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Status of Nature Reserves in Inner Mongolia, China

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Abstract: Nature reserves are an important component of the strategy to halt biodiversity loss caused by habitat fragmentation and loss, climate change and other anthropogenic factors. In the past decades, 184 nature reserves were designed for biodiversity conservation in Inner Mongolia. However, no studies have quantified the general condition of these reserves. In this paper, we summarized the history, distribution and effects of human interference on these reserves in Inner Mongolia. The results showed that: (1) The total area of nature reserves is 138,047 km^2 in Inner Mongolia. This constitutes 11.7% of its geographic area, which is lower than the national (14.9%), and the global average (13%). These reserves are mainly forest (68) and inland wetland (31) ecosystems. However, in terms of area, desert (40,948 km^2), forest (26,141 km^2) and inland wetland ecosystems (25,540 km^2) are predominant; (2) nature reserves have increased rapidly in number and area since 1995, especially at the province, city, and county levels; (3) the evergreen coniferous (26.4%), wetland (20.2%) and deciduous needle-leaf forests (19.6%) were sufficiently protected according to the 2020 target of 17% set by the Convention on Biological Diversity, while the other eight natural vegetation types, i.e., evergreen broad-leaved forests (14.2%), shrubs (13.5%), meadow vegetation (12.5%), typical steppe (10.2%), open forests (8.9%), desert vegetation (6.2%), desert steppe (2.9%), and sand vegetation (1.6%) were insufficiently protected; (4) the effects of human activities on these vegetation types were different. Open forest, sand vegetation, shrub, typical steppe, meadow steppe, evergreen broad-leaved, and evergreen coniferous forest were more affected than other vegetation types. Our results indicated that a more scientific approach is needed to effectively manage nature reserves in Inner Mongolia.

Keywords: Inner Mongolia; nature reserve; vegetation type; human interference; protection strategy

1. Introduction

Degradation of biodiversity affects the structure and functioning of ecosystems and may ultimately alter human survival and development [1–3]. Increasingly, due to the associated burgeoning threats to biodiversity and habitats, researchers have raised the alarm over the impacts of exotic species and introduced pathogens due to human population growth, habitat conversion, and global warming [4]. Indeed, human activity has already altered the composition of biological communities by increasing the rate of species extinctions from local through to global scales [1]. For example, by 2007, 16,306 of the 41,415 species on the Red List of International Union for Conservation of Nature were threatened with extinction [4], and the extinction rate of wild species has now surpassed the background rate 100- to 1000-fold [5].

Protected areas (PAs), defined as areas of land/or sea especially dedicated to protect and maintain biological diversity, natural and associated cultural resources [6,7], are considered as one of

the most powerful and efficient tools to safeguard nature [8,9]. They play an important role in mitigating the negative effects of external pressures on biodiversity [10,11]. Since 1872, when the United States of America established the world's first natural protected area (Yellowstone National Park), protected areas have been rapidly established and expanded in many countries. Currently, more than 209,000 nature reserves encompass 15.4% of the planet's terrestrial and inland water areas and 3.4% of marine areas [12,13]. However, they still do not cover all of the global biodiversity hotspots [2,14] or reach the Aichi Biodiversity Target of the Convention on Biological Diversity (CBD) of protecting 17% terrestrial and inland waters between 2011 and 2020 [15].

China is one of the eight countries with the richest biodiversity in the World [16]. The country had established 2669 nature reserves by 2012, which represented 14.9% of its terrestrial area [7,17]. However, these reserves are unevenly distributed, with most areas located in the southwest regions, while Eastern China is the least protected [18]. Among the 31 provinces, Tibet has the highest proportion (34.3%) of areas protected, while less than 10% of land is protected across the other 21 provinces. The number and area of nature reserves has also varied with time [18,19].

Inner Mongolia is an important part of the Central Asian sub-region of the Eurasian Steppe, which is the world's second largest grassland. The area has a high diversity of native plants and animals [20], a variety of ecosystem types, and a unique biodiversity because of its broad longitude span, wide gradients of temperature and precipitation, diverse habitat heterogeneity, and geologic and evolutionary history. In total, Inner Mongolia has 2498 species of vascular plants and about 550 species of vertebrates [21–24]. Notably, the desert region is one of the eight biodiversity centers of the country, and the only one in the arid and semiarid region of China. The area has more than 100 endemic species [25]. A number of natural reserves have been established to protect the rich biodiversity in Inner Mongolia.

A key to biodiversity conservation is habitat protection [26]. However, although Cao et al. [9] analyzed the challenges facing the protected area network in China, there have been few studies that have investigated the distribution and status of nature reserves in Inner Mongolia despite their biodiversity importance [7,16]. In this paper, we investigate the status of nature reserves based on different vegetation types in Inner Mongolia. The history of protection, representation in protected areas of different habitat types, and the effects of human activity in the reserves are investigated as a baseline to develop scientific approaches to underpin effective management and conservation of the biodiversity of the region.

2. Methods

2.1. Study Area

Inner Mongolia lies on the northern edge of China (east longitude of 97°10′–126°09′ and north latitude of 37°24′–53°20′) and covers 1.18 million km^2. Inner Mongolia is marked by elevated plains, mountains, inland lakes, wetlands and deserts. The temperate continental climate due to its inland location in the mid-latitudes of the Northern Hemisphere is characterized by long and cold winters, and warm and short summers. The mean annual temperature ranges from −5 °C to 9 °C. The overall mean precipitation in the region is 340 mm. However, the annual precipitation decreases from east to west from 600 mm to less than 100 mm [20].

2.2. Data and Analysis

2.2.1. Nature Reserves

By the end of 2011, 184 nature reserves in Inner Mongolia were established. We collected information (including name, the level, area, establishment date, protected objects, protected category and location) of all the nature reserves in Inner Mongolia from the database of the Ministry of Environment Protection of the People's Republic of China [27]. Data pertaining to the distribution and

border of nature reserves were obtained from the World Database on Protected Areas (WDPA) [28]. Border data of 106 large and high-level nature reserves were available, while for the other 78 small nature reserves only information on location and total area were available.

2.2.2. Vegetation Types

The distribution of different vegetation types were determined from the digitized version of the Inner Mongolia vegetation map [29]. The 11 natural vegetation types in Inner Mongolia are deciduous needle-leaf forest, evergreen coniferous forest, evergreen broad-leaved forest, shrub, open forest, typical steppe, desert steppe, meadow steppe, desert, wetland, and sand vegetation. Borders of 106 nature reserves and locations of 78 nature reserves were overlaid on the vegetation map. We calculated the protected area of each vegetation type. According to the 2020 Convention on Biological Diversity (CBD) target (17%) [30], the protected ratios of each natural vegetation type were subsequently divided into insufficiently protected (0%–17%) and sufficiently protected (>17%) areas.

2.2.3. Human Interference

Global land use/cover data, with a resolution of 300 m × 300 m, were obtained from the European Space Agency [31]. We extracted the land cover data for each nature reserve, and within a 1000-m buffer around each reserve [32]. We first calculated different land use areas of each nature reserve and its buffer zone, and subsequently calculated the degree of human interference in each nature reserve using the following formula [33]:

$$\text{Human interference } (\%) = \frac{\text{Cultivated area} + \text{The land area of urban residents}}{\text{Total land area}}$$

We calculated the human interference ratio of each vegetation type by averaging human interference values of all the nature reserves using the following formula:

$$\text{HIRVT} = \frac{S_1 \times D_1 + S_2 \times D_2 + \ldots + S_n \times D_n}{S_1 + S_2 + \ldots + S_n}$$

HIRVT is the human interference ratio of vegetation types, and n denotes the nature reserves (from 1–184). S represents the area of the vegetation type in each reserve, and D represents the level of human interference in each reserve.

3. Results

3.1. Current Status of Nature Reserves

The 184 nature reserves in Inner Mongolia covered a total area of 138,047 km^2, accounting for 11.7% of its area. These reserves were divided into three categories: wildlife nature reserves, natural ecosystem nature reserves and natural relics (Table 1). In addition, these reserves are unevenly distributed in Inner Mongolia, and are mostly located in the east (Figure 1).

Table 1. Current status of nature reserves in Inner Mongolia.

Class	Number	Ratio (%)	Area (km^2)	Ratio (%)
Wildlife nature reserves	30	16.3	26,046.11	18.9
Natural ecosystems	134	72.8	108,835.3	78.8
Natural relics	20	10.9	3165.97	2.3

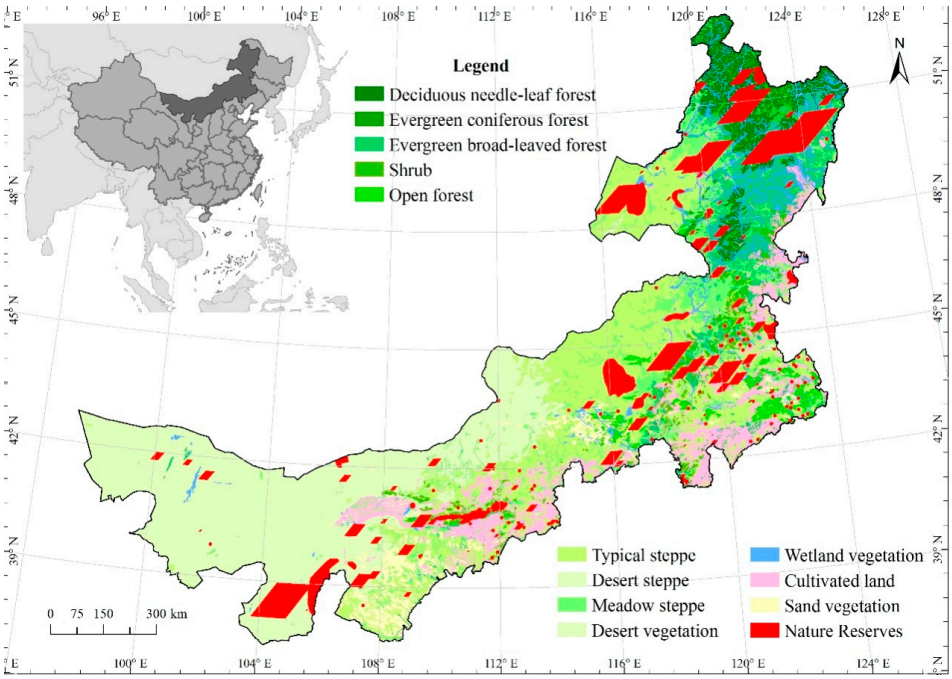

Figure 1. Distribution of nature reserves in Inner Mongolia. Vegetation type determined from digitized Inner Mongolia vegetation map [29]. Data pertaining to the distribution and border of nature reserves were obtained from World Database on Protected Areas (WDPA) [28].

3.2. Temporal Pattern of Nature Reserves in Inner Mongolia

The first nature reserve in Inner Mongolia was established in 1979, named as Baiyinaobao (Mongolian name, meaning "beautiful and resourceful"). The number and area of nature reserves initially increased rapidly after 1995. However, since 2004, the rate of increase has been minimal (Figure 2). The four levels of nature reserves, i.e., national, provincial, city and county level nature reserves, showed different temporal patterns. By 1995, the number of reserves at these four levels was 13, two, one and two, respectively (Figure 3a). Since 1999, the number and area of reserves at the national level has stalled although since 1995 the number of reserves at the other three levels has increased rapidly in number and area.

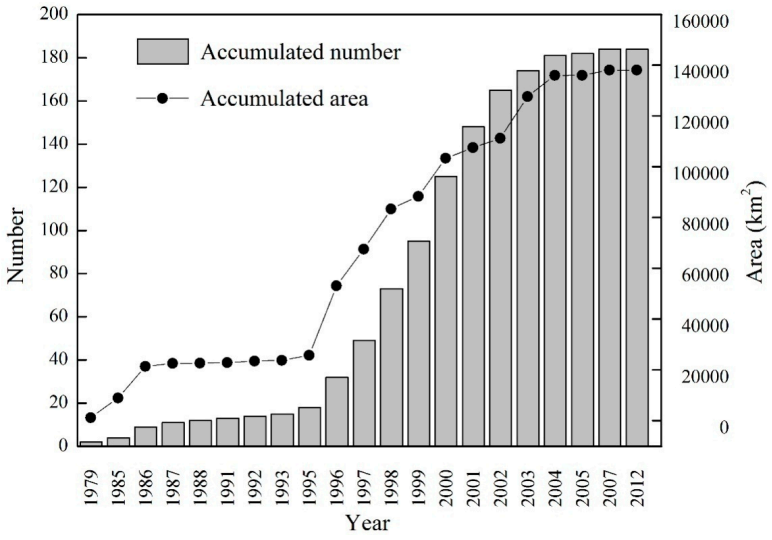

Figure 2. Changes in the number and area of nature reserves with time in Inner Mongolia.

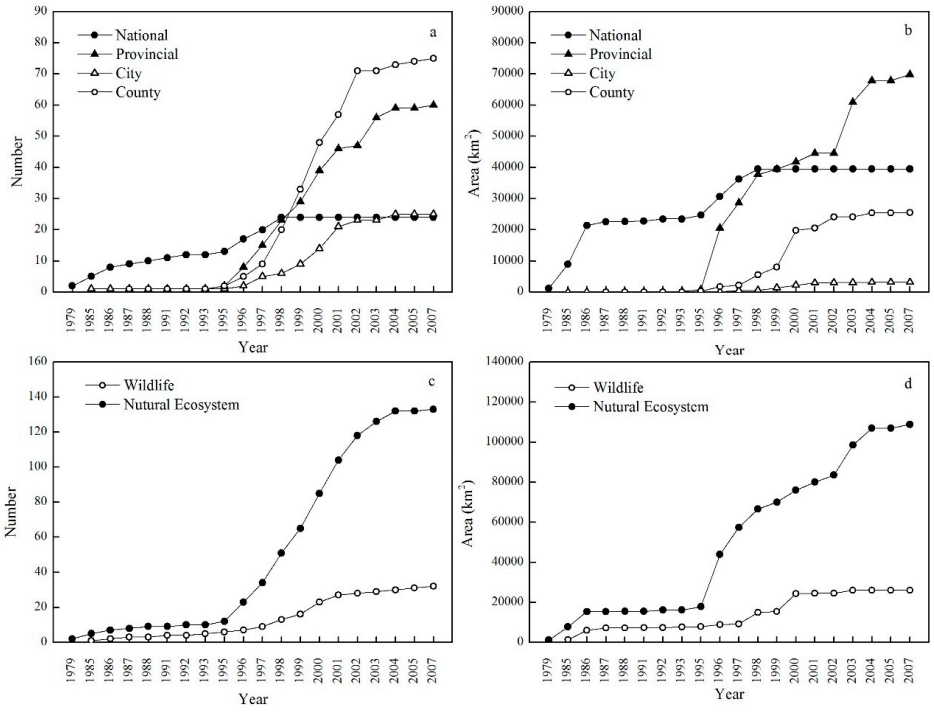

Figure 3. Changes in the number and area of nature reserves with time in Inner Mongolia as: (**a**) number and (**b**) area of the reserves at the four levels of Chinese governance; (**c**) number and (**d**) area comparing the proportion of wildlife and natural ecosystem reserves.

3.3. Protection Ratio of Vegetation Types and Human Interference

The vegetation type with the highest ratio of protection is evergreen coniferous forest, followed by wetland, and deciduous needle-leaf forest. Protection ratios of these three types exceeded 17%, and were thus considered to be sufficiently protected. Protection ratios of the other eight vegetation types were less than 17%, and were considered to be insufficiently protected (Figure 4). The degree of human interference ranged from 2.8% (deciduous needle-leaf forest) to 17.7% (shrub), with a mean value of 9.3% (Figure 4). There is no widely accepted standard regarding human interference and, therefore, we arbitrarily divided the interference pattern into two categories according to the mean value, i.e., weak (0%–9.3%) and strong (>9.3%).

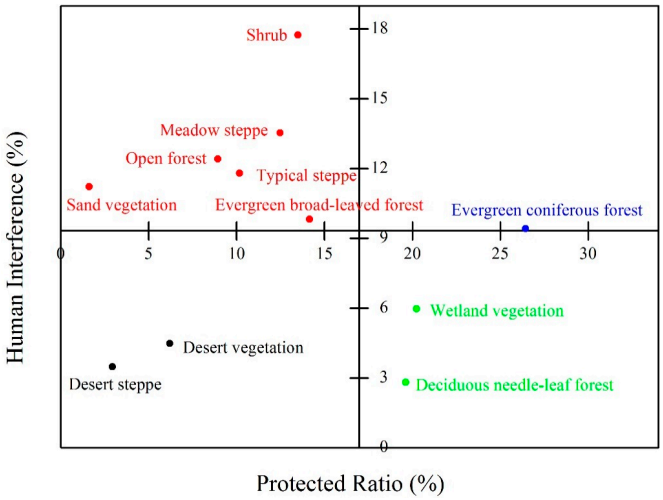

Figure 4. Protection ratio and human interference in 11 vegetation types of Inner Mongolia.

Based on the protection ratios and degree of human interference, all the vegetation types were divided into four categories: (1) sufficiently protected and exposed to weak human interference, including deciduous needle-leaf forest and wetland vegetation; (2) sufficiently protected but with strong human interference, including evergreen coniferous forest; (3) insufficient protection and weak human interference, including desert vegetation and desert steppe; (4) insufficient protection and strong human interference, including sand vegetation, open forest, evergreen broad-leaved forest, meadow steppe, shrub and typical steppe (Figure 4).

4. Discussion

4.1. Changes in Nature Reserves of Inner Mongolia

Design of nature reserves is an important strategy for biodiversity conservation. The first nature reserve in Inner Mongolia, Baiyinaobao National Reserve, was established in 1979. It is established to protect the *Picea mongolica*, which is very rare and is only distributed in Inner Mongolia. Additionally, since then the number and area of nature reserves in Inner Mongolia have increased greatly, especially since 1995. This pattern is consistent with the national and global trend. For instance, the first nature reserve of China, Dinghu Mountain National Reserve, was established in 1956. And the number of nature reserves in China has rapidly increased since 1982 [7]. This has also occurred globally. Since the world's first nature reserve, Yellowstone National Park, was established in 1872, the number of such reserves has increased to 162,000, covering 28.4 million km^2 of the Earth's surface [34]. A recent report showed that, between 1962 and 2014, the number of protected areas has increased from 9214 to 209,429 [35]. The distribution of these protected areas varies among regions. For example, 14.6% are in North America, 65.6% are in Europe, 8.3% in Oceania, and only 5.4% in Asia [35]. The great expansion of protected areas in Inner Mongolia over this period is therefore part of a worldwide trend in developing protected areas.

Several factors may have contributed to the increasing trend of nature reserves in Inner Mongolia, including economic development, public awareness, and greater access to funding. Initially, the national government of China did not have sufficient funds to establish substantial numbers of protected areas [36], and those that existed were primarily created to protect the most threatened flora, fauna and habitat types. With the development of national economy, the Chinese government provided more financial support for additional nature reserves [37]. At the same time, because the economic develop of Inner Mongolia has also been very rapid and high than the national average, especially in the past decade [38], nature reserves have been developed at provincial and local levels at a higher rate than at the national level.

Conservation biologists have argued that ecosystems and communities rather than species should be the focus of conservation efforts [26]. Consistent with this principle, the number of nature ecosystem reserves have grown faster than wildlife reserves in Inner Mongolia. Natural ecosystems could effectively protect the target species and their living environment, and such ecosystem conservation is a large-scale management effort that aims to protect the ecological composition and functional mechanisms of ecosystems [26]. Along the east–west precipitation gradient, Inner Mongolia has a range of zonal ecosystem types, the most important being deciduous needle-leaf forest, evergreen coniferous forest, evergreen broad-leaved forest, open forest, meadow steppe, typical steppe, desert steppe, steppe desert and desert. In addition to the zonal ecosystem types, several non-zonal ecosystem types, mainly sandy lands and wetlands, are also found in the region. Major sandy lands include Horqin and Hulunbuir in the east, Hunshandak in the center, and Maowusu and Kubuqi in the west [20,29]. Because of this array of ecosystem types, Inner Mongolia plateau has developed a diverse and unique flora and fauna. Thus, it is necessary to strengthen network construction of nature reserves in this region.

4.2. Protected Areas and Human Interference

Adequate protection of the targeted biota is one of the most important issue facing construction and management of nature reserves [39]. The area covered by nature reserves in Inner Mongolia was 11.7%, substantially below the Chinese national (14.9%) and global average (13%) [7,40]. Some areas, for example, Central America (28.2%) and South America (25.0%) have much higher protected lands than China [41]. The lower number and lower proportion of land covered by protected area in Asia (including Inner Mongolia) than in regions, such as the Americas, suggest that more nature reserves are needed in Asia, which has higher biodiversity than Europe or North America [41].

However, the protected ratio of typical steppe (10.2%) and inland wetland (20.2%) in Inner Mongolia was higher than that of China (1.5% and 19.5%). According to the CBD 2020 target of 17% [15], three vegetation types including evergreen coniferous (26.4%), wetland (20.2%), and deciduous needle-leaf forests (19.6%) of Inner Mongolia were sufficiently protected, although the entire Inner Mongolia (11.7%) was insufficiently protected. In particular, sand vegetation (1.6%) is the least protected and should be protected with special attention in the future. Sand vegetation, being one of the main vegetation types in Inner Mongolia, also has rich biodiversity. For instance, the vascular plants in Hunshandake sandy represent 85 families, 392 genera and 1083 species [42]. Maowusu sandy land is considered as a "shrubs kingdom" in northern China, because of its abundant shrub species (92 species) [43]. Because of the habitat loss, a lot species have been threatened and become endangered rare species, such as *Ammopiptanthus mongolicus*, *Tetraena mongolica*, *Potaninia mongolica* and *Helianthemum songaricum* [43].

In the current study, the human interference varied among vegetation types, ranging from 2.8% (deciduous needle-leaf forest) to 17.7% (shrub) (Figure 4). Human activities significantly affect biodiversity conservation efforts [14,44]. Different types of human activities affect this vegetation. First, agriculture accounts for about 70% of the projected loss of terrestrial biodiversity worldwide [15], which is similar in Inner Mongolia. The total cultivated area in Inner Mongolia increased from about 5.3 million ha to 7.4 million ha from 1978 to 2000 [20]. These newly cultivated grasslands are mainly distributed in the eastern and south-western parts of Inner Mongolia [45]. Second, mining is also a significant factor. Since 2000, coal production increased from 58.30 million to 459.35 million tons of standard coal energy [20]. Third, grazing on meadows, typical and desert steppes affected biodiversity [46,47]. The livestock population increased from about 45 million in 1978 to more than 75 million in 2000, and exceeded 100 million in 2005 [20]. Overall, these three factors mainly affected the eastern and central regions of Inner Mongolia, with several vegetation types stronger than those in western regions, such as open forest, shrub, meadow and typical steppe.

4.3. Recommendations for Sustainable Management

Nature reserves should be established based on scientific information and effectively managed to conserve biodiversity. However, our results suggest that human interferences have affected the 11 types of vegetation with different degrees. According to the ratios of protection and degrees of human interference, these 11 vegetation types could be divided into four categories (Figure 4). There is no doubt that vegetation types that are insufficiently protected and exposed to strong human activities (sand vegetation, open forest, evergreen broad-leaved forest, meadow steppe, shrub and typical steppe) are the priority for future conservation, which should not only be increased in their protected area but also be effectively managed. In contrast, vegetation types that are sufficiently protected and exposed to weak human interference (deciduous needle-leaf forest and wetland vegetation) are currently safe but still should be maintained in their current condition, although wetlands are particularly vulnerable to human interference [48].

The relative importance of the other two vegetation types, i.e., insufficiently protected vegetation types facing weak human interference (desert vegetation and desert steppe) and well-protected with high human interference (evergreen coniferous forests), is an interesting topic. A study on biodiversity conservation in Limpopo province, South Africa suggested that areas with high biodiversity and high

possibility of being disturbed should be the conservation priority [49]. Therefore, we think that the evergreen coniferous forests, which is well-protected with high human interference, should be the priority of conservation. In addition, for the desert vegetation and desert steppe, they are not high priority at this stage for managers because of the low human interference. However, protection for them should ultimately be expanded in the future.

5. Conclusions

This study, the first one that has investigated the general condition of nature reserves in Inner Mongolia, has shown that proportions of protection and effects of human activities for different vegetation types vary. Vegetation that is insufficiently protected and exposed to strong human activities, i.e., sand vegetation, open forest, evergreen broad-leaved forest, meadow steppe, shrub and typical steppe, need special attention in future plans.

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Conflicts of Interest: The authors declare no conflicts of interest.

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