# Butterfly Community Diversity in the Qinling Mountains

Subjects: Biodiversity Conservation

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The Qinling Mountains are one of the oldest mountain ranges in China and a global biodiversity research and conservation hotspot. However, there is a lack of systematic research and survey of butterfly diversity in this region. Based on the butterfly taxa, combined with the changes in natural climate, altitude gradient and season in the Qinling Mountains, the butterfly diversity and community structure changes in 12 counties in the middle Qinling Mountains were analyzed by transect surveys and platform data analyses. A total of 9626 butterflies were observed, belonging to 427 species across 175 genera and 5 families. The species richness on the southern slope of the Qinling Mountains is higher than that on the northern slope.

Keywords: butterfly diversity ; conservation ; habitat ; altitude ; season

## 1. Introduction

Biodiversity is the material basis for human survival and development, as well as the premise of ecosystem sustainability [1]. However, the scale of population growth and human intervention, to a great extent, has led to a loss of biodiversity [2][3][4]. In recent years, the protection of biodiversity has attracted more attention from the international community [5][6]. The quantification of the spatial distribution of species diversity is an important prerequisite for biodiversity conservation [7]. Climate change indicators are closely linked to threats to biodiversity [8]. For example, in the northern hemisphere, species abundance increases with the increase in temperature and natural conditions and there is a distinct spatial pattern (i.e., a temporal classification alteration) [9].

Butterflies are excellent for studies at the population and ecosystem levels, because they are easily monitored, caught, tagged and identified in nature [10]. In the face of increasing global change and habitat degradation, butterflies have become the preferred indicator for monitoring and evaluating environmental changes in their habitats due to their sensitivity to environmental changes [11][12]. For example, in North America, a major climate-induced shift in butterflies is slowly under way, with warm-adapted species expanding northward and cold-adapted species retreating [13]. In temperate regions, microclimate is also a key factor affecting insect population dynamics. Different butterfly lineages have different microclimate and microhabitat responses [14]. Butterflies also play important roles in the ecosystem, such as pollinating plants [15][16][17][18][19]. Theoretically, maintaining the species diversity and abundance of pollinating butterflies should guarantee the pollination service function of agroforestry ecosystems to a certain extent [16]. Butterfly diversity makes up about 25 percent of Western Mediterranean fauna, the vast majority of which consists of non-cryptic species. Although the frequency of cryptic species was uniform, their distribution pattern determines most of the replacement of beta diversity [20].

As one of the oldest mountain ranges in China, the Qinling Mountains occupy an important position in the biogeography of China [21][22]. It is the dividing line between the subtropical zone and the warm temperate zone and also the dividing line between the Palearctic region and the Oriental region in the world zoogeographic divisions [23][24]. Taibai Mountain, the main peak of the Qinling Mountains, is 3767 m above sea level and is to the east of the Qinghai–Tibet Plateau [25][26]. The complex vegetation types and diverse climate make Qinling a “treasure house of biodiversity” [22][27]. As early as 1996, the Global Environmental Protection Fund (GEF) invested more than USD 10 million in the construction of the Qinling Nature Reserve group. The vegetation types in the middle Qinling Mountains are well known, but there has been little research on butterflies [28][29][30]. The species composition, richness and spatial distribution pattern of butterfly biodiversity in this region are not clear, which poses obstacles to resource conservation. At present, there are many studies on butterfly community diversity and its influencing factors, especially the effects of habitat differences and climate factors on butterfly diversity [31][32][33]. For example, changes in altitude can significantly change the richness of butterflies [34][35]. In the study of the mountains in northern Oaxaca, Mexico, the increase in altitude leads to changes in temperature and humidity, which reduces the abundance of butterfly species [36]. However, in Pyrcz’s research, the abundance of butterflies in the higher elevations of the Ecuadorian Andes was higher than that in the lower elevations [37]; seasonal variation plays a

decisive role in the spatial distribution of butterfly communities. Butterfly species usually synchronize their life cycles with seasonality, different seasons bring different precipitation, which directly affects the change in butterfly species. In the study of Rio Doce State Park, butterfly diversity was more abundant in the dry season than in the wet one and their contribution to species turn over and nestedness variations overlap with seasonal variations [38].

## 2.Butterfly community diversity in Qinling Mountains

The counties in the middle part of the Qinling Mountains are divided into two types. One includes the warm temperate coniferous, broadleaf mixed and deciduous broadleaf forests and the northern slope mountain brown soil and mountain brown land zone. Their butterflies belong to the Palearctic Realm (including WB, CC, ZZ, TB, northern HY and QS). The other group is the deciduous broad-leaved mixed forest with evergreen broad-leaved tree species in the northern subtropics and the southern slope of yellow–brown soil and yellow–brown land zone. Their butterflies belong to the Oriental Realm (including FP, NS, LB, TB and southern CG). Overall, the southern slope of the northern mountains shows abundance of butterfly species by blocking the cold of the north Qinling. The north and south form two different climate regions, where the northern region is cold and dry, while the southern one is hot and humid; butterflies in the middle part of the Qinling Mountains seem to prefer the southern slope with higher temperature and humidity [39][40][41]. In addition, the species richness of TB, ZZ and NS counties is relatively high, which is closely related to human disturbance factors and degree of protection. In the transect survey, we found that these three counties have more protected areas, less human disturbance and more virgin forests and undeveloped ecosystems. In terms of species and numbers, the closer the county is to the Qinling Mountains, the richer and higher the butterfly diversity.

Combined with our collected data and platform data, the biodiversity of butterflies in the ecosystem of the middle Qinling Mountains is affected by altitude gradient, seasonal change and habitat type. The dilution curve of Alpha species richness indicates that more species could be observed in plots with different seasons, elevation gradients and habitat types. From the perspective of spatial and temporal distribution patterns, although butterfly communities in different altitudes and seasons share some species, species composition differs greatly and community similarity is low, which provides a scientific basis for species diversity monitoring and conservation in this region.

Butterfly groups are sensitive to environmental and climate changes and are good ecological probes [11]. Elevation gradient changes are an important factor affecting biodiversity because there are many environmental variables, notably temperature and humidity [31][32][33], and different combinations of vegetation types that contribute to environmental heterogeneity at different altitudes [34]. In the mountain ecosystem, altitude is also an important factor shaping butterfly community composition. Species richness along the altitude gradient presents three modes: increasing, decreasing or a mid-altitude peak [35]. In studies of butterfly communities in the Himalayan Yanshan Mountains and the Alps, butterfly populations first increase and then decline sharply with altitude. In this study, the highest butterfly diversity was observed in the mid-altitude area of the central Qinling Mountains, which supports the peak pattern of mid-altitude diversity. At the highest altitudes (>3000 m), on the top of Taibai Mountain, the peak of the middle part of the Qinling Mountains in Taibai county, only a small number of Nymphalidae and Papilionidae butterflies were found, which were all collected during the summer. Butterfly communities were the most abundant in coniferous and broadleaved mixed forests.

In addition, butterfly groups may respond to seasonality to some extent, which may be related to rising temperature and precipitation. The seasonal effects of precipitation on species diversity reflect the general operation of non-neutral mechanisms in natural communities. The optimum development period of butterfly larvae is correlated with the availability of plant leaves and new plant tissues and the availability of resources regulates the activity patterns of butterflies and affects butterfly diversity [42][43]. The precipitation in the middle part of the Qinling Mountains is mainly concentrated from August to October. The butterfly community richness and abundance were highest in summer, because it was in the period of the highest temperature and drought transition, which was consistent with Lourenço's study [38]. Interestingly, the number of species and species abundance in spring were significantly higher than in autumn, but the Shannon diversity and Simpson diversity indices were lower than in summer, indicating that the effective number of common species and dominant species was higher in autumn than in spring and that species abundance could not accurately reflect the level of biodiversity. Because estimates of abundance assign equal weight to all species, they do not contain information about relative abundance of species.

Moreover, the NMDS map analysis indicated that butterfly communities in farmland, protected areas and marginal interlacing areas were highly similar, that most butterfly communities overlapped and that only a few butterflies were unique in their respective habitat types. The protected area surveyed was the most abundant habitat type and it is clear that the protected area had the most abundant and diverse butterfly species. Farmland with greater human disturbance has fewer species and simpler community structures [44][45]. However, there were no significant community differences in

different habitats, indicating that butterflies in the Qinling Mountains live in a wide range and many butterflies appear in different environments.

According to the *Red List of Species in China (Volume iii): Invertebrates*, we evaluated the endangered species level of the 427 butterfly species collected, including 170 endemic species in China, 44 protected species and 2 wild animals under state key protection of Class II in China. We also found seven protected species in the IUCN Red List of Threatened Species. This could help develop better conservation measures for these endangered butterfly species. Understanding the combined impact of climate change and habitat loss on biodiversity is urgent in the field of ecology and conservation. Our research study on the middle Qinling area on butterfly diversity provides a database to help biologists provide more suitable protection schemes, reduce human activities and maintain the stability of the habitats. This is a basis to protect the butterfly species diversity, minimize the interference of secondary forest and mixed forest understory economic crops and promote the natural restoration or increase the heterogeneity of the environment. For example, more protected areas, more diversity monitoring and seasonal observation in areas where protected species are common would help protect endangered species. At the same time, in farmland planting areas, advocating the implementation of green ecological planting and the rational use of pesticides, as well as reducing environmental pollution, would effectively protect species diversity.

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