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Comprehensive Impact of Plateau Pika on Biota and Soil Structure in Its Habitat—A Case Study of the Tibetan Plateau

Shengjie Liu[1*] and Dicong Xu[2]

[1]*Jiang Su Tianyi High School, Wuxi 214031, China*

[2]*Department of Management and Marketing, Durham University, Durham, DH1 3LE, England*

**Corresponding author: Shengjie Liu, E-mail: lsj20071122@163.com*

Abstract

Plateau Pika (*Ochotona curzoniae*), a key species on the Qinghai-Tibetan Plateau, along with its ecological impact, has been paid extensive attention to. This paper aims to comprehensively assess the ecological impact of pika on vegetation, soil and biodiversity in the Qinghai-Tibet Plateau. Through the review of previous studies, it was found that the foraging behavior of Plateau Pika affected plant community structure and diversity, which decreased plant evenness but increased species richness. Its activities changed soil organic matter, microbial community and greenhouse gas emissions. In terms of animal diversity, it is a food source for many predators and is interdependent with some symbiotic other animals. However, considering pika's competitiveness with domestic animals for food, population control should be implemented. In order to maintain the ecosystem balance and biodiversity on the Qinghai-Tibet Plateau, self-transmitted contraception control, increasing the planting of non-eating vegetation and controlling the number of livestock and grazing intensity, instead of traditional poisoning method, can be adopted.

Keywords

Tibetan plateau, plateau pika, ecological impact, population management, biodiversity

1. Introduction

The Qinghai-Tibetan Plateau, often called the "Roof of the World," is renowned for its extreme elevation and unique ecological conditions. This high-altitude region supports a diverse range of flora and fauna adapted to its harsh climate. Among its inhabitants, the Plateau Pika (*Ochotona curzoniae*) is a keystone species that significantly impacts the ecological dynamics of this environment.

The Plateau Pika plays a critical role in shaping its habitat through its foraging and burrowing activities. Research has shown that Pikas influence vegetation patterns by selectively grazing on plant species, which can alter plant community composition and biodiversity (Li & Wang, 2018). Additionally, their burrowing behavior contributes to soil aeration and nutrient cycling, which affects soil structure and fertility (Chen et al., 2021).

Despite the documented importance of Pikas, there remains a need for a comprehensive evaluation that integrates their ecological impacts on both biota and soil structure. Previous studies have focused on isolated aspects of their influence, but a holistic understanding of how Pikas interact with their environment and contribute to ecosystem processes is still lacking. This study aims to fill this gap by providing a detailed analysis of the Plateau Pika's effects on vegetation diversity, soil composition, and overall ecological balance in the Tibetan Plateau. By investigating the multifaceted roles of Plateau Pikas, this research will offer valuable insights into their ecological significance and inform conservation strategies for this fragile and rapidly changing environment.

2. Effects of Plateau Pika on the Community of Plants

Numerous studies indicate that the foraging behavior of the plateau pika (*Ochotona curzoniae*) contributes to a reduction in grassland productivity, a factor that adversely affects grassland stability. However, alternative research highlights the plateau pika’s involvement in the energy flow and material circulation within grassland ecosystems through its activities, including feeding, digging, and excreting. This body of work suggests that the plateau pika may function as an ecosystem engineer, potentially stabilizing the ecosystem through its interactions with plant communities. Despite ongoing debate regarding whether the plateau pika is the principal driver of alpine meadow degradation, its impact on plant communities remains significant. This section aims to provide a comprehensive evaluation of the plateau pika's effects on grassland plant communities, considering both its potential role as a disruptive force and its contributions to ecosystem stabilization.

2.1 Effects of Plateau Pika on Plant Community Structure

Previous research has elucidated the pivotal role of plateau pikas (*Ochotona curzoniae*) in influencing plant community structures. Investigations have identified Elymus nutans, *Oxytropis hansuensis*, and *Oxytropis coerulea* as key components of the plateau pika’s diet (Liu et al., 2008). Increased feeding pressure from plateau pikas has been associated with significant reductions in both the aboveground biomass and average height of these preferred plant species. Specifically, the average height of grasses and sedges in pika-affected areas was reported as 2.24 ± 1.16 cm, in contrast to 3.97 ± 0.38 cm in areas unaffected by pika disturbance (Wu et al., 2024; Xu et al., 2018).

Moreover, plateau pika activities often lead to a shift in plant community composition towards less palatable species, such as *Lancea tibetica* and *Lamiophlomis rotata*, thereby decreasing the quality of grazing resources (Wei et al., 2007). Recent studies have also documented that pika behaviors, including their foraging, gnawing, and burrowing activities, facilitate the spread of complex and toxic weed species like *Euphorbia fischeriana*, Morina kokonorica, Saussurea japonica, and *Ajuga lupulina*. Conversely, the implementation of rodent exclusion measures has been shown to reduce the prevalence of these toxic species and enhance the presence of species such as *Poa pratensis* and *Koeleria litvinowii* within grassland ecosystems (Wu et al., 2024).

2.2 Effects of Plateau Pika on Plant Diversity

The role of plateau pika in influencing plant diversity has been consistently demonstrated across various studies. Disturbance caused by plateau pika was found to significantly diminish the plant evenness index while simultaneously increasing the plant abundance index. Specifically, species richness in non-pika disturbed plots was recorded at 8.67 ± 0.88, compared to 7.33 ± 0.33 in pika-disturbed plots, indicating a 15.4% reduction in species richness in the presence of pika disturbance (Jin et al., 2017; Wu et al., 2024). Field investigations further revealed that the extent of pika disturbance notably affects plant diversity dynamics. Species richness initially increased with moderate disturbance but declined at higher disturbance levels. The lowest species richness was observed in both undisturbed areas and those with the highest disturbance intensity (1633 effective openings per hectare), while the highest species richness was found at intermediate disturbance levels (710 effective openings per hectare). β-Diversity, which indicates the turnover rate of species composition along environmental gradients (Whittaker, 1960), also exhibited a pattern of increase followed by a gradual decrease with rising pika disturbance intensity. The β-diversity index reached its peak at 710 effective openings per hectare, highlighting that pika-induced disturbance can alter species turnover rates and enhance habitat heterogeneity (Li et al., 2021; Yang et al., 1999). These findings underscore the complex role of pika disturbance in shaping plant community diversity.

3. Effects of Plateau Pika on Soil

The impact of plateau pika activity on soil properties remains a subject of debate among researchers. Some studies argue that the excavation of tunnels and the disruption of sod and vegetation by plateau pikas exacerbate grassland degradation, leading to the formation and expansion of degraded areas (Liu et al., 2010). Conversely, other research suggests that plateau pika activities can enhance soil surface organic matter in alpine meadows, thereby altering soil physical and chemical properties. This alteration promotes nutrient cycling within the ecosystem and can contribute to increased plant community productivity and species richness (Li & Zhang, 2006; Liu et al., 1999). Given these differing perspectives, this section will provide a comprehensive analysis of the effects of pika activity on soil dynamics.

3.1 Effects of Pika Activity on Soil Organic Matter

The stoichiometric ratios of carbon (C), nitrogen (N), and phosphorus (P) in soil are key indicators of nutrient cycling, reflecting the levels of soil organic carbon and nutrient availability, which are critical for plant growth and development (Peñuelas et al., 2012). Variations in these ratios can induce changes in plant community structure, suggesting that the interplay between plant species diversity and soil stoichiometric ratios is crucial for maintaining plant community structure and overall grassland ecosystem health and stability.

Research has demonstrated that disturbances caused by plateau pika (*Ochotona curzoniae*) significantly alter soil organic matter content. First, pika activity, such as soil covering, buries above-ground plant material, thereby increasing organic matter input (Zhang et al., 2016). Second, pika excreta further contributes to the organic matter enrichment of the soil (Pang & Guo, 2017). Third, the burrowing activities of plateau pika enhance soil porosity, which, combined with reduced vegetation cover, leads to elevated soil temperatures and accelerated organic matter decomposition (Kirschbaum, 1995; Qin et al., 2019; Yu et al., 2016).

The intervention of plateau pika (*Ochotona curzoniae*) led to a notable increase in soil organic carbon and total nitrogen content. Consequently, the ratios of carbon to nitrogen (C/N) and carbon to phosphorus (C/P) were elevated, while the nitrogen to phosphorus (N/P) ratio remained relatively unchanged. The elevated ratio of carbon to nitrogen (C/N) indicates a higher nitrogen availability, primarily due to more increase in carbon inputs compared to nitrogen inputs (Yang et al., 2019). In alpine meadows, this enhanced nitrogen availability supports the growth and productivity of grass species.

Additionally, field studies have revealed that the concentrations of ammonium nitrogen, nitrate nitrogen, and inorganic nitrogen were higher in soils affected by pika activity compared to control sites. Significant differences in organic matter content were observed in the 0-5 cm and 31-50 cm soil layers, while differences in the 6-10 cm and 11-15 cm layers were also significant. In contrast, no significant differences were found between the 16-20 cm and 21-30 cm soil layers (Liu et al., 2023; Liu et al., 1999).

3.2 Effects of Plateau Pika on Soil Microbial Community

Pika activity has a pronounced effect on the diversity of soil microbial communities in alpine meadows. Compared to undisturbed alpine meadows, pika-induced disturbances result in an increased richness index for soil bacterial communities, while the diversity index decreases (Zhang et al., 2023). This shift is likely attributable to changes in soil nitrogen and phosphorus concentrations and their ratios due to pika activities, which introduce variability into the soil environment. Consequently, the microbial richness index rises as microorganisms adapt to these altered conditions (Fierer, 2017). Investigations reveal that pika activity induces notable changes in microbial community structure across various soil layers, identifying 104 distinct microbial communities. These observations imply that pika activities may alter microbial community composition by modifying the physical and chemical characteristics of the soil, leading to an increase in the relative abundance of dominant bacterial groups such as Proteobacteria and Acidobacteria (Zhang et al., 2023). Proteobacteria are crucial for energy metabolism, and their relative abundance notably increases in the topsoil impacted by pika activity, suggesting that pika disturbances may enhance the metabolic activity of soil microorganisms (Bryant & Frigaard, 2006; Mukhopadhya et al., 2012). Similarly, Acidobacteria are vital for organic matter decomposition and nutrient cycling, and they produce various secondary metabolites, including antibiotics and iron carriers, which are significant for microbial-environment interactions (Eichorst et al., 2018; Fang et al., 2018).

3.3 Effects of Plateau Pika on Soil Respiration and Greenhouse Gas Emission

The activity of plateau pika significantly impacts soil nutrient composition and microbial communities, which in turn affects greenhouse gas emissions from the ecosystem. Specifically, pika disturbances lead to increased soil respiration rates, thereby influencing the carbon cycle within the ecosystem. Under the influence of plateau pika, the soil respiration rate shows an increase of 9.58%. For example, during spring, the diurnal soil respiration rate in areas affected by plateau pika was 2.41 $\mu mol \cdot m^{-2} \cdot s^{-1}$, compared to 2.85 $\mu mol \cdot m^{-2} \cdot s^{-1}$ in undisturbed regions. In summer, the rate in disturbed areas increased to 10.78 $\mu mol \cdot m^{-2} \cdot s^{-1}$, while it was 10.73 $\mu mol \cdot m^{-2} \cdot s^{-1}$ in undisturbed areas. In autumn, the respiration rate in disturbed areas was 2.74 $\mu mol \cdot m^{-2} \cdot s^{-1}$, compared to 2.08 $\mu mol \cdot m^{-2} \cdot s^{-1}$ in undisturbed areas (Ding et al., 2019).

Additionally, plateau pika activity has a pronounced effect on soil emissions of methane (CH_4) and nitrous oxide (N_2O). Disturbances caused by pika increase soil carbon and nitrogen levels, which in turn stimulates higher emissions of these greenhouse gases (Fang et al., 2014; Yan et al., 2018). Specifically, at pika isolation (RI) sites, CH_4 and N_2O fluxes were measured at -204.99 ± 50.23 $\mu g \cdot m^{-2} \cdot h^{-1}$ and -4.48 ± 1.02 $\mu g \cdot m^{-2} \cdot h^{-1}$, respectively. In contrast, at control (CK) sites, the fluxes were -36.23 ± 15.34 $\mu g \cdot m^{-2} \cdot h^{-1}$ and -0.14 ± 0.31 $\mu g \cdot m^{-2} \cdot h^{-1}$. These results indicate that CH_4 and N_2O emissions at RI sites were significantly higher, with increases of 465.8% and 3100.0%, respectively, relative to CK sites (Wu et al., 2024).

4. Effects of Foraging Behavior of Plateau Pika on Animal Diversity

As previously mentioned, the foraging behavior of the plateau pika can affect the plant species and soil structure of its habitat to varying degrees. This impact on the ecosystem will inevitably involve other species that live in the same area as the plateau pika. Although the plateau pika has been regarded as a major factor affecting animal diversity due to its environmentally destructive behavior, studies have shown that the plateau pika is a keystone species for wildlife diversity on the Tibetan Plateau, which provides important ecosystem services. In order to evaluate the positive and negative effects of the plateau pika on the Tibetan Plateau's animal diversity from a comprehensive perspective, this section will critically discuss specific impacts of the plateau pika on animal populations that relate differently to them in their living environment.

4.1 Effects on Predators

Relevant research indicates that the majority of Tibetan Plateau predators consume pika on the plateau (Smith et al., 1990). Moreover, this animal does not hibernate, therefore they may be the only source of food for many predators in winter. This could explain why the plateau pika has become a keystone species for wildlife diversity in its habitat, considering that the presence of this species allows more carnivores to have access to adequate food sources. In this case, a sharp decline in the population of plateau pikas is likely to result in a concomitant decline in associated predators due to a lack of adequate food sources.

Pech et al. (2007) investigated the impact of the poisoning of plateau pikas in China. As a result, other carnivores such as raptors, foxes, and weasels (Schaller, 1998) were also reduced in areas where plateau pikas were poisoned compared to areas where they were not poisoned (Smith et al., 2016), further confirming the high dependence of many carnivores on plateau pikas for food, and that a reduction in the number of plateau pikas will have a negative impact on the diversity of species in this area.

4.2 Impacts of the Plateau Pika on Its Commensal Populations and Livestock

In addition to relying on plateau pikas as prey, plenty of species in the wild have a symbiotic relationship with them because they become reliant on the micro-habitats that the pikas create (Wangdwei & Foggin, 2022). For example, the burrows they excavated are prime habitats for a variety of small birds and lizards (Wangdwei & Foggin, 2022). In this case, there is a strong correlation between the number of plateau pikas and such small commensal species. As an example of the analysis of the population distribution of white-rumped snow finches in related studies, both spring and fall data for this species indicate that their density is highly dependent on the density of plateau pika's burrows in the landscape (Arthur et al., 2008), which demonstrates this pika's contribution on biodiversity at Tibet Plateau.

Based on the exploration of predators and symbiotic species, in general, the plateau pika plays a role in the conservation of biodiversity on the Tibetan plateau. However, they are seen as pests by some people because they seem to compete with livestock for food resources (Fan et al., 1999). The controversial point is that while a portion of the study proposes that the plateau pika takes food from livestock and has an impact on grazing, it appears that there may be some symbiotic relationship between the plateau pika and large livestock based on the study by Li et al. (2019). The study found that an increase in livestock herds, especially large livestock such as yaks, would lead to an increase in plateau pika populations, that digging of holes by plateau pikas would improve soil conditions to provide a more comfortable environment for yaks to live in, and that yak munching would reduce the height of the vegetation to provide a preferred open habitat for plateau pikas (Li et al., 2019).

5. Discussion of Methods for Managing Plateau Pika Populations on the Tibetan Plateau

Excessive populations of plateau pika are generally recognized as one of the main causes of pasture degradation (Harris, 2010). In response, different management approaches have been adopted in an attempt to control the population of this species, such as poisoning, preventing livestock from grazing in enclosures, and establishing grass to safeguard vegetation (Li et al., 2019).

However, as previously mentioned, plateau pikas are a key species of the biodiversity of the Tibetan Plateau, thus over-poisoning them can seriously damage the local ecosystem. The ecological sustainability of the Tibetan Plateau cannot be effectively achieved through this management approach. In addition, the costs of poisoning plateau pikas are expensive (Smith et al., 1990), and this only temporarily controls the population of plateau pikas, with the remaining populations quickly recovering (Liu et al., 2013).

Relevant literature reviews a range of measures to control plateau pika populations and concludes that pikas cannot be eradicated because people cannot change their habitat, and ecology problems as mentioned should be considered. In this situation, researchers have also proposed two more effective management options: one is to adopt self-disseminating contraceptive control, which can control the pika's population to a certain extent, and the other is to increase the planting of high vegetation, which is not preferred by pikas (Liu et al., 2013). As the latter is extremely demanding in terms of funding, the former program may be the most appropriate management tool at this time.

Furthermore, the analysis mentioned the relationship between plateau pika and livestock and concluded that they can coexist, with pika populations increasing in response to increases in livestock numbers. In this case, reducing grazing might also be a management approach to controlling pika's number. According to the results of relevant studies, overgrazing does lead to grassland degradation (Xu et al., 2016). Greater damage to vegetation from overgrazing is one reason for this, and it may also be correlated with increased numbers of plateau pikas, causing further environmental damage.

Overall, the aim of managing plateau pika populations is to maintain the ecosystem of the Tibetan Plateau, and a number of complementary management programs are needed to achieve this. In order to promote the ecological restoration of alpine grasslands, controlling the number of livestock and reducing the intensity of grazing are necessary conditions (Xu et al., 2016). These measures, used in conjunction with the previously mentioned increased vegetation planting and self-disseminating contraceptive control of plateau pikas, could restore the plateau's ecosystem to a much larger extent.

6. Conclusion

In conclusion, the Plateau Pika plays a crucial role in the Tibetan Plateau's ecosystem by influencing vegetation patterns, soil composition, and overall biodiversity. While the presence of Pikas may reduce plant evenness, it has the potential to enhance plant diversity and contribute to a more varied ecosystem. Their burrowing and foraging activities affect soil nutrients and microbial communities, which are essential for maintaining soil health and fertility. Given their significant impact on ecological dynamics, eliminating Plateau Pikas is inadvisable. Instead, a balanced approach that incorporates controlled management and conservation efforts will help sustain the Plateau's delicate ecosystem while preserving its rich biodiversity.

In this regard, the future research direction of environmental protection on the Qinghai-Tibet Plateau can focus on multiple aspects (such as reasonable control of species quantity, reasonable control of grazing area and quantity, and cultivation of relevant vegetation to enrich plant diversity and thus regulate ecology) to jointly formulate conservation strategies, so as to effectively prevent the degradation of the Tibet Plateau.

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