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Task Team 2
Living Marine Resources and Biodiversity

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Executive Summary

Feeding more than nine billion people by 2050 while protecting biodiversity and the natural systems on which life depends is one of the greatest planetary challenges we face today. As one of the world's top seafood producing nations, China has a significant stake in solving this challenge.

The ocean shelters a vast array of species, produces most of the oxygen we breathe and nourishes billions of people who depend upon the sea for food and livelihoods. However, while the ocean's ability to produce food is enormous, it is limited. About one-third of fisheries for which data exist are overexploited or collapsed; the actual number may be even higher as many countries do not have capacity to measure their fisheries' output, much less manage them.

Aquaculture production has nearly surpassed wild fisheries as a source of food, and there is considerable potential in the ocean for even greater production. Still, aquaculture can have negative impacts: it can displace native coastal and marine ecosystems, require large inputs of wild fish for feed, introduce non-native species and diseases and cause significant pollution. Sustainably managing living marine resources to optimize economic production over the long term while minimizing damage to the ecosystem is not an easy task, although there are many proven solutions and new ones in development to achieve these goals.

Unfortunately, climate change will likely increase the challenge of feeding people sustainably. Warming and acidifying waters are altering the productivity of many marine species and driving others across borders, intensifying the struggle for resources among competing countries. More extreme storms, altered weather patterns and disrupted water and nutrient cycles will increasingly stress coastal food production systems. To date, few countries have found ways to handle these changes effectively at scale.

China's challenges in managing its living marine resources are similar to those facing other countries. However, the scale of China's economy makes its situation more extreme. Rapid economic growth along China's coasts over the last 40 years has imposed significant cost on the coastal and marine environment. Development, mariculture and pollution have damaged more than half of the country's coastal wetlands, nearly 60% of mangroves, 80% of coral reefs, and significant portions of the seagrass beds, tidal marshes and tidal flats that once provided critical habitat for a diverse array of marine life. China produces enormous quantities of wild and farmed seafood—by far, it is the world's top producer by volume (though not by value)—but the rate of extraction and exploitation have outstripped the ability of marine ecosystems to absorb the impact, and top marine predators have been almost entirely eliminated. In addition, China employs more people in the fishing and aquaculture sector than any other nation, making the social dimension of bringing these industries under control much more challenging.

Despite the difficulty, China has begun making significant progress in addressing these challenges. President Xi Jinping has committed to creating an ecological civilization, a balanced integration of economic and environmental goals that is now enshrined in the constitution. And the government has followed with bold, concrete actions, including strengthening the seasonal closings of nearly all domestic fisheries each year, protecting habitat and establishing marine reserves, imposing stricter standards for discharging pollutants into the sea, shutting down illegal mariculture operations and establishing a total acreage limit for mariculture.

However, more must be done if China is to reestablish healthy coastal and marine ecosystems that can sustainably provide the levels of nutritional and economic benefits historically enjoyed. To create an ecological civilization, legal protections for living marine resources must be strengthened, monitoring expanded and compliance improved, and more critical habitat restored and protected. Furthermore, because climate change is affecting living marine resources on a global scale, and because so many of these resources are shared, especially within Asia, an ecological civilization at home depends upon stronger regional and global governance to ensure living marine resources are managed sustainably at scale.

Although these challenges are not easy, solving them will produce enormous direct benefits for China by securing a large and sustainable supply of high-value seafood and livelihoods in its own waters. It will also create tremendous opportunities for China to demonstrate regional and global leadership on oceans. President Xi's Maritime Silk Road initiative represents a historic opportunity for China to promote global marine governance and advance the UN Sustainable Development Goals. By collaborating with countries along the Silk Road, China can promote the conservation of marine biodiversity, empower women and small-scale fishing communities to develop their marine resources sustainably and feed themselves, and create a platform for countries to work together to manage the impacts of climate change on living marine resources.

This report proposes several recommendations to guide China's next steps as it endeavors to create an ecological civilization domestically and abroad for living marine resources.

1. **Strengthen legal protections for coastal and marine ecosystems, while promoting sustainable production.** China should consider enacting a new aquaculture law that places limits on facilities' waste discharge and resource use and which should mandate stock reporting by all facilities, authorize routine onsite inspections and include other provisions that mitigate the industry's impacts on coastal and marine ecosystems. Ongoing efforts to shift toward output control in its capture fisheries should be integrated with rights-based approaches that allocate

portions of the catch or local fishing areas to the fishing industry and communities. A Marine Habitat Conservation Law (MHCL) should also be enacted, to strengthen protections for coastal and marine habitats and encourage significant rehabilitation of lost ecosystem functions and resiliency.

2. **Implement a high tech monitoring system to combat corrupt and illegal activities that undermine compliance and to improve marine science.** China's innovation in sensors, networking technologies and artificial intelligence can help create a transparent system that can operate across agencies, and even globally, to facilitate enforcement and promote compliance in protecting marine ecosystems. In addition to promoting compliance, a high-tech monitoring system will generate data for ecosystem understanding, emergency contingency actions, and climate change response and mitigation measures.
3. **Restore lost coastal and marine ecosystem functions needed to support fisheries production, biodiversity conservation and resilience to development, pollution and climate change.** Further actions than the ongoing redlining process need to be taken to restore lost habitat, including mangroves, seagrass beds, tidal marshes and flats, and coral reefs. If China's coastal and marine ecosystems are to withstand the impacts of pollution and climate change and continue to be a source of tremendous prosperity and food production, China should consider i) establishing a national "marine ecological report card" on the health of China's coastal and marine ecosystems; and ii) develop a national plan of action to restore lost ecosystem functions and services.
4. **Create a network of partnerships among countries along the Maritime Silk Road to promote sustainable marine governance and achieve the Sustainable Development Goals.** The Maritime Silk Road Initiative represents a historic opportunity for China to demonstrate leadership in global marine governance and advance the UN Sustainable Development Goals. Under this Initiative, China should consider creating a network of partnerships to encourage mutual learning and promote joint actions that promote a healthy ocean. Sustainability along the Marine Silk Road can also be promoted by information sharing and capacity building on developing and managing living marine resources sustainably. China's leadership could be further demonstrated by using the Maritime Silk Road Initiative to catalyze the development of regional and global approaches that can mitigate the impact of climate change on living marine resources.
5. **Assess the effects of climate change on living marine resources and evaluate ways to mitigate the impacts.** China could promote more research into the impact of climate change on capture fisheries and mariculture, and the natural ecosystem services upon which these industries

depend. China may wish to consider ways to not only mitigate the effects of climate change, but effectively adapt to it.

The planetary challenge the world faces—namely, how to feed a growing population without destroying the ecosystem that supports us—is unquestionably not China's challenge alone. However, given the enormity of seafood it produces and consumes, the size of its marine economy and the multitudes it employs in its seafood industries, perhaps few other countries have as much at stake in ensuring the planet's marine resources are sustainable. Likewise, few others are as influential regionally and globally and have as much to offer diplomatically, technically and scientifically. As China seeks to create an ecological civilization there is both an opportunity and a need to join with other countries to protect the ocean that nourishes and sustains us all.

1. Introduction

1.1 The value of living marine resources

Ocean ecosystems harbor immense biodiversity, an abundance of life that provides numerous benefits for people. These living marine resources have cultural value in many places, playing a central role in mythology, religion, symbols and stories worldwide, from antiquity right up to modern times. Many people enjoy directly interacting with ocean life through scuba diving, birdwatching, sport fishing and other forms of recreation, and these activities support a lucrative global tourism industry. Living marine resources also provide important regulating and supporting services, such as oxygen production, nutrient cycling, water filtration, carbon sequestration and storm buffering. The value of these services to a growing ocean economy is difficult to estimate, but is likely on the order of hundreds of billions, if not trillions, of U.S. dollars worldwide each year (de Groot et al., 2012). Yet, the full breadth of services provided by living marine resources is not well appreciated. Consequently too many policies fail to safeguard living marine resources, biodiversity is in decline and ecosystem services and the value they provide are being lost; this poses a risk to human health, food security, poverty and livelihoods.

Perhaps the most significant and widespread ecosystem service delivered by life in the oceans is provision of seafood through wild capture fisheries and mariculture. For some, seafood makes for a more interesting and varied diet and provides a deeper connection to the sea. For others, especially in many parts of the developing tropics, seafood is a critical component of food and nutrition security. Indeed, 20% of the world's population is critically dependent upon seafood as a source of micronutrients, so called because only small amounts are required to fulfill vital physiological functions (Golden, 2016). Fisheries and mariculture not only provide food, but income and livelihood, to 13.8 million fisheries practitioners in

China. These benefits are not limited solely to those who harvest food from the sea, but also extend to the many support services—gear manufacturers, vessel mechanics, etc.—as well as processors, restaurants and other businesses along the supply chain that are also built on seafood. The value of these other seafood-dependent industries can substantially add to the employment and revenue generated by the production sectors.

These promising findings notwithstanding, most future increases in the global supply of seafood will come from mariculture production. The volume of seafood generated by mariculture has long been on the rise, and likely will soon equal and surpass production from wild capture fisheries. Moreover, there is considerable potential for additional mariculture production worldwide (Gentry et al., 2017).

On the other hand, mariculture can also pose considerable risks to marine ecosystems and other values generated by living marine resources, including wild capture fisheries. For example, large-scale infestations of green algae *Ulva prolifera* off the coast of the northern Yellow Sea have occurred repeatedly in recent years, threatening the valuable tourism industry in the region. While multiple factors contributed to these infestations, the most important driver has been identified as coastal seaweed farms from as far away as Jiangsu Province that provided substantial additional surface area for algal growth (Pang et al., 2010; Liu et al., 2013).

Of course mariculture can also produce ecological benefits, including water filtration and creation of nursery habitat by seaweed aquaculture (Liu et al., 2017), but these benefits are typically ancillary rather than planned or optimized.

1.2 China's living marine resources

The exclusive economic zone (EEZ) of China covers a wide coastal ocean area from a coastline that spans 18,000 kilometers across more than 20° of latitude. This EEZ stretches from the tropical waters of the Beibu Gulf and South China Sea, through the sub-tropical East China Sea, and into the temperate Yellow Sea in the north. China's EEZ and the Bohai Sea represent three of the world's large marine ecosystems (LMEs), and their pronounced biogeographic gradient means that the diversity of living marine resources in China is substantial. Indeed, the ocean economy, including the value generated by living marine resources and other aspects of marine ecosystems, has become an important part of China's economic growth, generating more than 700 billion RMB annually, or more than 9% of GDP in 2017 (SOA, 2018a).

Of the many values provided by living marine resources, China today depends most heavily on domestic production of seafood, which fulfills most of its demand (Figure 1). Chinese seafood production is consumed largely within China, accounting for 85-95% of domestic aquatic product consumption. The export volume of aquatic products is only around 6% of total production; however, China's seafood export is at the high-value end. In 2016, the export value of aquatic products was US$20.7 billion, or 28% of China's gross export of agricultural products. By comparison, the import value of aquatic products was US$9.4 billion, much of which was low-value fishmeal (BOF, 2017).

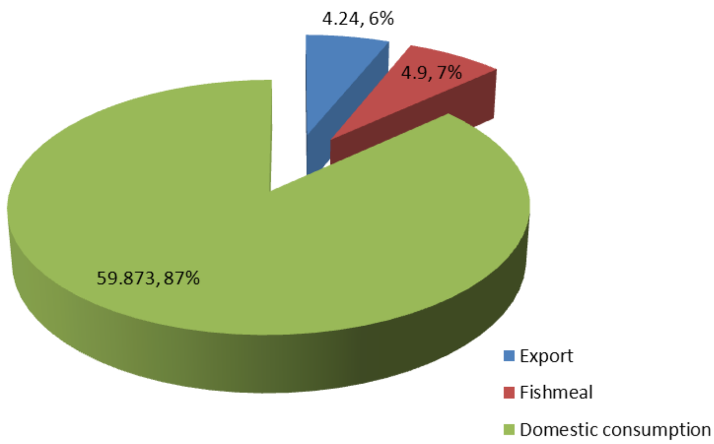

Figure 1| Markets for Aquatic Products in China, 2016 (data in million metric tons and percentage)(BOF, 2017)

China's demand for seafood and other high-value marine products is growing and China is increasingly importing seafood, especially high-value products from foreign sources (MOA, 2018). Marine ecosystems around China are overexploited and degraded, reducing China's ability to produce high-value seafood and rendering its ecosystems more vulnerable to climate change and at risk of collapse. Few fisheries in distant waters offer significant potential for additional supply and often lack the necessary investments for sustainability (e.g. technical expertise, technology, financing). Similarly, overseas sources of mariculture products will need to be developed sustainably in order to ensure a reliable long-term supply. If China is to meet the growing demand for high-value seafood that its increasingly affluent population prefers, it will need to restore its domestic marine ecosystems, make domestic seafood production sustainable and find ways to encourage other countries to manage their resources sustainably, all while building resilience to climate change. These changes can protect and grow the diverse industries beyond the production sectors that depend on seafood in China.

In 2016, the total value of China's fishery economy was 2.366 trillion yuan, of which the output value of fisheries was 1.2 trillion yuan, and the related industry and construction, circulation and services' output value was about 1.16 trillion yuan. The largest proportion of fishery output value was freshwater aquaculture (581.3 billion yuan), followed by mariculture (314 billion yuan) and marine capture fisheries (197.7 billion yuan). Recreational fisheries accounted for 66.45 billion yuan and continue to rise. There were about 9,700 aquatic product processing enterprises in the country, and the annual processing capacity was about 21.65 million tons, including 17.75 million tons of processing capacity for seafood (Figure 2).

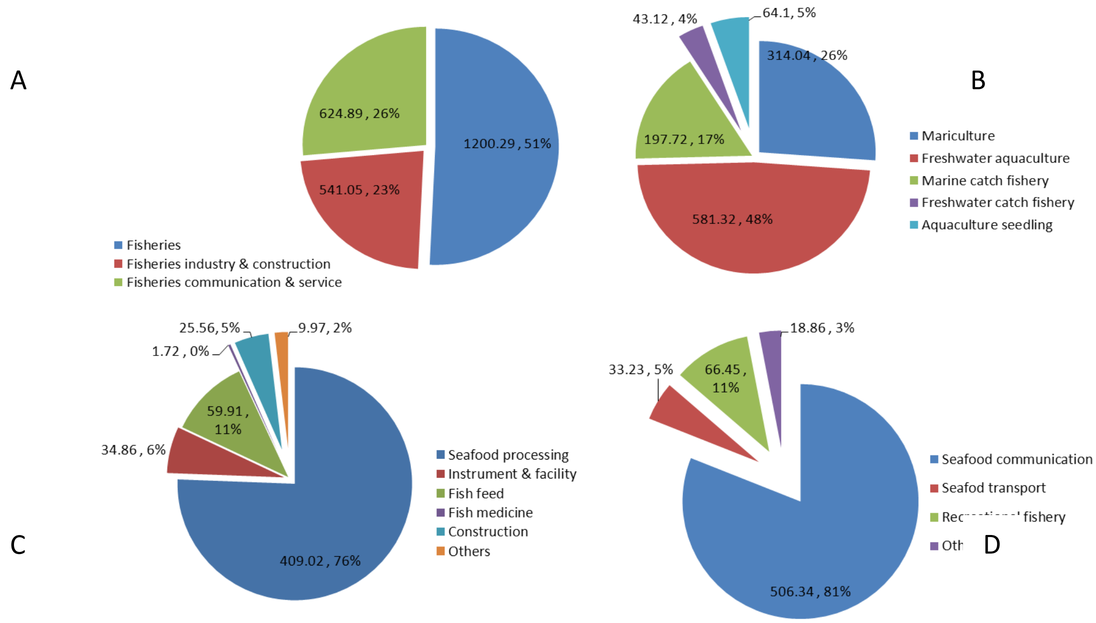

Figure 2 | Structure and Composition of China's Seafood Economy, 2016 (BOF, 2017)

A. Value and percentage of major components for China fisheries economy;

B. Value and percentage of major components for China fishery;

C. Value and percentage of major components for China fishery-related industry and construction;

D. Value and percentage of major components for China fishery-related communication and service

2. Status and Trends

2.1 Aquatic food demand in China

For nearly half a century, China's aquatic food apparent consumption has been steadily growing, and now represents around 37% of all aquatic food produced globally. In the last decade, 65% of the increase in the global demand for aquatic food can be attributed to China (Nikolik et al., 2018). From 1993-2013, growth in per capita apparent consumption of aquatic food in China increased 5% annually to 38kg/person, and reached 49.9 kg in 2016, already double the global average of just over 20kg/person (FAO, 2016). The rate of increase in aquatic food production has far outpaced China's relatively flat population growth, so aquatic food is becoming a larger component of the national diet (FAO, 2016). With a population of over 1.3 billion people continuing to grow modestly at 0.5% annually, the supply of aquatic food needed to meet the demand in China will continue to increase (World Bank, 2018). A recent estimate predicts that, over the next decade, 53% of global aquatic food consumption will increase solely due to demand in China, with per capita consumption expected to reach 50kg/person by 2026 (Nikolik et al., 2018). Economic value associated with this demand could increase at a 4% compound annual growth rate until 2020, reaching a market value of US$80 billion by 2021 (AAFC, 2017).

However, unlike some nations with high rates of aquatic food consumption, China's high rate of consumption does not necessarily reflect strong dependence on aquatic food for nutrition or food security. In 2011, fish comprised only 2% of the diet of China's rural population and 5% of the diet of the urban population, whereas the percentage of land-based sources of protein was nearly three times higher in either population (Liu, 2013). This rural/urban divide suggests that increasing aquatic food consumption reflects growing affluence in China and preference for, rather than dependence on, higher quality food. Indeed, China's demand for aquatic food and other high-value marine products is growing and China is increasingly importing seafood, especially high-value products, from foreign sources (MOA, 2018). In 2017, imports rose by 21.7% in volume and 21.03 % in value (Godfrey, 2018). Growth of China's middle class, improved product handling, storage and transportation infrastructure; and access to new markets are important drivers of changes in Chinese consumer preferences.

2.2 Mariculture production in China

China's aquaculture industry has grown markedly for more than six decades (Figure 3), increasing from fewer than 100,000 tons in 1950, to 3.6 million tons in 1985, and then to 51 million tons in 2016, making it the largest aquaculture producer in the world, and accounting for around two-thirds of global production. During this rapid growth, aquaculture has made significant contributions to safeguarding market supply, increasing rural income, improving the export competitiveness of agricultural products, improving people's diets and guaranteeing food security. In 2016 mariculture production was 19.6 million tons, or 56% of total seafood production in China. China currently contributes 60% of global mariculture production and now produces considerably more aquatic products through aquaculture than wild capture fisheries in both marine and freshwater systems (FAO, 2016). Freshwater products account for around 62% of total aquaculture production in China, but mariculture production is still substantial and continues to grow.

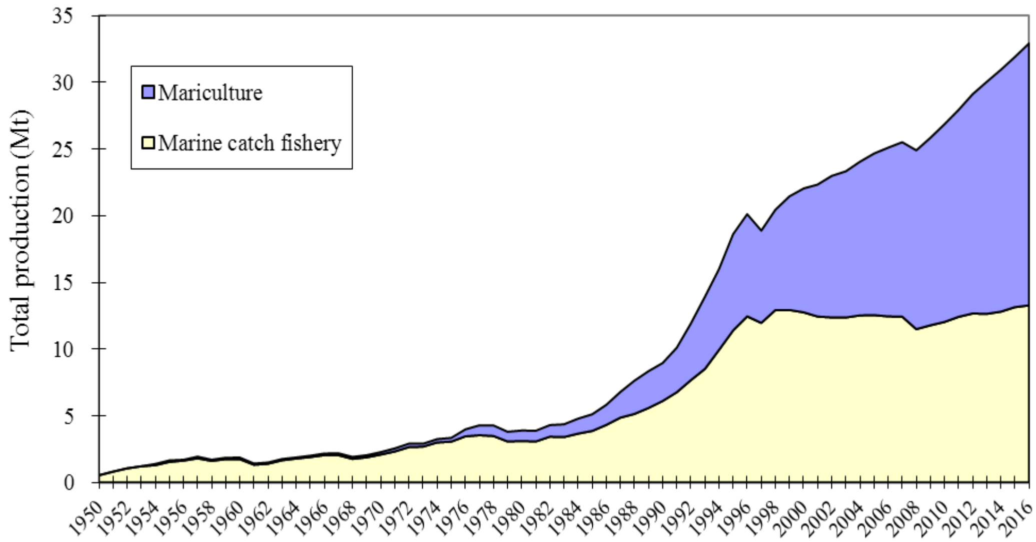

Figure 3 | Marine Fisheries Production in China, 1950-2016

China's mariculture industry is obviously different from that of other countries in the world. Major aquaculture countries, such as Norway rely mainly on one or a few dominant species, and the mode of operation is also relatively simple; China boasts a diversified range of cultured species, methods and scales. There are more than 70 registered mariculture organisms in China including finfish, shellfish, seaweed and sea cucumbers. A considerable proportion of them are grown by photosynthesis or filter feeding plankton; no feed is needed during the culture process. Only finfish and some shrimps and crabs are fed species; their total production accounts for about 15% of the total mariculture output (Figure 4).

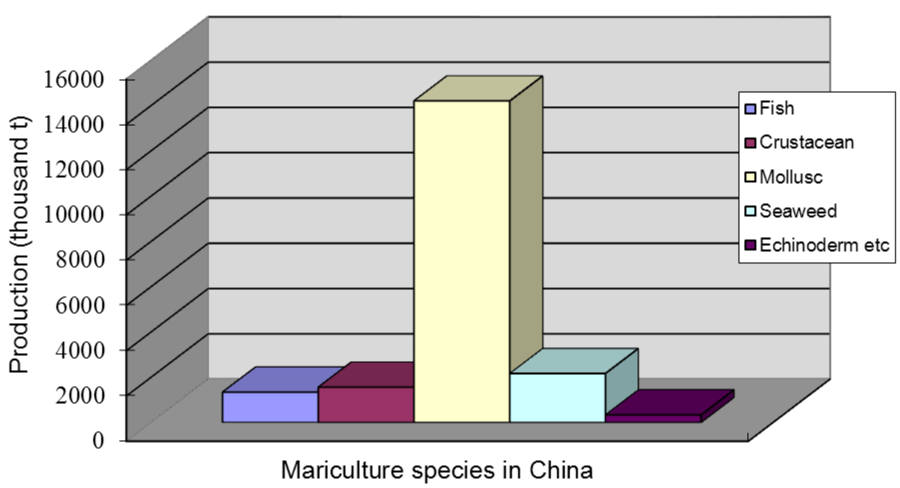

Figure 4 | Total Production of Mariculture Species in China, 2016 (BOF, 2017)

Backed by powerful policy, fiscal and technological support, mariculture has been an important driver of the rapid development of the ocean economy in past decades. Since 1950, the industry has enjoyed development opportunities in inland and coastal areas because the central government has adopted a "cultivation-focused" or "aquaculture priority" development policy, resulting in mariculture production doubling every four to five years. Five "mariculture tides", or great leaps forward in the scale of development, have greatly speeded up the scale of production and diversification. Backed by favorable policies, these leaps were further enabled by technical breakthroughs in the culture of kelp, scallops and shrimps; large-scale seedling production of marine fishes; and, more recently, development in mariculture of sea cucumbers and other high-value species. Since 1990, China has made considerable progress in breeding new varieties and strains of aquaculture organisms, disease control, culture technology optimization and harvest mechanization due to technological improvement and financial input from the central and provincial governments. Currently there are thousands of research teams from Chinese universities and institutes working on a full range of aquaculture-related topics.

Since the 12th Five Year Plan period (2011-2015), China has made a transformation in aquaculture policies by highlighting sustainable development. In April 2015 the China State Council issued the Water Pollution Prevention Action Plan, which clearly stipulates that an ecologically healthy aquaculture will be promoted, with aquaculture prohibition areas drawn for key rivers, lakes and coastal seas; upgrading of aquaculture facilities; strengthening the control over feeds and chemicals; and encouraging deep water aquaculture practices. An upper limit of 2.2 million hectares was also established for mariculture, while "volume reduction & value increase, quality and efficiency improvement, and green development" were set as targets for 2020 by the fisheries' 13th Five Year Plan and more recent regulations. In the long run, China's policy on mariculture will be "health and sustainability", and relevant laws and regulations have already been enacted so as to guarantee implementation.

The environmental impacts of aquaculture (e.g. waste discharge, misapplication of chemicals) have drawn marked public concern in China over the last few years, as awareness of ecosystems and environmental health increases; progress is noticeable in the mass closure of coastal farms and appearance of extensive coastal restoration projects. The clear division of responsibility in the new regulations, as well as the reorganization of ministries and shift in China's administration in 2017-2018, promises to significantly improve ocean and mariculture governance.

2.3 Fisheries production in China

China has recognized the importance of fisheries and become more dedicated to their conservation. For example, fishery management in China has evolved considerably in the past half century. Shen and Heino (2014) outline four major stages from the mid-20th century to the present: The first stage in the 1950s was characterized by steady economic and technological development, transforming fisheries from a previously underdeveloped and largely artisanal nature to a more significant industrial enterprise. The second stage in the 1960s saw the majority of fishery resources become fully utilized as industrialization commenced. The third stage, spanning the 1970s and 1980s, involved the subsequent predictable collapse of many stocks in the absence of effective management. The fourth and current stage beginning in the 1990s ushered in the era of more rigorous fishery management in China in response to the stock collapses experienced in the third stage.

Despite the rapid rise and expected continued growth of mariculture production in China, the importance of wild capture fisheries is still significant. China still leads the world in marine wild fisheries catch, by far. In 2013, China's fishing fleets harvested nearly 14 million tons, which is nearly three times the catch of the next largest fishing nation, Indonesia (Zhang, 2015). Approximately 90% of the catch is from domestic waters, with the remaining 10% from the distant water fleet (DWF) (Zhang, 2015). While, total catch from China's EEZ has changed little since the mid-1990s, the catch by the DWF has nearly doubled during that time (Shen & Heino, 2014; Zhang, 2015). The national fishing fleet tripled in size from 1990-2010 (Shen & Heino, 2014), despite domestic catch remaining static. However, in 2017, MOA set the "double control" goal, which stipulated that by 2020, the number of fishing vessels will be reduced by 20,000 and fleet power will be decreased by 1.5 million kilowatts, while also reducing the domestic marine catch to no more than 10 million tons. Therefore, the potential for continued growth in the supply of seafood from foreign waters harvested by the DWF will be an important factor in shaping the future of fisheries and fishery policies in China.

Fisheries remain an important economic driver in China. In terms of global markets, China is among the top three nations worldwide in the value of both seafood exports (#1 at nearly US$20 billion) and imports (#3 at US$8 billion) (Zhang, 2015). Although mariculture production now far exceeds that of wild fisheries, China's position in the global seafood supply chain, its world-leading volume of wild fisheries catch, and the size of its fisheries labor force mean that management of wild fisheries remains a critical policy issue for social, economic and environmental reasons.

The national fishing fleet in China is incredibly diverse, fishing from coastal waters, across the continental shelf and beyond. Furthermore, the fleet is distributed among 11 coastal provinces spanning China's 18,000 kilometers of coastline and three large marine ecosystems, and catches more than 1,000 species commercially (Liang et al., 2018). Generalizing such a vast and dispersed fleet that utilizes a diverse array of resources is not straightforward, although a few traits are widespread. These fisheries for the most part are highly multispecies and use fairly unselective gears; targeted single species fisheries are very rare. New national fishery policies in China intend to address these widespread traits, while also enabling management to be tailored to unique attributes at the regional and local levels.

2.4 Coastal and marine ecosystem health in China

China's diverse coastal and marine ecosystems, including estuaries, wetlands, mangroves, coral reefs, seagrass beds, upwelling systems and more, have the potential to provide a basis for China's transition to a blue economy, especially if China's fisheries and mariculture can be managed sustainably. Coastal and marine habitats in China are home to more than 20,000 species, including 3,000 species of fishes alone. China is home to approximately 5.8 million hectares of coastal wetlands, accounting for around 11% of the country's total wetland area. These wetlands provide US$200 billion worth of ecosystem services each year, such as food production and shoreline stabilization, accounting for 16% of the total ecological services provided by all ecosystems in the country (Ma et al., 2014). Wetlands are particularly important as feeding, spawning, nursery and overwintering habitats for wild fishes and invertebrates. In 2011, China's coastal wetlands provided 28 million tons of farmed and wild-caught seafood, accounting for 20% of the global total seafood production from fisheries and mariculture (Ma et al., 2014).

Despite their importance, China has cumulatively lost more than 50% of its coastal wetlands, 57% of mangroves and 80% of coral reefs, since the 1950s (Blomeyer et al., 2012; Ma et al.,2014). Coastal wetlands continue to disappear at rates around 2.4 times higher than those of wetlands further inland. During the last two decades, a nearly 11,000 kilometer seawall, lining around 60% of China's total coastline and exceeding the length of the Great Wall, has been constructed to defend storm surge and enclose coastal wetlands for mariculture, agriculture and industrial uses (Ma et al., 2014). The cumulative reclaimed area rose from an estimated 800,000 hectares in 1990 to over 1.5 million hectares in 2015, with roughly one-third of the total area devoted to mariculture development (Figure 5). Rich in biodiversity, the Yellow Sea region contains important fishing grounds and is an important stopover for migratory birds. Since the early 1980s the region has lost 35% of intertidal habitat area due to reclamation, especially along the coasts of Jiangsu and Shanghai at the southern extent. Much of the intertidal zone, especially in the Bohai Sea, is now occupied by mariculture ponds and cages. Loss of habitats can lead to degradation of associated ecosystem functions and services, and ultimately increase the risk of red and green tide outbreaks and vulnerability to natural disasters such as floods and storm damage. It is estimated that the annual economic cost of the loss of coastal wetlands in China is on the order of US$46 billion (An et al., 2007b).

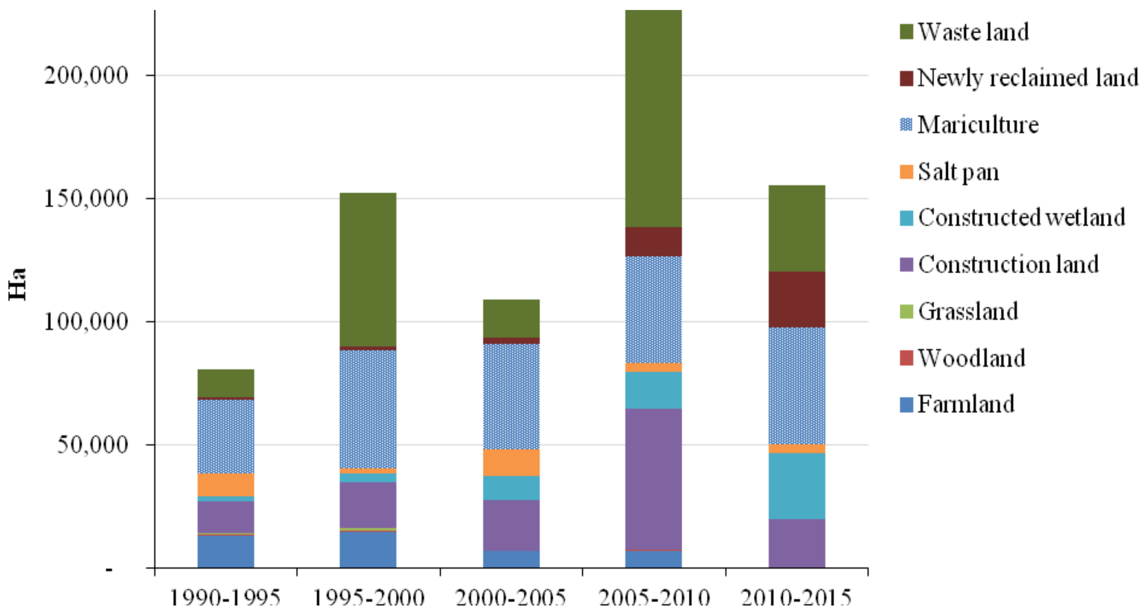

Figure 5 | Coastal Reclaimed Land Use in China, 1990-2015 (Cao et al., 2017)

It is not only coastal engineering and development that have driven habitat loss in China. Pollutants from mariculture, agriculture and other land-based industries have further eroded key habitats, including those further offshore that are buffered to some degree from alteration of the coastal zone. China's polluted ocean area exceeds about half of its total ocean area, resulting in an estimated economic loss of more than US$500 million annually to the country's marine fisheries (CCICED, 2013). Some marine ecosystems, most notably the Bohai Sea and northern Yellow Sea, have been severely degraded and become seasonally hypoxic (Gao et al., 2014; Zhai, 2018). Severe eutrophic pollution has occurred in Liaodong Bay, Bohai Bay, Jiaozhou Bay, Yangtze River Estuary, Hangzhou Bay, Minjiang Estuary and Pearl River Estuary, compromising survival of fishes and other living marine resources.

The wild fisheries and mariculture operations that depend upon the healthy marine ecosystems created by marine biodiversity are also one of the major threats to that diversity. Overharvesting and destructive fishing by trawls, fine nets and traps can lead to loss of nursery habitats for many economically important fish species. Over-development of large-scale mariculture can also strain coastal and marine ecosystems and reduce wild fish abundance and benthic biodiversity.

3. Challenges to the Management of Living Marine Resources

China's government has taken and continues to take great strides to strengthen management of the country's living marine resources. Doing so is not easy for any country, but it is especially challenging in China, whose living marine resources yield more wild fisheries and aquaculture production, employ more fishermen and fish farmers, and are perhaps under greater pressure from pollution and development than those of any other nation. It is unsurprising, therefore, that despite the progress China has made, it still faces challenges in making its living marine resources sustainable. In our review of the status and trends of China's living marine resources a few themes emerge as requiring the continued attention of the government. First, there is a widespread need for monitoring to improve compliance, to enable management to respond to changing circumstances and emergencies, and to improve the scientific understanding of the ecological system upon which production depends. Second, there is a need to integrate planning to optimize the use of marine space by aquaculture and other commercial uses and to identify critical habitats that need to be protected, restored or enhanced. Third, there is a need to make the production of value, rather than volume of catch, the goal of living marine resource management by continuing to apply output-based management and fishing rights, with which China has already begun to experiment. Fourth, there is a need to understand the impacts of climate change on China's living marine resources and develop policy options accordingly. And finally, there is a need to strengthen laws that protect the habitats and ecological services upon which depends the health of China's living marine resources, and therefore the enormous bounty that China produces from the sea.

What follows is an overview of the challenges China faces in managing the two economic sectors that most affect its living marine resources—mariculture and wild-capture fishing—and the challenges of protecting and conserving the habitat and ecological integrity upon which both industries depend. In addition to such internal challenges as lack of sufficient enforcement, we also describe the additional external challenges presented by climate change and gender issues. Lastly, because China is increasingly looking abroad to supplement its domestic supply of wild-caught seafood, we briefly describe the challenges other countries face in managing their living marine resources.

3.1 Mariculture

In China, mariculture permits are issued by the city or county level Ocean and Fisheries Bureau, which is under the administration of both the Ministry of Agriculture (MOA, now the Ministry of Agriculture and Rural Affairs) and the State Oceanic Administration (SOA, now an agency within the Ministry of Natural Resources). Due to a variety of reasons, some of the farms are unlicensed. Even when a fish farm is licensed, change of species or expansion of the scale of operation has not been constrained, which has resulted in pollution, environmental deterioration, prevalence of diseases and increasing difficulties in guaranteeing the quality and safety of aquatic products.

3.1.1 Ecological impact of mariculture

The ecological impacts of mariculture mainly include habitat encroachment, environmental pollution and displacement of wild living marine resources. The lack of scientific and rational spatial planning for mariculture is the main cause of many of these problems, which are rooted in policy gaps and manifest most significantly in over-capacity of many mariculture waters in China.

China's mariculture industry is mainly managed through the issuance of sea-use certificates and mariculture licenses. In principle, mariculture operations can only be conducted in national or community-owned waters once the two certificates are in place. Although the two licenses clearly define the water space that can be used, there are no restrictions on the density of the culture, species structure and culture layout (Liu, 2016). Since farmers tend to culture more profitable species or increase stocking density when prices rise, it is very difficult for the local authorities to know exactly what is being cultured and take measures or control the outputs and discharge in a particular region. Thus, the change of culture species or expansion of the scale of operation is not properly monitored, supervised and constrained. Before the 1990s, this permissive type of management played an important role in enabling the development of mariculture. However, with the continuous expansion of mariculture space and the scale of farming, the unrestricted increase in the cultured biomass has led to increased water pollution, reduced environmental quality, frequent disease occurrence and increasing quality and safety incidents of aquatic products. In addition, unlicensed mariculture has become very common due to conflicts in aquaculture sea use, which has led to overcapacity. Because the current law and legislations, and law enforcement in particular, are not strong enough to control this situation, functional and powerful tools for spatial planning are needed to place China’s aquaculture under strict governance.

Mariculture now occupies one-third of the coastal wetland area and 10% of shallow sea area in China (Liu and Su, 2017). China has also witnessed large-scale sea reclamation for mariculture (Wang et al., 2014), including cofferdam and earthen ponds, which has altered a large expanse of coastal landforms and degraded coastal wetland ecosystems. Approximately 240,000 hectares of shrimp ponds have been built in the coastal areas of southeastern China during the past 40 years, largely by destruction of mangroves and seagrass beds. According to the recent nationwide marine inspection (SOA, 2018b), reclamation and mariculture development in many provinces has been in violation of laws and regulations, but without adequate restriction by the local authorities. For example, the total area of shallow sea and reclaimed wetlands used for mariculture in Hebei Province is around 18,424 hectares, only 27% of which is licensed.

In Jiangsu Province, unlicensed mariculture operations took place in 137 sites and covered more than 13,000 hectares, with 9,954 hectares in conflict with Marine Protected Area (MPA) buffer zones and Ecological Red Line protected areas. Between 1989 and 2000, China lost 12,924 hectares of mangrove forests, more than 97% of which was due to the construction of shrimp ponds. Open violation of law and regulations in mariculture practice is prevalent, clearly reflecting weakness in law enforcement and inaction of government authorities.

Overcapacity in mariculture operations not only displaces many natural habitats, but also degrades remaining habitats by pollution. According to the 2014 report by the National Fisheries Environmental Monitoring Network, pollution of some coastal water bodies in the four China Seas remains severe, while the over-limit ratio for inorganic nitrogen, labile phosphate and petroleum in all samples was 72%, 34% and 39%, respectively, and mariculture was identified as a major source of all three pollutants (Jia et al., 2017). Furthermore, antibiotic pollution was also increasing, such as in the waters of the Beibu Gulf (Zheng et al., 2012). Specifically, erythromycin was detected in 100% of samples at concentrations ranging from 1.10-50.9ng/L, and sulfamethoxazole pollution was detected in 97% of samples at concentrations up to 10.4ng/L. Most of the mariculture output in China is from extractive species such as seaweed and mollusks (Figure 5), yet fed species including finfish and crustaceans are also cultured in large quantities in China. For fish culture, only about 27-28% of the nitrogen given as feed are redeemed as fish, and more than 70% of N is released into the environment (Hall et al, 1992). These species clearly contribute to marine pollution, especially when they are cultured in both large scale and high density. Nantong City is among the major whiteleg shrimp production sites in China; the scale of shrimp culture has expanded from 6,700 ha in 2013 to 12,700 ha in 2017. The rapid spread of small sheds across mudflats and farmland has led to a series of environmental problems such as soil salinization and over-extracting and polluting of shallow groundwater resources. Similar problems are also evident in major aquaculture areas in Hebei, Shandong and other provinces, and the cleaning and treatment of mariculture-discharged pollutants has become an important challenge for local governments. Control of aquaculture discharge is one major responsibility of the fisheries authorities at all levels, according to the Fisheries Law of China. However this task has been largely neglected or given way to increasing production; lack of monitoring expertise and waste discharge standards may partially share the blame.

An additional concern about the adverse environmental impacts of mariculture is the high volume of feed needed to produce certain fed species (such as fish and crustaceans), often derived from wild capture fisheries harvesting ecologically important forage fish. China’s aquatic feed industry has developed rapidly for more than 30 years. Its production increased nearly 24-fold from less than one million tons in 1991 to more than 18 million tons in 2012, representing 41% of global production. Accompanying this growth has been the development of the world’s largest aquatic feed manufacturing enterprises. The processing techniques and quality of some aquatic feeds have improved through time. For instance, the feed coefficient of prawn has dropped to 1.0-1.2, nearly meeting the international standard for efficient production (Liu et al., 2017). However, in some cases the feed coefficient, or the ratio of feed inputs to output of mariculture products, is still very high. Excessive use of feeds can exacerbate pollution and habitat impacts caused by other aspects of mariculture operations. Scientific and technological progress is very important for upgrading feed efficiency and comprehensive performance of aquaculture industry.

3.1.2 Operational and economic factors

Pollution of China's mariculture waters has become increasingly serious, resulting in occasional mass mortality accidents and huge economic losses. On the one hand, the trend of coastal water eutrophication is readily apparent in the increases in occurrence of red tides and green tides; on the other hand, various types of environmental toxins have increased more subtly, but these have caused more and more catastrophic mass mortality of cultured species. According to statistics of the Ministry of Agriculture, in 2014 a total of 284 fishery water pollution accidents occurred across the country, causing direct economic losses of 53.08 million RMB. The loss of fishery resources in 2014 due to the long-term cumulative impact of pollution on fishery habitat was 8.18 billion RMB, of which 6.98 billion RMB accrued in the marine sector, while 1.2 billion RMB was lost in inland waters (Liu et al., 2017). These negative external factors pose a severe challenge to the mariculture industry, which relies on science-based site selection and inlet water treatment to operate successfully. At the same time, an improved environmental monitoring and supervision system may also protect the industry from disastrous events.

In 2017, the Zhangzidao (formerly Zoneco Group Co.) sea ranch experienced a significant decline in shellfish production resulting in a 500-700 million yuan RMB loss in profits. Though several environmental factors were proposed as the cause, so far there is still no agreed upon explanation. The Zhangzidao incident exposed the serious potential problem of sea ranches that China has invested in heavily to construct at a large scale. At present, more than 200 sea ranches have been built or are under construction, yet most of their planning and site selection lack sufficient scientific research, and their operations lack consistent monitoring. These sea ranches are built mainly for commercial purposes and economic benefits. Although huge amounts of artificial reefs have been placed in these sea ranches, there have been insufficient systemic scientific studies and risk assessments on the ecological and natural conditions associated with such operations. The Zhangzidao incident is the result of a number of unfavorable factors and warns us about the importance of conducting scientific and technological research, and strengthening monitoring and governance on sea ranches.

Further adding to economic losses, increases in the prices of feed, energy and labor have eroded what was once reliable profitability in the early days of the industry; wide fluctuations in the prices of mariculture products and declining consumer confidence caused by successive aquatic product safety incidents have further exacerbated these impacts. In 1998, more than 300,000 people in Shanghai suffered a Hepatitis A infection from eating blood clams, which revealed the heavy pollution in China’s waters. However, at that time the government did not address the degraded environment, but simply banned the sale of blood clams. In the 20 years since the “blood clam incident”, China has experienced food safety issues not only in seafood but also in vegetables, cereals, meat, milk and eggs, many of which are due to environmental pollution. Over time, the health and economic impacts of these incidents have slowly motivated stronger government action, driven by consumer concern and confidence. Without comprehensive environmental governance, the aquatic food quality and safety problems cannot be solved completely.

3.1.3 Technical challenges

China's mariculture management lacks scientific and technological support. On the one hand, there is insufficient scientific and technological research and development to support management; on the other hand, China still lacks an independent scientific and technological consulting system, and management decisions are sometimes made without or in disregard of scientific considerations. Monitoring and scientific data collection are the most important tools for mariculture governance, and are inadequately deployed by fisheries authorities at all levels. Information system construction for fisheries governance is outdated, mariculture licenses may not correlate to each farm and management authorities at all levels have not set up a routine stock reporting system for respective farms. As a result, local Ocean and Fisheries Bureaus usually do not know exactly which species are cultured and how much is produced at respective fish farms. There has been little monitoring of the environmental impact of mariculture, including the amount of discharge by respective farms, partly due to the difficulty in data sharing between the governance and research institutions. This lack of data combined with the lack of data-support decision making has become a hindrance for effective mariculture governance.

Application of research findings is a long-standing problem in China. Channels for the extension of mariculture research findings are not smooth due to inadequate policy consistency among the government, research institutions and the industry, which means researchers for applied sciences are often unmotivated. Many research findings, patents and reports are written but not commercialized to create value and benefit. Despite these barriers, China has a relatively developed mariculture technology popularization system, with 13,463 aquaculture technology popularization stations (ATPS) at all levels, approximately 37,600 people engaged and around 3.7 billion yuan RMB spent on aquaculture technology popularization each year (BOF, 2017). This popularization system has played an important role in pushing ahead industrial development and promoting new culture techniques and species. However, because some ATPS leadership does not have adequate professional training, some techniques being promoted are not prominently advanced, while others are neither supported by accurate scientific data nor verified by practice. To inspire creativity in mariculture, China should nurture a deeper respect for science and technology and revise its policies at all levels to encourage innovation and vitality.

Environmental and fisheries policy in China is now evolving to confront many of the environmental impacts of mariculture, which at the same time present new challenges to the industry. Since the 18^{th} CPC National Congress in 2012, China has elevated its commitment to ecological civilization. As a result, China's environmental quality has improved, especially as the new National Environmental Protection Law entered into effect in 2015, with environmental supervision, ecological auditing, environmental law-enforcement and punishment for infractions increasing as a result. After decades of unconstrained investment and growth, these policy changes have imposed unprecedented pressure on the mariculture industry, which is now faced with a ban on sewage and sludge discharge and the use of coal-fired boilers. The industry are required to retreat once a conflict is identified with an MPA or the Red Line system, tourism, or certain other sea uses. Mariculture enterprises must decide whether to disband or reform their operations to comply. China's commitment to improving environmental quality and reducing carbon emissions will affect all economic sectors, including mariculture; as this poses an imminent burden on the industry, swift action should be taken to improve technology to enable less-carbon intensive pollution treatment and green development.

3.2 Fisheries

Overfishing is not only the most significant problem facing many fisheries worldwide, it is perhaps the most significant issue facing marine ecosystems overall. This is not to say that other issues are not important, and in some locales more severe than overfishing; however, because fishing fleets are vast and widespread, and cause direct mortality to harvested organisms—often with incidental impacts on habitat—overfishing remains a major threat to ocean health at the global scale. Indeed, recent estimates suggest that ending overfishing can promote recovery of marine wildlife, including mammals, birds and turtles, illustrating the severe ecosystem-level effects of overfishing (Burgess et al., 2018). The causes of overfishing are diverse and vary from fishery to fishery, though two of the most pervasive drivers include perverse economic incentives that are not aligned with needed environmental outcomes, and fishers being disconnected from decision-making processes and therefore less likely to accept and comply with regulations.

China is no exception to the severe consequences and drivers of overfishing. Marine ecoregions in China were once world famous for rich fishery resources and high quality seafood products. However, overfishing combined with other sources of deterioration of the marine environment in the past four decades has resulted in increasing occurrences of the “rare fish in the sea” phenomenon, whereby species that were once major components of China’s fishery yield have become infrequent in both the catch and the ecosystem. Fishing grounds in the Zhoushan archipelago, for example, covering an area of 220,000 square kilometers, were once so productive that the region came to be known as the home of fishing in China and the granary of the East China Sea. However, catch of large yellow croaker in the region that reached 170,000 tons in 1957 dropped to only 400 tons in 2015, a decline of more than 99%.

Declining trends in other Chinese fisheries have been similar, especially for the highest value species, although losses have been offset by increased catch of more abundant and low-value species (Szuwalski et al., 2016). New opportunities are also emerging in recreational fisheries and the DWF; although, if recreational fisheries and the DWF are not managed sustainably, these transitions might simply mean exporting overfishing problems in domestic commercial fleets to other fleets. In many cases, a similar combination of factors underlies fishery declines, including unconstrained development of overcapitalized fleets, technical challenges with stock assessment and management, and socioeconomic impacts associated with management reform and resource recovery.

3.2.1 Overcapacity

Nationwide catch in China climbed dramatically in the 1980s due to growth in the number of vessels and fishermen that accompanied growing recognition of fisheries as a significant economic driver; technological improvements that enabled fishermen to catch fish despite declining stocks; and government subsidies. However, eventually natural limits in resource productivity will prevent further increases and even lead to declines in the amount of catch in any fishery. This has been the case in China where the total volume of catch has changed little since the mid-1990s, but the amount of catch attributable to China’s distant water fleet has grown.

Fisheries policy and management have changed over time in China as these became stronger national priorities. Significant changes to China’s approach include a series of progressively more restrictive licensing schemes and periodic vessel surveys to better estimate the total fishing fleet, including unlicensed vessels. These measures have helped to make clear the extent of the significant overcapacity problems facing China’s fisheries (Figure 6). The total number of fishers in China has steadily increased over time, and although the number of vessels has decreased, the total engine power of the fleet has increased. This means that smaller vessels are being decommissioned while a smaller number of larger vessels go into operation, but the larger vessels require sufficiently large crews which leads to an increase in the fishing labor force. Although an increasing number of these are DWF vessels that leave Chinese waters to fish the high seas or other nations' EEZs, the DWF still accounts for a minority of the catch in China, and excessive pressure on domestic waters by overcapitalized fleets remains a pressing challenge.

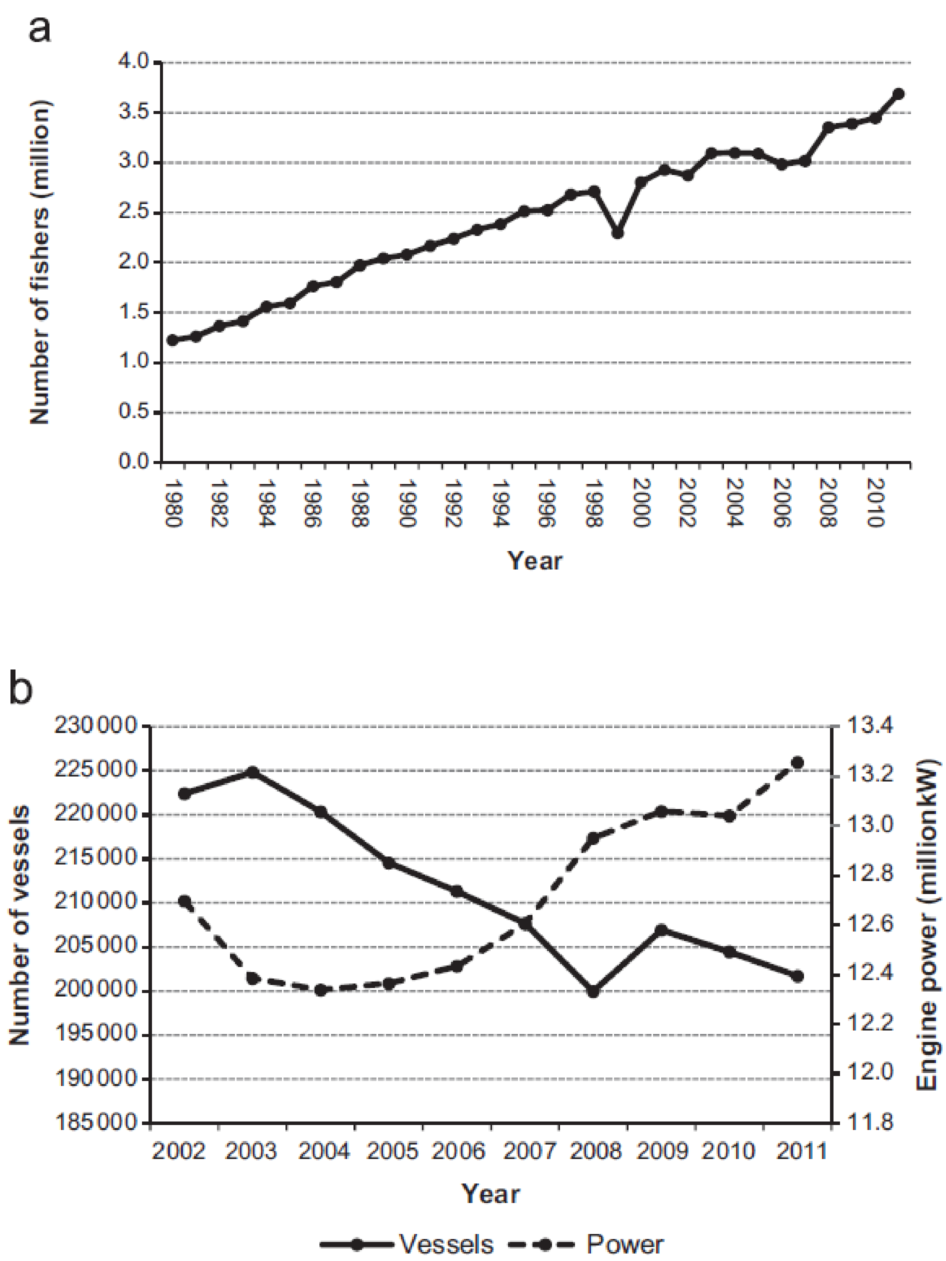

Figure 6 | Changes in the Total Number of Fishers (a) and Fishing Power in Terms of Both the Number and Engine Power of Vessels (b) in China Through Time (Shen & Heino, 2014)

Recent policy changes have aimed to address the severe overcapacity issues in order to bring nationwide fishing power in line with the biological limits of fishery resources. This challenge is made more difficult by the prevalence of illegal fishing gears and unlicensed vessels. For example, in Zhejiang province, the number of unlicensed and illegal fishing vessels peaked at 13,000 in 2013, when total catch in the East China Sea reached three million tons, despite the government having set a target for catch at two million tons. Inadequate numbers of enforcement personnel relative to the large number of fishers and vessels in China make it difficult to adequately monitor the fishing activity and catch of legally permitted vessels, let alone detect and punish illegal vessels.

3.2.2 Social and economic factors

Addressing overcapacity in fishing fleets is made more difficult by important and powerful social and economic forces. Pressure to maximize near-term economic gains, especially by impoverished rural communities with few other livelihood options, can cause long-term productivity and stability to be overlooked in favor of increasing yields in the here and now. Similar tradeoffs can be made when an unregulated industry sees an opportunity to capitalize on price trends or establish a strong position in supply chains. These tradeoffs eventually lead to ecological degradation, economic loss and social hardship. Unfortunately, these adverse outcomes encourage fishermen to fish even harder to offset their losses, which causes further degradation, creating a destructive cycle.

Arguably, the solution to fishery recovery and stability is straightforward on the surface: simply reduce fishing pressure to allow stock to recover, and then fish the recovered stock at a conservative rate. With a large fish population, even modest fishing pressure can generate high yields and profits because the underlying resource is abundant and catch efficiency is high. Indeed, a recent global analysis suggests that, despite the high number of overexploited and collapsed stocks worldwide, recovery and sustainable management can lead to even higher yields and profits in the future (Costello et al., 2016). However, very real economic and social pressures often prevent governments from undertaking the actions needed to recover. If aggressive action toward recovery is taken, fishing communities could undergo a period of hardship, especially if no other actions are taken to address these communities' economic needs. This may be a short-term problem if stock recovery is rapid, although any period of time without food or income could be devastating to fishing communities with few other viable economic options. Furthermore, overcapacity that contributed to fishery declines in the first place might require some participants exiting the fishery in order to achieve and maintain sustainability going forward.

Subsidies generally compromise the economic and ecological viability of fisheries (World Bank, 2009), although time-limited subsidies as investments in keeping fishing communities viable during periods of reform and recover can be an effective strategy. To date, this has not been the nature of fishery subsidies in China. However, in 2015, the Ministry of Finance (MOF) and MOA concluded that the extensive, large-scale and long-term fuel subsidy policy, which had been implemented since 2006, distorted price signals and was at odds with policies to reduce the size of fishing fleets and constrain harvests. Therefore, the central government announced that the fuel subsidy would be reduced to 40% of the 2014 peak by 2019, and to zero by the end of 2020.

Relocation of fishermen to other livelihoods is perhaps the most important in the series of actions through which Zhejiang has worked to address the “rare fish in the sea” problem and restore the East China Sea fishing grounds. Some displaced members of the commercial fleet have been able to remain employed in fisheries through new opportunities in the growing recreational fishing sector, while others have joined the DWF. Also, like other industries in the coastal zone, over time many fisheries in China have employed larger numbers of migrant laborers; for example, it is estimated that 30% of fishermen in Zhejiang are from other provinces. Generally welfare policies only apply to legal residents of a province, which means that relocation programs do not address the social and economic needs of the whole fleet, and welfare programs are often not applicable to middle aged or elderly fishermen who might still need a source of income to support their families.

3.2.3 Technical challenges

Limited stock assessments and issues with data quality and availability preclude rigorous evaluation of the full extent of China’s overfishing challenges. However, fisheries lacking scientific assessments are more likely to decline and collapse (Costello et al. 2012), which means that the perceived poor status of many Chinese stocks may likely be accurate. That China’s nationwide fishing fleet continued to grow as total catch remained largely unchanged suggests that stocks are in fact dwindling, as it is likely that only through increasing effort and growth of catch attributable to the distant water fleet that catch has been maintained.

Typically, sound science and sound policy reinforce one another: policies can drive demand for robust science, and science can improve the efficacy of policy. For example, mandates to define clear goals, targets and limits, and requirements for risk-averse management, require scientific information and can provide government and academic scientists a clear focus for their work, as do policies that require consideration of appropriate spatial scales in management and awareness of ecosystem factors that affect and are affected by fishery management decisions. The greater dedication to management in China has led to continued strengthening of national policies, but this progress has not kept pace with the magnitude of overcapacity and environmental degradation that have accumulated since China’s fishing industry began to substantially develop in the mid-20th century.

Despite these problems, China has the benefit of a strong scientific community to help meet its fishery management challenges. Academic institutions and research institutes in China are highly regarded across the globe, and fishery researchers in China have impressive publication records. Yet this capacity is not fully utilized due to structural barriers that unnecessarily compartmentalize individuals and institutions. Transparency and accessibility of fishery data are extremely limited, and consequently universities and provincial fishery research institutes often do not have full access to data collected by the larger regional fishery research institutes, which would enable them to do more innovative research and complete more and better stock assessments. Data-sharing can also pave the way for increased collaboration, which can improve the overall quality and quantity of technical analyses supporting fishery management.

Of course, even if these structural barriers are removed, and data begins to flow more freely and productive collaborations grow across institutions, fishery science in China will only be as good as the data feeding into models and analyses. In particular, accurate data on total catch of each stock, as well as higher resolution data such as catch by different gears, in different seasons or areas, or at different life stages of exploited organisms, are important in any fishery management program. Unfortunately, inadequate catch monitoring also means that these data are often of low quality or altogether nonexistent. Improving monitoring is arguably the single most important challenge facing fishery management in China.

The importance of monitoring lies not only in its scientific benefits, but its value for enforcement and shaping fishing behavior. As monitoring improves in a fishery, the range and effectiveness of management strategies that can be adopted also improves. For example, global experience shows that the implementation of total allowable catch (TAC) management, especially with quota allocated to individuals, vessels, communities, cooperatives or other entities, can be a highly effective strategy for fishery management (Costello et al., 2008). However, without effective monitoring, these approaches can incentivize unreported discarding of catch at sea, which results in management targets being missed and scientific assessments based on faulty data. In the absence of the monitoring necessary to allow China to adopt output controls, China has instead relied primarily on input controls. Some of these have had important benefits, but they cannot address all of China's management needs and often introduce inefficiencies that exacerbate socioeconomic strains on fishing fleets and communities.

The catch of fisheries in China is highly multispecies due to the nature of China's ecosystem, the use of unselective gears and the absence of limits on the harvest of individual species. Chinese consumers also have a broad palate for seafood so there is less market pressure on fishing fleets to be selective in their catch. Sustainably managing such diversity only increases the need for collaborations across scientific institutions and improved data streams that greater catch monitoring can provide. Furthermore, new scientific tools and management strategies will need to be developed to avoid ecosystem-scale degradation.

3.3 Habitat and biodiversity

China has recognized the importance of marine habitats and started to conserve them in a much more dedicated manner. As discussed further in section 5, this has been compelled by stronger policy imperatives, backed by government support for increased monitoring, research and protection and restoration projects in many important coastal and ocean areas. Despite this progress, important challenges remain and overall management effectiveness is limited. The most important challenges lie in continued deficiencies in the policy architecture—particularly in the establishment of a strong, clear and comprehensive governance system—and an inadequate technical foundation that precludes both effective implementation of existing policies and creation of stronger policies.

3.3.1 Governance issues

The importance of healthy habitats and biodiversity as a basis for sustaining the renewal of living marine resources is still not fully recognized and evaluated in China. There are still significant gaps in the available data with the breadth of living marine resources values such as seafood production, recreation, aesthetics, and regulating services. Despite those gaps, China has introduced a number of laws and regulations to protect coastal habitats and living marine resources, such as the Fisheries Law and Action Plan on Conservation of Living Aquatic Resources. However, implementation and enforcement of these laws and regulations remains deficient. China also lacks comprehensive national legislation for management of living marine resources, which exacerbates conflicts between the mariculture and fisheries sectors, while almost entirely omitting many other values provided by living marine resources from regulatory decisions. Encouragingly, the prominence given to creation of ecological civilization in the 13th Five-Year Plan and the 2018 amendment to the national constitution sets the stage for such a policy, but its development has not commenced. In particular, relevant national policy lacks the following critical requirements:

- Assessment of critical ecosystem functions and status of key living marine resource values;
- Identification of species and areas necessary to protect to maintain those functions and values;
- Requirements to protect or restore those species and areas where possible;
- Monitoring and enforcement to ensure compliance.

The absence of a national living marine resources policy is manifested in a variety of ways throughout the governance system, all of which contribute to habitat and biodiversity remaining at risk.

Lacking strong mandates from the central government, local governments lack incentives to prioritize protection and restoration initiatives, and instead favor near-term economic gains. Even where government motivation for conservation is strong, unclear or conflicting authorities among agencies lead to poor or ineffective decision making. One particularly poignant example of this ambiguity is that boundaries for nature reserves and other types of protected areas are often not clearly delineated, so even these bedrock conservation measures are not often effectively implemented. Insufficient enforcement also compromises conservation and restoration efforts.

Furthermore, local decision makers do not have the necessary training and capacity-building in the complex scientific and policy dimensions of living marine resources management, so leaders on the ground are often not sufficiently equipped to meet the challenges they face. Similarly, public awareness of the threats facing, and full breadth of values provided by living marine resources is limited, which means civil society is not voicing its support for conservation or contributing where possible to monitoring, enforcement or problem solving. Although NGOs are increasingly promoting the broader values of living marine resources and associated conservation needs, the importance of direction from the central government in China means that a national mandate is still essential.

Quite a number of aquaculture species have been introduced into China over the years, including the popular and high-value species such as turbot and whiteleg shrimp. None of these have been subject to robust biosafety checks, and it is unknown if any introduced aquaculture species will likely result in biological invasion. However, cordgrass *Spartina* spp., which was introduced to China as an aquatic fodder species, did become invasive in many locations.

3.3.2 Technical challenges

Although the technical basis for productive and sustainable mariculture and fisheries is certainly complex, that of comprehensive conservation of habitat and biodiversity is even more complex due to the much greater number of impacts and outcomes considered. Adding to this complexity, many living marine resource values cannot be quantified as readily as the revenue generated by seafood sales. For example, whereas a 10% increase in fishery yield will in most cases results in an approximately 10% increase in revenue, it is not as straightforward to say that a 10% increase in abundance of a popular wildlife species will result in 10% more tourism revenue. Both the impact on and value generated by habitats and biodiversity are characterized by uncertainties, nonlinearities and complex interactions. Overcoming these challenges is hindered by insufficient research and monitoring; researchers have too few incentives to tackle these questions rather than focus on those with more directly quantifiable economic outcomes.

Precautionary policies that establish conservative thresholds for habitat and biodiversity conservation, and information about the extent of adverse impacts on those assets, can address this knowledge gap. However, such approaches may incur undue economic costs on the affected industries, or fail to adequately protect habitat and biodiversity if thresholds are not conservative enough or if management actions are unintentionally misplaced.

3.4 Climate change

Climate change has had an increasingly dominant effect on global ocean ecosystems, which are affected by changes in temperature and pH, dissolved oxygen, salinity, current patterns and other factors. Although some marine ecosystems are more affected than others—in particular, coral reefs and other biotic coastal habitats that depend upon a very precise combination of environmental variables—all experience these effects to some degree. Changes in ecosystem affect species that are grown through mariculture operations, harvested by fisheries or provide other living marine resource values.

Climate change affects marine organism productivity and distribution, either directly through environmental changes, or indirectly through effects on important prey, habitats or other ecosystem components (Gaines et al., 2018). Changes in productivity affect the potential available yield for mariculture and fisheries, as well as the recovery potential of species affected by these or other factors. Changes in distribution can introduce species that might compromise mariculture production and affect which species are available for local fisheries, tourism and other uses.

Climate change represents a system-scale impact that will affect management of individual sectors and more comprehensive living marine resource policies; thus, these factors should be considered to ensure that future policies remain effective as environmental conditions evolve.

3.5 Gender aspects

Women account for 50% of the workforce in fisheries and aquaculture worldwide when accounting for the secondary industry sectors that include processing, marketing and selling seafood products (FAO, 2016). Although they play a vital role in the seafood sector, women in many countries around the world face challenges of inequitable access to opportunity, minimal representation and unequal benefits received from their participation. In addition to achieving fundamental human principles of social justice and fairness, there is a growing body of evidence that gender equality can lead to improved household income, productivity and nutritional security (Hillenbrand et al., 2015). Addressing the issue of gender inequality is a critical component of sustainable development globally, so much so that it is promoted by United Nations SDG #5: Achieve gender equality and empower all women and girls.

Approximately 14 million people are employed directly or indirectly by fisheries and aquaculture in China (BOF, 2017). Women account for 20% of the total professional workforce (WB/FAO/WFC, 2012), indicating that about 1.6 million women are employed full time in production and post-harvest work (BOF, 2017). Aquaculture farms and processing factories help close the gender gap by employing more women as temporary workers. According to our survey, larger aquaculture companies in China tend to employ more male than female workers, with male employees comprising more than 70%, and up to 95%, of the fixed workforce; the ratio of male temporary workers is much lower. Female temporary workers usually earn less than males, and considering the technical and labor-intense requirements, small or family-owned fish farms or seafood processing companies in particular tend to employ more female than male temporary workers.

Table 1 | Employment (Including Full-Time and Part-Time) in China's Fisheries and Aquaculture

			1995	2000	2005	2010	2012	2016
China	FI + AQ	(thousands)	11 429	12 936	12 903	13 992	14 441	13 817
		(index)	*89*	*100*	*100*	*108*	*112*	*107*
	FI	(thousands)	8 759	9 213	8 389	9 013	9 226	9 226
		(index)	*104*	*110*	*100*	*107*	*110*	*110*
	AQ	(thousands)	2 669	3 722	4 514	4 979	5 214	5 022
		(index)	*59*	*82*	*100*	*110*	*116*	*111*

Source: FAO (2014). The index is with respect to the 2005 baseline.

Since the 11th Five-Year Plan, efforts have been directed towards creating new economic and social conditions throughout the rural areas, including in fishing villages (Xu et al., 2012). Though women are expected to take on greater economic roles in the coastal economies, there remains a considerable knowledge gap about the role of women in fisheries and aquaculture. Additional efforts are needed to understand the gender gap and improve women's education, social and economic opportunities and responsibilities in fisheries and aquaculture in China.

3.6 Living marine resources in other countries

Chinese fisheries are increasingly looking to overseas fisheries to help meet seafood demands beyond the scope of domestic production. Under the 13th Five-Year Plan, the contribution of China's distant waster fleet to the country's total wild catch is expected to grow from 14% in 2017 to 23% (Huang Shuolin, personal communication). However, today most of the world's assessed fisheries are fully exploited, meaning that target yields are being obtained and no additional yield is likely. Most of the world's assessed fisheries are fully exploited, meaning that target yields are being obtained but no additional yield is likely. Around one-third of assessed fisheries are overexploited or collapsed, which means that current yields are either unsustainable or have already declined. Those fisheries that have collapsed represent a potential source of additional yield, if stocks can be rebuilt and renewed harvests are at sustainable levels (Costello et al., 2016). The proportion of overexploited and collapsed fisheries might actually be higher given that many countries do not have the capacity to assess their fisheries, and unassessed fisheries, which are not included among the global trends, are more likely to be depleted (Costello et al., 2012).

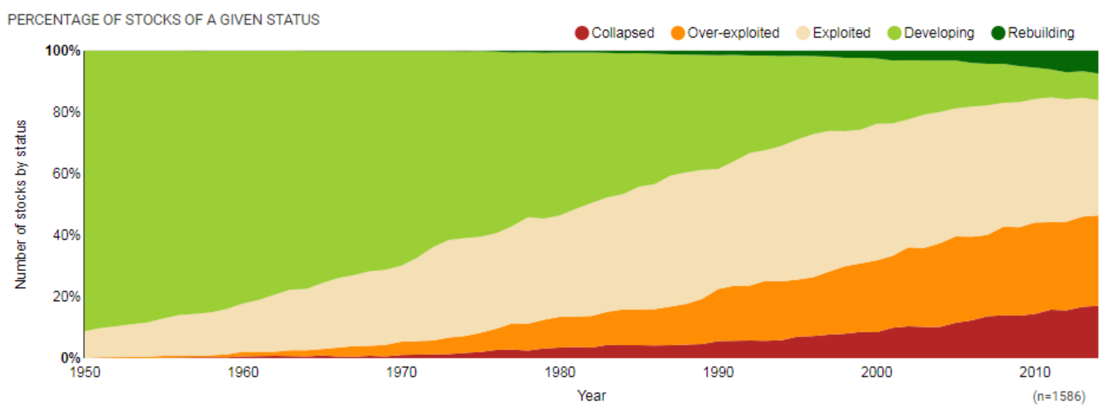

Figure 7 | Status of World Fish Stocks, 1950-2015 (Pauly and Zeller, 2015)

Overfishing is the most significant problem facing many fisheries worldwide today. Because fishing fleets are vast and widespread, and cause direct mortality to harvested organisms, often with incidental impacts on habitat, overfishing remains the major threat to ocean health and biodiversity at the global scale. Indeed, recent estimates suggest that ending overfishing can promote recovery of marine wildlife, including mammals, birds and turtles, illustrating the severe ecosystem-level effects of overfishing (Burgess et al., 2018). One important driver of overfishing is that many countries, especially in the developing world, lack the scientific expertise, governance capacity and financial resources needed to manage their resources sustainably. Of course, other stressors beyond fishing affect fishery resources, including pollution, coastal development and, perhaps most significantly, climate change.

Encouragingly, bioeconomic modeling suggests that improved fishery management can counterbalance impacts of climate change, which, depending upon the severity of climate change the world experiences, could enable overall worldwide fishery yields to be maintained, or perhaps even modestly increased (Gaines et al., 2018).

While overfishing and the struggles of mariculture management have been globally shared experiences, the solutions and technical expertise accumulated by developed countries in addressing those issues has not been as universal. In fact, research suggests that as developed countries began to regulate their fisheries throughout the 1990s, there was a shift in focus to the largely unassessed fisheries of developing countries (Worm et al., 2009). Developing countries' fish production, both wild caught and farmed, has doubled in the last 30 years and now accounts for over half of global fish exports (Roheim, 2004). The fisheries we know the least about and that have the least management in place are being increasingly exploited.

4. Progress on Policies for Management of Living Marine Resources in China

Commitment to ecological civilization has taken a firm hold in China's national policies. Through the 13th Five-Year Plan, President Xi's report to the 19th National Party Congress, the 2018 Constitutional Amendment and other prominent policy instruments, China is repeatedly making a clear declaration that economic progress and social evolution will only continue in ways that ensure environmental protection. Indeed, the philosophy underlying modern policies in China recognizes that achieving economic, social and environmental outcomes does not occur at the expense of one another. Rather, these goals can only be achieved, and more importantly sustained, in concert with one another. Economic progress that degrades environmental resources will undermine the basis for many economic sectors, while declining social conditions will incur welfare and other costs that offset increased profits. Conversely, environmental protections that do not allow economic prosperity will create social costs, fail to gain public support and ultimately fail.

China signaled this new philosophy to the world through its clear commitment to the U.N. Sustainable Development Goals (SDGs), which likewise aim to achieve the triple bottom line outcomes of economic, social and environmental progress. In 2016, China developed and released a national implementation plan for the 2030 Agenda for Sustainable Management, in which it has created action plans for each SDG target. Since implementation of the plan, China has already undergone one round of reporting on its targets. There have already been notable achievements in environmental protection, for example, in the areas of energy consumption and air pollution, which relate to SDG #13 on combating climate change. In 2016, China's energy consumption per unit of GDP fell by 5%, while carbon dioxide emissions per unit of GDP fell by 6.6.% (MFA, 2017). China has also made tremendous progress in addressing SDG #2, which is focused on poverty alleviation. Disposable income per capita increased by 6.3% in real value, while the number of rural residents living in poverty was reduced by 12.4 million; based on this progress it is estimated that China may be able to achieve its SDG #2 target 10 years ahead of schedule (MFA, 2017).

With regard to SDG #14, China has taken several significant steps to conserve and sustainably use the living marine resources, including drawing redlines for conservation that place 30% of China's sea areas and 35% of coastlines under redline development. It has expanded the total area under protection and intensified law enforcement; imposed more stringent standards for discharging pollutants into the sea; and improved pollution treatment facilities and sewage pipe networks in coastal regions. The government has increased subsidies for reduction of fishing boats and offered subsidies for scrapping fishing vessels, setting limits on the number and total power of fishing boats that decline over time. Finally, China is providing assistance to build aquaculture facilities in countries along the Belt and Road Initiative (BRI)—one of the country's most prominent and powerful vehicles for international engagement in the modern era—thus emphasizing the need to work towards environmental and social goals in tandem with economic goals.

In the maritime realm, the path for achieving a triple bottom line internationally through the BRI has been outlined in the *Vision for Maritime Cooperation under the Belt and Road Initiative* issued jointly by China's State Oceanic Administration and National Development and Reform Commission in 2017. The *Vision* addresses the importance of living marine resources and specifies the need to improve management of mariculture and fisheries, and conservation of habitat and biodiversity across the region.

China's international leadership through BRI and other channels will be stronger as it develops domestic success stories than can inform policy changes in other countries. To that end, a series of important domestic policy developments that are improving living marine resource management in China will play an important role. As discussed previously, even before the ecological civilization mandate was elevated during the 13th Five-Year Plan period, China began to address the unreasonable growth and environmental impacts of mariculture through new policies, such as the setting of an upper limit for total mariculture area by 2020, and the "volume reduction & value increase, quality and efficiency improvement, and green development" principles put forward by the Fisheries 13th Five-Year Plan. Permitting, monitoring and enforcement are also becoming stronger, which is leading to reduced overdevelopment in the coastal zone, although continued improvements in all of these areas are needed.

The 13th Five-Year Plan prompted MOA to issue a sweeping and ambitious new national fishery policy early in 2017. The policy sets national targets for reductions in total catch and the number and total engine power of fishing vessels. Furthermore, the policy attends to the detailed mechanics of fishery management at provincial and local scales, including improved stock assessments, monitoring to support stock assessments and ensure compliance with regulations, use of fishing rights and opportunities for collaboration in management by the fishing industry, and a shift toward greater use of output controls. Because policy evolution in China relies so strongly on pilot projects that enable provincial and municipal governments to figure out how to operationalize national objectives, and because output controls represent such a fundamental change from how China has managed its fisheries to date, the MOA policy also initiated pilot projects in total allowable catch (TAC) management in five coastal provinces.

The MOA fishery policy focuses not only on improved management of harvested species, but on protection of ecosystems as a whole from adverse effects of fishing. These provisions will be important steps toward more holistic and integrated management of living marine resources. Other policies and pilot projects have also taken important steps in this direction. For example, the integrated ecosystem-based planning pilot in Xiamen has aimed to define space for mariculture, fisheries, shipping and other uses, while minimizing the impacts of these uses on one another and ensuring conservation of critical ecological resources. The pilot strives for this complex balance in a heavily urbanized coastal area, which requires a strong technical foundation and co-management by multiple agencies and levels of government. Notably, the project has been successful in protecting a small but stable population of the Chinese white dolphin, the northernmost extent of the species.

Integrated management of living marine resources might be most effectively achieved not only through holistic policies and coordinated governance, but also by harmonizing management with local traditions and values. Since 2013, China has begun moving in this direction on land through the “Beautiful Countryside” concept, which formally promotes human wellbeing, quality of life and cultural factors into policy. Building from this concept, “Beautiful Fishing Villages” can be a powerful means for incorporating local perspectives, objectives and knowledge into living marine resource management strategies tailored to the unique social, economic and ecological attributes of different places.

5. International Experience in Management of Living Marine Resources

Given the scale of China’s population, length of its coastline and sheer number of people dependent on living marine resources for their livelihoods, China faces some unique challenges. However, there is still much that can be gained from examining approaches and solutions from other nations, which have shared many of the same fundamental challenges in the management of living marine resources. The following case studies demonstrate ways in which other countries have found opportunities to enhance management of living marine resources in the areas of strengthened monitoring, holistic and integrated spatial planning, managing climate change impact, promoting long-term value over volume in marine fisheries and helping accelerate and scale solutions internationally through exchange. These stories can provide valuable experiences and ideas to draw from as China forges its path towards ecological civilization.

5.1 Strengthening Monitoring

When living marine resource management is attempted without accurate or complete information, challenges inevitably emerge. In the context of living marine resources, monitoring can involve data collection to improve the performance or management of aquaculture operations, fisheries or ecosystem health. Monitoring can help indicate the success or failure of management, sometimes exposing unexpected patterns or information, which can help advance the state of the science of a particular issue. In addition, monitoring can also help detect non-compliance of rules and regulations, which can lead to stronger enforcement. Therefore, while increased efforts in monitoring can lead to better management, decision making and outcomes, lack of capacity and funding often poses a barrier to expanding such efforts. The following case studies demonstrate the value of monitoring and explore innovative ways to conduct monitoring to advance living marine resource management.

5.1.1 Information transparency facilitates governance in Norway

Collecting, analyzing and sharing data on different marine production systems can help operators, fishermen, business, managers and other stakeholders make more informed decisions about living marine resource management. One example of information being collected and used to improve management comes from salmon farming in Norway.

Norway is the largest exporter of aquaculture products in Europe and the sixth largest globally. However, given Norway's geography, 80% of the population lives less than 10 kilometers from the sea, making it crucial to keep all aquaculture clean and well monitored. For salmon farming, the Norwegian Fisheries Directorate has a website that contains not only the location, capacity and operational status of every facility the government licenses, but also the environmental impact assessment results of each. All licenses for salmon farming in Norway are registered with this GIS-based system and each farm is required to submit weekly stock reports to the fisheries authority through the website. Government inspectors make routine checks on farms on a monthly basis. This near real-time sharing of data greatly facilitates mariculture governance and enables scientists to predict the environmental impact of facilities, such as the spreading of sea lice.

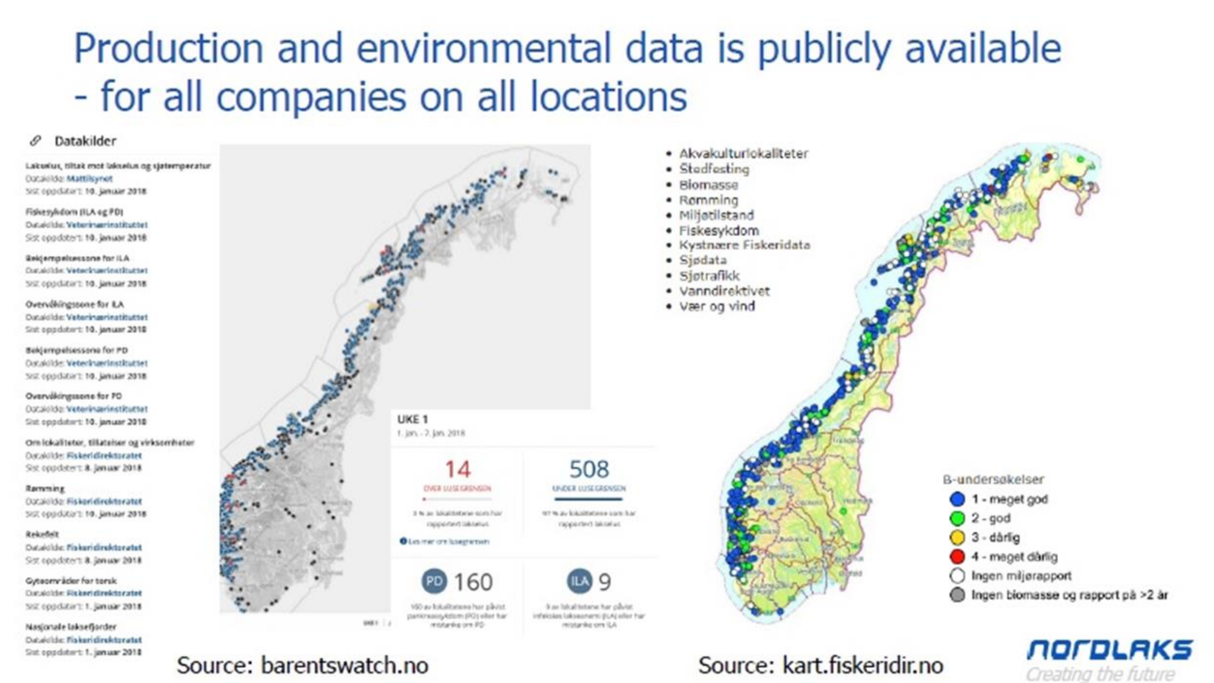

Figure 8 | Aquaculture Farm Production and Environmental Data Published on the Norwegian Fisheries Directorate Website

Making data publicly available helps stakeholders understand government decisions, facilitates trust between the groups and creates a strong system of accountability. Scientists can review the data and propose better solutions, and the owners and operators of salmon farms are able to observe nearby environmental issues or disease outbreaks and prepare accordingly. By gathering more data, the government is able to obtain a more accurate picture of the issues affecting and resulting from aquaculture and use that data to improve management overall.

China does not have such toolkits to help with fisheries governance. Although efforts were made by the Ocean and Fisheries Bureau of Shandong Province, for example, to set up a pilot-scale aquaculture data collecting system (the Fisheries Information Transection Platform), the lack of incentives or pressure on farms to report production data has deemed the system a failure.

5.1.2 Electronic monitoring in U.S. Pacific whiting fishery

Even when fishers and managers recognize the importance of monitoring and data collection, implementing a system can prove to be expensive and resource intensive. Utilizing technology to assist with the collection and processing of information offers great potential in overcoming such challenges.

The following study shows how technology can address this problem by supplementing and even supplanting traditional observer-based monitoring systems in marine fisheries.

Comprised of around 35 vessels, the Pacific whiting fishery is managed with an annual quota for total allowable catch (McElderry, 2013). Initially, vessels were only accountable for the catch that they brought to shore. However, this incentivized greater offloading at sea of undesirable catch and bycatch. Therefore, the government revised the system and created new regulations that required fishermen to account for all catch, including fish discarded at sea. To ensure compliance with this new system, the fishery needed a new comprehensive monitoring system that included at-sea accountability. The nature of the fishery (i.e. many very short trips with very little notice) made it difficult to maintain a human observer system, so instead, the government partnered with Archipelago Marine Research to design an automated electronic monitoring system.

In the electronic monitoring system, boats were equipped with up to four video cameras, fishing gear sensors and a GPS receiver. The data collected by these tools were stored on the boat and retrieved by technicians every two weeks. Fishers were still required to keep logbooks as a means for comparison with the automated data (Lowman et al., 2013). Technicians regularly examined the automated data, searching for unreported discards and fishing activity in prohibited areas, and generally collecting vital statistics about the fishery that would prove helpful for fishers and managers. Over the seven years of the program, discard frequency decreased by 90% and data collection success increased to 98%. Unfortunately, the program was brought to an end in 2011 after the government mandated that the fleet had to use 100% observer-based monitoring as part of a broader set of reforms in the region. However, the requirement that a human observer accompany every boat that leaves the harbor has proven costly for the industry, which is now attempting to revert to electronic monitoring once more.

In China, electronic monitoring could help government authorities understand how many fish are being caught in real- or near real-time. Advanced imaging and processing technologies could even help detect which species are being caught, where and at what time, all of which could help the government implement an output-based management system and give scientists a better understanding of the health of China’s marine ecosystem.

5.2 Holistic understanding and integrated planning

Holistic management of living marine resources will require the need to evaluate and balance tradeoffs between competing activities within the marine space. Research and science underpinning spatial planning, ecosystem services, proper aquaculture density and other activities can greatly improve the information that is used to make decisions about spatial planning. Combined with a robust planning process that involves multiple agencies and stakeholders, this holistic approach to management can help ensure that the benefits from marine uses can be maximized, while minimizing environmental impact and conflict among stakeholders. Below are several examples of how holistic and integrated management have been utilized for living marine resources in other countries.

5.2.1 Ecological prioritization in Norway

The ocean area of Norway is six times larger than its land area. In its marine space, a multitude of economic activity takes place, including fisheries, maritime transport, and petroleum and energy. Norway has recently finished designing and implementing a comprehensive system for the coordinated management of all ocean uses. Beginning in 2001, Norway began by implementing a single integrated management plan for one portion of its waters (Otterson et al., 2011). To create the plan, the government first worked to determine the biological, social and economic basis of the ecosystem and all activities that occur in the space. The government then conducted impact assessments for all use sectors to see how the various activities could interact with or impact each other and the larger ecosystem (Pettersen, 2015). This first plan, the Barents Sea-Lofoten area, took four years to develop. The process was then replicated in the remaining two sea sections for a total of three marine plans. Each plan aims to produce greater value in these ecosystems, by pursuing the sustainable use of its resources while simultaneously upholding the integrity of natural ecosystems (Schive, 2018).

To balance these sustainable resource uses with ecological conservation, the planning and management process has involved a tremendous number of government agencies, repeated input from stakeholders and intensive scientific study. One particularly valuable approach to manage such a complex process has been to establish ecological priorities at the start of the process. The main criteria used for prioritization include value—based on productivity or biodiversity—and vulnerability, based on concentration of all organisms, key life stages taking place, abundance of sessile organisms, migratory routes, etc. (Winther, 2018). Examining these key conditions establishes an ecological foundation which the other uses must work around and not adversely impact. While each marine use is managed individually on a day-to-day basis, management is integrated into a higher level of governance which is bound by these ecological priorities, allowing the system to operate within a broad and connected vision.

5.2.2 Ecological restoration in the Chesapeake Bay and South Atlantic region, United States

The Chesapeake Bay, located in the United States' Mid-Atlantic region, is the largest estuary in the country. The ecosystem has been highly altered by heavy land use on all sides (i.e. urban, residential, agricultural), as well as extensive in-water uses (e.g. fishing, boating, shipping, etc.). Over time, this heavy use and high degree of alteration has led to serious deterioration in the water quality and fishing prospects in the bay. Even when stakeholders and governments noticed the problem, the large number of authorities involved on the land and in the water (e.g. private landowners, municipalities, states and the federal government) made it exceptionally difficult to implement and enforce overarching policies.

In response to a grim Congressional research study that identified excessive nutrient loading as the cause of a steep decline in the living marine resources, the Chesapeake Bay Program was formed in 1983. The program is a multi-jurisdictional and multi-stakeholder partnership established to coordinate policies, funding and technical capacity, and set ambitious, quantifiable goals with deadlines. Today, many impacts from unchecked development and utilization remain, but measurable improvements in water quality, habitat and oyster, blue crab and other wildlife populations have been achieved through reducing pollution and other adverse impacts, protecting healthy habitats where possible, and widespread restoration efforts.

This model of integrated habitat protection has also been used with great success elsewhere in the United States. For example, the South Atlantic Fishery Management Council protects essential fish habitat through its Habitat Plan and Fishery Ecosystem Plan; the Albemarle-Pamlico National Estuary Partnership in North Carolina has created the Comprehensive Conservation and Management Plans under the auspices of the National Estuary Program; and the state of North Carolina has developed its own Coastal Habitat Protection Plan. By continuing to consider all uses, while placing a premium on underlying ecology, integrated management plans can help resource users achieve greater collective returns over the long term.

5.2.3 Spatial management on the Great Barrier Reef

After a particularly destructive outbreak of crown-of-thorn starfish in the Great Barrier Reef, Australian legislators took action to protect a natural wonder and cultural icon from ongoing environmental issues. In 1975, a federal law created the Great Barrier Reef Marine Park, designed to be multi-use for fishing, recreation and shipping, among other sectors. To design it, the park authority split the park into smaller sections and then zoned within each area (Gershman et al., 2012). However, throughout the 1990s, more and more scientific evidence accumulated to show that this piecemeal approach was not effective.

Instead of continuing with an ineffectual approach, the government reexamined the evidence and began a new strategy. A comprehensive and science-based planning process was launched to define representative areas covering the range of habitats, species and communities across the entire park, rather than first breaking the park into sections. It was a long, participatory and consultative process. Authorities considered social and economic impacts and sought alternatives that met environmental goals while minimizing adverse impacts. While the process was lengthy, it was crucial to investigate all of the factors and consider all options, so that the design proved more effective and more durable in the long term. The plan, finalized in 2006, placed 33% of the Great Barrier Reef into no-take zones and protected 70 different bioregions that were defined during the process. Not only has this system proven successful for Australia, which has seen increases in fish density and average size, but internationally the process is a valuable anecdote about the importance of adaptive management and the significance of taking the time at the start of a system to truly learn all of the information and involve all of the stakeholders.

5.2.4 Development of marine spatial planning tools

As coastal waters become more crowded with agriculture, fisheries, shipping and a growing list of sectors, managing and planning for each sector separately is proving to be an inefficient and suboptimal approach. Taking on a comprehensive, integrated marine spatial planning process can appear overwhelming, but an increasing number of tools have emerged to assist with the task. SeaSketch, developed by researchers at the University of California–Santa Barbara, is a tool for non-experts to generate hundreds of possible marine spatial plans for their regions. These plans are run through analytics that report predicted biological, social and economic performance; the resulting information can be used to better evaluate benefits and explore tradeoffs among different zoning plans. The platform even allows for stakeholder input on different plans and peer collaboration. The SeaSketch tool has been used in an extensive zoning plan for Barbuda (the Barbuda Blue Halo Initiative) and in the Hauraki Gulf of New Zealand (Sea Change), among other places. Frameworks like SeaSketch continue to emerge and improve, integrating greater amounts of data and introducing more thorough tradeoff analyses (e.g. Lester et al., 2018). Armed with these tools, managers can more confidently and efficiently make successful integrated plans.

Aquaculture spatial planning is currently being done in pilot-scale in China; for example, Sanggou Bay of Rongcheng City has been divided into aquaculture permitted zone, restricted zone and prohibited zones (Sun et al., 2018).

5.3 Managing for climate change

The effects of climate change are already impacting and will increasingly impact all ocean ecosystems and every country's living marine resource management. The threats range from changes in stock distribution and productivity to questions of food security and fisher safety. However, the severity or combination of climate change impacts will differ across contexts. There is no universal solution to this problem. Some stocks will increase in some regions; some will disappear. Some mariculture operations might thrive from temperature changes; some might fail from extreme weather (De Silva and Soto, 2009). Countries are already being confronted with these challenges. One contentious example is the so-called "Mackerel Wars" between Britain (backed by European Union) and both Iceland and the Faroe Islands. As Iceland discovered a greater and greater number of mackerel in its waters, driven north by rising sea temperatures, they increased their quota significantly. Without a corresponding decrease in quota by another nation, the mackerel fishery became unsustainable and eventually lost its MSC certification in 2012 (Jensen et al., 2015).

While climate change impacts are diverse and a great deal of uncertainty can exist, managers can research and plan for different scenarios. For example, the International Council for the Exploration of the Seas (ICES) is working with NGOs—including EDF— to compile the correct questions and push forward innovative solutions for a changing landscape. It will prove crucial to cultivate strong regional partnerships and develop large ecosystem-based approaches (Moustahfid, 2017). Institutions should begin to incorporate uncertainty into management frameworks and all new policies should consider climate change from the start.

5.4 Promoting long-term value over volume in wild fisheries

International experience shows that when fisheries are sustainably managed, they can provide more food, more prosperous livelihoods and a healthier marine environment. In many examples, fishermen have transitioned from maximizing their catch volume in the short term to successfully increasing the fishery's long-term value. While the management tactics underlying such a transition can vary, providing fishermen, communities and the fishing industry with strong access rights has proven effective to flip the incentive equation and cultivate a conservation ethic, as in the below case studies.

5.4.1 TURF management in Belize

In 2009, after years of rising fishing effort, but declining catch of lobster and conch, the government of Belize began an effort to improve the country's fisheries governance. More than just important sources of protein, lobster and conch are the country's two most valuable export species and vital for the income of the nation's fishermen. With such high stakes, the government, assisted by NGOs, launched ambitious TURF (Territorial Use Rights for Fishing) pilot projects in two communities. At the pilot sites, access was restricted to local fishermen who had fished in the area historically. These fishermen were then granted the right to fish in exchange for respecting no-take zones and other fishing regulations. This resulted in less competition on the water day-to-day and more investment in the future health of their resources (Casteñeda et al., 2011); fishing violations also dropped by 60%.

The government scaled the program nationally in 2016 to include all domestic waters. All conch and lobster fishing is now governed through a network of TURFs and co-managed between the national government and local committees comprised of elected fishers. According to the Health Reefs Initiative, Belize's Southern Barrier Reef has improved in health from 2016-2018 to achieve an overall "good" health rating, one of only three reefs in the Mesoamerican Reef to do so (McField et al., 2018). The initial focus on lobster and conch is now being expanded to the high-diversity finfish fishery through the application of data-limited tools. Fishermen are invested in and supportive of strengthening and expanding the network of marine protected areas, so as to improve the quality of their resources. To leverage the better product quality, the cooperatives have partnered with NGOs to create a local seafood certification program with Belizean restaurants and hotels (Fujita et al., 2019). This new market of local businesses opens the door to a premium price for a sustainable product and rewards fishers for upholding their sustainable practices in the long term.

5.4.2 ITQ management of red snapper in the Gulf of Mexico

The Gulf of Mexico supplies more than 40% of the United States' domestic seafood. Among the catches of crab, shrimp, groupers and swordfish is the commercially and recreationally prized red snapper. Red snapper underwent a rapid depletion of the population starting in the 1950s. By 1990, spawning potential had declined to just 2%, compared to the target spawning potential of 26% (NOAA, 2018). Recognizing a dire situation, management authorities attempted an aggressive series of reforms, such as creating a catch limit, to improve the situation. Instead, the efforts led to a dangerous race to fish, the repeated lowering of the catch limit and a continuing decline in the population. A new approach was needed; on January 1, 2007, the fishery implemented an individual transferable quota (ITQ) program to reduce overcapacity and eliminate the problems associated with derby fishing.

The ITQ program decreased the number of fishers on the water and assigned each of them an individual share of the fishery's total allowable catch (TAC). The TAC is set annually by the Gulf of Mexico Fishery

Management Council based on regular scientific stock assessments and with the advice of a committee of scientific and statistical experts. In 2007, at the start of the program, the TAC was drastically lower than in 2006 (Agar et al., 2014). In some cases, the harsh reduction and resulting small individual quotas caused real hardship for fishers. However, by 2009, assessments indicated the stock was rebuilding and managers increased the TAC. As the program has continued, the number of fishing trips has decreased, the number of discarded fish has decreased, fish stocks have rebuilt, the catch limit has doubled, and there has been a 100% increase in revenue for fishers (EDF). This revenue increase is due to the fact that fishers are now able to fish when market demand and prices are higher—for example, during the season of Lent—and they are catching higher quality fish. As systems like this have been slowly implemented across the country, there are more and more success stories. In 2017, the number of overfished stocks reached the lowest ever level in the United States (NOAA, 2017).

5.5 Accelerating and scaling solutions internationally

It is no coincidence that there is such little data about fisheries in developing contexts. These countries' fisheries are often small-scale, multi-species and dispersed, making centralized data collection difficult (Purcell and Pomeroy, 2015). More fundamentally, there is a severe lack of technical, financial and governance capacity in many of these fisheries. As developed nations innovate and improve their living marine resource management, these lessons should be shared and replicated in developing countries before their living marine resources fall prey to the same misfortune. Domestically, improving the technical, financial and governance capacity of developing country fisheries provides better food security for populations where fish is normally a vital source of protein (Hall et al., 2013). Internationally, growing our global knowledge and management of living marine resources ensures more stable markets and healthier oceans for all involved.

The Oceans and Fisheries Partnership is a shared effort between USAID and the Southeast Asian Fisheries Development Center to use improved regional relationships to prevent and stop illegal, unreported and unregulated (IUU) fishing and improve the Asia-Pacific region's fisheries and biodiversity. The partnership uses an array of tools grounded in an ecosystems approach to fisheries management. For example, the collaboration pursues the development of catch documentation and traceability systems that help encourage transparency, identify and combat IUU, and improve available data. The partnership also examines entire supply chains to leverage private sector investment to increase impacts, create new market incentives and ensure sustainable sources of funding across all its participating geographies (USAID, 2018). These large-scale collaborations are essential and benefit all parties by advancing information exchange and scaling knowledge and capacity to address some of the biggest challenges facing fisheries.

6. Recommendations

China faces an emerging crisis in its coastal and marine ecosystems wrought by pollution, widespread coastal habitat destruction, overfishing and overcapacity in aquaculture. Furthermore, climate change threatens to not only severely test the resiliency of China's marine ecosystems, but to exacerbate global and regional tensions as it puts pressure on aquaculture production and causes wild stocks to shift across borders. China has an opportunity to address these challenges domestically, and play a leadership role on oceans conservation regionally and globally, with a comprehensive suite of actions:

6.1 Strengthen legal protections for coastal and marine ecosystems, while promoting sustainable production.

China has already begun to transform its sprawling aquaculture industry into a sustainably managed engine of safe, high quality food production, but further progress will require the creation of stronger legal tools. China should consider enacting a new aquaculture law that places limits on facilities' waste discharge and resource use. The law should require science-based spatial limits that take into account the carrying capacity of the local environment, enabling the industry to optimize the value of aquaculture production while minimizing environmental impacts; these limits could be incorporated into China's National Marine Functional Zone plans. The law should also mandate stock reporting by all facilities, authorize routine onsite inspections and include other provisions that mitigate the industry's impacts on coastal and marine ecosystems, such as limits on use of antibiotics or other chemicals.

China has already begun to shift toward limiting the amount of fish caught in its capture fisheries. Such an approach has proven more effective when combined with rights-based approaches that allocate portions of the catch or local fishing areas to the fishing industry and fishing communities. Rights-based approaches will enable the government to address social issues by equitably allocating access to fish among large and small industries, commercial and recreational fishing sectors and small-scale fishing communities. As China improves fisheries monitoring and data, rights-based approaches will become increasingly practical, and fisheries law should be modified to promote their adoption.

Healthy habitats are necessary for productive coastal and marine ecosystems. China should enact a strong Marine Habitat Conservation Law (MHCL) that strengthens protections for coastal and marine habitats and encourages significant new rehabilitation efforts that restore lost ecosystem functions and resiliency. The law should require the development of a network of marine and coastal protected areas large enough to support a biodiverse ecosystem and the production of high-value economic benefits from capture and recreational fisheries over the long term.

6.2 Implement a high-tech monitoring system to combat corrupt and illegal activities that undermine compliance and to improve marine science.

In China, as in many countries, multiple government agencies struggle to control long coastlines, vast numbers of fishing boats and aquaculture facilities, and marine protected areas and the red line system. Advanced monitoring technologies promise to make this job much easier. China's innovation in sensors, networking technologies and artificial intelligence can help create a transparent system that can operate across agencies, and even globally, to facilitate enforcement and promote compliance with the rules that are established to protect marine ecosystems. Applied domestically, such a system could enable China to expand monitoring to nearly all of its domestic fishing vessels, landing sites, aquaculture facilities and coastal and marine protected areas; applied globally, China could play a leadership role in helping other countries ensure the sustainability of their resources.

In addition to promoting compliance, a high-tech monitoring system has other benefits. It will create a wealth of new data to vastly improve China's understanding of the health of its coastal and marine ecosystems; enable the government to respond in real time to pollution hazards and other emergencies to protect public health and food safety; and it can help other nations understand the impacts of climate change and collaborate with China in designing ways to mitigate them.

6.3 Restore lost coastal and marine ecosystem functions needed to support fisheries production, biodiversity conservation and resilience to development, pollution and climate change.

China has already taken important steps to conserve coastal and marine ecosystems through the redlining process. However, more should be done to restore lost habitat, including mangroves, seagrass beds, tidal marshes and flats and coral reefs. These habitats provide a valuable array of ecosystem services, including providing nursery and spawning grounds for a diverse array of marine organisms, filtering and detoxifying pollutants, protecting the coast from erosion and buffering the effects of climate change. It is not enough merely to protect existing coastal and sea areas. If China's coastal and marine ecosystems are to withstand the impacts of pollution and climate change and continue to be a source of tremendous prosperity and food production, China should consider the following steps to undertaking a large scale effort, guided by ecological science, to restore lost ecosystem functions and services:

6.3.1 Establish a national "marine ecological report card" on the health of China's coastal and marine ecosystems.

China's economic goals for marine capture fisheries, aquaculture, marine tourism and other industries should be based on a sound ecological understanding of what the country's coastal and marine ecosystems can support. To develop a strong scientific foundation, China should consider establishing a comprehensive ecological assessment, i.e., a "marine ecological report card," on the health of the country's marine and estuarine zones. The report should assess the cumulative effects of the intense uses of China's living marine resources by fisheries and mariculture, and the impacts of pollution, development, tourism industries and climate change, on the health of China's coastal and marine ecosystems. It should evaluate the integrity of key ecosystem functions and services, such as water and nutrient cycles and critical habitat, and measure their resiliency to climate change and other future pressures. The report should also recommend ways that China can improve the capacity and resilience of coastal and marine ecosystems to support seafood production and tourism and conserve biodiversity. The report should be made publicly available and regularly updated.

6.3.2 Develop a national plan of action to restore lost ecosystem functions and services.

Because in China, as in most countries, several different government agencies have authority over the country's marine and estuarine zones, China should consider developing a comprehensive plan to coordinate efforts. The plan should seek to ensure that the actions, taken collectively, preserve the value of ecosystem services and functions and optimize China's economic benefits over the long term. The plan should include the Ministries of Agriculture and Rural Affairs, Ecology and Environment, and Natural Resources, as well as the related provincial and local agencies along the coasts. It should also provide guidance for a wide variety of actions; for example, setting catch quotas in capture fisheries, allocating area for mariculture production, protecting habitat through the redlining process, restoring coastal and marine habitat, restricting pollution and designating areas for functional uses through China's marine spatial planning processes.

6.4 Create a network of partnerships among countries along the Maritime Silk Road to promote sustainable marine governance and achieve the Sustainable Development Goals.

There is but one global ocean and we are all affected by the health of its ecosystems. The Maritime Silk Road Initiative represents a historic opportunity for China to demonstrate leadership in global marine governance and advance the UN Sustainable Development Goals. Under the Silk Road Initiative, China should consider creating a network of partnerships with countries from Asia, Africa and Europe to encourage mutual learning and promote joint actions that promote a healthy ocean.

China's leadership is important because, while many developing countries face similar challenges in managing their living marine resources, they typically lack China's scientific and technical expertise, governance capacity and financial resources. As a result, the marine resources in these countries are among the most poorly managed and threatened in the world. China can promote sustainability along the Marine Silk Road by promoting information sharing and collaborations that build educational, scientific and technical capacity in partner countries. Key topics could include managing marine resources sustainably, promoting economic development, improving food security for vulnerable peoples, combatting illegal fishing and building the capacity of women in fishing communities and supply chains.

China could also continue to demonstrate leadership by using the Maritime Silk Road Initiative to catalyze the development of regional and global approaches that can mitigate the impact of climate change on living marine resources. In Asia and Africa, climate change could lead to greater conflict among nations as wild fish migrate across borders and changes in the productivity of mariculture and catch fisheries strain the ability of nations to produce food. The Maritime Silk Road Initiative could provide the region with the leadership and institutional platform to develop urgently needed, collaborative solutions to mitigate the impact of climate change on marine ecosystems.

6.5 Assess the impacts of climate change on living marine resources and evaluate ways to mitigate the impacts.

Climate change is already having a wide variety of significant effects on living marine resources around the world, which threaten to become worse over time. China could develop solutions to this issue by promoting more research into the impact of climate change on the country's capture fisheries and mariculture, and the natural ecosystem services upon which these industries depend. It is also important to evaluate how climate change will likely affect fisheries and food production across the entire Asia Pacific region and around the world. Assessments should take into account the potential impacts of warming waters, acidification, and altered weather, nutrient and water cycles.

In addition, China may wish to consider ways to not only mitigate the effects of climate change, but effectively adapt to it. For example, scientists could examine how provincial governments could work together to manage fisheries, how the industry could remain profitable as species shift in their ranges, how research programs could be designed for breeding heat- or acid-tolerant mariculture species, and how international fish sharing agreements could be developed or strengthened.

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