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elsewhere; where this understanding informs identification of management objectives and construction of problem-specific management models; where these models are calibrated – wherever they are needed – using cutting-edge methods of data collection and statistical inference; where society has confidence in what ecology predicts; and where curiosity-driven empirical and theoretical research discovers ever new possibilities for understanding and managing ecological systems.

Ecological research will always form a spectrum from purely empirical work through data-driven modelling to theoretical analysis of fundamental principles [1,2,5,9]. It is essential however that all participants have a basic understanding and a joint sense of ownership of the entire spectrum [5,20]. Only then can knowledge and understanding flow effectively in both directions, bringing to full fruition the unity and utility of our science.

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Science & Society

Transforming Protected Area Management in China

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We discuss institutional reforms to China's protected area management. Currently (as elsewhere), protected areas suffer fragmented management, lack of a comprehensive classification, inadequate coverage of biodiversity and ecosystem services, and divided, inconsistent legislation. We recommend establishing a new system of protected area management that can address past difficulties by using ongoing institutional reforms as unprecedented opportunities.

Protected Areas in China

Establishing protected areas is the major strategy for conserving biodiversity worldwide [1]. Global aspirations such as the United Nation's Sustainable Development Goals 14 and 15 (https://sustainabledevelopment.un.org/sdgs) emphasise their importance and inescapable connections. The International Convention of Biological Diversity's Aichis targets (https://www.cbd.int/sp/targets/) specify quantitative targets for areas protected (target 11), stopping the loss of natural habitats (target 5), and species extinction (target 12), while underscoring the vital services natural ecosystems provide (target 14).

China has exceptional biodiversity: its ecosystems range from permanent ice fields to tropical moist forests [2], and it holds 15% of the world's vertebrate and 12% of its plant species [3] in about 6% of the Earth's land surface. As with other countries [4], it encounters major obstacles to conserving this biodiversity, limiting its ability to meet international commitments. China's experiences in protected area management have important implications for the rest of the world, particularly given the upcoming 15th Conference of Parties (COP 15) to the Convention on Biological Diversity in China in 2020.

Problems in Managing China's Protected Areas

By 2017, China had established 2750 nature reserves (the strictest type of protected area) covering 1.47 million km^2. Since the establishment of the first reserve in 1956, the total area increased rapidly, especially between 1990 and 2000. As with the total global area [1,5], it has plateaued or even decreased slightly since then. Since 2000, China has also established numerous other types of protected areas. These have multiple goals for ecosystems, landscapes, natural resources, relics, and others, yet their combined area is small. In total, China has over 12 000 protected areas, covering 20% of its land surface [6] (see Figure S1 in the supplemental information online).

The central problem has been the fragmented management of these different protected areas. One or more departments or agencies within the corresponding district or county government (Table S1 in the supplemental information online) manages each protected area. According to their designated responsibilities, these entities set goals and corresponding management rules for protected areas under their jurisdiction. Three other major problems arose from this.

First, there is no comprehensive classification of protected areas. Different departments created categories, including scenic spots, forest parks, and water parks, from their own, varying goals (see online supplemental materials Table S1). The disjointed protected area categories may have similar functions, especially those generating direct economic returns, such as tourism or recreation, yet overlook vital ecological functions (e.g., biodiversity or ecosystem services). Thus, the protected area categories cannot meet national requirements, for example, ones to achieve the Aichi targets. Furthermore, they have no clear correspondence and so cannot readily be aligned to international schemes, especially those of the International Union for Conservation of Nature (https://www.iucn.org/theme/protected-areas/about/protected-area-categories).

Second, the quantity and spatial allocation of protected areas fall short of meeting the needs of biodiversity conservation and the provisioning of ecosystem services [7,8]. Each department has its own agenda. Even when applied to the category of nature reserves, no overall plan meets national conservation targets. Besides, many nature reserves were established 'bottom-up', in places that suffered serious threats or where local governments were strongly motivated to do so. For instance, local governments prefer protected areas that attract tourists (e.g., forest parks and wetland parks) over strictly regimented nature reserves. Without comprehensive planning, the current protected area system does not match key areas for biodiversity and ecosystem services. The largest protected areas are in western China, especially in the Qinghai-Tibet Plateau. Many of the key areas for biodiversity and ecosystem services (such as water retention) are in eastern or southern China and are seriously underrepresented [8].

Conversely, this fragmented management 'overprotects' some areas. Several administrative bodies may have overlapping management responsibilities, as they do elsewhere [9], putting different administrations into potential conflict. Protected areas in Hainan and Sichuan provide examples (Box 1).

Third, the lack of effective legal mechanism determines the roles, benefits, and authority of multiple stakeholders in protected areas. Under the current mechanisms, regulations and policies (e.g., goals and rules) are incomplete, disjointed, lack coordination, or even conflict. They are thus less effective in accomplishing relevant national goals and international commitments. Challenges in accountability arise if players are also judges. What departments should be accountable for what issues? How should a protected area's management performance be monitored? Who is to be blamed or rewarded? One example is the Sanjiangbingliu areas in Yunnan Province, where several types of protected areas overlap substantially, and regulations contradict, offset, and even cancel one another (Box 1).

Opportunities from Institutional Reforms

China's government is now implementing institutional reforms. Some closely relate to ecological protection. Four reforms are critical for highly efficient and standardised management of protected areas.

Restructuring Government Agencies

The number of ministries or branches of the State Council has decreased by 15 from 79 since March 2018, as some departments were merged or subordinated to an upper authority (http://sg.weibo.com/user/rmrb/4217176971870338). Upon completing these nationally, the reforms will be applied locally. Some reforms closely related to ecological protection will benefit China's re-establishment of a uniform, normative, and efficient system for protected area management. This change should address the central problem of fragmented management. Fewer government agencies, with better aligned goals and responsibilities, should reduce functional overlap or conflict.

Ownership Shift

The ownership of all state-owned natural resources and assets in China transferred from multiple departments to one ministry: the newly established Ministry of Natural Resources. This ministry has the authority to consider both development and conservation goals simultaneously when establishing national land planning, including protected area plans. This ownership shift should help solve problems relating to spatial overlapping, lack of coordination, and

Box 1. Management Problems

Overlapping Management in Hainan and Sichuan Provinces

Among 118 terrestrial and coastal protected areas categorised into six types in Hainan Province, at least 50 (16.6% of the total protected area amount) experience administration overlap. Nature reserves, forest parks, and scenic spots show the largest extent of administrative overlap (see Figure S2 in the supplemental information online).

Since 1978, the State Forestry Administration has managed the famous Jiuzhaigou in Sichuan Province as a national nature reserve for giant pandas (*Ailuropoda melanoleuca*). Since 1982, the Ministry of Housing and Urban-Rural Development has also managed it as a national scenic spot. It became a national geopark in 2004 for the conservation of its geological landscape and was entrusted to the Ministry of Land Resources. Thus, it had three names and three different government departments manage it. In practice, it had the same administration and staff, but the different responsibilities may conflict. When conservation clashed with development, the administration easily chose the latter. Tourism brought greater economic benefits but likely harmed conservation effectiveness. At least seven pandas were in this reserve in 1988, but only two in 2000 and three in 2013 based on the national panda surveys. In contrast, the panda population size increased in the surrounding mountain ranges [10].

Law and Policy Conflicts at Sanjiangbingliu in Yunnan

The Sanjiangbingliu (Three Parallel Rivers) region was designated as a national scenic spot in 1989 and a world natural heritage site in 2003. Simultaneously, it is a national nature reserve, geopark, and forest park with large spatially overlapping areas. The 'Nature Reserve Regulation Rules of the People's Republic of China' prohibit development or commercial activities in the buffer and core zones, while the 'Regulation Rules of Scenic Spots' allows herding, logging, hunting, and other activities that benefit local villagers economically. Consequently, local governments and related administrations allowed land claims and deforestation. They even approved construction of roads that cross the nature reserve's core and buffer-zone areas. These activities, though giving rise to landslides, soil erosion, and degradation of wildlife habitat, are legal under the scenic spot rules. If ecological degradation continues, it is difficult to punish the accountable parties as the actions that lead to soil erosion comply with those rules [11].

conflict in management goals or rules, arising from previous multiple administrations.

Establishing a National Park Administration

A new body, the National Park Administration under the Ministry of Natural Resources manages forests, wetlands, and grasslands. Managing protected areas that previously reported to a range of departments, it is responsible for ongoing national park reform. It aims to solve the overlapping and fragmented management by multiple branches and protect the integrity of natural ecosystems. The reforms will also promote establishing national parks as a new type of protected area, covering large areas, such as the Giant Panda National Park [12]. The original small protected areas that different departments managed inside these national parks will be repealed once the national park is established (Figure 1). This change may offer a great opportunity to address the second problem related to the quantity and spatial allocation of protected areas.

Separation of Management from Monitoring and Supervision

One adjusted department, the Ministry of Ecology and Environment, has been released from managing some nature reserves and is only charged with monitoring and supervising the management performance for all types of protected areas. It overseas management performance of all ecological conservation efforts, including protected area management, independently. This reform addresses the problem of inadequate legal mechanisms. When players are no longer judges, the monitoring and assessment of protected areas status and management should be more objective.

Recommendations for Unresolved Problems

The reforms mentioned above have led to important changes. For instance, in September 2018, the new Ministry of Ecology and Environment responded quickly to mismanagement (e.g., logging, mining, real estate development) in seven protected areas that conserve endangered species, including Chinese alligators (*Alligator sinensis*), Manchurian tigers (*Panthera tigris altaica*), and Asian elephants (*Elephas maximus*). The ministry mandated the relevant local governments solve serious development problems (http://dy.163.com/v2/article/detail/DSN22NTG0530SM99.html).

Although institutional reforms should address the problems discussed above, several issues need further attention. We recommend the following:

(i) Recategorise all types of protected areas to meet the conservation requirements of biodiversity and ecosystem services to ensure the ecological security of China and neighbouring countries. With institutional reforms, especially restructuring governmental agencies, a new challenge ensues. When two agencies merge, how do they deal with the different categories, goals, and rules they bring? When speaking to China's international commitments, how can it translate its protected area concepts and types into ones that other countries understand? China's protected area types must have a clear relationship to international categories. The central government newly proposed the concept of three major types (i.e., national parks, nature reserves, and nature parks). We propose a more detailed system including national parks, nature reserves, germplasm resources reserves, nature parks, and ecosystem services reserves [6]. New systematic protected area categories should consider different conservation objectives, including natural resources, species

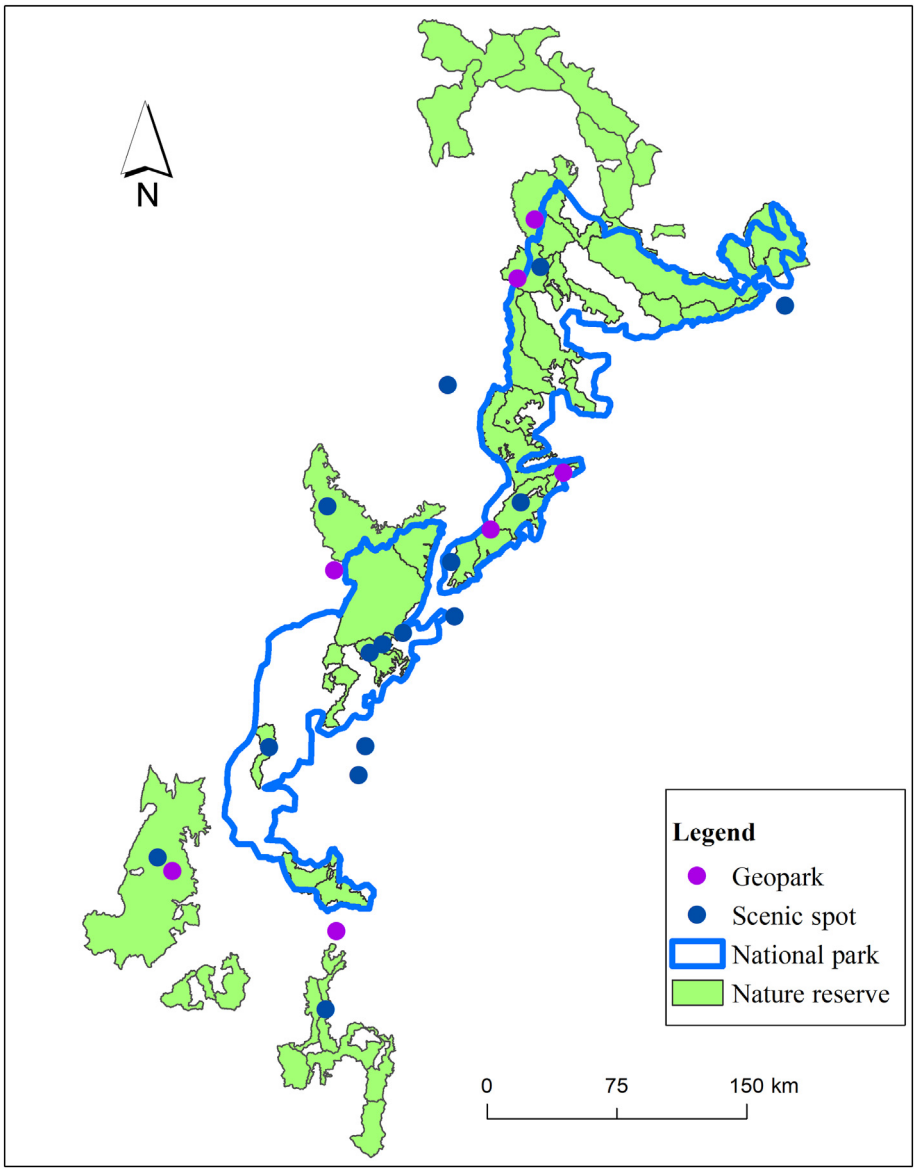

Figure 1. Protected Area System within the Giant Panda Distribution in Sichuan and Gansu Provinces. After the institutional reform, the original small protected areas (e.g., nature reserves, geoparks, and scenic spots) that different departments managed inside the proposed Giant Panda National Park will be repealed once the National Park is established. Outside the National Park, one type of protected area will be retained, where several overlapped. Data from [6,12].

and ecosystems, the intensity of conservation and development, and the practicality of management, to enable more effective conservation.

(ii) Establish comprehensive spatial planning that considers the nation's diversity of representative species, ecosystems, and natural landscapes. It should establish quantities and boundaries of various protected area types that comply with our recommendation above. This action should solve problems of where to establish national parks and other types of protected areas, and how to identify unique types in protected areas reassignment (Figure 1). China should be cautious in reassigning strictly protected areas to less strict ones. Subsequently, this planning may provide a foundation for delineating the boundaries of all types of protected areas, since many protected areas exist only on paper, and identify gaps in their quantity and distribution.

(iii) Create an integrated legal system with regulations for different types

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of protected areas. A protected area law proposed several years ago failed mainly due to the disagreement amongst the multiple departments in charge of protected areas. The recent reforms provide a new opportunity. This legal system should address the problem of the roles, benefits, and authority of multiple stakeholders in protected areas. This system should contain an integrated protected area law, regulations for different types of protected areas, and specific regulations for each protected area.

Our recommendations will enhance protected area management, likely better balancing ecological conservation and economic development and pave the way for green development in China. These efforts should substantially move China forward towards achieving the goals that the Chinese government established in response to the 2020 Global Biodiversity Targets [13]. Even more significantly, they will confirm China's international leadership within COP15. This event comes at a time when there are ambitious goals to protect large fractions of the land (up to half) [14,15] and large areas of the oceans, and challenging debates on how to protect species globally and within China itself [16].

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Supplemental Information

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Book Review

The DNA around Us

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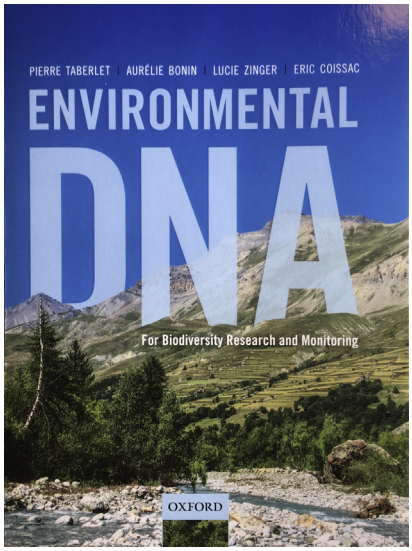

Our planet is unique from a cosmic perspective since, as far as we know, life only exists here. Anyone who spends a few hours outside in nature will quickly appreciate the rich diversity of life that is thriving in the variety of ecosystems that Earth has to offer.

What fewer people realise is, that besides the rich diversity of living organisms – from bacteria to blue whales – Earth is also rich in DNA traces left behind by these very organisms. Some of this DNA is inside living cells of the smallest bacteria, while some is left behind by shedding of skin cells and excretion of body fluids from the largest organisms. Such environmental DNA (eDNA) can be sampled and analysed – especially thanks to the rapidly evolving DNA sequencing technology, as well as ever-more-powerful computers. For billions of years living organisms have shed DNA to the environment. Most of this is long gone due to chemical and biological degradation of the molecules, but