

Postprint: Analysis of Vertebrate Population Size and Habitat Changes in Northwestern China, 1980-2015

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Date: 2021-12-14T00:00:00+00:00

Abstract

The vast Northwest China region boasts a unique geographical location with a distinctive and rich fauna, yet its ecosystems are fragile and vulnerable to environmental changes, severely impacting species populations and habitat conditions. This study utilizes satellite remote sensing and ground-based species survey data as primary data sources, employing the Living planet index (LPI) to analyze biodiversity levels and trends, thereby characterizing species population changes; land use data were reclassified into six ecosystem types, with forest, grassland, desert, water body, and wetland ecosystems defined as natural habitats, while settlement and cropland ecosystems were defined as artificial habitats, with their areal extent representing species habitat conditions. A comprehensive analysis of trends in vertebrate population numbers and habitat conditions from 1980 to 2015 reveals that vertebrate populations in Northwest China have exhibited an overall declining trend since 1980, decreasing by 57.83% by 2013, though showing a gradual recovery after 2005; populations of *Gymnocypris przewalskii*, *Procapra przewalskii*, and *Nipponia nippon* increased by 55.77%, 26.03%, and 304%, respectively, having experienced declines before 2000 but increasing significantly thereafter; however, populations of *Camelus ferus* and *Testudo horsfieldii* have declined exponentially, with this trend yet to be alleviated; areas of grassland and desert ecosystems decreased, while those of forest, water body, and wetland ecosystems increased, representing an overall shift from natural to artificial habitats. This study holds significant importance for understanding animal and environmental changes in the research area and for ecological conservation, providing valuable insights for developing measures to control species populations and predict population fluctuations, while also benefiting research and management of biodiversity conservation in Northwest China.

Full Text

Analysis of Vertebrate Population Dynamics and Habitat Changes in Northwest China from 1980 to 2015

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Abstract: Northwest China encompasses a vast territory with a unique geographic location and a distinctive, species-rich fauna, yet its ecosystems are fragile and vulnerable to environmental changes. This study employs satellite remote sensing data and ground-based species surveys as primary data sources, utilizing the Living Planet Index (LPI) to analyze biodiversity levels and trends, thereby characterizing species population dynamics. Land use data were reclassified into six ecosystem types, with forest, grassland, desert, water body, and wetland ecosystems defined as natural habitats, while settlement and farmland ecosystems were classified as artificial habitats. Habitat status was represented by the area of these ecosystem types. A comprehensive analysis of vertebrate population trends and habitat conditions from 1980 to 2015 reveals that vertebrate populations in Northwest China declined overall, dropping by 57.83% by 2013, but showed gradual recovery after 2005. Populations of *Gymnocypris przewalskii* (Qinghai Lake naked carp), *Procapra przewalskii* (Przewalski's gazelle), and *Nipponia nippon* (crested ibis) increased by 55.77%, 26.03%, and 304%, respectively, with numbers declining before 2000 but increasing significantly thereafter. Conversely, populations of *Camelus ferus* (wild camel) and *Testudo horsfieldii* (four-toed tortoise) declined exponentially, with no alleviation of this trend. The area of grassland and desert ecosystems decreased, while forest, water body, and wetland ecosystems expanded, representing an overall conversion from natural to artificial habitats. This research provides crucial insights into animal population dynamics and environmental changes in the study area, informing species management measures and population forecasts while supporting biodiversity conservation research and management in Northwest China.

Keywords: vertebrata; population change; biodiversity; habitat; ecosystem

1 Introduction

Biodiversity constitutes the foundation for human survival and provides immense value to ecosystems. Habitat represents the living space for species, and

habitat loss and fragmentation severely impact species dispersal, migration, and colonization, consequently affecting population sizes. Forests, grasslands, and wetlands serve as critical habitats for wildlife, yet growing human populations and infrastructure development have accelerated land conversion and environmental degradation, causing serious damage to biological habitats. Many studies have integrated ground surveys with remote sensing monitoring techniques, employing biodiversity indices and environmental factors to construct ecological assessment models for biodiversity research and species richness evaluation, thereby providing decision-making and technical support for conservation efforts. With the widespread application of “3S” technology (Remote Sensing, Geographic Information Systems, and Global Positioning Systems), research utilizing remote sensing for biodiversity assessment and ecological monitoring has increased, enabling rapid acquisition of ecological factors and real-time monitoring of large-scale environments. Numerous scholars have leveraged remote sensing platforms to obtain broad-scale habitat information for species, using GIS spatial analysis techniques to evaluate habitat suitability for important species such as gorals (*Naemorhedus goral*), red-crowned cranes (*Grus japonensis*), Przewalski’s gazelles (*Procapra przewalskii*), golden snub-nosed monkeys (*Rhinopithecus*), African elephants (*Loxodonta*), and giant pandas (*Ailuropoda melanoleuca*), providing scientific foundations for species population planning, protection, management, and decision-making.

Northwest China is located in arid and semi-arid regions with fragile ecosystems that are highly sensitive to environmental changes. The region hosts numerous rare and endangered species, including wild camels (*Camelus ferus*) and four-toed tortoises (*Testudo horsfieldii*), whose populations continue to decline under threat. Compared with other regions such as Northeast China, nature reserves in Northwest China were established relatively late, with some covering excessively large areas. Additionally, due to limited investment and other factors, management measures in some reserves remain inadequate, lacking systematic and comprehensive monitoring and protection systems, resulting in limited conservation effectiveness. This study focuses on Northwest China, using literature, reports, ground species survey data, and satellite remote sensing data as primary sources to analyze vertebrate population dynamics and habitat changes from 1980 to 2015. This work is significant for understanding habitat changes and their potential impacts on animal populations and distributions in the region, representing a valuable exploration of integrating survey and remote sensing data for biodiversity conservation and management.

2 Study Area

Northwest China covers a vast territory of approximately 3.25×10^6 km², encompassing Xinjiang, Qinghai, Gansu, Ningxia, Shaanxi, and western Inner Mongolia (Alxa League), involving 61 prefecture-level cities. The terrain is dominated by plateaus and basins, including parts of the Qinghai-Tibet Plateau, Weihe Plain, Tarim Basin, Qaidam Basin, and Qinling-Daba Mountains. The

climate is arid with severe desertification, making it a sensitive zone for climate change and an ecologically fragile region in China where damage is difficult to reverse. Vegetation types are diverse, primarily consisting of scrub, grassland, desert, and meadow formations. According to *China Vegetation*, Northwest China contains 18 vegetation types (46.7% of the national total) and 173 formation types (65.6% of national formation types). The fauna is special and rich; according to *Rare and Endangered Animals in Northwest China* and *Protection and Research of Rare and Endangered Plants*, the region hosts over 200 mammal species and more than 500 bird species, with numerous rare and endangered species.

3 Data and Methods

3.1 Data Sources

3.1.1 Species Data Species data were obtained from the *China Terrestrial Vertebrate Population Time Series Database* established by the Institute of Zoology, Chinese Academy of Sciences, based on published research papers, monographs, nature reserve surveys, and professional institution reports. The database includes ground-based population survey data for 215 vertebrate species in Northwest China from 1980 to 2015.

3.1.2 Habitat Status Data Land use data (100 m spatial resolution) for habitat status were derived from the Resource and Environment Science Data Center of the Chinese Academy of Sciences (<http://www.resdc.cn>). The original land use classification includes 6 primary and 25 secondary land use types, which were reclassified into six ecosystem types (forest, grassland, desert, water/wetland, settlement, and farmland) to characterize ecosystem type changes from 1980 to 2015. MODIS satellite data were used to obtain annual water area during high-water and low-water periods for Qinghai Lake.

3.2 Analysis Methods

3.2.1 Species Population Analysis Method The Living Planet Index (LPI), one of four indicators adopted by the Convention on Biological Diversity to measure global biodiversity health, was used as the primary metric. The LPI was stratified by ecosystem, region, and taxonomic group to assess biodiversity levels and trends in Northwest China. The calculation steps are as follows:

- 1) Calculate annual population change trend for a species:

$$d_t = \log_{10} \left(\frac{N_t}{N_{t-1}} \right)$$

where d_t is the population change trend, t is the year, and N_t is the population count in year t . For species with multiple population data in

the same year, the population change trend is calculated as:

$$\bar{d}_t = \frac{1}{n_t} \sum_{i=1}^{n_t} d_{it}$$

where \bar{d}_t is the population change trend for a species with multiple populations, i is the i th population, t is the year, n_t is the number of populations in year t , and d_{it} is the change trend of the i th population in year t .

- 2) **Calculate the average change trend across all species for each year:**

$$I_t = \frac{1}{m_t} \sum_{i=1}^{m_t} d_{it}$$

where I_t is the average change trend for all species in year t , and m_t is the number of species in year t .

- 3) **Set the base year:** The initial year (1980) is set as $I_0 = 1$. For species with population time series data, the above calculations can be applied. For species with multiple population time series, a Generalized Additive Model (GAM) is used to calculate predicted values, which are then processed using the above method to obtain \bar{d}_t and final index values. Bootstrap resampling is performed to generate confidence intervals.

3.2.2 Habitat Status Analysis Method Habitat provides living space for wildlife, and changes in habitat area inevitably affect species populations and biodiversity. In this analysis, ecosystem type area serves as the primary indicator to characterize habitat status, describing both total area and spatial change characteristics. Natural habitats were defined as forest, grassland, desert, water body, and wetland ecosystems, while artificial habitats comprised settlement and farmland ecosystems.

4 Results

4.1 Vertebrate Population Changes

The survey data were used to calculate the vertebrate population trend index for Northwest China. Results indicate that vertebrate populations declined by 57.83% from 1980 to 2013, though the rate of decline slowed after 2000 and showed gradual recovery after 2005. As shown in [Figure 1: see original paper], animal populations in grassland and desert ecosystems experienced significant declines, particularly around 2000, with the trend only gradually easing in the early 21st century. In contrast, forest and wetland ecosystem populations increased by 61.43% and 31.71%, respectively.

4.2 Habitat Status Changes

From 1980 to 2015, natural habitats accounted for 92.05% of the total area in Northwest China, while artificial habitats comprised 7.95%. The primary natural habitat types were desert (35.59% of total area) and grassland (34.05%), followed by forest (4.77%) and water/wetland ecosystems (3.43%). The main artificial habitats were farmland and settlement ecosystems. Overall, natural habitat area decreased by 0.96%, while artificial habitat area increased by 1.22%, indicating a conversion from natural to artificial habitats.

4.2.1 Grassland and Desert Habitat Changes Desert and grassland vegetation dominate Northwest China, with forest vegetation accounting for only about 5.00%. Grassland ecosystems covered 34.05% of the total area, primarily distributed in Xinjiang, Qinghai, Gansu, Ningxia, and Shaanxi. Compared with 1980, grassland area decreased by 2.10%, mainly converted to farmland and desert. Desert ecosystems occupied 35.59% of the total area, primarily in Xinjiang, northwestern Qinghai, northern Gansu, and Inner Mongolia within the region. Desert area decreased by 0.86% compared with 1980, with reduced desert areas mainly converted to grassland.

4.2.2 Forest Habitat Changes Forest ecosystems cover only 4.77% of the total area in Northwest China, mainly distributed in central and southern Shaanxi, southern Gansu, eastern and southern Qinghai, and parts of northwestern Xinjiang. As shown in [Figure 3: see original paper], forest ecosystem area increased overall from 1980 to 2015, with a slight decrease before 2000 followed by gradual increase after 2000. Compared with 1980, forest area increased by 4.06%, primarily converted from grassland.

4.2.3 Water and Wetland Habitat Changes Water and wetland ecosystems in Northwest China are mainly distributed in southwestern and central Xinjiang and the Altai region. Animal populations in these ecosystems declined, and water/wetland area also decreased. Due to limited survey data for amphibians and reptiles, species data for water/wetland ecosystems are dominated by birds. Different bird species have varying habitat quality requirements, and their survival characteristics can indicate habitat ecological conditions. As birds are sensitive to climate and wetland conditions, they can effectively reflect habitat fluctuations.

4.3 Key Species Cases

4.3.1 *Gymnocypris przewalskii* (Qinghai Lake Naked Carp) The Qinghai Lake naked carp is an endangered species and a national first-class protected animal distributed in Qinghai Lake and its tributaries. Qinghai Lake, located in northeastern Qinghai-Tibet Plateau, is China's largest inland lake. As shown in [Figure 4: see original paper], Qinghai Lake's water area fluctuated significantly

from 1980 to 2015. The high-water period area in 2015 increased by 2.59% compared with 1980, with perennial water area increasing by 4.02%. The naked carp population decreased by about 82.21% from 1980 to 2000, primarily due to overfishing. From 2000 to 2010, the population showed minor fluctuations with a slight downward trend, reaching its lowest point in 2010. After 2010, Qinghai Province implemented a lake closure and fish breeding program, and as Qinghai Lake's water area increased, the naked carp population grew rapidly, increasing by 55.77% by 2015 compared with 2010.

4.3.2 *Procapra przewalskii* (Przewalski's Gazelle) Przewalski's gazelle is a unique and endangered ungulate species in China, primarily distributed around Qinghai Lake. As shown in [Figure 5: see original paper], the surrounding grassland area showed a decreasing trend, with a 2.46% reduction in 2015 compared with 1980. The gazelle population decreased from 1980 to 2000, with 2000 numbers only 33.43% of 1980 levels. This decline was associated with habitat area reduction and increased livestock populations. After 2000, with the promulgation of wildlife protection laws and increased conservation attention and investment, the gazelle population recovered to 1980 levels by 2005 and continued to increase, reaching 26.03% higher than 1980 levels by 2015.

4.3.3 *Nipponia nippon* (Crested Ibis) The crested ibis is a globally endangered bird and a national first-class protected species that inhabits sparse forest areas. Its roosting areas in China are mainly distributed in Yang County, Ningshan County, and Chenggu County of Shaanxi Province. As shown in [Figure 6: see original paper], forest area in these three counties decreased slightly in 2000 but recovered thereafter. The ibis population was very small in 1980, with only 7 individuals discovered. Population growth was extremely slow before 2000, but increased rapidly after 2000, reaching 304% higher by 2015 compared with 1980. This increase primarily resulted from effective species and habitat protection measures.

4.3.4 *Camelus ferus* (Wild Camel) The wild camel is one of the world's most critically endangered even-toed ungulates, living in deserts and primarily distributed in the Kumtag area of China, which accounts for about 60.88% of the total Kumtag area. As shown in [Figure 7: see original paper], artificial habitat area (including farmland and settlement) in the Kumtag area increased by 6.29% in 2015 compared with 1980, with rapid increases during 1980-2000. Intensifying human activities pose a severe threat to wild camels, severely damaging habitat quality. From 1980 to 2015, the wild camel population consistently declined, decreasing by 99.80% compared with 1980. The decline was most rapid during 1980-2000, with a 98.78% reduction. After 2000, the decline rate slowed, though the population continued to decrease slightly.

4.3.5 *Testudo horsfieldii* (Four-Toed Tortoise) The four-toed tortoise, also known as the steppe tortoise, is a national first-class protected species in

China, found only in Huocheng County, Xinjiang. As shown in [Figure 8: see original paper], from 1980 to 2015, grassland area in its habitat decreased by 4.49%, farmland area increased by 16.41%, and settlement area increased by 4.40%. The reduced grassland was mainly converted to farmland and settlements, causing habitat fragmentation and retreat, with human activities degrading habitat quality. As reptiles move slowly, have weak dispersal ability, and low adaptability to environmental changes, their populations are significantly affected by environmental changes. From 1980 to 2015, the four-toed tortoise population declined continuously.

5 Discussion

Habitat provides food and living space for wildlife, and changes in habitat area inevitably impact species populations. Among natural habitats in Northwest China, animal populations in grassland and desert ecosystems showed significant declines from 1980 to 2015, particularly around 2000, with the trend only gradually easing in the early 21st century. Grassland ecosystem area also decreased overall, with the declining trend becoming more pronounced around 2000. Grassland quality degradation, overgrazing-induced grassland degeneration, area reduction, intensified competition for space and resources between livestock and wildlife, and increased human disturbance from western development programs represent the greatest threats to wildlife population recovery in recent decades.

Forest ecosystem area has increased overall since 1980, with animal populations also increasing. The significant population growth in forest ecosystems is strongly correlated with data distribution patterns. Most primary forests in Northwest China are located within nature reserves, and species data primarily originate from protected species within these reserves, such as giant pandas, golden snub-nosed monkeys, and takins. These species showed significant declining trends before 2000, but have entered stable recovery phases since reserve establishment due to effective habitat and species protection measures. Additionally, severe forest destruction outside reserves has caused species to concentrate within protected areas, particularly mobile, wide-ranging bird species with strong reproductive capacity, contributing to increased species indices in forest ecosystems. The scarcity of survey data for forest species outside reserves also contributes to the apparent upward trend.

Animal populations in water and wetland ecosystems declined, and water/wetland area also showed a decreasing trend. Due to limited survey data for amphibians and reptiles, species data for water/wetland ecosystems are dominated by birds. Different bird species have varying habitat quality requirements, and their survival characteristics can indicate habitat ecological conditions. As birds are sensitive to climate and wetland conditions, they can effectively reflect habitat fluctuations.

In recent years, ecological protection policies, ecological construction projects,

and species recovery programs in Northwest China have achieved initial success. Species with narrow habitat distributions and effective protection measures, such as Qinghai Lake naked carp, Przewalski's gazelle, and crested ibis, have shown significant population increases. Combining ecological construction projects with wildlife protection, emphasizing preservation and restoration of original habitats, and strengthening biodiversity conservation effectiveness evaluation can maximize habitat degradation avoidance.

The LPI method used in this study is an indicator for measuring biodiversity change. The World Wide Fund for Nature (WWF) and Zoological Society of London (ZSL) publish the *Living Planet Report* biennially, representing the most comprehensive global biodiversity assessment. Scholars worldwide have used LPI to evaluate global vertebrate population trends, terrestrial and freshwater habitat biodiversity in the Netherlands, and bird diversity in Poyang Lake, achieving certain conservation and management successes. However, due to limited scientific research and baseline surveys in Northwest China, this study lacks necessary historical data, resulting in low data density and short population time series, leading to incomplete and unstable trends. We urge relevant departments to strengthen baseline surveys of wildlife populations and accelerate the implementation of integrated ground-satellite monitoring systems.

6 Conclusions

- 1) **Population trends:** Vertebrate populations in Northwest China declined overall from 1980 to 2013, decreasing by 57.83%, but showed gradual recovery after 2005. Examining the ecosystems supporting these vertebrates, grassland and desert ecosystem populations decreased significantly by 82.21%, while forest and water/wetland ecosystem populations increased markedly by 61.43% and 31.71%, respectively.
- 2) **Habitat changes:** Natural habitats accounted for 92.05% of Northwest China's total area, while artificial habitats comprised 7.95%. The main artificial habitat types were farmland and settlement ecosystems. Approximately 0.96% of the region's area converted from natural to artificial habitats. Natural habitat area decreased by 1.13%, with forest and water/wetland areas increasing by 4.06% and 2.96%, respectively, while grassland and desert areas decreased by 2.10% and 0.86%. Artificial habitat area increased by 13.07%.
- 3) **Key species:** Northwest China's ecosystems are fragile with numerous rare and endangered species. Populations of Qinghai Lake naked carp, Przewalski's gazelle, and crested ibis increased significantly, likely due to their narrow habitat distributions and effective protection measures. However, the declining trends for wild camel and four-toed tortoise populations have not yet been alleviated.

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