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Changes in area and number of nature reserves in China

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Abstract

Nature reserves (NR) are the cornerstone of biodiversity conservation. Over the past 60 years, the rapid expansion of NRs in China, one of the world's megadiverse countries, has played a critical role in slowing biodiversity loss. Yet we show that despite the continuing increase in the number of NRs, the total area of China's NR declined by 3% from 2007 to 2014. This loss resulted from downsizing and degazettement of existing NRs and a slowdown in the establishment of new ones. NRs in regions with rapid economic development suffered a greater decrease in area, suggesting that downsizing and degazettement of NRs are closely related to the intensifying conflict between economic growth and conservation. As an example, boundary adjustments to national NRs, the most strictly protected NRs, along China's Yellow Sea coast, a global biodiversity hotspot with a fast-growing economy, resulted in the loss of one-third of the total area. Tidal wetlands, one of the most significant habitats in the NRs, decreased by 27.8% due to boundary adjustments. Additionally, 25.2% of tidal wetlands within NRs disappeared due to land reclamation. Taken together, these results suggest that conservation outcomes are declining in the Chinese NR estate. Although the designation of protected areas that are primarily managed for sustainable use has rapidly increased over recent years in China, we propose that NRs with biodiversity conservation as their main function should not be replaced or weakened.

Keywords

boundary adjustment; conservation outcome; downsizing; degazettement; protected area; Tidal wetlands; Yellow Sea

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Supporting Information
Additional Supporting Information may be found in the online version of this article at the publisher's website.

Article impact statement: Positive conservation outcomes have declined in China's natural reserves in recent years.

Introduction

Designation of protected areas (PAs) is a key measure for safeguarding species and ecosystems globally (Watson et al. 2014). China, one of the world's megadiverse countries, had established a total of 2,729 nature reserves (NRs), the most strictly protected type of PA, by the end of 2014; these NRs encompass 147 million ha and cover 14.8% of China's land area (MEP 2015). China's NRs have played a critical role in biodiversity conservation. For example, the threatened giant panda (*Ailuropoda melanoleuca*) and crested ibis (*Nipponia nippon*) have been protected in NRs, and their populations have gradually recovered from the verge of extinction (MEP 2015). Given China's huge human population and rapid economic growth, the expansion of the NRs is a remarkable achievement and an important effort toward achieving the UN's Sustainable Development Goals and the Aichi Biodiversity Targets (ABTs) for conservation (CBD 2010; UN-DESA 2015).

Although the functions of NRs are well established (Watson et al. 2014), tension between economic growth and conservation is a long-standing and globally pervasive issue. Over the past century, many NRs have been subject to downgrading, downsizing, or degazettement (PADDD) as a result of the growing human population and intensifying competition for land (Mascia & Pailler 2011; Mascia et al. 2014). Since the late 1970s, China has implemented a policy of reform to promote economic growth. With an annual economic growth rate averaging 10% over the past few decades, China has become the second largest economy in the world (Miller-Rushing et al. 2017). During this period, NRs in China have suffered increasing pressure from human activities (Liu et al. 2001, 2003; Chen 2016). For example, although exploitation is prohibited in NRs (The State Council of PRC 2005), it nevertheless occurs in many sites; some NRs have been degazetted to make way for construction projects (Ma 2016). Increasing numbers of China's NRs have undergone boundary adjustments in recent years (Xie et al. 2012; Chen 2016; Ma 2016, Table S1), but it remains unclear whether these boundary adjustments have improved conservation outcomes or have simply made space for economic growth, impairing the conservation function of the NRs.

NR boundaries are usually conceptualized as fixed in perpetuity to protect the biodiversity within, yet environmental changes can reshape the spatial distribution of species and ecosystems (Hickling et al. 2006; Pecl et al. 2017), and some existing NRs are poorly placed with regard to conservation value (Fuller et al. 2010; Watson et al. 2014). As a consequence, the strategical adjustment of the boundaries of existing NRs to replace underperforming parts coupled with the designation of new NRs to fill conservation gaps could be important for improving conservation outcomes (Hannah et al. 2007; Fuller et al. 2010). Economic incentives, however, can strongly affect NR management (Mascia & Pailler 2011; Xie et al. 2012; Visconti et al. 2015), and some boundary adjustments may have been made to create space for development rather than reflecting changed or better understood conservation priorities.

The rapid development of China's NRs is well documented (e.g., Liu et al. 2003; Xu et al. 2017; Zhang et al. 2017), yet there remains no formal assessment of PADDD in China. Here we examine the changes in the number and area of China's NRs over the past 60 years, explicitly accounting for newly established NRs and those that have undergone boundary adjustment or full or partial degazettement. We then provide a regional study focusing on the national NRs along the Yellow Sea coast, a global biodiversity hotspot with huge pressure from exploitation by a fast-growing economy (MacKinnon et al. 2012; Murray et al. 2014; Melville et al. 2016), where we assess the impacts of land-use transformation and boundary adjustments on NRs. Finally, we discuss the causes of PADDD in China and propose suggestions for improving conservation outcomes.

Methods

Data on China's NRs were obtained from information officially published by the Ministry of Environmental Protection (MEP), which was the authority for NR management in the central government. China's NRs are classified into local (provincial and county) and national NRs. Local NRs can be recommended for promotion to national NRs (NNRs) by local governments subject to approval by the central government. NNRs have the highest conservation priority and are given the strictest protection (The State Council of PRC 2005). We analyzed the number and area changes of NRs (both total and national NRs) since the 1950s, when the first NR was established in China.

All of the boundary adjustments to NNRs are made public, with detailed information about the changes to boundary and area. Boundary adjustments to local NRs, however, are seldom announced. To determine the number and area changes for all of the NRs, we compared the checklists of NRs from 2005 to 2014. This enabled us to calculate the number and area of newly established, boundary-adjusted, and degazetted NRs as well as to determine area changes of NRs subject to boundary adjustments. For NNRs, we further analyzed change in area of the three function zones (core area, buffer zone, and transition area). When collecting the data of boundary adjustments to NNRs, we only included adjustments that had been approved by the central government (the State Council or the MEP, supporting information).

Linear models were used to test the effect of economic development on the change in area of NRs in China from 2005 to 2014. The increase of gross domestic product per person (GDP), which is significantly related to human population density (Pearson $r = 0.68$, $P < 0.001$), was collected from the statistical yearbook for each administrative region (provincial level, $n = 31$) and was used as an indicator of regional economic development. The area of the NRs as a percentage of the total land area in the administrative region, and the regional location (inland or coast) were also included in the models as independent variables. Additionally, generalized linear models (with a binomial distribution and logit link function) were used to analyze the effects of NNR size (area, logarithmically transformed), location (inland or coast), year of establishment, and habitat type (forest, grassland/wilderness, inland wetland, or coast & sea) of the NNRs on their boundary adjustment (adjusted or not adjusted).

Complementing the national analysis, we conducted a regional study along the Yellow Sea coast, the region supporting the fastest-growing economy in China (MacKinnon et al. 2012), to detect the magnitude of land-use change and boundary adjustments on coastal NNRs. The tidal wetlands of the Yellow Sea have extremely high conservation value because they support numerous waterbirds and aquatic organisms as well as provide an ecological barrier that protects the densely populated coastal area against extreme weather events (MacKinnon et al. 2012; Murray et al. 2014). A total of 14 NNRs have been designated along the Yellow Sea since 1980 (Fig. S1; Table S2). The Yellow and Yangtze Rivers transport huge amounts of sediment to the Yellow Sea, resulting in seaward expansion of the tidal wetlands. As a consequence, adjustments to NR boundaries so as to exclude the inland drylands and to add newly formed tidal wetlands have been commonly practiced to improve conservation. However, rapid economic development requires substantial land resources which has led to land reclamation (land claim) on a large scale, where intertidal areas and shallow seas have been converted into dry land for industrial and aquacultural development (MacKinnon et al. 2012; Murray et al. 2014). This has brought strong pressure on biodiversity conservation.

Because the area of tidal wetlands is an effective indicator of conservation achievements in coastal regions (Murray et al. 2014), we used the change in area of tidal wetlands within the NNRs in different time periods to indicate the changes of conservation outcomes; any increase in area suggests improving conservation, and any decrease in area suggests a failure to improve conservation. To detect the change in area of tidal wetlands, we used all TM and ETM+ images from 1984 to 2015 in the Google Earth Engine Cloud Platform, and more specifically, we used the surface reflectance data set (a total of 11,264 images, http://ledaps.nascom.nasa.gov/). We extracted the lowest tidelines using the "waterline mapping algorithm" (Chen et al. 2016, supporting information). One cloud-free Landsat image was selected in each year to delineate artificial shorelines along the coasts through visual interpretation. We digitized the boundaries of the 14 NNRs along the Yellow Sea coast when they were designated and updated these to track boundary adjustments, calculating any change in area from 1985 to 2015. We analyzed changes of three major land-cover types: enclosed regions (inside artificial shorelines), tidal wetlands (between artificial shorelines and the lowest tidelines), and sea area (outside the lowest tidelines), in each NNR and in the Yellow Sea in different periods using ArcGIS 10.1. Linear models were used to detect the effect of boundary adjustments on the change in area of tidal wetlands, and the models also included the following independent variables: boundary adjustment (yes or no; binary), area of tidal wetlands in the NNR when designated (logarithmically transformed), and year of designation.

The second-order-bias corrected Akaike's information criterion (AICc) was used to select the most parsimonious model from those models with delta AICc < 2 (Burnham & Anderson 2002). Data were analyzed using R (Version 3.3.2), and results are reported as means ± SD.

Results

Change in number and area of China's nature reserves

The number and area of China's NRs increased slowly following the establishment of the first NR in 1956 until the late 1970s, by which time fewer than 50 NRs had been established. Both the number and area of NRs then increased rapidly from the 1980s, with over 2,600 NRs (over 95% of the total) being established by 2014. The fastest growth of NRs occurred from the late 1990s to the early 2000s, with over 1,800 NRs (66% of the total number and 46% of the total area) established from 1996 to 2005. Subsequently, establishment of new NRs slowed (Fig. S2). The total area of NRs peaked in 2007 at 152 million ha. Since then, although the total number of NRs increased by 198 between 2007 and 2014, the total area decreased by 4.9 million ha (Fig. 1a).

There were 428 NNRs in 2014 (15.7% of the total NRs), covering a total of 96.5 million ha, i.e., approximately 10% of China's land area. Both the number and area of NNRs have increased over the past two decades, but the rate of increase in area has become much slower than that of number (Fig. 1b) because the new NNRs have been comparatively small.

A total of 403 NRs were degazetted from 2005 to 2014, resulting in a loss of 4 million ha of protected area (Fig. 2). All of the degazetted sites were local NRs. Fifty NNRs had their boundaries adjusted, including seven with two adjustments during the period (Table S1). Nearly half (49.1%, 28 of 57) of those boundary adjustments resulted in a reduction in total area, 22.8% (13 of 57) resulted in no change in area, and 28.1% (16 of 57) resulted in an increase in area. Taken together, all boundary adjustments of NNRs caused a net loss of 2.8 million ha of protected area, which is 15.1% of the area of adjusted NNRs and 2.9% of all of the NNRs in China. The total core area, the most strictly protected zone of an NNR, shrank by 22.3% as a result of boundary adjustments. The buffer zone and the transition area shrank by 10.3% and 8.7%, respectively (Table S1).

Linear model analysis indicated that change in area of NRs was significantly related to regional economic development: the greater the increase in GDP, the greater the decrease in NR area. Furthermore, NRs in coastal regions and in regions where NR comprised a higher percentage of the regional land area also showed a greater decrease in area (Fig. 3, Table S3). Generalized linear models indicated that NNRs with larger area and that were established earlier and were located in coastal regions were more likely to undergo boundary adjustment than small NNRs or those established later or located inland. NRs with various habitat types exhibited a similar probability of boundary adjustment (Fig. 4, Table S4).

A Regional Study: Boundary adjustments to NNRs in the Yellow Sea

Along the Yellow Sea coast, eight NNRs underwent boundary adjustments, including three that were adjusted twice (Table S2). A total of 2.01 million ha, including 199 000 ha of tidal wetlands, 1.17 million ha of sea area, and 674 000 ha of enclosed region, was included in the NNRs when they were designated. The total area of coastal NNRs reached its maximum in 2006 (2.00 million ha) and then decreased as a result of boundary adjustments. The total area of the NNRs in 2015 (1.32 million ha) was only 66.1% of that in 2006 (Fig. S3). Boundary adjustments excluded a total of 453 000 ha of wetlands from NNRs that had been subject to land reclamation, and added 13 800 ha of tidal wetlands to NNRs. However, boundary adjustment also removed 51 200 ha of tidal wetlands from the NNRs, and these regions excluded from NNRs were subject to development projects such as the construction of ports, industrial zones, and infrastructure. Overall, the area of NNRs decreased by 49.6% for the enclosed regions, 48.2% for tidal wetlands, and 21.4% for sea area from the time of designation of the NNRs to 2015 (Fig. 5).

NNRs with boundary adjustment exhibited significantly greater loss of tidal wetlands (the annual average loss was 3.1% ± 2.5%, n = 8) than those without boundary adjustment (the annual average increase was 1.9% ± 4.1%, n = 6; $P = 0.01$, Fig. 6, Table S5). From the time of designation of NNRs until 2015, sites without boundary adjustments suffered a net loss of 14.5% of total tidal wetland area due to land reclamation. In contrast, tidal wetland area in the NNRs with boundary adjustments suffered a net loss of 54.6%, including 27.8% due to boundary adjustments and 26.8% directly due to land reclamation. Meanwhile, the area of claimed land decreased by 55.1% in the NNRs with boundary adjustments but increased by 17.1% in the NNRs without boundary adjustments (Fig. 5). Moreover, NNRs with a large tidal wetland area were likely to be subjected to more tidal wetland loss than those with a small tidal wetland area ($P = 0.03$; Fig. 6, Table S5).

Under the dual influence of land reclamation and boundary adjustments, tidal wetlands in NNRs suffered a net loss of 31.8% from 2000 to 2015, which was close to the decrease of tidal wetland area outside NNRs (34.8%) in the Yellow Sea region. Consequently, the proportion of the total tidal wetland area in the Yellow Sea within NNRs remained stable during the period 1990 to 2015 (Fig. S4). The tidal wetland area in the NNRs represented 33.9% of the total in the Yellow Sea in 2015.

Discussion

Causes of PADDD in China

China's NR estate has expanded substantially since the 1980s but although the total number of NRs in China has increased, the total area of NRs has decreased in recent years due to the degazettement and shrinkage of some established NRs. We found that NRs in regions with rapid economic development suffered a greater decrease in area, suggesting that the downsizing and degazettement of China's NRs is closely related to the intensifying conflict between economic growth and conservation, as also found in other countries and regions (Mascia & Pailler 2011, Mascia et al. 2014). In the Yellow Sea region, boundary adjustments have removed a large area of tidal wetlands with the highest conservation value from the NNRs, highlighting that boundary adjustments have failed to improve conservation and instead are likely to have resulted in an overall decrease in biodiversity conservation outcomes.

China has a "bottom-up" system of NR management. Establishment of new NRs and promotion of NRs from local to national level are the responsibility of local governments. Administration, including the allocation of human resources and operating expenses of all NRs including NNRs, is also determined by local governments. This local control and lack of national planning (Liu et al. 2003; Wu et al. 2011) may explain why the NR system is unlikely to fulfill national conservation priorities (Xu et al. 2017).

The management of China's NRs is currently implemented according to weak regulation rather than strong national law (Xie et al. 2014). Because the management of nature reserves belongs to various administrative departments and is related to different administrative levels, the lack of laws increases the difficulty of management (Xie et al. 2014). Our results show that no NNRs have been degazetted, perhaps because the NNRs are supervised by the central government, which implements strict management of the NNRs. Some unreasonable requests by local government for boundary adjustments to NNRs have been rejected by the central government (Ma 2016). However, the jurisdiction of local NRs belongs to the local governments, which makes boundary adjustment and even degazettement of local NRs more arbitrary. Our results indicate that over 400 local NRs were degazetted over the past few decades. Most of which were directly degazetted by local governments for the purpose of exploitation without implementation of any assessment procedure (Chen 2016). It is therefore unclear what conservation values have been lost. In 2017, the MEP surveyed a total of 660 local NRs and found that exploitation occurred in all of those surveyed (MEP 2017), strongly suggesting that local NRs have been less effective in conservation than NNRs.

China's NRs have increased rapidly since the 1990s, which is closely related to the increased emphasis on ecological conservation by central government. China became a party to the Convention on Biological Diversity in 1993; the Regulations on the Management of Nature Reserves was promulgated in 1994; and sustainable development was adopted as a national strategy in 1995. In the late 1990s, the National Wildlife and Natural Reserve Development Program was established, putting forward the target that NRs should cover 18% of the total land area of China by 2050. The central government also created special funding mechanisms to encourage the establishment and management of NRs (Xu et al. 2012, Miller-Rushing et al. 2017). These factors led to the rapid increase in both the number and area of China's NRs.

However, some NRs established in the early period were not well-designed, such as densely populated villages and towns being included within the boundary (Liu et al. 2001, 2003; Xu et al. 2012). Many NRs have been poorly managed. A major problem is that most land within the NRs is collectively or individually owned, which means that NRs have no legal rights to manage the land, adding to the difficulty of conservation. Local people often settle in NRs and depend on the resources for their livelihood and for commercial use (Liu et al. 2001, 2003; Xu et al. 2012). Although sustainable use of resources inside the NRs benefits local economic development, the absence of effective management of the human activities ensures a conflict between conservation and economic benefit, a conflict that intensifies with economic development (Liu et al. 2003).

Because the development of NRs depends highly upon the support of local governments, whose attitude greatly affects the conservation outcomes. Local governments, however, have long given priority to the promotion of vigorous economic growth, which requires increasing land exploitation (Ma 2016). Following the rapid economic growth that began in the late 1970s, there has been an increasingly acute shortage of land suitable for development. Due to constraints on the exploitation of NRs by regulations, many local governments have changed their attitude from being enthusiastic to unwilling to establish new NRs. Some local governments even believe that existing NRs are obstacles to economic growth (Xie et al. 2012; Ma 2016).

Against this background, it is not uncommon for NRs to be downsized in order to facilitate exploitation when conflicts between conservation and economic growth occur (Xie et al. 2012; Chen 2016; Zhang et al. 2017). Compared with inland regions, the coastal regions support higher population densities and more rapid economic growth (Melville et al. 2016) such that coastal NRs have suffered intense pressure from land exploitation. We found that boundary adjustments to NNRs resulted in a net loss of 2.8 million ha of protected area, which largely offsets the increase of protected area due to establishment of new NRs. Our results indicate that among the three function zones of NNRs, the core area suffered the largest decline in area after boundary adjustments. This could be related to the fact that the core area is under the highest level of protection, with development activities being completely prohibited, whereas some activities are allowed within buffer zone and transition area (The State Council of PRC 2005). Reducing the core area can free up more space for development.

There has been dramatic loss and degradation of tidal wetlands in the Yellow Sea (MacKinnon et al. 2012; Murray et al. 2014, 2015). However, the current study further demonstrates that even within the strictly protected NNRs, downsizing (by boundary adjustment) and destruction and degradation (by land reclamation) have caused extensive loss of supposedly protected tidal wetlands in the Yellow Sea. Because biodiversity is greater in NRs than in non-protected areas, loss of tidal wetlands in NRs has greater negative effects on conservation than loss of wetlands outside of NRs. An assessment of the conservation effectiveness of NNRs along China's coasts has indicated that nearly half of the NNRs are in a poor condition (Zheng et al. 2012), suggesting that PADDD is not limited to the Yellow Sea.

The percentage of tidal wetland area protected by NNRs in the Yellow Sea in 2015 (>30%) was much higher than that required by ABTs (17%) by 2020 (CBD 2010). However, the fact that the percentage of tidal wetlands protected within NNRs has been maintained despite the dramatic decrease in the area of NNRs highlights that maintaining a mandatory minimum percentage as protected area cannot be the only criterion used to evaluate conservation outcomes. In the Yellow Sea, some sites with high conservation priority remain unprotected and suffer from increasing pressure from land reclamation (Melville et al. 2016). The dramatic decline of biodiversity and ecosystem services in the Yellow Sea (Murray et al. 2015; Studds et al. 2017) in recent years further demonstrates the inadequacies of tidal wetland conservation. Because biodiversity is unevenly distributed, a uniform criterion based on the percentage of area protected is unsuitable for distinguishing between regions that are sufficiently protected and those that need additional protection (Rodrigues et al. 2004; Pouzols et al. 2014).

We found that NNRs with relatively large areas exhibited a larger decrease of conservation outcomes both at the national level and in the Yellow Sea. This suggests the larger NNRs, which have high opportunity costs, suffer from more exploitation pressure than the smaller ones (Symes et al. 2016). Because some species and ecological processes require large areas (Xie et al. 2014), a decrease in the area of large NRs in China is likely to be accompanied by a decrease in conservation quality.

In recent years, the central government in China has increasingly emphasized conservation. Since 2013, MEP required a "no net loss" of protected area, especially from the core area, when boundaries of NRs are adjusted (The State Council of PRC 2013). Some applications by local governments for boundary adjustments to reduce the area of NNRs were rejected (Zhang et al. 2017). This curbed the reduction of area caused by boundary adjustments: the loss of protected area in boundary-adjusted NNRs decreased from 21.8% before 2013 to 12.8% from 2013 to 2015. Some local officers have even been punished for being responsible for the illegal exploitation of NNRs (MEP 2016; 2017). There is still reason for concern, however, because many boundary adjustments to NRs have been made by replacing areas with high conservation value with areas of low conservation value in order to facilitate exploitation (Chen 2016; Zhang et al. 2017). Such boundary adjustments, including direct exclusion of high-conservation-value areas or alternative protection of ‘land nobody wants’, result in an overall decrease of conservation outcomes (Visconti et al. 2015).

Prospects

By 2014, China’s NRs covered nearly 15% of the country’s land area, and the total area of all PA types accounted for 25.5% of the land area (Zhang et al. 2017). PA coverage in China was significantly higher than the global average (15.4%) and exceeded the ABT of 17% by 2020 (CBD 2010). However, many conservation gaps still exist. For example, a recent nationwide assessment on the effectiveness of China’s NRs indicates that they are insufficient to protect either biodiversity or key ecosystem services (Xu et al. 2017). Across their annual cycle, less than 10% of migratory birds are adequately covered by China’s NRs (Runge et al. 2015); some critical habitats for maintenance of globally threatened migratory bird populations remain unprotected (Melville et al. 2016). By 2014, moreover, China’s NRs covered only 1% of the marine area (Zhang et al. 2017), which is much lower than the ABT of 10% by 2020 (CBD 2010).

Because of the increasing pressure of a huge human population and the increasing exploitation of natural resources, it is unlikely that the area of China’s NRs will increase substantially in the future; on the contrary, the current PADDD suggests an overall reduction in conservation achievement. There is therefore an urgent need for effective measures to improve conservation outcomes of NRs.

First, overall planning and prioritization of NR designation are required at the national level. Establishing new NRs and promotion of NRs from local to NNRs should be based on ecological representativeness, biodiversity hotspots, and conservation priorities rather than the willingness of local governments. Second, the biodiversity status and conservation outcomes of existing NRs should be periodically assessed to provide a basis for NR management. Boundary adjustments to NRs should achieve the target of improving conservation outcomes. Strict procedures for the degazettement of NRs are also required. An effective classification and management system for all PA types should be established (Xia et al. 2011). Some NRs that have relatively less value for biodiversity conservation can be redesignated as another PA type that mainly targets sustainable use. Third, it is necessary to formulate an effective NR law that clarifies the duties, rights, and obligations of authorities at various administrative levels. Legislation should also endow the NR management agency with the right to manage all areas within NRs (Xie et al. 2012) and assist in preventing unreasonable administrative interference by local governments in NR management. And finally, international communication and cooperation will be helpful for sharing experiences and lessons in NR management. The challenges of PADDD are not unique to China but occur in many countries worldwide (Mascia & Pailler 2011). The root of the problem, which

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is the pressure of resource exploitation in NRs, is similar among many NRs (Mascia & Pailler 2011, Watson et al. 2014). Sharing knowledge about conservation planning, making regulations, coordinating requirements among agencies, and encouraging public participation in conservation will help improve the management of China's NRs. Solutions to the issues in China will also provide examples that will improve NR management globally (Miller-Rushing et al. 2017).

China's central government has strengthened biodiversity and ecosystem conservation in recent years to achieve the target of "eco-civilization" (Anon 2015). In 2015, a strategic project about Delineation and Defense of Ecological Protection Red Lines was launched to integrate all the regions that provide critical ecosystem services and ecological security into a protection system with unified and strict management (He et al. 2018). The central government is also exploring a comprehensive national park system that will protect important ecosystems and wildlife as well as ensure sustainable use of natural resources (Xu et al. 2017). These efforts should improve the management of NRs. A clear understanding of the challenges faced by NRs, together with solutions to those challenges, will be crucial as this process unfolds. In recent years, other PA types with the main function of sustainable use (e.g., scenic spots, forest parks, and wetland parks) have increased rapidly in China (Zhang et al. 2017). While recognizing the importance of such 'public' PAs, we propose that NRs with biodiversity conservation as their main function should not be replaced or weakened. Given the increasing impact of human activities on the planet, strictly protected NRs will become increasingly important for the maintenance of biodiversity and healthy ecosystems, upon which human well-being ultimately depends.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments:

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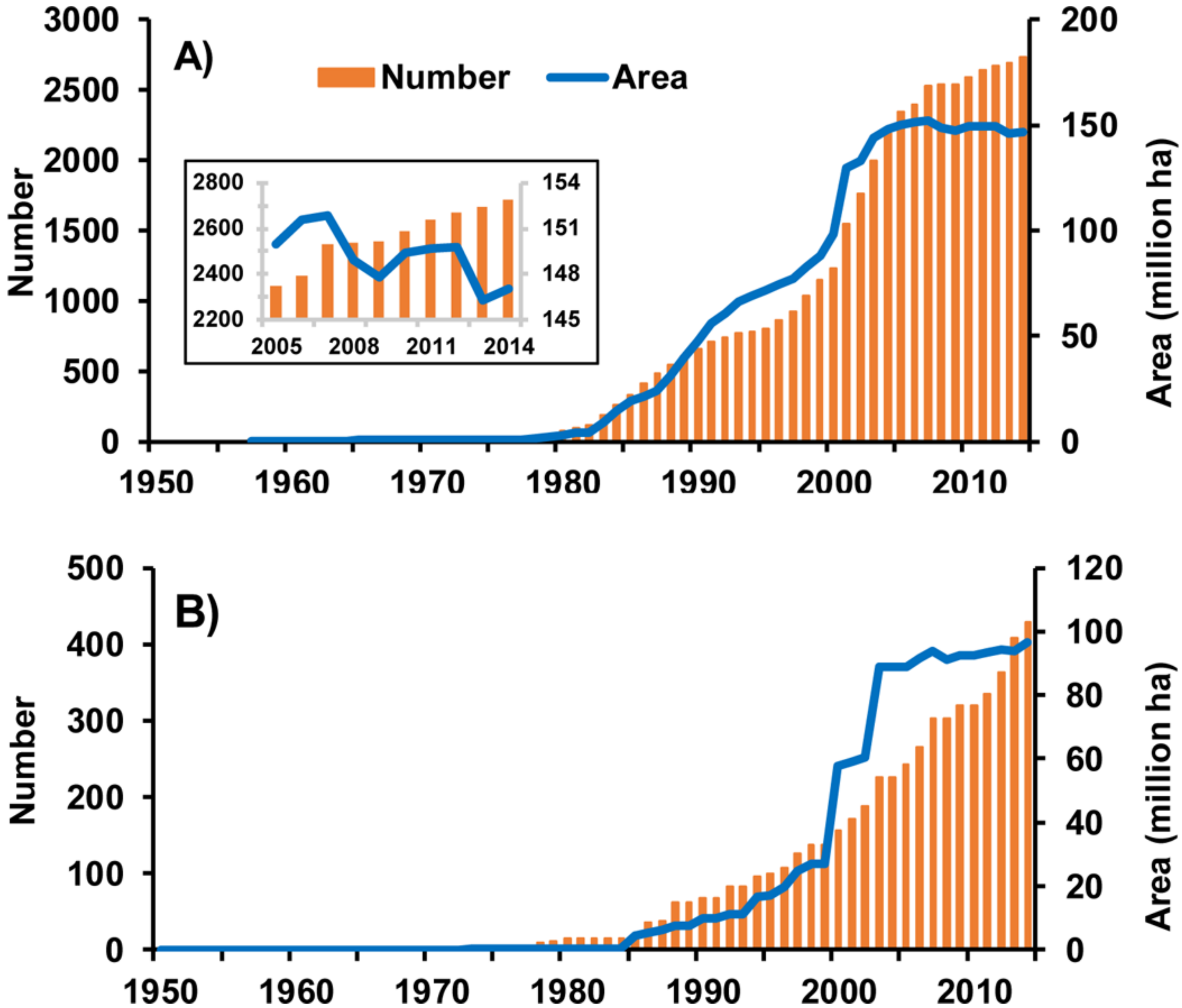

Fig. 1.

Number and total area of all China's nature reserves (A) and national nature reserves (B) from 1950 to 2015. The insert in (A) shows changes in China's Nature Reserves from 2005 to 2014.

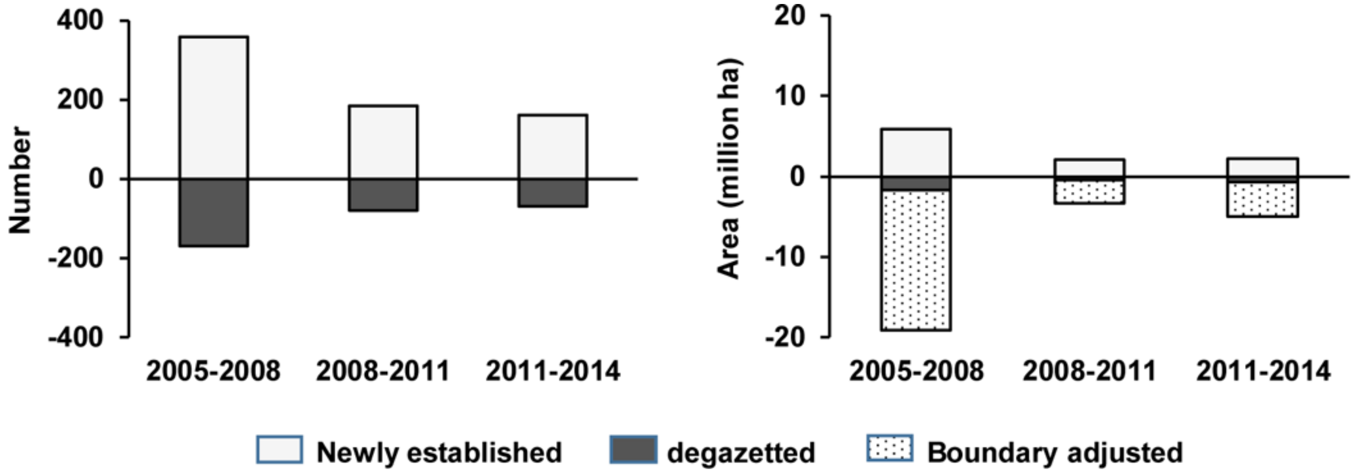

Fig. 2.

Number and area of the newly established, degazetted, and boundary-adjusted nature reserves in China from 2005 to 2014. Establishment of new nature reserves increased the total area, but degazettement and boundary adjustments resulted in an overall net loss of area.

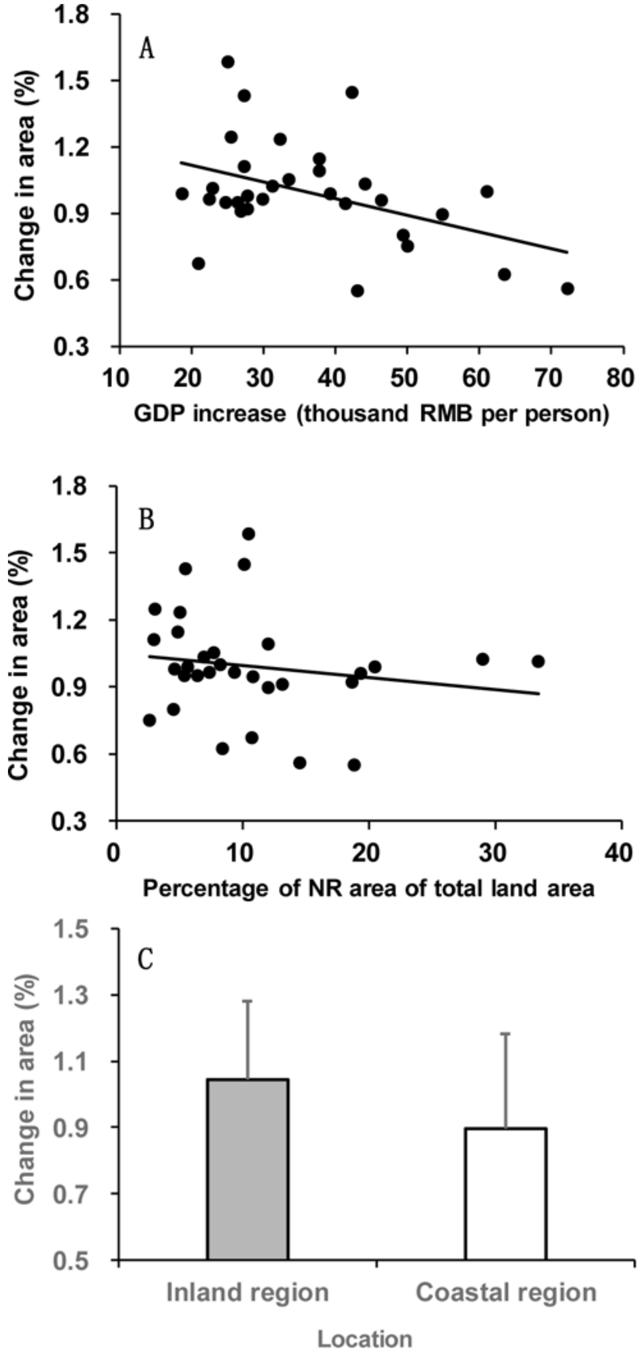

Fig. 3.

Relationship between change in area of nature reserves in the period 2005 to 2014 in each administrative region and (A) the increase in the gross domestic product (GDP increase) in the region, (B) the percentage of nature reserve (NR) area relative to the total land area in the region, and (C) the location of the administrative region (inland or coastal).

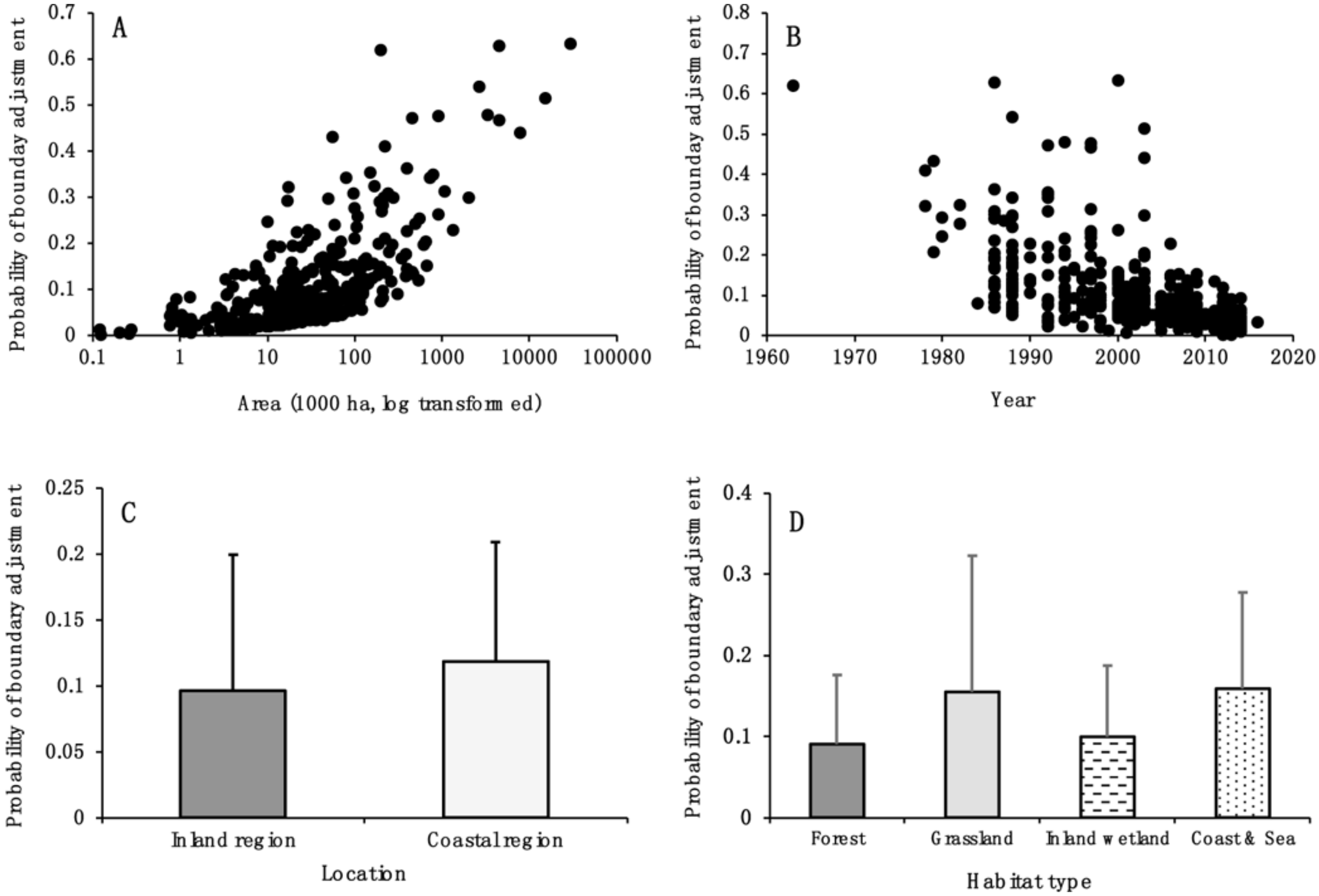

Fig. 4.

Generalized liner model for predicting the relationship between whether a boundary of a national nature reserve was adjusted and (A) the national nature reserve's area when established, (B) the location of the national nature reserve, and (C) year of its establishment.

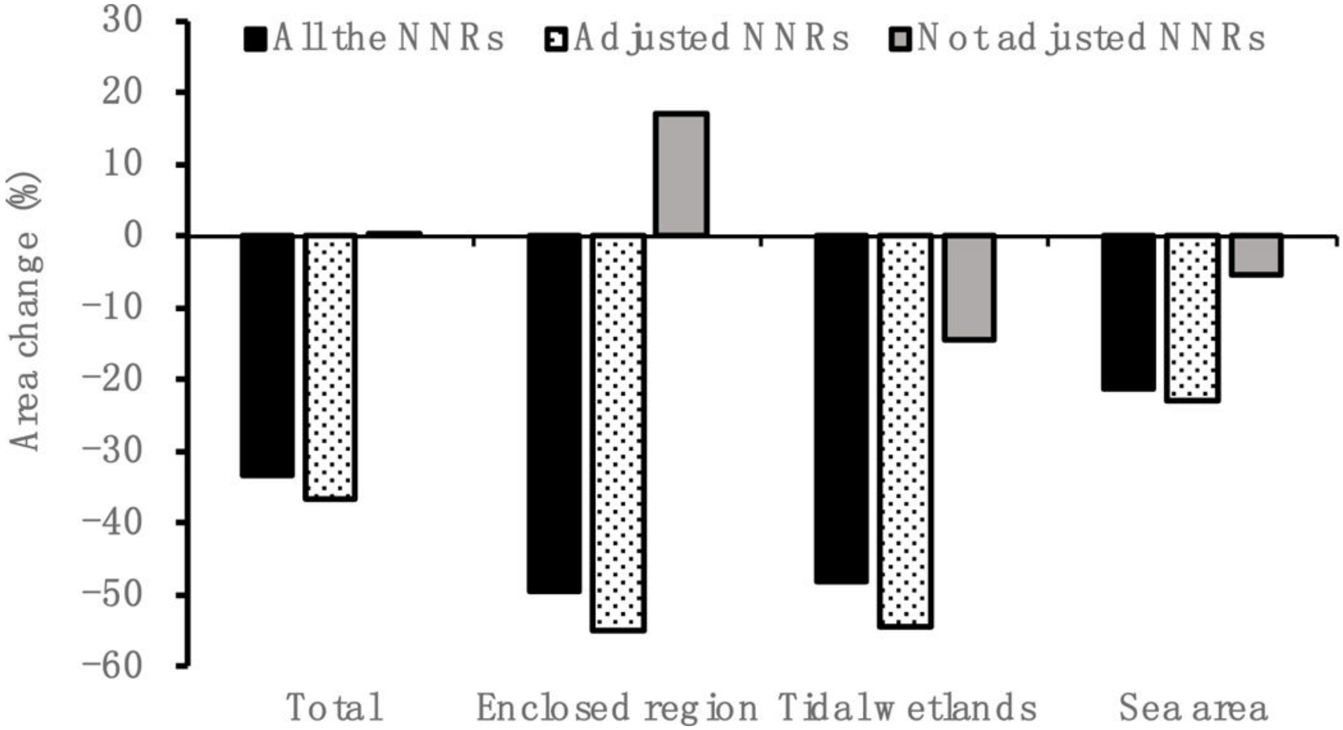

Fig. 5.

Change in the area of total, enclosed region, tidal wetlands, and the sea in national nature reserves with boundary adjustment (Adjusted NNRs) and without boundary adjustment (Not adjusted NNRs) along the Yellow Sea coast in China.

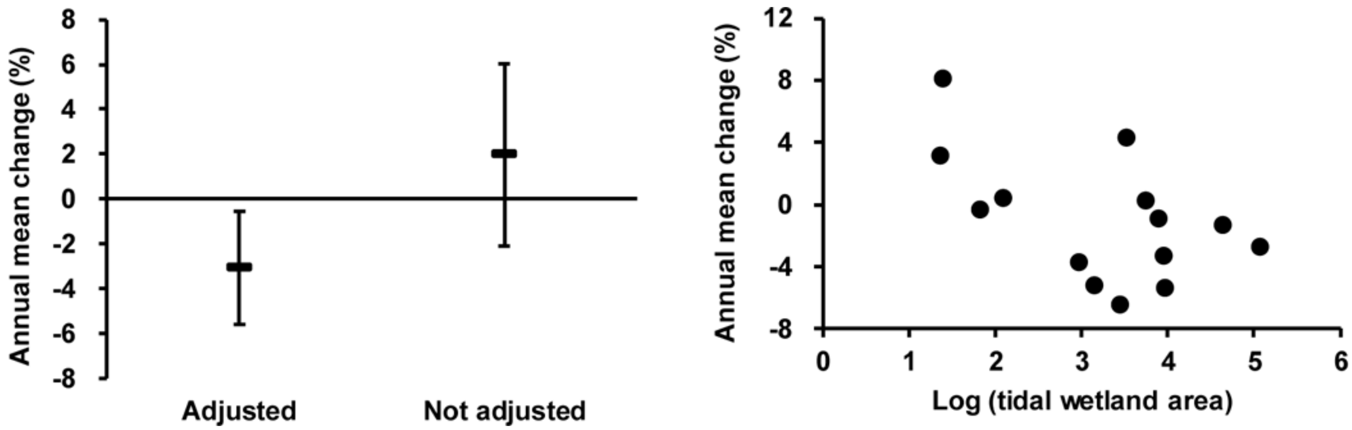

Fig. 6.

Annual mean change in tidal wetland area in the national nature reserves (NNRs) on the Yellow Sea coast as related to (a) whether the boundaries were adjusted (n = 8) or not (n = 6) and (b) NNR tidal wetland area (ha).