MOA announced a plan to lower it by 60%, from 3.7 billion US dollars in 2014 to 1.5 billion US dollars in 2019 (35). This plan, if effectively implemented, will have a profound influence on the number of vessels and capacity of China's marine fishing fleet. However, the Chinese government also provides a large subsidy for distant water fishing vessel construction. Although the latter aims to maintain adequate fish supplies for the country without further depleting domestic fisheries, it has largely failed to meet this objective. Roughly one-half of China's distant water catch, mainly composed of high-value species, is sold to foreign markets in developed countries and is not transported back to China (36, 37).

Fishing for Volume or Ecosystem Resilience?

Despite the multitude of stresses on its marine ecosystems, China has been remarkably successful at maintaining a steady volume of wild fish catch over the past 25 years—and indeed at increasing total catch volume slightly since 2008 (Fig. 1). In 2010, four-fifths of China's marine catch biomass within its exclusive economic zone (EEZ) came from stocks classified as fully exploited (65.5%), developing (15.1%), or rebuilding (0.6%), whereas less than one-fifth came from stocks that were overexploited (18%) or collapsed (0.7%) (Fig. 2A) (38). By contrast, China's marine fishery status by the number of fish stocks tells a different story; roughly 57% of the country's fish stocks are overexploited or collapsed (Fig. 2B). Putting these trends together, it appears that a limited number of highly abundant fish stocks are supporting the steady volume of China's wild fish catch over time, whereas the remaining fish stocks are in decline or have collapsed. The share of fish captured from stocks that are overexploited has doubled since the late 1990s (Fig. 2A).

These trends are consistent with evidence on the changing trophic structure of China's marine catch. Half a century ago, China's catch volume was small and composed mainly of large demersal species with high economic value (*SI Appendix, Table S3*). In recent decades, about 80% of the catch in China's EEZ has consisted of low-valued, small pelagic fish such as anchovies, mackerels, and scads—many of which are overfished (*SI Appendix, Fig. S5 and Table S4*). Available data suggest that China has been substantially “fishing down the food web” (38). The mean trophic level of its marine capture fisheries has declined from 3.7 to 3.46 during the past half century, reflecting more than a 50% decrease in the primary production required to sustain its wild catch (39, 40). A similar pattern has occurred in many other countries and large marine ecosystems, although fishing up and fishing through the food chain have also been evident in several regions (40, 41) (*SI Appendix, Fig. S6*).

The combination of sustained catch volume and declining trophic depth, although not intentional, has been tolerated in China because it has provided short-term benefits in the form of domestic fish supplies and fishing incomes (42). Local authorities have been able to report progress in contributing to centrally planned targets for economic growth and food production by maintaining a steady volume of fish biomass. China's massive aquaculture sector, its expanding distant water fishing sector, and its rising fish imports have also helped the country to meet its rising domestic demand for fish—and have thus permitted government officials to skirt tough regulations on its capture fisheries. Until recently, it appears that restoring trophic balance through an ecosystem-based approach (43, 44)—to increase resilience, avoid the risks of fishery depletion, and obtain long-term profits—has ranked relatively low among government priorities, particularly when short-run economic or social costs have been incurred.

Reassessing the trade-offs between conservation and exploitation for food and income has become increasingly critical in China as several of its coastal ecosystems experience irreversible decay. Two key goals of marine resource management in China (and in many other countries) are to preserve the option for future use and, accordingly, to build ecosystem resilience in the face of climate change and other anthropogenic stressors (45). To achieve these goals, there will need to be a concerted effort to preserve marine food webs and ecosystem structure through a combination of well-functioning MPAs and fisheries reform. To minimize social trade-offs, the government will need to continue to promote sustainable aquaculture development that does not damage marine ecosystems, and invest in new job opportunities for fishing communities. Lessons on sustainable fisheries management can be drawn from the successes and failures in other countries, particularly in neighboring countries that share some of China's cultural values on marine resource management (*SI Appendix, Fig. S6*).

A Paradigm Shift?

China's 13th Five-Year Plan now lays the foundation for significant policy reforms in marine fisheries. At least three important new initiatives are worth mentioning as the central leadership's agenda for ecocivilization unfolds. First, the MOA is developing a Five-Year Plan for fisheries (expected to be released by year-end 2016), which will focus on modernization of the traditional fishing industry, sustainable aquaculture, marine environment protection, and sustainable use of wild fish resources (46). Although the interpretation of the latter phrase remains unclear, the plan includes a reduction in the total marine catch volume to 10 mmt (from ~15 mmt currently) by 2020 (46). In November 2016, MOA convened a high-level meeting on limits to distant

water fishing fleets (47). In addition, various measures for domestic fisheries volume control are currently being tested in pilot projects in Zhejiang and Shandong, which set the stage for future applications of volume control throughout China. Specific attention to volume control represents a pivotal change in Chinese fisheries management.

Second, there appears to be a genuinely stronger commitment toward accountability, compliance, enforcement of regulations, monitoring, and public data reporting in China's marine fisheries. Proposed amendments to China's Fisheries Law (2016) include the use of new technological applications such as electronic logbook systems (e-logs) for monitoring commercial fish catch (species and volumes). E-logs will also be used to improve public data collection for legal enforcement of catch volume, seasonal closures, and spatial restrictions. In addition, MOA has recently announced plans to extend seasonal closures to 4.5 mo (from May 1 to September 16) per year in all of China's seas, effective from 2017. This specific action represents a critical step forward in tackling ecological degradation and ecocivilization reform in China's 13th Five-Year Plan.

Third, China's State Oceanic Administration (SOA) is introducing a new system of marine ecological redline regions (MERRs), which will delineate specific boundaries between shoreline development areas and ecologically protected zones. The proposed MERRs will cover at least 30% of China's total ocean area (48). Legal rights of use will be established in specific planning areas, and environmental impact assessments will be required before any type of construction in China's oceans begins. Under the new program, all sea use and coastline construction must be transparent and fully disclosed to the public (49). In addition, SOA plans to implement an ecological liability system whereby any party violating ecological restrictions will be subject to financial penalties for damages. The main intention of the MERRs program, however, is to prevent further ecological damage from occurring in the first place.

These initiatives are impressive and demonstrate a clear commitment to elevating the ecological objectives in fisheries management. By adding marine ecosystem protection as a policy priority alongside economic growth and food production, the Chinese leadership is making a strong investment in the health of future fisheries as well as other ocean uses. In a recent assessment of global fisheries stocks, Costello et al. (3) highlighted China's enormous potential for enhancing fisheries biomass, stocks, and profits in the next few decades through management reform, especially given the country's size and nonselective catch practices. There is no "one-size-fits-all" management strategy that will achieve the desired balance between food production, economic growth, and ecological resilience in all of China's fishing regions. Simply agreeing on the desired balance is a daunting task given China's large population, expanding labor force, and overarching goal of social stability. A more general conclusion from Costello et al.'s (3) assessment is therefore worth emphasizing: the greatest economic and ecological improvements in China's fisheries will come from reshaping institutions. Without institutional change, China will be unable to implement widely accepted ideas on sustainable fisheries management.

What types of institutional change are needed in China to realize its plans for fisheries recovery and marine ecosystem resilience in the 13th Five-Year Plan? We suggest six specific measures:

- i) The introduction of regional science management councils, whereby all important stakeholder groups are well represented, and the best available science is used in the decision-making process for marine fisheries management. Within such a system, fishing limits would not exceed scientifically determined

sustainable levels, and fishermen would need to comply with these limits. Key stakeholder groups would include government, industry, independent scientists, and civil society.

- ii) The introduction of incentives that improve fishing incomes without increasing fishing effort and aggregate fish catch, for example, through the allocation of individual fishing limits or quotas. Funding programs to remove excessive fishing capacity and to promote alternative employment opportunities and workforce training would enhance the success of this initiative, as would the removal of most existing subsidies to the fishing industry.
- iii) The expansion, effective implementation, enforcement, and sustained financing of MPAs throughout China's EEZ to enhance the recovery of fisheries stocks and the resilience of marine ecosystems.
- iv) The implementation of uniform management and enforcement mechanisms across provinces in China to ensure that communities and the fishing industry throughout the country are subject to equivalent and effective fisheries regulations.
- v) The promotion of educational opportunities for scientists and fisheries managers to learn from the successes and failures of other nations in marine resource management.
- vi) The establishment of a public process for data sharing and transparency on fisheries practices, catch, stock status, and ecological impacts.

If China is able to carry out these institutional reforms, it will likely experience a true paradigm shift in fisheries management. To be successful, however, the government will need to commit financial resources to cover the transition costs of institutional change. Without adequate funding, efforts to transform fisheries management in China will likely be futile.

Based on the cultural characteristics that underpin China's economic model and resource use, it is clear that some of these institutional changes will be easier to achieve than others. For example, promoting scientific education for fisheries managers and improved mechanisms for data sharing will be easier to implement than creating institutions for public participation in the decision-making process. Strengthening the ties between central and local leadership is feasible—and essential—for marine fisheries reform in China, as is the harmonization of regulations and enforcement mechanisms across all coastal provinces. Using the best available science in decision-making for all fishing regions and introducing secure access approaches in selected areas in line with science-based recommendations are also highly achievable goals.

This is a pivotal time for fisheries and marine ecosystems in China. The central government has the power to implement transformative change in marine fisheries management that could benefit its citizens substantially, as well as position the country to be a global leader in fishery reforms and marine protection. Reforms will not be easy, but firm groundwork has been laid, and policies are moving in the right direction. Because the window of time to make the transition is closing as wild fish stocks become further depleted, time is of the essence. As the classic Chinese saying goes, "Ten thousand years are too long. Seize the day, seize the hour." We urge Chinese leaders to pursue their agenda of ecocivilization reforms vigorously within the 13th Five-Year Plan.

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