Research on a Biodiversity Conservation Value Assessment Method Based on Habitat Suitability of Species: A Case Study in Gansu Province, China

Xiaojiong Zhao 1,2,3, Jian Wang 1,*, Junde Su 4, Wei Sun 3 and Haoxian Meng 3

Abstract: Quantitative assessment and evaluation of ecological parameters and biodiversity conservation are prime concerns for long-term conservation of rare and endangered species and their associated habitats in any ecological region. In this study, Gansu Province, a biodiversity hotspot, was chosen as the research area. We predicted the distribution patterns of suitable habitats for rare and endangered species. The replacement cost method was adopted to calculate the conservation value of rare and endangered species. The suitable habitat distribution area of rare and endangered wild animals reached 351,607.76 km$^2$ (without overlapping area), while that of plants reached 72,988.12 km$^2$ (without overlapping area). The conservation value of rare and endangered wildlife is US $1,670.00 million. The high-value areas are mostly concentrated in the south and north of Gansu Province. The conservation value of rare and endangered wild plants is US $56,920.00 million. The high-value areas are mostly concentrated south of Gansu Province. The conservation value is US $58,590.00 million a year, and its distribution trend is gradually decreasing from northeast to southwest, with the highest in the forest area south of Gansu Province, followed by the Qilian Mountain area in the north. These results are of great significance for future improvement of the evaluation index system of ecosystem services and the development of ecosystem services and management strategies.

Keywords: biodiversity; biodiversity conservation priority zone; rare and endangered species; replacement cost method; Gansu province

1. Introduction

Biodiversity is an important fundamental feature of this vibrant planet and is important for the promotion of the survival and sustainable development of human society. Protecting biodiversity is not only essential for maintaining the function of the Earth’s ecosystems, it is also the basis for the diversification of ecosystem services and is of great significance to human wellbeing [1,2]. With the development of social productivity, the capacity of human beings to transform nature is constantly improving. Such activities of conquering and transforming nature enrich the material foundation of human beings. However, improper land use, such as blind urbanization, industrialization, expansion of farmland, and deforestation, can lead to the degradation of natural habitats, and decline and loss of biodiversity [3,4]. In particular, rare and endangered species are the most affected. According to a recent study [5], rare species can make substantial contributions to some ecosystem services in many ways. With the decline of biodiversity, some species become scarce, and their marginal value therefore increases. In other words, the value of biodiversity is generated by scarcity; thus, only scarcity is valuable.
At present, the evaluation of biodiversity value is actually calculated as the evaluation of the economic value of one or several biological resources [6–9]. The economic value of biodiversity is similar to that of ecosystem services, but the role and value of genes, species, and ecosystems are more emphasized [10]. The evaluation of biodiversity can reflect the direct benefits of the various organisms as resources for food, material, medicine, and so on. However, it is difficult to valuate biodiversity through ecosystem services such as supporting, regulating, and cultural. These values include indirect values such as protecting species and their habitats, scientific research, etc., which can also provide human wellbeing.

With the deepening of biodiversity conservation research, some unique and globally important ecosystems are more important for the protection of rare and endangered species and their habitats [11]. At present, global biodiversity management focuses on the protection of rare and endangered species and ecosystems. To protect these species and ecosystems, China has established 32 priority biodiversity conservation areas, accounting for 28.76% of the total land area [12]. These rare and endangered species rely on the ecosystem, which cannot be replaced by other regions, for their survival. Quantitative assessment of the protection value to the habitats of rare and endangered species is a hot topic in biodiversity conservation research [13]. The Millennium Ecosystem Assessment (MA) [14] framework holds that biodiversity and ecosystem services have multiple interrelationships. Biodiversity supports various ecosystem services from various scales, thus increasing the human wellbeing via various mechanisms. To avoid double counting, no value assessment is placed on it. However, if all biodiversity values are used as supporting services, some indirect values of biodiversity will be omitted. According to research results [15], as a part of biodiversity value, the protection value of biodiversity does not overlap with other services, and the protection of rare species and their habitats is not reflected in other ecological services; therefore, it is necessary to carry out quantitative assessment.

The resources of rare and endangered species have their own public attributes, and people cannot use the traditional economic methods to evaluate the economic value [16], so people have no intuitive understanding of its importance, which is also one of the important reasons for the continuous reduction of species habitat and the acceleration of the sharp deceleration rate of species [17]. Therefore, it is the premise used when formulating relevant conservation policies to make clear the conservation value and importance of different regions through the valuation of rare and endangered species [18]. However, due to the public nature of wildlife resources, people cannot use traditional economic methods in this assessment. Since 1991, when the environmental committee of the International Federation of Sciences proposed the quantitative assessment of biodiversity value, researchers have performed significant exploratory research on biodiversity valuation methods [17,19–21]. Valuation methods can be divided into three categories: the actual market approach, alternative market approach, and virtual market approach [10,22]. The above three methods can be used to evaluate the value of biodiversity from different aspects, and they all have different scopes of application: the market price method is applicable to the evaluation of service and product with market price, the alternative market method is applicable to the evaluation of the indirect use value of biodiversity without market price, and the simulated market method is mainly applicable to the evaluation of non-use value of biodiversity. The biodiversity conservation value calculated in this study is an indirect use value, which is suitable for the alternative market method. This method indirectly infers people’s preference for the environment by examining people’s market-related behaviors, especially the price paid or the benefits they obtain in the market closely related to the environment, in order to estimate the economic value of environmental quality change. This method is relatively mature and is especially suitable for the calculation of non-physical use value and indirect use value.

Scholars have also carried out exploratory studies on the value of biodiversity conservation [6,23–25]. However, from the perspective of research objects, scholars have conducted research on the value of single species, such as single wild animal species [8,26,27]
and single wild plant species [28,29]. Of course, scholars are more inclined to study wildlife species, and little research has been conducted on wild plants. In addition, scholars prefer to study flagship species with important conservation value, as well as rare endangered animal and plant species with high market value, such as Pantholops hodgsonii [8], Ailuropoda melanoleuca [27], and Panthera tigris ssp. altaica [28]. The research area is usually primarily concentrated in nature reserves [20,30–32] and lacks comprehensive assessment of a multi-species value of river basins and regions, especially in areas with rich biodiversity. Moreover, the valuation method of the above research is the simulated market method, that is, using a questionnaire survey to reveal the public’s preference for species protection and deduce the public’s willingness to pay for species protection, to obtain the value of species. However, this method has some problems, including strong subjectivity, unable to realize the accounting of multi-species value, accounting standards are not unified, and great changes in the credibility of the valuation results. In addition, it cannot provide the spatial heterogeneity information of biodiversity value, which leads to the low reference value of its scientific research results in the actual management decision-making.

Gansu Province is a global biodiversity conservation hot spot [33]. Endemic species such as Panthera uncia [34], Pantholops hodgsonii [35], and Taxus chinensis [36] are distributed in Gansu Province, which plays an important role in the protection of rare and endangered species, and their habitats. In recent years, the development of the social economy in Gansu Province has resulted in the destruction of the natural ecological system, wildlife reproduction habitat shrinking, and a large decrease in the number of species, even those that are endangered. One of the most important reasons for these occurrences is that the value of biodiversity conservation is not widely accepted.

In this study, 95 kinds of rare and endangered species were selected as the research objects in Gansu Province. The distribution range of the research objects covered different ecosystem types. Based on the published literature and field survey data, the spatial distribution range and population density data of several rare and endangered species were obtained by using a habitat suitability valuation model, and the population density was creatively introduced into the valuation of rare and endangered species conservation value. This paper attempts to objectively and comprehensively assess the conservation value of several rare and endangered species in biodiversity hotspots, so as to expand and enrich the research methods and ideas of biodiversity conservation value assessment. It will provide the reliable theoretical basis and technical support for the decision-making of biodiversity conservation in Gansu Province.

2. Materials and Methods
2.1. Study Area and Data Source
2.1.1. The Study Area

Gansu Province is located in the northwest inland of China (Figure 1), at the intersection of the three major plateaus of the Loess Plateau, the Qinghai Tibet Plateau, the Inner Mongolia Plateau, and the three natural regions of the northwest arid region, the Qinghai Tibet alpine region, and the eastern monsoon region. Gansu Province is a long and narrow region with complex and diverse geological landforms and climate types. In addition to the marine ecosystem, the six continents ecosystems, including forests, grasslands, deserts, wetlands, farmland, and cities, are well developed, with a total land area of 425,800 km². The major range systems of Gansu Province include Altun Mountain, Qilian Mountain, Minshan Mountain, Qinling Mountain, Ziwu Mountain, and Liupan Mountain. It is located in the Qinghai Tibet plateau ecological barrier, the Loess Plateau Sichuan Yunnan ecological barrier, and the north sand belt in the Chinese “two screens and three belts” ecological security strategic pattern. It is also an important water conservation and supply area in the upper reaches of the Yangtze River and the Yellow River.
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Figure 1. Map showing the location of the Gansu Province in Northwest China.

2.1.2. Data Sources

1. Ecosystem types

We used the national ecosystem type datasets produced by the Satellite Application Center of the Ministry of Ecology and Environment and Chinese Academy of Sciences through interpretation of the Landsat TM or ETM images at a 30 m resolution, SPOT 5 images at a 5 or 2.5 m resolution, ENVISAT image at 30 m resolution, and HJ-1 images at a 30 m resolution, for classification of ecosystems in the Gansu Province during the years 2000–2015. Combined with the data of 2508 ground verification points, the overall accuracy of classification with ground-based survey data was over 85% [37]. These data include 38 different ecosystem types in the Gansu Province, and these types were integrated into a database with 21 ecosystem types in the research area, according to the research needs, as shown in Figure 2. These were as follows: (1) deciduous broad-leaved forest, (2) evergreen coniferous forest, (3) coniferous broad-leaved mixed forest, (4) deciduous broad-leaved shrub, (5) meadow, (6) grassland, (7) other grassland, (8) paddy field, (9) non-irrigated farmland, (10) garden land, (11) herbaceous wetland, (12) lake, (13) reservoir, (14) river, (15) urban green land, (16) construction land, (17) bare rock, (18) bare land, (19) desert, (20) saline alkali land, and (21) glacier.
2 Protected species

In this study, data of threatened species of higher plant volume and vertebrate volume were collected: these species are classified as “vulnerable, near threatened, endangered, and critically endangered” in the China Red List of Biodiversity. We also referred to China level I and II important protected species, provincial or local important protected species, regional endemic species, and endemic species of China, and data on species distribution in the counties of Gansu Province.

There are seven priority areas for biodiversity conservation in Gansu Province (Figure 3): the Qilian mountain priority areas for biodiversity conservation, West Ordos Helan Mountain-Yinshan biodiversity conservation priority area, Qiangtang-Sanjiangyuan biodiversity conservation priority zone, Kumtag biodiversity conservation priority zone, Liupanshan-Ziwuling biodiversity conservation priority zone, Minshan-Hengdushan biodiversity conservation priority zone, and Qinling Mountain biodiversity conservation priority zone [12]. Biodiversity priority reserves were designated in Gansu Province, according to relevant research [38], by not only considering the high species richness of ecosystems and the distribution area of rare and endangered species of ecosystems, but also reflecting the zonal and a zonal typical ecosystem area, in the distribution area of ecosystems in China. Therefore, this study believes that the protected species in the seven biodiversity conservation priority areas represent the biodiversity conservation species in Gansu Province. Therefore, to facilitate the research, the species in the seven biodiversity conservation priority zones in Gansu Province were selected as the research subjects. The types, levels, and quantities of species protected are shown in Appendix A.
3. GDP and population data

The GDP and population data of Gansu Province from 2015 were used in this study and spatially distributed on a 1 km grid. The data were obtained from the Data Registration and Publishing System of the Resource and Environment Science Data Center of the Chinese Academy of Sciences (http://www.resdc.cn/DOI (accessed at 11 December 2017)).

The characteristics of the habitat factors of each species were obtained based on the list of rare and endangered wild animals and plants in Gansu Province and relevant research records. With the support of GIS spatial analysis, various habitat factors were superimposed and analyzed to obtain the spatial distribution of habitats. Combined with investigation and literature information, the cost of ex situ conservation of species was obtained. Finally, the value of species protection was obtained (Figure 4).

2.2. Methods for Habitat Suitability Analysis of Rare and Endangered Wildlife

2.2.1. Habitat Suitability Assessment Procedure

The main objective of habitat analysis and assessment is to determine the distribution range and characteristics of habitat by analyzing the requirements of biological habitat and its matching with the local natural environment [39]. The habitat suitability model was used to evaluate the habitat suitability of species. First, the habitat requirements of the target species were analyzed to identify the limiting or dominant factors affecting their population and behavior. Second, the evaluation criteria of each factor were established, and the suitability of each factor was evaluated. Finally, comprehensive habitat analysis and evaluation were carried out according to certain criteria to clarify the suitability characteristics of each space unit to the target species.
2.2.2. Selection of Factors Affecting Habitat Suitability

Generally, the factors affecting wildlife habitat suitability are divided into three categories: physical environmental factors, biological environmental factors, and human activity factors [39]. The selection of these factors was mainly based on the field survey data and related literature of previous studies [40–42]: (1) Physical environmental factors: elevation and slope, were selected as the main habitat factors reflecting physical environmental factors. (2) Biological environmental factors: vegetation type and vegetation coverage, were selected as biological environmental factors. (3) Human activity factors: towns, residential areas, farmland, railways, highways, and mining areas, were selected as influencing factors.

2.2.3. Habitat Suitability Assignment

The habitat of each species was assigned through field investigation and reference to the description of physical environmental factors and biological environmental factors of species suitable distribution in relevant literature. Suitable habitats were assigned as 1, and other habitats were assigned a value of 0. At the same time, the county-level distribution range of important species was determined using the county-level distribution data of Gansu Province. If the species had no distribution in a county, the suitable habitat for the region was also assigned 0.

2.2.4. Evaluation Model of Habitat Suitability

There are many environmental factors affecting the survival of species, some of which are important to this survival. Therefore, we put forward the following hypothesis: if one of the main habitat factors is not suitable for the survival of the species, even if other factors are suitable, the result is not suitable for the survival of the species. Therefore, in this study, the fuzzy evaluation quadrature method was used to evaluate the species habitat [43]. The calculation method was as follows:

$$S_j = \prod_{i=1}^{n} U_i$$

where $S_j$ represents the comprehensive suitability value of different assessment units for the habitat of a species, $n$ represents the habitat factors, and $U_i$ represents the importance value of the impact degree of different habitat factors on the habitat suitability of the species. When the factor $U_i$ is 0, $S_j$ will be 0.
2.3. Population Density Survey of Rare and Endangered Wild Animals

Population density data were determined mainly by referring to the relevant literature (Appendix A Table A1, Literature Sources). The specific principles are as follows:

1. If the population density of a species in Gansu Province is found in the literature, the research data of recent years will be directly quoted.
2. If the population density of a species is not found in the relevant literature, but there are quantities of species in the literature, the population density is calculated according to the quantity of the species.
3. If population density data of a species in different regions in Gansu Province are found in the relevant literature, the average population density of the species is taken as the population density.
4. If the population density of a species in Gansu Province is not found in the relevant literature, the overall population density in China will be consulted as the population density in Gansu Province. If there are multiple population density data, the average will be taken.

According to this principle, the population density of the 69 species of wild animals included in the national key protection of Gansu Province and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) in Gansu Province or China were obtained, as shown in Appendix B.

2.4. Determination of the Cost of the Protection of Species in Different Places

2.4.1. Cost of Offsite Protection of Rare and Endangered Wild Animals

To obtain the cost of offsite protection of rare and endangered wild animals, zoos in Gansu Province, such as Lanzhou City Zoo, Wuwei Desert Safari Park, we carried out the survey on all the costs of wild animals, including their feed costs, the labor cost of raising animals, minimum standards for housing costs, the cost of water, and the cost of animal excrement treatment. The costs were determined in this study according to the animal feeding standard data [44,45], and the costs of offsite protection of rare and endangered wild animals investigated in Qinghai Province [46]. For species without investigation and literature materials, the costs refer to the costs of similar species, as shown in Appendix C.

2.4.2. Cost of Offsite Protection of Rare and Endangered Wild Plants

To determine the protection cost of rare and endangered wild plants in different places, the botanical garden and market of Lanzhou City were investigated, including labor cost, pest control cost, land lease cost, and agricultural irrigation cost in Gansu Province. According to the minimum wage of US $226.15/(month • person) calculated in Gansu Province, the labor cost was determined as $384,615.39 per km², the land lease cost was $76,923.08 per km², and the forest pest control drug was 75,000.00 g/km², with a unit price of $0.92 per gram, so the forest pest control cost was $69,000/km². The medicine for disease and pest control in grassland was 180 g/km², and the unit price was $5.54 per gram, so the grassland pest control cost was $9.97/km². Trees were watered five times a year and herbs were watered eight times a year, and each time the cost was $2307.69/km², so the agricultural irrigation cost for trees was $11,538.45/km², and herbs was $18,461.52/km². Finally, the cost of offsite protection of tree species was the sum of the above four, which was $542,615.38/km², and that of herbaceous plants was $480,461.54/km².

2.5. Protection Value of Rare and Endangered Wild Species

2.5.1. Protection Value of Rare and Endangered Animals

In order to overcome the shortage of population density data in large-scale studies, a linear relationship between habitat suitability and population density was assumed in this study. Previous studies have shown that the habitat suitability models of most species have a significant linear relationship between habitat suitability and species population density [47]. Therefore, according to the data of population density and population number in the literature, combined with the distribution range of species suitable habitat and the
cost of offsite protection, the following formula [44] was used to obtain the spatial distribution pattern of the economic value of endangered animals protected by the ecosystem using ArcGIS:

\[ EV_1 = \sum_{i=1}^{n} RV_i \cdot A_i \cdot \rho_i \]

where, \( EV_1 \) is the economic value of wildlife species, \( RV \) is the cost value of \( i \) species’ individual offsite protection, \( A_i \) is the suitable habitat distribution area of species \( i \), \( i \) is the population density of species \( i \), and \( i \) is 1~n.

2.5.2. Protection Value of Rare and Endangered Plants

Combined with the distribution range of species suitable habitat and the unit offsite protection cost price of planted plants, we adopted the following formula, and the protective value of rare and endangered wild plants was evaluated by ArcGIS in this study. The formula is as follows:

\[ EV_2 = \sum_{i=1}^{n} RV_i \cdot A_i \]

where \( EV_2 \) is the economic value of the wild plant species, \( RV \) is the cost value of \( i \) species’ individual offsite protection, \( A_i \) is the suitable habitat distribution area of species \( i \), and \( i \) is 1~n.

3. Results

3.1. Suitable Habitat Spatial Distribution of Rare and Endangered Wild Species

On the basis of obtaining the county-level distribution range of rare and endangered wildlife and plants, and the suitable habitat type of species, the suitable habitat spatial distribution range of 68 kinds of rare and endangered wild animals and 27 kinds of rare and endangered wild plants in Gansu Province were extracted using the habitat suitability analysis method for rare and endangered wild animals and plants (Figures 5 and 6).

As seen in Figure 5, the suitable habitat distribution range of rare and endangered wild animals is mainly distributed in Jiuquan, Jiayuguan, Zhangye, Jinchang, and Wuwei City to the west of Gansu Province, and Gannan, Longnan, and Tianshui City to the south of Gansu Province. The distribution area of 68 species of rare and endangered wild animals is 351,607.76 km² (without overlapping area), and the overlapping area of their distribution area is 209,358.80 km², accounting for 59.54% of the suitable habitat area. The distribution area of birds is 328,699.65 km² (without overlapping area), and that of mammals is 165,093.43 km² (without overlapping area). Animals with a large range of suitable habitat distribution included *Aquila chrysaetos* (42.96%), *Falco tinnunculus* (34.03%), *Gazella subgutturosa* (32.04%), *Accipiter nisus* (27.78%), and Argali sheep (26.86%). The suitable habitat area of 5 kinds of animals reached 211,275.80 km², accounting for 60.09% of the total suitable habitat distribution area.

As can be seen in Figure 6, the suitable habitat distribution range of rare and endangered wild plants is mainly distributed in Jiuquan and Zhangye City in the west of Gansu Province, and Gannan, Longnan, Tianshui, and Qingyang City in the south of Gansu Province. The distribution area of 27 species of rare and endangered wild plants in Gansu Province were extracted using the habitat suitability analysis method for rare and endangered wild animals and plants (Figures 5 and 6).

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The overlapping area of the suitable habitats of rare and endangered wildlife and plants is 30,029.97 km² and is mainly distributed south of Gansu Province. The high water
and heat determine suitable plant growth in the south of Gansu Province, while there is a suitable habitat for wildlife in the northwest of Gansu Province. There are many contiguous deserts in this area, which is also the region with the largest area of Nature Reserves in Gansu Province (such as Anxi extremely arid desert National Nature Reserve, Minqin Liangucheng National Nature Reserve). This region provides an ideal living environment for desert animals (such as blue sheep, North goat, Mongolian wild donkey, etc.).

3.2. Biodiversity Conservation Value of Rare and Endangered Wildlife and Plants

3.2.1. Biodiversity Conservation Value of Rare and Endangered Wildlife

According to the method of the protection value of the rare and endangered wildlife in this study, the protection value of 68 kinds of rare and endangered wildlife in Gansu Province is estimated to be $1670.00 million, and the spatial distribution pattern is shown in Figure 7. At present, the species with large single species values are Pseudois nayau, Argali, Argali sheep, Procapra picticaudata, Equus kiang, Cervus elaphus, and Capricornis milneedwardsii. Because these species are widely distributed, the current population is large, and the cost of protected single species is high. Lutra lutra, Ursus arctos, Moschus berezovskii, and Ailurus fulgens had less value of a single species in Gansu Province. High-value areas are mainly concentrated in Gannan City in the south of Gansu Province, and Jiuquan, Zhangye, Wuwei, and other places in the north. By comparing the distribution map of the biodiversity protection priority area with the distribution map of the protection value of rare and endangered wildlife, we showed that the high-value areas of rare and endangered wildlife protection are mainly located in the Qilian Mountain Biodiversity protection priority area and the Minshan Hengduanshan biodiversity protection priority area. In terms of the total protection value of the biodiversity priority area, the protection value of wildlife in Qilian Mountain priority area is $573.92 million and that in Minshan Hengduan Mountain Biodiversity Protection priority area is $176.77 million, accounting for 44.83% of the total protection value of rare and endangered wildlife.

3.2.2. Biodiversity Conservation Value of Rare and Endangered Wild Plants

According to the evaluation method of the protection values of rare and endangered wild plants in this study, the protection values of 28 kinds of rare and endangered wild plants in Gansu Province were calculated, including 16 kinds of woody plants with a total economic value of $23,420.00 million and 13 kinds of herbaceous plants with a protection value of $33,500.00 million. The protective value of 29 rare and endangered wild plants in Gansu Province is $56,922.92 million. From the perspective of the spatial value distribution pattern (Figure 8), the high-value areas are mostly concentrated in Longnan and Gannan in the south of Gansu Province.

By comparing the distribution map of the priority area of biodiversity protection with the distribution map of the protection value of rare and endangered wild plants, it can be seen that the high-value areas of rare and endangered wild plants protection are mainly located in the Qiangtang Sanjiangyuan and Qinling biodiversity protection priority areas. In terms of the total protection value of the biodiversity priority area, the protection value of plants in the Qiangtang Sanjiangyuan priority area is $70,120.00 million and that in the Qinling Biodiversity Protection priority area is $10,000 million, accounting for 29.89% of the total protection value of rare and endangered plants. At the same time, it can also be seen that the high-value areas of rare and endangered wild plants protection in the central and southern part of Longnan City are not included in the biodiversity protection priority areas, which forms the protection vacant area.
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3.3. Biodiversity Conservation Value

Based on the actual input estimation of the cost of offsite protection, the protective value of ecosystem biodiversity in Gansu Province is $58,595.23 million per year. From the perspective of the spatial distribution pattern (Figure 9), the overall trend in biodiversity protection value distribution gradually decreases from northeast to southwest, with the highest in the southern forest region of Gansu Province, followed by the northern Qilian mountain region. The low-value areas are mainly distributed in the Loess Plateau. These regions accounted for 7.32% of the land area of Gansu Province, 25.72% of GDP in 2015, 19.51% of population, and 162.24 people/km² population density. These regions have a high population and a high level of industrialization; therefore, the biodiversity protection value is lower than that in other areas.

Figure 7. Distribution map of protection values of rare and endangered wildlife in Gansu Province.

Figure 8. Protection value distribution map of rare and endangered wild plants in Gansu Province.
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According to the protective value of each city (Table 1), the top five cities are Longnan, Gannan, Jiuquan, Tianshui, and Qingyang City. Most of the cities, such as Baiyin, Lanzhou, Linxia, and Dingxi, located in the Loess Plateau, have low values of biodiversity protection. In particular, Jinchang and Jiayuguan have the lowest value of biodiversity protection, which are only $9.85 million and $1.08 million, respectively. These cities are established due to the development of mineral resources, and there are few suitable environments for wildlife and plants.
Table 1. Statistics of biodiversity conservation value of cities and prefectures in Gansu Province.

| City      | Value (US Dollar, Million) |
|-----------|----------------------------|
| Baiyin    | 30.92                      |
| Dingxi    | 219.69                     |
| Gannan    | 14,238.46                  |
| Jinchang  | 9.85                       |
| Jiuquan   | 9538.15                    |
| Lanzhou   | 31.85                      |
| Linxia    | 57.08                      |
| Longnan   | 20,779.08                  |
| Pingliang | 1297.85                    |
| Qingyang  | 3051.85                    |
| Tianshui  | 5913.54                    |
| Wuwei     | 699.08                     |
| Zhangye   | 2726.62                    |
| Jiayuguan | 1.08                       |
| Total     | 58,595.23                  |

The overall spatial pattern of species protection value in Gansu Province gradually increases from northeast to southwest, showing an obvious gradient distribution. The protected species in Gansu Province are mainly distributed at an altitude of more than 2900 m. In terms of ecological geographical distribution, the main endangered species in Gansu Province are regularly replaced from the northeast to the southwest in the order of temperate desert, semi-desert, alpine desert, alpine shrub meadow, temperate forest shrub, and north subtropical forest shrub. The fauna of the temperate desert and semi-desert in the northeast mainly includes Equus kiang and Gazella subgutturosa, the unique fauna of the Alpine desert in the northwest, such as Equus kiang, Pseudois nayaur, and Argali sheep, the alpine grassland meadow animal, which has unique species in the Qinghai Tibet Plateau, such as Procapra picticaudata, the temperate forest shrub animal group, which includes Moschus berezovskii and Panthera pardus, and the north subtropical forest shrub animal group, which mainly includes Rhinopithecus, Ailurus fulgens, and Ursus thibetanus.

Based on the biodiversity protection value calculated in Gansu Province, this study further calculated the biodiversity protection value of seven biodiversity protection priority areas in Gansu Province as $39,457.69 million, accounting for 67.34% of the total value of biodiversity protection in Gansu Province, indicating that the biodiversity protection priority areas play a better role in biodiversity protection value. However, by comparing the distribution map of the biodiversity protection priority area with that of the biodiversity protection value, it can be seen that there are high-value areas of biodiversity protection in the central and southern part of Longnan City, the northern part of Gannan City, and the southern part of Pingliang City, which are not included in the priority area of biodiversity protection, forming a protection vacant area.

4. Discussion

4.1. The Value of Protecting Rare and Endangered Wildlife in Gansu Province

Species protection is the most urgent environmental problem faced by contemporary society [48]. Protected species have a certain economic value [15]. The economic valuation of rare and endangered species is of great concern [49–51]. In this study, the economic value of rare and endangered species in Gansu Province was $58,595.23 million per year. At present, there is no evaluation result for species protection from any province.
Based on the results of this study, there are also large regions of high-value areas for biodiversity conservation in the south of Gansu Province. Currently, these areas are located between the Qinling Mountains and the Minshan Hengduanshan Mountains biodiversity conservation priority areas. They are distributed in continuous and flaky patterns and are not included in the strict protection of natural reserves. That is to say, they form a protective gap area, which is also confirmed by the research results of Zhao et al. [42] on habitat quality in Gansu Province. In these regions, some high-quality habitat areas are not classified as nature reserves for management. Of course, this is also consistent with the conclusion of Li’s study [52] on the protection value evaluation and reasonable layout of the nature reserve of the national forest type. He pointed out that the protection value of this area is high, and the main protection objects are coniferous broad-leaved mixed forest ecosystems, rare and endangered wild animals, and plants such as Rhinopithecus and their habitats. However, this area has not been fully included in the management of nature reserves. Sun [53] pointed out that the biodiversity in this area is extremely sensitive, but the existence of a protective gap in this region will become a hidden danger of ecological security in Minshan Hengduan Mountain. Therefore, it is necessary to protect ecosystem integrity, and these high-value areas should be included in the nature reserves or priority areas for protection. In view of the need for ecosystem integrity protection, these high-value areas should also be included in nature reserves or priority areas for protection.

In this study, the research methods and ideas of biodiversity assessment are expanded and enriched by substituting the offsite protection cost of animals and plants for the protection value of the ecosystem for biodiversity. Species diversity is the major feature and content of biodiversity, the basic building unit of biodiversity and ecosystem, and the carrier of ecosystem functions and services. Rare and endangered species not only play an irreplaceable role in the research and protection of species diversity but also are the priority protection objects of biodiversity protection [54]. The problems confronted by the sustainable survival of these species have become the main basis for decision-making for the formulation and implementation of regional ecological protection and construction. This method is based on simple theory and has strong operability. It is hoped that this method can be applied to research and evaluation of biodiversity in other regions and can provide a reference for the delimitation of ecological red lines and the design of national parks.

4.2. Validation of the Validity and Reliability of Biodiversity Conservation Value Assessment

At present, Costanza et al. [1] provided databases of values for global research, ecosystems, and biodiversity economics [55,56] for research in China, which are commonly used in the evaluation of the value of ecological services. At present, scholars often valuate biodiversity conservation, including the equivalence factor method and conditional value method. Therefore, combined with the determination method of the standard equivalence factor in Xie et al. [56], the conservation value and unit area value of each kind of ecosystem calculated for rare and endangered species are calculated in this study, and are subsequently used to calculate the equivalency factor of the protection value of different ecosystems for rare and endangered wildlife in Gansu Province (Figure 5). It was found that the value equivalent factors of forest and grassland ecosystem types in Gansu Province obtained from the calculated value of biodiversity protection in this study match with those of Xie et al. [56] but are higher (Table 2). The reason for this is that Xie et al.’s [56] research results are mainly determined by the expert experience method, which is an average estimation of the value of ecosystem types in China, indicating that there are great differences in the degree of attention paid to different ecosystems in China, and scholars in China underestimate the value of biodiversity protection of forest and grassland ecosystems in Gansu Province, especially the rare and endangered wild species living in the ecosystem type. However, the value equivalent factor of wetland ecosystems in this study was less than that of Xie et al. [56]. The area of wetland ecosystems in Gansu Province accounts for only 0.6% of the land area of Gansu Province, and the importance of
maintaining the biodiversity value is lower than that of the forest ecosystem and grassland ecosystem, which account for 13.22% of the land area. The value equivalent factors of desert ecosystem types are the same as those of Xie et al. [56]. By comparing the equivalent factors calculated in this study with the equivalent factors in the relevant research results, we can see that the equivalent factors determined in this study have a certain rationality, which objectively reflects the value of different ecosystem types in maintaining biodiversity in Gansu Province. The results can provide data support for the evaluation of ecosystem services in Gansu Province in this study.

Table 2. Comparison of biodiversity conservation values and related research in main ecosystems in Gansu Province.

| Ecosystem Type          | Equivalent Factor of This Study | Xie et al. [56] Equivalency Factor |
|-------------------------|---------------------------------|-----------------------------------|
| Forest                  |                                 |                                   |
| Deciduous broad-leaved forest | 10.09                          | 2.60                              |
| evergreen coniferous forest | 2.85                           | 1.88                              |
| Mixed coniferous and broad-leaved forest | 7.61                          | 2.6                               |
| Shrub wood              | 1.1                             | 1.57                              |
| Grassland               |                                 |                                   |
| Meadow                  | 7.62                           | 1.27                              |
| Steppe                  | 3.72                           | 0.56                              |
| Other grassland         | 2.54                           | -                                 |
| Wetland                 |                                 |                                   |
| Lake                    | 0.01                           |                                   |
| Reservoir               | 0.03                           | 2.55                              |
| Rivers                  | 0.11                           |                                   |
| Wetland                 | 1.71                           | 7.87                              |
| Desert                  |                                 |                                   |
| Saline alkali soil      | 0.05                           | -                                 |
| Bare soil               | 0.07                           |                                   |
| Bare rock               | 0.12                           | 0.02                              |
| Desert                  | 0.07                           |                                   |
| Sand                    | 0.06                           | 0.12                              |

In this study, based on the actual input estimation of the cost of offsite protection, the protective value of ecosystem biodiversity in Gansu Province was calculated as $58,595.23 million per year, which includes $1672.31 million for rare and endangered wild animals and $56,922.92 million for rare and endangered wild plants. Thus, the protection value of rare and endangered wild plants is much higher than that of rare and endangered wild animals. At present, there is little research on the protection value of rare and endangered wild plant species. According to Xie et al. [21], the value evaluation results of key protected species at all levels in China through the Willingness to pay (WTP) method show that the average protection value of a single plant species is $2123.08 million, while the average protection value of a single plant species in this study is $2032.92 million, with no significant difference. There are numerous studies on the protection value of rare and endangered wild animals [17,20,57,58]. The average protection value of a single animal species is between $6.15 million and $47.69 million, while the average protection value of a single animal species in this study is $24.62 million. Considering the differences in research areas and research methods and the span of research time, the accuracy of the results of this study is acceptable.
4.3. The Error of Biodiversity Protection Valuation

The results of this study are based on the regional rare and endangered species to quantify the spatial distribution of biodiversity values. In this study, the quantitative assessment of biodiversity value in the study area was spatialized. The protection value and importance of different areas are clarified, and the integrity and protection vacancies can be directly recognized. The above results can directly guide protection and management work. The representativeness of rare and endangered species and the comprehensiveness and accuracy of environmental factors in this method have a significant influence on evaluation results. In this study, we focus on the main factors that cause this deviation. In this research, we can deal with the deviation by consulting the relevant research results as much as possible for the population density or population number of wild animals. Through screening, we can discard the achievement data that is significantly higher or lower than the number and density of rare and endangered wild animals in Gansu Province. The mean value method is used to reduce the data deviation for multiple research results. For the reference of similar research results, the research of adjacent areas or areas with similar physical and geographical conditions in Gansu Province was used as much as possible. For the selection of the cost data of wild animal offsite protection, the relevant research results of adjacent areas in Qinghai Province were mainly referred to and combined with the investigation results of zoos in Gansu Province. The reference of wild plant offsite protection results is based on the investigation results of botanical gardens in Gansu Province.

In this study, we only obtained the population density of rare and endangered wild animals, not the population density of rare and endangered wild plants. The reason is that the population density of rare and endangered wild plant species involved in this study is very low. Scholars have only studied the population density of individual species, such as *Torreya fargesii* [59], *Picea brachytyla var. complanata* [60], and *Kingdonia uniflora* [61]. In view of the lack of population density survey data for most rare and endangered wild plant species, this study abandoned the population density of rare and endangered wild plant species as the parameter of conservation value calculation. Due to the lack of population density of rare and endangered wild plant species, directly taking the simulated suitable habitat as its distribution area will certainly overestimate the protection value of this species, to a certain extent. However, according to the existing research on the conservation value of rare and endangered wild plant species [16,19,57], using population density as a parameter to calculate the conservation value, although there was some error in the calculation of protection value in this study, the result is reasonable. In the next step, we will attempt to introduce vegetation coverage as an alternative index of population density of rare and endangered wild plants, to comprehensively determine their protection value, and thus greatly reduce protection value overestimation.

There are insufficient investigation results on biodiversity resources in Gansu Province, especially on endangered animals and plants. Most of the existing investigations are scientific and lack quantitative investigation, resulting in negligible data accumulation. Therefore, in this study, only one value is set for the population density of a species for rare and endangered wild animals in the entire province, without considering regional differences, which will affect the calculation of wildlife protection values. This created some uncertainty for the results, so we need to take the visualization techniques as a more reliable means to assess the uncertainty of these data in the future [62]. The selection of species in this study was limited by the lack of research on the habitat characteristics of species, and thus does not fully include all the rare and endangered wild species in Gansu Province. For some species without relevant research results, a protective value evaluation will not be conducted temporarily.

The suitable habitat of species is affected by many factors. In this study, the suitable habitat of species was determined by mainly considering terrain elevation, ecosystem type of species distribution, and the county distribution range of rare and endangered species in the existing related studies. A suitable habitat range is comprehensively determined.
without considering better factors. According to the suitable habitat distribution range determined by this method to estimate the value of biodiversity conservation, there may be an overestimation. If more factors affecting species distribution can be considered in this study, the consequences will be more convincing.

Although there are many limitations in the assessment method of biodiversity value based on suitable habitat, it does reveal the importance of an ecosystem in Gansu Province for maintaining biodiversity and the important role of biodiversity protection in Northwest China, or even China as a whole. The spatial distribution of biodiversity value in Gansu Province was objectively evaluated, which can provide a scientific basis for local residents to have a better understanding of the importance of biodiversity protection in their area, and for the government’s public decision-making [63]. The evaluation method of biodiversity value based on suitable habitat is still an effective method to evaluate biodiversity protection.

5. Conclusions

In this study, Gansu Province was regarded as the research area. Based on the research data of rare and endangered wild animals and plants and the estimation of offsite protection cost, and on the basis of habitat suitability analysis of rare and endangered wild animals and plants, an evaluation method for the conservation value of rare and endangered wild species was constructed, and the conservation value of 95 rare and endangered wild species was developed, with results revealing that:

1. In the absence of detailed information on larger areas, the simulation method of habitat suitability is a more appropriate and effective technique to assess the potential distribution range of the species concerned. The range of suitable species habitats determined in this study is consistent with the distribution range of biodiversity priority reserve in Gansu Province, and this provides a reference for us to protect the living environment of species.

2. Although the population number of rare and endangered wild species is low, or the distribution range is limited, the marginal value is relatively high because of its rarity. The biodiversity conservation value in the priority zone of biodiversity conservation in Gansu Province accounts for two-thirds of the total value of the province, which indicates that the limited resources should be concentrated on the protection of rare and endangered wild species, and the priority zone of biodiversity conservation plays a significant role in the maintenance of the biodiversity conservation value. There is an urgent need to establish conservation areas to combat existing and potential anthropogenic threats and environmental unpredictability.

3. Based on the results of this study, there is a large area of high-value biodiversity conservation areas outside the priority biodiversity protection areas in Gansu Province (such as the central and southern areas of Longnan City), forming a vacant protection area. Owing to the demand for integrity protection, these areas are also included in the protection area, and will provide technical support for local governments to formulate management measures for ecosystem services.

4. Taking Gansu Province as an example, based on the scarcity of rare and endangered species, the annual value of 68 major conservation objectives was estimated to be $58,595.23 million per year, using the alternative cost method. This study is a useful attempt to assess the ecosystem service value in a biodiversity-rich zone and lays the foundation for further study of regional ecological compensation standards and the establishment of an ecological compensation system.

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Appendix A

Population density data were determined mainly by referring to relevant literature. The population density of 69 species of wild animals included in the national key protection of Gansu Province and CITES appendix in Gansu Province or China was obtained, as shown in Table A1 below.

Table A1. Population density of rare and endangered wild animals in Gansu Province.

| Number | Scientific Name        | Population Density/km² | Literature Sources                                                                 |
|--------|------------------------|-------------------------|-------------------------------------------------------------------------------------|
| 1      | *Przewalskium albirostris* | 0.2400                  | Yanchiwan National Nature Reserve, Gansu [64]                                        |
| 2      | *Ovis ammon*            | 0.9600                  | Tashkurgan nature reserve, Xinjiang [65]; Tashkurgan area, Xinjiang [66]; Kudi area, Yecheng County, Xinjiang and malyang area, Tashkurgan Autonomous County [67]; National Nature Reserve, Tomur peak, Xinjiang [68] |
| 3      | *Macaca thibetana*      | 1.9487                  | Baishuijiang Nature Reserve, Gansu [69]                                              |
| 4      | *Procapra gutturosa*    | 0.2446                  | Yanchiwan Nature Reserve, Gansu Province [70]                                         |
| 5      | *Panthera uncinia*      | 0.0140                  | Tianshan Tuomuer Mountain Nature Reserve, Xinjiang [71]; Beita mountain, Altai mountain, Kunlun Mountain, Eastern Tianshan Mountain, Tuomuer mountain, Xinjiang [72] |
| 6      | *Pseudois nayaur*       | 1.6382                  | Yanchiwan Nature Reserve, Gansu [70]; Gansu Dongdasha Nature Reserve [73]; Yanchiwan Nature Reserve, Gansu Province [74] |
| 7      | *Capra sibirica*        | 0.9803                  | Yanchiwan nature reserve, Gansu [70]; bayingolinzhou, Xinjiang [10]                |
| 8      | *Ursus arctos*          | 0.0023                  | Altun mountain and Kunlun Mountain, Xinjiang [75]                                      |
| 9      | *Ailurus fulgens*       | 0.2300                  | China [76]                                                                            |
| 10     | *Camelus ferus*         | 0.0680                  | Lop Nur Wild Camel Nature Reserve, Xinjiang [77]                                      |
| 11     | *Lutra lutra*           | 0.0097                  | Changbaishan Nature Reserve, Jilin [78]                                              |
| 12     | *Lynx lynx*             | 0.0322                  | Yanchiwan Nature Reserve, Gansu Province [74]                                         |
Table A1. Cont.

| Number | Scientific Name              | Population Density/km² | Literature Sources                                                                 |
|--------|------------------------------|-------------------------|-----------------------------------------------------------------------------------|
| 13     | *Procapra picticaudata*      | 0.1100                  | Dalai Lake area, Inner Mongolia [79]; Altun Mountain Nature Reserve, Xinjiang [80] |
| 14     | *Equus hemionus*             | 0.7903                  | China [81]; karamaili hoof Nature Reserve, Xinjiang [82,83]; China [84]           |
| 15     | *Gazella subgutturosa*       | 0.1363                  | Yanchiwan Nature Reserve, Gansu Province [76]                                     |
| 16     | *Cervus nippon*              | 0.9670                  | Qingliangfeng Nature Reserve, Zhejiang [85]; Ruoergai, Sichuan [86]              |
| 17     | *Cervus elaphus*             | 1.2645                  | Nanshan Mountain Area in Urumqi, Xinjiang [87]; Aibi Lake Wetland National Nature Reserve [88]; Helan mountain in Ningxia [89]; Dongdashi Nature Reserve in Gansu [73] |
| 18     | *Equus kiang*                | 0.0914                  | Yanchiwan Nature Reserve, Gansu Province [74]                                    |
| 19     | *Moschus berezovskii*        | 0.9160                  | Southwest of China [90]; Gannan mountain [91]; Qinba mountain area, Shaanxi [92]; Fengxian County, Shaanxi [93] |
| 20     | *Rhinopithecus roxellana*    | 1.9189                  | Gansu province [94]; Zhouzhi National Nature Reserve, Shaanxi [95]                |
| 21     | *Panthera pardus*            | 0.0251                  | Liupanshan Nature Reserve, Ningxia [97]                                           |
| 22     | *Pardofelis temminckii*      | 0.0900                  | Changqing Nature Reserve [98]                                                    |
| 23     | *Ursus thibetanus*           | 0.1275                  | Minshan Mountain System [44]; Hanzhong region, Shaanxi Province [99]; Ganzi region, Sichuan Province [100] |
| 24     | *Martes flavigula*           | 2.5000                  | Lishan National Nature Reserve, Shanxi [101]                                     |
| 25     | *Capricornis milneedwardsii* | 2.5800                  | Baima Snow Mountain National Nature Reserve [102]                                |
| 26     | *Anser albifrons*            | 15.0000                 | Yanchiwan Nature Reserve, Gansu Province [74]                                    |
| 27     | *Cygnus cygnus*              | 0.0500                  | Inner Mongolia Baiyiin Kulun Relict Gull Nature Reserve [103]; Bayinbuluk Nature Reserve [104] |
| 28     | *Otis tarda*                 | 0.0500                  | Bustard of China [105]                                                           |
| 29     | *Bonasa sewerzowi*          | 8.6050                  | Lianhuashan Nature Reserve, Gansu [106]; Gansu Lianhuashan Nature Reserve [107]; Duoper Nature Reserve, Gansu [108] |
| 30     | *Crossoptilon auritum*       | 0.4906                  | Zecha forest area, Gansu [109]; Duoper Nature Reserve, Gansu [108]              |
| 31     | *Athene noctua*              | 1.0250                  | Qishan County, Shaanxi Province [110]; big and small Sugan Lake [111]            |
| 32     | *Tetraophasis obscurus*      | 0.0700                  | Baiyu County, Ganzi Prefecture, Sichuan Province [112]                           |
Table A1. Cont.

| Number | Scientific Name          | Population Density/km² | Literature Sources                                                                 |
|--------|--------------------------|-------------------------|------------------------------------------------------------------------------------|
| 33     | *Asio otus*              | 0.0810                  | Yanggetai Forest Farm, Shanxi [31]                                                 |
| 34     | *Tragopan temminckii*    | 2.8700                  | Laojunshan Nature Reserve, Pingjiang County, Sichuan Province [113]; Duoer Nature Reserve, Gansu Province [108] |
| 35     | *Ithaginis cruatus*      | 6.7100                  | Niubeliang Nature Reserve, Shaanxi [114]; Lianhuashan Nature Reserve, Gansu [107]; Duoer Nature Reserve, Gansu [108] |
| 36     | *Aegypius monachus*      | 0.0020                  | Global [115]                                                                        |
| 37     | *Lophophorus lhuysii*    | 2.1100                  | Xiaozaizigou National Nature Reserve, Sichuan [20]; Baishuijiang Nature Reserve, Gansu [116]; Duoer Nature Reserve, Gansu [108] |
| 38     | *Falco cherrug*          | 0.0053                  | Western of China [117]                                                              |
| 39     | *Chrysolophus pictus*    | 0.0026                  | Sanguanmiao, Foping, Qinling [118]; Foping, Shaanxi [119]; Zhouzhi, Shaanxi [120]; Taibai, Shaanxi [121]; Liupanshan, Ningxia [122]; Beichuan, Sichuan [123]; Kuankuoshui, Guizhou [124]; Three Gorges Reservoir Area [125]; Duoer Nature Reserve, Gansu [108] |
| 40     | *Ciconia nigra*          | 1.4459                  | Bayinbrook Nature Reserve [104]                                                     |
| 41     | *Gypaetus barbatus*      | 0.0200                  | Qinghai Tibet Plateau [126]                                                         |
| 42     | *Falco tinnunculus*      | 0.1089                  | Beijing area [127]; big and small Sugan Lake [112]; Anxi extremely arid desert Nature Reserve [58] |
| 43     | *Otus sunia*             | 0.9150                  | Getai forest farm, Shanxi Province [128]                                            |
| 44     | *Haliaeetus albicilla*   | 0.0073                  | Gansu, Xinjiang [129]                                                               |
| 45     | *Platalea leucorodia*    | 0.0130                  | Minqin Shiyanghe National Wetland Park [130]; Qixinghe Nature Reserve, Heilongjiang [131] |
| 46     | *Accipiter gentilis*     | 0.2400                  | Duoer Nature Reserve, Gansu [108]                                                   |
| 47     | *Bubo bubo*              | 0.5000                  | Kuitun oasis, Xinjiang [132]                                                        |
| 48     | *Aquila nipalensis*      | 0.1269                  | Bayinbrook National Nature Reserve [104]                                            |
| 49     | *Buteo buteo*            | 0.0130                  | Kuitun oasis, Xinjiang [132]                                                        |
| 50     | *Buteo hemilasius*       | 0.5380                  | Baiyin Kulun Relict Gull Nature Reserve, Inner Mongolia [99]; Sugan Lake [111]; Duo‘er Nature Reserve, Gansu [108] |
| 51     | *Aquila chrysaetos*      | 0.6667                  | Big and small Sugan Lake [111]; Anxi extremely arid desert Nature Reserve [58]       |
| 52     | *Circus aeruginosus*     | 0.0250                  | Baiyin Kulun Relict Gull Nature Reserve, Inner Mongolia [103]; Sugan Lake [117];    |
| Number | Scientific Name       | Population Density/km² | Literature Sources                                                                 |
|--------|-----------------------|-------------------------|-------------------------------------------------------------------------------------|
| 53     | *Milvus migrans*      | 0.0400                  | Baiyin Kulun Relict Gull Nature Reserve, Inner Mongolia [103]; Bayinbrook National Nature Reserve [104] |
| 54     | *Circus cyaneus*      | 0.4467                  | Bayinbrook National Nature Reserve [104]                                            |
| 55     | *Accipiter virgatus*  | 0.0600                  | Bayinbrook National Nature Reserve [104]                                            |
| 56     | *Falco amurensis*     | 0.0100                  | Bayinbrook National Nature Reserve [104]                                            |
| 57     | *Falco subbuteo*      | 0.0334                  | Baiyin Kulun Relict Gull Nature Reserve, Inner Mongolia [103]; Bayinbrook National Nature Reserve [104]; Beijing area [127] |
| 58     | *Larus relictus*      | 0.2650                  | Baiyin Kulun Relict Gull Nature Reserve, Inner Mongolia [103]                        |
| 59     | *Gyps himalayensis*   | 0.2610                  | Qinghai Tibet Plateau [126]; Bayinbuluk Nature Reserve [104]; Duoer Nature Reserve, Gansu [108] |
| 60     | *Accipiter nisus*     | 0.1300                  | Duoer Nature Reserve, Gansu [108]                                                   |
| 61     | *Tetraogallus himalayensis* | 3.2373                  | Dongdashan Nature Reserve, Gansu Province [133]                                      |
| 62     | *Haliaeetus leucoryphus* | 0.0663                  | Big and small Sugan Lake [111]                                                       |
| 63     | *Accipiter virgatus*  | 0.1100                  | Duoer Nature Reserve, Gansu [108]                                                   |
| 64     | *Tetraogallus tibetanus* | 1.4523                  | Tibet [134]                                                                          |
| 65     | *Falco naumanni*      | 0.0105                  | Kuitun oasis, Xinjiang [132]                                                         |
| 66     | *Aix galericulata*    | 0.0017                  | Shiqian Yuanyang Lake National Wetland Park, Guizhou [135]                           |
| 67     | *Cygnus columbianus*  | 1.4827                  | Wuliangshuai, Inner Mongolia [136]                                                  |
| 68     | *Falco columbarius*   | 0.0070                  | Kuitun oasis, Xinjiang [132]                                                         |
### Appendix B

Table A2. Types, levels, and numbers of species protected in Gansu Province.

| Priority Area | Number of Protected Plants | Number of Protected Animals | Number of Protected Birds |
|---------------|----------------------------|-----------------------------|---------------------------|
| 1 Qilian mountain biodiversity conservation priority area | 4 species of plants, including 1 species of national endangered and 3 species of national level II plants. | 51 species of animals, including 2 species of national protected level I endangered species, 1 species of national protected level I vulnerable species, 2 species of national protected level I near endangered species, 1 species of national protected level I critically endangered species, 7 species of national protected level II endangered species, 1 species of national protected level II near endangered species, 1 species of national protected level II critically endangered species, and 2 species of national protected level II species | 34 species of birds, including 2 species of national protected level I endangered species, 2 species of national protected level I vulnerable species, 2 species of national protected level I near endangered species, 1 species of class II endangered species, 9 species of national protected level II near endangered species, 2 species of national protected level II vulnerable species, 2 species of national protected level I species and, 14 species of national protected level II species |
| 2 West Ordos Helan Yinshan biodiversity protection Priority area | 2 species of plants, including 1 species of national level II endangered species and 1 species of national protected level II species; | 2 species of animals, including 1 species of national protected level I critically dangerous species and 1 species of national protected level II species | 12 species of birds, including 1 species of national protected level I endangered species, 3 species of national protected level II near endangered species, 1 species of national protected level I protected species and 7 species of national protected level II protected species |
| 3 Qiangtang Sanjiangyuan biodiversity conservation priority area | 4 species of plants, including 1 species of national protected level II vulnerable species and 3 species of national level II protected plants; | 10 species of animals, including 1 species of national protected level I endangered species, 1 species of national protected level I near endangered species, 1 species of national protected level I critically endangered species, 5 species of national protected level II endangered species, 1 species of national protected level II near endangered species, 1 species of national protected level II vulnerable species, and 1 species of national protected level II endangered species | 14 species of birds, including 1 species of national protected level I endangered species, 1 species of national protected level I vulnerable species, 1 species of national protected level II endangered species, 1 species of national protected level II near endangered species, 3 species of national protected level I protected species, and 7 species of national protected level II protected species. |
| 4 Kumtag biodiversity conservation priority area | 3 species of plants, including 1 species of national protected level II endangered species and 2 species of national protected level II species; | 12 species of animals, including 1 species of national protected level I endangered species, 5 species of national protected level II endangered species, 1 species of national protected level II endangered species, 1 species of national protected level II vulnerable species, 2 species of national protected level I species, and 1 species of national protected level II species | 19 species of birds, including 4 species of national protected level I endangered species, 1 species of national protected level I endangered species, 2 species of national protected level II endangered species, 3 species of national protected level I endangered species, and 9 species of national protected level II endangered species. |
| Priority Area | Number of Protected Plants | Number of Protected Animals | Number of Protected Birds |
|---------------|---------------------------|-----------------------------|--------------------------|
| 5 Liupanshan Ziwuling biodiversity conservation priority area | 6 species of plants, including 2 species of national endangered and 4 species of national protected level II species; | 4 species of animals, including 1 species of national protected level I critically endangered species, 1 species of national protected level II endangered species, 1 species of national protected level II near endangered species, and 1 species of national protected level II critically endangered species | 19 species of birds, including 2 species of national protected level I endangered species, 1 species of national protected level I endangered species, 2 species of national protected level II endangered species, 1 species of national protected level II endangered species, and 9 species of national protected level II endangered species |
| 6 Minshan and North section of Hengduanshan biodiversity conservation Priority area in the | 19 species of plants, including 1 species of national protected level I vulnerable species, 1 species of national protected level II near threatened species, 4 species of national protected level II vulnerable species, 2 species of national protected level I, and 11 species of national protected level II species. | 19 species of animals, including 4 species of national protected level I endangered species, 2 species of national protected level I critically endangered species, 2 species of national protected level II endangered species, 1 species of national protected level II near endangered species, 3 species of national protected level II vulnerable species, 1 species of national protected level II critically endangered species, and 4 species of national protected level II endangered species | 36 species of birds, including 2 species of national protected level I endangered species, 2 species of national protected level I endangered species, 2 species of national protected level II endangered species, 2 species of national protected level II endangered species, 1 species of national protected level II endangered species, 3 species of national protected level II endangered species, and 11 species of national protected level II endangered species |
| 7 Qinling Mountains biodiversity conservation priority area | 13 species of plants, including 1 species of national protected level II endangered species, 5 species of national protected level II vulnerable species, 1 species of national protected level I, and 6 species of national protected level II species. | 8 species of animals, including 1 species of national protected level I endangered species, 2 species of national protected level II endangered species, and 1 species of national protected level II endangered species. | 24 species of birds, including 1 species of national protected level I endangered species, 2 species of national protected level I vulnerable species, 1 species of national protected level II endangered species, 12 species of national protected level II endangered species, 2 species of national protected level II vulnerable species, and 6 species of national protected level II endangered species. |
Appendix C

In this study, by visiting and investigating the representative zoos in Gansu Province, we understand the cost of a single wild animal. For the species without investigation data and literature, the cost of offsite protection was determined by referring to the cost of similar species. The costs of offsite protection of rare and endangered wild animals in Gansu Province are shown in Table A3.

Table A3. The costs of offsite protection of rare and endangered wild animals in Gansu Province.

| Species                          | Single Price (US$) | Species                          | Single Price (US$) |
|----------------------------------|--------------------|----------------------------------|--------------------|
| Przewalskium albirostris         | 1746.15            | Chrysolophus pictus              | 449.23             |
| Anser albifrons                  | 52.31              | Ursus thibetanus                 | 3466.15            |
| Cygnus cygnus                    | 1721.54            | Ciconia nigra                    | 1900.00            |
| Otis tarda                       | 1353.85            | Martes flavigula                 | 2583.08            |
| Bonasa sewerzowi                 | 710.77             | Capricornis milneedwardsii       | 1481.54            |
| Crossoptilon auritum             | 770.77             | Pardofelis temminckii            | 2196.92            |
| Otis ammon                       | 2409.23            | Gypaetus barbatus                | 5058.46            |
| Macaca thibetana                 | 1606.15            | Falco tinnunculus                | 1023.08            |
| Procapra gutturosa               | 1921.54            | Otus sunia                       | 3598.46            |
| Panthera uncia                   | 5973.85            | Haliaeetus albicilla             | 2778.46            |
| Pseudois nayaur                  | 2409.23            | Platalea leucorodia              | 2140.00            |
| Capra sibirica                   | 2010.77            | Accipiter gentilis               | 1612.31            |
| Athene noctua                    | 1606.15            | Bubo bubo                        | 1176.92            |
| Ursus arctos                     | 3733.85            | Aquila nipalensis                | 3664.62            |
| Tetraophasis obscurus            | 683.08             | Buteo buteo                      | 3227.69            |
| Asio otus                        | 3598.46            | Buteo hemilasius                 | 490.77             |
| Ailurus fulgens                  | 4678.46            | Aquila chrysaetos                | 3567.69            |
| Camelus ferus                    | 1538.46            | Circus aeruginosus               | 5058.46            |
| Tragopan temminckii             | 760.00             | Milvus migrans                   | 3227.69            |
| Ithaginis cruentus               | 683.08             | Circus cyaneus                   | 5058.46            |
| Equus kiang                      | 5575.38            | Accipiter virgatus               | 1612.31            |
| Aegypius monachus                 | 3664.62            | Falco amurensis                  | 1023.08            |
| Lutra lutra                      | 453.85             | Falco subbuteo                   | 2049.23            |
| Lynx lynx                        | 1166.15            | Larus relictus                   | 35.38              |
| Procapra picticaudata            | 1947.69            | Gyps himalayensis                | 4133.85            |
| Equus hemionus                   | 5575.38            | Accipiter nisis                  | 1612.31            |
| Gazella subgutturosa             | 1226.15            | Tetraogallus himalayensis        | 1023.08            |
| Cervus nippon                    | 1746.15            | Haliaeetus leucoryphus           | 2778.46            |
| Cervus elaphus                   | 3156.92            | Accipiter virgatus               | 1612.31            |
| Species                     | Single Price (US$) | Species         | Single Price (US$) |
|-----------------------------|-------------------|-----------------|-------------------|
| Lophophorus lhuysii         | 760.00            | Tetroagallus tibetanus | 683.08            |
| Moschus berezovskii         | 1327.69           | Falco naumanni   | 1023.08           |
| Falco cherrug               | 2638.46           | Aix galericulata | 2140.00           |
| Rhinopithecus roxellana     | 1606.15           | Cygnus columbianus | 1721.54           |
| Panthera pardus             | 4769.23           | Falco columbarius | 1023.08           |

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