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The effectiveness of the zoning of China's protected areas

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ABSTRACT

Increasing human numbers and aspirations threaten protected areas worldwide. China faces especially strong pressure since many people live inside protected areas. It has sought to balance human needs and conservation goals within them by creating mixed zoning schemes loosely based on UNESCO's Man and the Biosphere Programme. These include strictly-protected core zones, buffer zones allowing limited human use, and experimental zones that examine different land-use options. To test the efficacy of this zoning, we employed field surveys and remote sensing to assess the penetration of agricultural and urban land into 109 national nature reserves in China for 2000 and 2010. Human disturbance was lowest in core zones and highest in experimental zones in both 2000 and 2010. Over this period, 82% of the reserves were unchanged or had decreased human disturbance. Nonetheless, overall human disturbance increased by 7%, 4%, and 5% in the core, buffer and experimental zones respectively. Almost all the increase in the core zone was in four wetland reserves, where human actions converted large areas to agriculture. Some 58% of reserves experienced some human disturbance in core zones in 2010, demonstrating a need for more effective zoning. The findings have broader implications for protected area management globally because they highlight the strengths and weaknesses of zoning for balancing human needs and species conservation.

1. Introduction

Protected areas are the principal means of stemming the current loss of biological diversity that now sees extinctions a thousand times faster than the background rate (Pimm et al., 2014). Terrestrial protected areas have more than quadrupled in extent since the 1970s (Watson et al., 2014). Currently, there are >290,000 of them worldwide, covering 15.4% of the total land area (Juffe-Bignoli et al., 2014) and 3.4% of the total ocean area (Juffe-Bignoli et al., 2014). International biodiversity targets aspire to protect 17% of the land by 2020 (Tittensor et al., 2014). But do protected areas protect biodiversity? First, they are not always in the right places to do so (Rodrigues et al., 2004). For example, they cover from 4 to 25% of major biomes with those in cold or very dry (and so often remote) areas covering proportionately more habitat than areas suitable for human use (Jenkins and Joppa, 2009).

Second, human activities within protected areas vary greatly from near total exclusion to strong encouragement. IUCN places protected areas into various classes that reflect these different uses and human impacts (Dudley, 2008, Juffe-Bignoli et al., 2014). This paper's general objective is to ask: what model of protection works best, given that totally excluding people may be counterproductive?

In 1974, UNESCO's Man and the Biosphere Programme answered by proposing mixed zoning (UNESCO, 1974, Batisse, 1986, Ishwaran et al., 2008). There can be three zones (Liu and Li, 2008, Ma et al., 2009), variously given different names by different countries. One zone (often referred to as the "core" zone) is for conservation. It allows only a few human activities. The second zone is for human activities and regulated development. A third zone is a buffer zone to lie in between these two zones. It has some allowable human activities, thereby aspiring to soften the impact of human activities from the human activity zone on the core zone (Liu and Li, 2008). The potential benefit to these zoning designations is that they may provide a set of guidelines for spatial arrangements of multiple and sometimes competing uses across space. This model aspires to enhance biodiversity protection by acknowledging and accommodating the needs of local communities (Ma et al., 1998, Naughton-Treves et al., 2005, Ma et al., 2009, Coetzer et al., 2014). This paper examines the efficacy of this zoning.

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Many countries have adopted this zoning scheme, either as part of belonging to the Biosphere Programme or as a separate and independent regulation for protected area management (Batisse, 1997). Globally, zoning has had mixed effectiveness. Some report that it succeeds in allowing humans and nature to coexist without compromising the needs of the other (Kenchington and Day, 2011). Others point out challenges with successful zoning stemming from logistical constraints of demarcating boundaries between zones and enforcing zoning rules (Hull et al., 2011). Many questions remain. Most evaluations have been on designing zoning schemes to maximize coverage of conservation targets (Villa et al., 2002, Sabatini et al., 2007, Geneletti and van Duren, 2008). Fewer studies evaluate the functioning of zoning schemes after they are in place. Most studies on zoning efficacy are also single case studies that are difficult to place in broader context. There are few comprehensive analyses of zoning at larger regional scales to identify common factors influencing success or failure.

Here, we conduct an analysis of the efficacy of zoning designations in protected areas across China. China's protected areas face particular challenges. Despite their protected status, over 10 million people still live inside of them (Xu et al., 2016). To both manage conservation and human development goals, the Chinese government has stipulated that all officially designed national nature reserves be zoned according to the UNESCO guidelines. In the Chinese system, the three zones that are required for every nature reserve are referred to as the core zone (for biodiversity protection), the experimental zone (for human activities — equivalent to UNESCO MAB's "transition zone"), and the buffer zone (to soften the boundary between the two). We adopt a spatially explicit approach to quantify amounts of human disturbance and trends in ecosystem changes in protected areas across these zones from 2000 to 2010.

As the world's most populous nation and one undergoing a rapid industrialization, China has faced severe environmental problems in recent years (Liu and Diamond, 2005). For instance, up to 90% of the nation's grasslands are degraded via a variety of threats including overgrazing, climate change, and mining. Soil erosion from deforestation has created massive flooding in the nation's major rivers that has produced billions of dollars in damages (Liu and Diamond, 2005). Other issues include species endangerment, invasive species, and poor water and air quality (Liu and Diamond, 2005). Establishment of protected areas has been one of the primary means the government has employed to combat these threats (Liu et al., 2003, Xu et al., 2009). One of the primary types of protected areas is nature reserves. By the end of 2014, China had created 2729 nature reserves, encompassing roughly 15% of its land area (Ministry of Environmental Protection of the People's Republic of China, 2015). By 2010, 319 were national nature reserves — the highest level of protection.

Several already-known issues with the implementation of zoning schemes in China and elsewhere include lack of clear regulations for how to structure the spatial arrangement of zones and lack of guidelines that dictate which factors should be considered (Liu and Li, 2008). There is also a lack of regulatory framework to manage zoning revisions that have commonly taken place to allow for future development in areas previously designated as the "core" (Hull et al., 2011). A few select studies evaluate the efficacy of zoning schemes in China's protected areas (Hull et al., 2011). These are isolated case studies of single reserves. They prevent drawing broad conclusions and identifying national trends. We quantify amounts of human disturbance and trends in ecosystem change in different zones in protected areas from 2000 to 2010. We also reflect on the role that zoning can play in broader conservation initiatives in China and elsewhere.

2. Methods

2.1. Nature reserve selection

We selected a subset of China's nature reserves from a dataset from the Nanjing Institute of Environmental Sciences of Ministry of Environmental Protection (MEP) to include in the analysis. For selection, a nature reserve needed to satisfy four criteria. First, it must be in mainland China: Taiwan, Hong Kong, and Macao have different classification systems for protected areas. Second, it must be a national nature reserve — a formal designation. Information on zoning of regional nature reserves was not available. National nature reserves were well represented in each province and each type of major ecosystem including forest, grassland, wetland and desert. Third, it must be established and updated to a national level before 2000. Finally, it must have had no zoning boundary adjustments between 2000 and 2010. The selected 109 nature reserves were in 30 provinces of the 31 provinces— the exception was Tianjin — and they covered 5.9% of the land surface of China (Fig. 1). They accounted for 25–38% of the total numbers of national reserves numbers in seven regions of China (i.e. Northeast, North, Northwest, Southwest, South, East, and Middle) (Fig. 1).

2.2. Evaluation of zoning effectiveness

We obtained land cover data from the MEP and the Chinese Academy of Sciences. These data used an objected-oriented classification of Landsat TM and HJ imagery (30 m × 30 m resolution) based on extensive field surveys from >100,000 plots covering the entire country. Eight land cover types were classified in both years. The two of most interest were the agricultural land and urban land. These two types of land cover are available in most of land cover datasets and constitute our measures of human disturbance. We combined these as an indicator of human disturbance. Classification accuracy ranged from 76 to 97% across the 8 classes and was 95% for both agricultural land and urban land (Ouyang et al., 2016). We compared the amounts of agricultural and urban land between 2000 and 2010 across core zones, buffer zones, and experimental zones. Paired-sample *t*-test was carried out in SPSS for detecting the differences between different zones.

3. Results

3.1. Human disturbance across core, experimental and buffer zones

In 2000, 108 of the 109 reserves had human disturbance inside them, with the average proportion of 1.7% of their total human disturbance area of 9932 km^2 (Fig. 2 provides examples and Fig. 3 summarises the results.) There was more human disturbance in reserves in the east — where more of China's population live — than in the west. The average proportion was 0.4% in southwest and northwest regions, but was 15.4% in the remaining regions (e.g. northeast, north, east, south, and middle). Average amounts of urban land (<1%) were lower than agricultural land (1–3%) across the three zones. In 2000, the proportion of human disturbance in the core zone, 1.2%, was significantly lower than buffer zones, 1.4%, ($p < 0.001$) and it was significantly lower than experimental zones, 2.7% ($p = 0.001$). These same differences were also significant in different management zones in 2010.

From 2000 to 2010, area of urban and agricultural land increased in each of the three management zones. This increase occurred at 18% of the core zones, 24% of the buffer zones, and 38% of the experimental zones. Urban land increased by 8.8% (or 8.6 km^2), 8.7% (12.8 km^2) and 11.0% (or 40.0 km^2) in the core, buffer and experimental zones respectively. Agricultural land increased by 6.7% (or 157.3 km^2), 3.4% (86.1 km^2) and 4.4% (or 195.0 km^2) in the core, buffer and experimental zones respectively. Combined, the human disturbance areas increased by 6.8%, 3.7%, and 4.9% in the core, buffer and experimental zones respectively.

3.2. Human disturbance in core zones

There was human disturbance in most of the core zones of the nature reserves we evaluated. In 2000, 64 (59%) of reserves had human disturbance in core zones. Among them, 28% had human disturbance