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Administrative Level May Be the Key Factor to Improve Protection Effectiveness of Nature Reserves in China

Xuhui Sun [1], Yicong Cao [2], Xiaobin He [3], Rongxing Wang [1], Peng Zeng [4], Yanpeng Li [1,5,6,7,*], Zhipang Huang [1,5,7,*] and Wen Xiao [1]

1 Institute of Eastern-Himalaya Biodiversity Research, Dali University, Dali 671003, China; sunxh@eastern-himalaya.cn (X.S.); wangrx@eastern-himalaya.cn (R.W.); xiaow@eastern-himalaya.cn (W.X.)
2 Nujiang Administrative Bureau of Gaoligongshan National Nature Reserve, Nujiang 673200, China; njlccyc@163.com
3 Baima Snow Mountain National Nature Reserve Administrative Bureau, Diqing 674500, China; a49709462@163.com
4 College of Science, Northeastern University, Boston, MA 02115, USA; deideipzz@gmail.com
5 Yunling Black-and-White Snub-Nosed Monkey Observation and Research Station of Yunnan Province, Dali University, Dali 671003, China
6 School of Life Sciences, Central China Normal University, Wuhan 430079, China
7 International Centre of Biodiversity and Primates Conservation, Dali University, Dali 671003, China
* Correspondence: liyp@eastern-himalaya.cn (Y.L.); huangzp@eastern-himalaya.cn (Z.H.)

Abstract: Nature reserves (NRs) have been the backbone of biodiversity conservation and the construction of China's 'ecological-civilization' since the 1950s. With over 11,800 protected areas (PAs) covering 18% of the country's land area, Chinese NRs have made a great contribution to global biodiversity conservation. At this point, better protection effectiveness can be achieved by optimizing the management organization rather than expanding the area. We analyzed the management structure of Chinese NRs by looking at their ranks, the hierarchy of administrative organs, number of grass-root stations, manpower, and financial resources, among other variables. We found that the average number of staff employed and yearly financial input per km^2 of Chinese NRs were both higher than the world and US averages. However, the range was extremely high, revealing great unbalance among different regions and ranks of NRs. In particular, the western part of China, which is less developed and features the least disturbed ecosystems, received less funding and staff resources than the developed east. A further analysis of the highest-ranked nature reserves, i.e., the national nature reserves (NNRs), showed that administrative organs of different hierarchical statuses (the lowest being Deputy family, the highest being Division level) could be in charge of them. Unexpectedly, we found that the amount of human and financial resources injected into NNRs was correlated with the level of their administration but dissociated from other important factors such as the reserve's size or ecological value. Furthermore, the management organization was inadequate, with many NRs lacking key departments as defined by Chinese nature reserve regulations. We suggest that the administrative levels of management organization in NRs should be unified, and through the existing ecological transfer payments policy, strengthen the financial and staffing input in the western NRs of China. Moreover, the internal structure of NRs management should include all relevant departments with specific tasks and the creation of grass-root stations should be promoted without neglecting the capacity building to improve staff's knowledge.

Keywords: nature reserve; administrative level; staffing; financial input; unbalance

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1. Introduction

Biodiversity is the material basis on which human beings depend, the environmental cornerstone of ecological safety, and the prerequisite for developing an ecological civilization [1]. Since the industrial revolution, the utilization of natural resources and

environmental change have greatly accelerated biodiversity loss [2,3]. Together with climate change, biodiversity loss represents a global environmental issue that is seriously threatening the sustainable development of human societies [4,5]. Among the several ways to approach these problems, protected areas (PAs) are among the most effective, especially for the conservation of high-value ecological assets and biodiversity [6–8]. Several studies reporting on the effectiveness of PAs have shown lower rates of biodiversity loss inside their boundaries than outside, as well as decreasing loss after their establishment, especially in developing countries [9–11]. Thanks to their success, the number of PAs keeps increasing worldwide, reaching over 251,000 in 2018 according to the International Union for Conservation of Nature (IUCN) [12]. On the same date, the number of PAs in China was above 11,800, covering 18% of the country's land area, a number largely above the standards agreed by the Convention on Biological Diversity. In addition to nature reserves (NRs), other types of PAs implemented in China include national parks, scenic areas, forest parks, geological parks, water scenic spots, wetland parks, urban wetland parks, marine special nature reserves, and world heritage sites [13]. This very diversified network constitutes a central element in the Chinese governmental strategy to conserve the country's vast biodiversity. China features several ecosystem types hosting over 30,000 species of vascular plants and more than 2340 species of terrestrial vertebrates, accounting for more than 10 % of the world total in both cases [14]. As such, the Chinese PA system has contributed significantly to nature conservation on a global scale [15]. However, despite these efforts, the rate of species extinction remains high and the pressure from the growing human population keeps increasing, inevitably raising the concerns of the organs in change of conserving natural areas. How can the PAs system continue to support biodiversity? What would be the most effective approach among the expansion of existing protected areas, building more PAs in different locations, or improving the management of the network? Certainly, all of these approaches have great potential if considered together but different regions may require one or other solutions according to their specific realities.

In China, NRs are the pillar of the PAs system because their approach to protection has been the most effective in the past 65 years [16–18]. Those classified at the highest administrative level, i.e., national nature reserves (NNRs), have consistently reduced the trend of forest loss and slowed down biodiversity loss inside their perimeters [10]. The first NNR, Dinghushan National Nature Reserve, was created in 1956 [19] and since then, the institutions in charge gained significant management and operation experience. With the Chinese economy developing rapidly in the past decades, the 18th National Congress of the Chinese Communist Party which took place in 2012 paid particular attention to the country's ecological and environmental issues, and decided to increase the financial input and staffing of NRs, as well as promoting their development. In fact, it was found that an imbalanced development and low efficiency of the existing NRs represented the major obstacles to their protection effectiveness [10,20]. Similar to other countries [21–26], especially in Asia, Africa, and Latin America [27–29], the Chinese NR system faces several key managerial and operational issues such as a lack of working staff [30,31], shortage of funding [15,32], low staff's professional ability and specialized knowledge [33]. Moreover, the legislative organs of NRs tend to be slow and defective [15] attaching more importance to building the parks than their maintenance and effective operations. The overall management system is not smooth [34,35], plagued with structural inadequacies such as the common phenomenon of multi-head management often caused by the poor coordination of NRs between different administrative levels [20,36], and a weak scientifically-based monitoring system [32,34]. Chinese NRs follow a hierarchical ranked following the four administrative levels: national, provincial, municipal, and county. However, the offices in charge of their management are also highly hierarchical but poorly coordinated with the other sectors of public administration [32,37]. Consequently, the allocation of economic resources and manpower among other key decisions may be affected by the complexity of this structure, resulting in the ineffectiveness of the NRs daily work.

In this study, we evaluate the current status of China's NRs human and financial resources by looking at the government's public accounts and overall plan of NRs. We aim to answer the following questions: Are the staffing and financial input situation of Chinese NRs in line with the global average level? Is the allocation of staff and funds well-balanced among NRs of different level? Can the staffing and financial input be affected by the level of NRs? Is there a unified administrative level of the same rank NRs and can the staffing and financial input be affected by the different administrative levels as a case of NNRs? The results of this analysis will provide a reference for improving the management effectiveness of NRs in China.

2. Materials and Methods

2.1. Data Sources

The database of Chinese NRs, which includes basic information such as area, establishment time, rank (administrative level), location, and departments in charge, was obtained from 'The List of Nature Reserves in China 2017' [38], available on the website of the Ministry of Ecology and Environment of the People's Republic of China (http://big5.mee.gov.cn/gate/big5/www.mee.gov.cn/ywgz/zrstbh/zrbhdjg/201908/P020190807402905727057.pdf, last accessed on 13 April 2022). More detailed data, such as the number of active staff and grass-root stations, as well as funding information were collected from the NR's official websites, official published reports, statements, and master plans. Information on the Chinese national ecological security barrier area was retrieved from Fu et al. [39].

The budgets and human resources data for PAs at the global level were found in a report from the World Conservation Monitoring Centre of 1999 [40], Because of the outdated information, we also included recent figures of the American national parks budgets and staff as provided by the National Park Service [41].

The hardest task of the data collection for this study was a clear definition of the organs in charge of each nature reserve. We found clear information for 220 NRs, of which 134 were from NNRs owing to their highest rank in the administrative structure. The administrative organs for NNRs are named as follows, from the highest level to the lowest: division (equal to county level, in Chinese is Zhengchuji), deputy division, family (equal to town level, in Chinese was Zhengkeji), and deputy family.

In summary, the NRs samples analyzed in this study were 245 for number of staff, 203 for financial input, 159 for number of grass-root stations, and 290 for number of inner departments. The ranks of NRs (national, provincial, municipal, county level) were found for 473 of them. Figure 1 shows the distribution NRs in China. The NRs samples distribution pattern is shown in Figure 1.

2.2. Data Analysis

As mentioned before, NRs are divided into four ranks: national, provincial, municipal, and county levels. Because of scarce data in the three lower ranks, we grouped them for further analysis. *t*-tests were performed to compare the differences in number of inner departments, number of active staff, number of grass-roots stations, and financial input conditions between national nature reserves and lower-level ones. The bivariate Pearson's correlation test was employed to uncover links between these four variables and the NRs' area.

An analysis of the management organs of NNRs followed. The deputy family level was excluded because of an insufficient number of samples. Because of non-normal distributions, the differences in number of staff and financial input were assessed using the non-parametric Kruskal-Wallis test, with Dunn-Bonferroni post-hoc test between pairs.

To assess whether the provincial distribution of NRs funding and manpower is in favor of the Chinese ecological security barrier area, we grouped and averaged the values of NRs located within each province and displayed the results on maps.

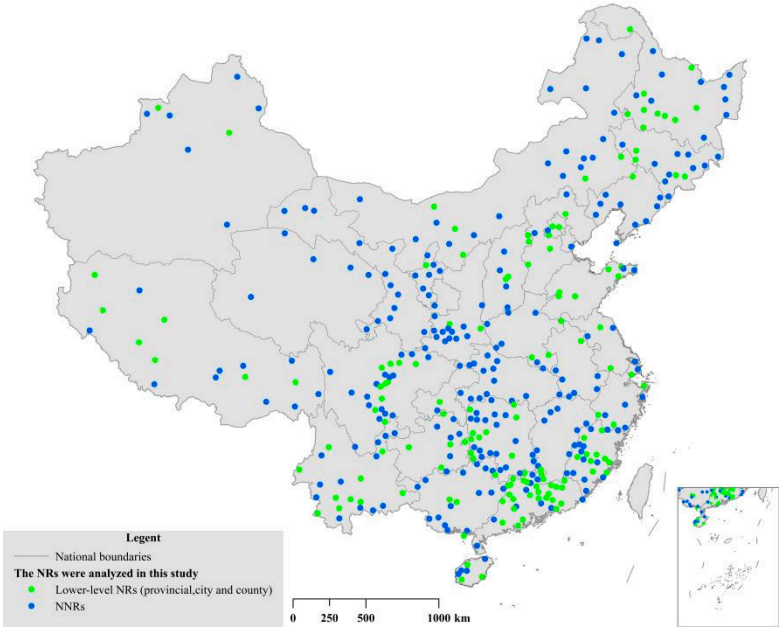

Figure 1. Distribution pattern of the nature reserves analyzed in this study. NNRs: national nature reserve, Lower-level NRs: provincial, municipal, and county level nature reserves grouped.

The exchange rate of 6.3746 CNY for 1 USD was based on Bank of China values on 30 January 2022 at 11:00 Beijing time.

Statistical analyses were performed using Origin Pro 8.0 software (https://www.originlab.com/origin, last accessed on 13 April 2022) and maps were drawn with Qgis (https://www.qgis.org/en/site/, last accessed on 13 April 2022).

3. Results

3.1. The Organizational Structure in Chinese NRs

A The differences of administrative level of management organizations in NNRs

Among the 134 national nature reserves, there were four administrative levels of management organization in NNRs, with nearly 50% belonging to the highest level (division), the lowest level was the deputy family (Table 1).

Table 1. The administrative level of management organizations in national nature reserves *.

Levels	Division	Deputy Division	Family	Deputy Family
Number	66	47	18	3
Percentage	49.25%	35.08%	13.43%	2.24%

* administration level, Division equal to 'Chuji' and Family equal to 'Keji' in Chinese.

B Inner departments situation of management organizations in NRs

The average number of inner departments belonging to NNRs was 5.52 (N_{NNR} = 215, SD = 2.46, range 1–19), while for lower-level NRs it was 4.36 (N_{LNR} = 75, SD = 1.71, range 1–11). The average number of departments in NNRs was significantly higher than lower-level NRs (5.52 vs. 4.36, N_{NNR} = 215, N_{LNR} = 75, t = 4.470, df = 186.313, $p < 0.001$). Among 290 NRs, 21% had less than three inner departments (Figure 2). In detail, 47.19% of NRs lacked an Advertising department, 43.07% of NRs lacked a Resource Monitoring department, 47.19% without Community Affairs departments, 78.65% without Scientific Research related departments, and even 28.46% of NRs without Natural resources Protection departments.

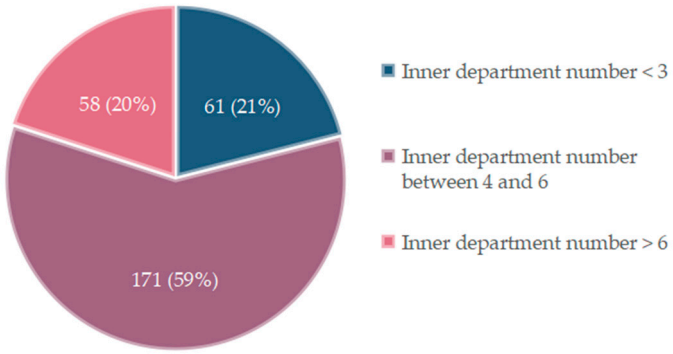

Figure 2. The inner departments setting situation in Chinese nature reserves.

C Number of grass-root stations

The average number of grass-root stations in NNRs was 8.48 (N_{NNR} = 159, SD = 9.52, range 1–72), and the in lower-level NRs was 5.77 (N_{LNR} = 47, SD = 4.65, range 1–30). The number of grass-roots stations in NNRs was significantly higher than lower-level NRs (8.48 vs. 5.77, N_{NNR} = 159, N_{LNR} = 47, t = 2.772, df = 163.844, $p < 0.01$). There was no correlation between the number of grass-roots stations and the NRs' area ($r^2 = 0.001$, $p = 0.94$, N = 206). The average management area per station in NNRs was more than 400 km^2, an extremely high value. For example, Qiangtang national nature reserve reached a management area of 40,000 km^2 per station.

3.2. The Difference of Manpower Status in Chinese NRs

A Number of staff in NNRs and lower-level NRs

The average number of staff in all levels NRs was 45.38 (N = 245, SD = 70.91, range 3–793), the average number of staff in all NRs was 28.24 per 100 km^2 (N = 245, SD = 55.10, range 0.03–555.56). The average number of staff in NNRs was significantly higher than the lower-level NRs (45.38 vs. 19.17, N_{NNR} = 168, N_{LNR} = 77, t = 5.688, df = 206.150, $p < 0.001$). But the staffing per 100 km^2 in NNRs was significantly less than lower-level NRs (22.58 vs. 40.74, N_{NNR} = 168, N_{LNR} = 77, t = 2.408, df = 241.811, $p < 0.01$) (Table 2).

Table 2. The difference of staffing status in Chinese nature reserves *.

Object	Rank	Average	SD	Range	Sample Number
Staffs number per reserve	NNR	57.39 ***	81.86	5–793	168
	LNR	19.17 ***	20.15	3–112	77
Staff number per 100 km2	NNR	22.58 **	28.45	0.03–163.93	168
	LNR	40.74 **	88.35	1.29–555.56	77

* NNR = national nature reserve, LNR = lower-level nature reserve (including provincial, municipal, and county levels). *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.

B Distribution of manpower among the administrative levels of management organs in NNRs

Management organizations of higher levels (Division, Deputy division) disposed of higher number of staff than lower-level ones ($N_{Division}$ = 40, $N_{Deputy\ Division}$ = 33, N_{Family} = 18, df = 2, $p < 0.001$). Pairwise results showed significant differences between Division and Family level (Z = 3.97, $p < 0.001$), as well as Deputy division and Family level (Z = 3.23, $p < 0.001$), but the difference between the two highest ones was not significant (Z = 0.33, $p > 0.05$), see Figure 3.

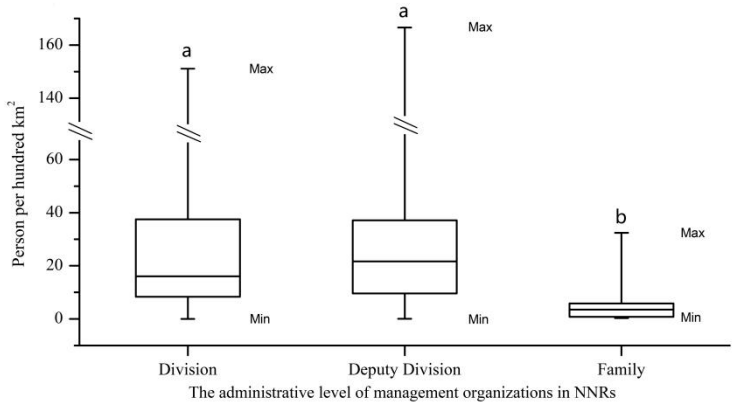

Figure 3. The condition of approved staff number among different administrative levels in national nature reserves, the same letter means that the difference was not significant $p > 0.05$, different letter means that the difference was significant $p < 0.001$.

A The difference of staff number in NRs among different provinces

The provincial distribution of staff per 100 km^2 of NRs area was extremely uneven, the highest found in Jiangsu province, followed by Hebei. Several provinces had less than 10 staff per 100 km^2. Most of them are part of the Chinese ecological security barrier region, namely Qinghai (1.75 staff per 100 km^2), Tibet (2.01 per 100 km^2), Neimenggu (8.33 per 100 km^2), and Xinjiang (8.36 per 100 km^2). These results can be seen in Figure 4.

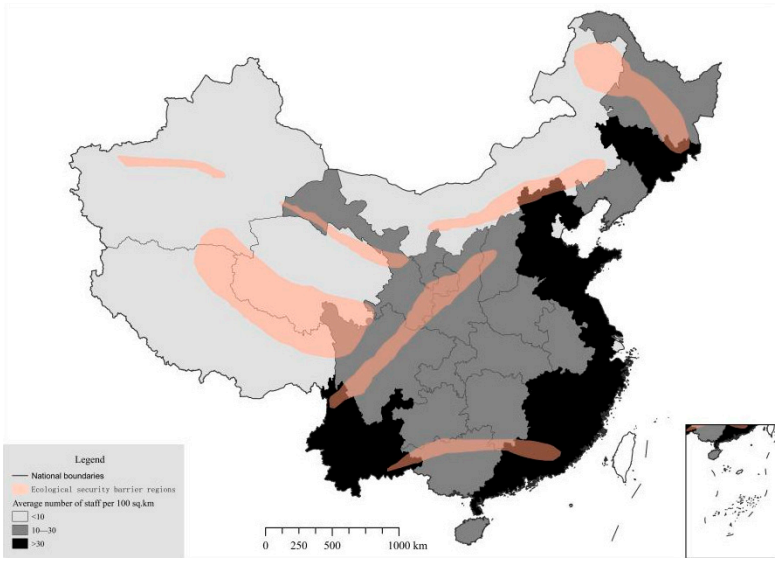

Figure 4. The average number of staff per 100 km^2 in Chinese nature reserves in different provinces.

3.3. Differences of Financial Input Status in Chinese Nature Reserves

A The difference of financial input between NNRs and lower-level NRs

The average value of financial input in NRs was 33,420 USD per km^2 (N = 203, SD = 197,010, range 7.54–2,752,923 USD), The average value in the lower-level NRs was much higher than NNRs, but difference was not significantly difference between NNRs and lower-level NRs (N_{NNR} = 113, N_{LNR} = 90, t = 1.003, df = 201, $p > 0.1$) (Table 3).

Table 3. The difference of financial input between NNRs and lower-level NRs *.

Rank	Average	SD	Range	Sample Number
NNR	16,380	32,370	7.5–246,631	113
LNR	54,820	293,160	137–2,752,923	90

* NNR = national nature reserve, LNR = lower-level nature reserve (including provincial, municipal, and county levels).

B The difference of financial input among different administrative levels of management organization in NNRs

Similar to the results of number of staff, NNRs ran by management organizations of higher level received significantly more funding than lower-level ones ($N_{Division}$ = 18, $N_{Deputy\ Division}$ = 15, N_{Family} = 4, df = 2, $p < 0.01$). Funding for the three groups was 19,704, 8308 and 2257 USD per km^2 for Division, Deputy division, and Family, respectively. Pairwise comparisons showed significant differences (Z = 2.314, $p < 0.05$) between Division and Deputy division level, as well as Division and Family level (Z = 2.469, $p < 0.05$), but not between Deputy division and Family level (Z = 1.60, $p > 0.05$), see Figure 5.

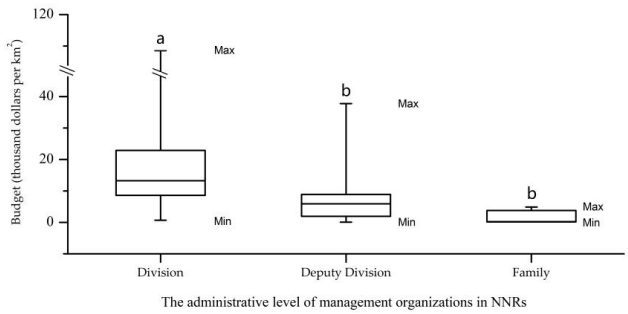

Figure 5. The difference of financial input among various administrative levels of management organization in national nature reserves. The same letter means that the difference was not significant $p > 0.05$, different letter means that the difference was significant $p < 0.01$.

C Difference of financial input in NRs among provinces

The provincial distribution of financial input was also extremely uneven, similar to the one of the manpower. The best-funded reserves all concentrated in the developed eastern provinces of China, as can be observed in Figure 6. The highest value was found in Beijing, which enjoyed a yearly financial input of 83,830 USD per km^2, followed by Hebei, and Guangdong. The provinces located within the Chinese ecological security barrier, received fairly lower financial resources, in detail, Qinghai (60 USD per km^2), Tibet (80 USD per km^2), Neimenggu (2080 USD), and Xinjiang (2770 USD), see Figure 6.

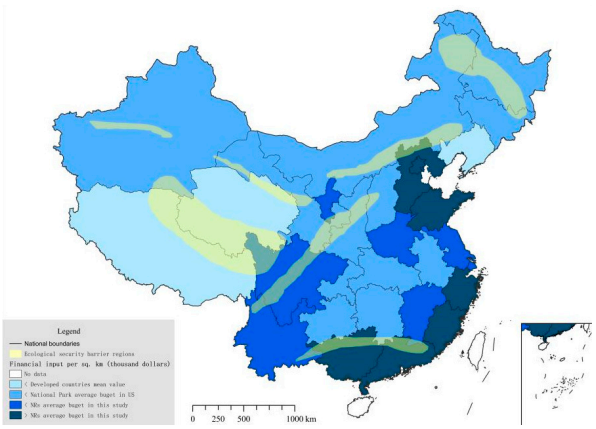

Figure 6. The situation of yearly financial input (thousand USD per km^2) of Chinese nature reserves in different provinces.

4. Discussion

The setup of nature reserves in China contributes greatly to the country's biodiversity conservation priorities. However, it seems that the system suffers from several issues mainly related to the management that could be improved with a better understanding of the root causes. Firstly, although the allocated staff in Chinese NRs (28.24 staff per 100 km^2) was much higher than the average value of the global PAs (2.7 staff per 100 km^2) [40], we found that its distribution among NRs ranks and regions was very unbalanced. Owing to their ecological value, nature reserves at the national level (NNRs) are those with the highest importance and priority, both in China and in the world. We expected the status of NNRs to be reflected in a higher number of employees but we observed a significantly lower value than in the other NRs (provincial, municipal, and county). The administrative level of the managing organ of NNRs was also confusing, with more than 50% of the NNRs with lower-level organs. In 2.24% of the cases, the NNRs were managed by a deputy family office, the lowest level in the Chinese administration system. The most striking finding was that the allocation of staff was more correlated with the level of the management office than the status of the nature reserve. The unbalance of staff allocation was also evident in its regional distribution. As mentioned previously, Chinese NRs enjoy a high number of manpower, especially in NNRs where 84% of them are above the world's average. However, most Chinese NNRs are located in the central, eastern, and southeastern provinces, which are the most developed, and populated, and where NRs are smaller. The remaining 16% of NNRs suffer from a serious staff shortage. They are located in Tibet, Qinghai, Xinjiang, and Neimenggu, four provinces characterized by a lower economic development but greater ecological integrity and wider NRs belonging to the Chinese ecological security barrier [39].

Secondly, the Chinese NRs system showed unevenness in financial input, although its average of 33,420 USD per km^2 is much higher than the global PAs which was 890 USD per km^2 in 1999 [40,42], and higher than the financial input of the national parks of the United States in 2019 (11,500 USD per km^2) [41]. However, the range of financial input in China is huge, with many NNRs reporting very low expenditures, as low as 7.5 USD per km^2 and reaching over 2,700,000 USD per km^2. Again, the uneven distribution of financial resources was observed in the hierarchy of NNRs managing organs, whit the highest level (division) being better funded than the lower ones. This pattern was further confirmed by the significant differences among provinces, with the western ones such as Tibet and Qinghai reporting a financial input of around 100 USD per km^2, but with the southeastern ones such as Beijing and Guangdong reporting a financial input of more than 80,000 USD per km^2.

Thirdly, the management organization of NRs was not in line with the requirements of the 'Regulations of the People's Republic of China on Natural Reserves' [43]. Several departments that should be integral parts of the system were missing, such as Advertising, Resources Monitoring, Community Affairs, R&D, and Natural Resources Protection. Moreover, several NRs did not have any grass-root stations.

As discussed above, it appears that the level of the managing organs (in the case of NNRs) and the rank of the nature reserve determines the amount of funding and human resources allocated. These two variables are the key for a better administration and protection effectiveness of the PAs as shown by other studies in other world regions [44–46]. However, the primary factor determining the resources needs of an NR should be its ecological value and its size, together with its situation within the territory, such as the amount of population living around the boundary and their relationship with the environment. Our results showed no correlation with the NR area. We believe that this condition is unfavorable for the construction and optimization of the Chinese NRs system and that the distribution of resources, as well as the administration structure, should be redesigned.

5. Conclusions and Suggestions

With more than 11,800 protected areas covering 18% of its land surface, China contributes considerably to global biodiversity conservation. Instead of expanding this already remarkable area, a sound management system would make an even greater contribution in terms of protection effectiveness. The current situation of Chinese NRs, especially NNRs, shows evident signs of managerial inadequacy, reflected by a confusing hierarchical structure of managing organs, and an unreasonable distribution of manpower and financial resources among reserves of different rank, size, and ecological importance. Based on these findings, we list here a few recommendations for future improvements:

A In order to redesign the administrative structure of NRs, a high-level conservation management agency should be created. This organ will define particular needs and targets of single NRs and allocate a sufficient amount of resources that will maximize the output. As analyzed in the present study, the area under protection and ecological value should be the main factors to take into consideration.

B Based on the existing policy of 'ecological transfer payments' which aims to strengthen regional ecological security, particular attention should be put on the less developed but less disturbed western region that is in need of financial input and manpower.

C The internal structure of NRs management organs should also be improved. In particular, the relevant inner departments with clear functions and tasks should be created.

D Promote the creation of grass-root stations highly focused on nature conservation and supported by capacity-building mechanisms that will improve the professionalism and skill set of the staff.

Author Contributions: Y.L., Z.H. and W.X. conceived the project; Y.L. and X.S. performed the data analysis; Y.L., X.S., Y.C., X.H. and R.W. collected the data; X.S., Y.L., Z.H. and P.Z. wrote the manuscript with the contribution of all authors. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: All data generated or analyzed during this study are included in this published article, its publicly available repositories.

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