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The distribution and behavioral characteristics of plateau pika (*Ochotona curzoniae*)

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Abstract

Plateau pikas (*Ochotona curzoniae*) are regarded as one of the main reasons for the degradation of alpine meadows in the Qinghai-Tibet Plateau (QTP). The population density of plateau pikas is directly related to the degree of grassland damage. In this study, a one-week field observation was conducted in the southeastern QTP in August 2019. Based on the photos and videos, the random encounter model (REM) was used to estimate the population density of plateau pikas, and the frequency of different behaviors was counted. The effects of water source distance and terrain on the distribution of plateau pikas were also investigated. In addition, the frequency of different behaviors of plateau pikas under different population densities was also explored. The observations and knowledge derived from this study provide a reference for the population control of plateau pikas.

Keywords

field observations, population density, Qinghai-Tibet Plateau (QTP), random encounter model (REM)

Introduction

The Qinghai-Tibet Plateau (QTP) is the highest plateau in the world, with an average altitude of 4500 m and is known as the roof of the world. Alpine meadows widely grow in the QTP, accounting for more than 50% of the total area of the QTP(Chen et al. 2014;

Gao et al. 2013), especially in the source areas of the Yangtze, Yellow, and Lancang Rivers. Alpine meadows play a very important role in forage production, water conservation, climate regulation, biodiversity maintenance and so on(Chen et al. 2008; Wen et al. 2013; Yao et al. 2019). Due to the special climatic conditions and natural environment, the ecosystem of the QTP is fragile. Once destroyed, it is difficult and takes a long time to recover(Du et al. 2004; Schleuss et al. 2015). However, the degraded area of alpine meadows in the QTP has reached 4.67 $\times 10^6$ hm^2 so far, accounting for 25% of the total area of the region; in particular, 50% of the total area of alpine meadows are black soil degraded grasslands with an area of 2.13 $\times 10^6$ hm^2(Dong et al. 2013). This "black soil beach" is the product of severe degradation of alpine meadow grassland, and has extremely low production capacity. The appearance of bald patches is an important feature of these black soil beaches, which is also the reason for the formation of black soil beaches(Ma 2006). In recent years, the black soil beach has continued to expand, and there are few countermeasures for this problem. Degraded alpine meadows seriously affect the sustainable development of the ecological environment and animal husbandry of the QTP(Shang and Long 2007).

Previous studies have indicated that overgrazing, rampant rodent damage, climate change and glacier retreat are the main reasons for the degradation of alpine meadows in the QTP(Wang and Cheng 2001; Yan and Jia 2003). Rodent damage mainly refers to damage caused by *plateau pika*, also known as *Ochotona curzoniae*. This small nonhibernating herbivore belongs to the family of *Lagomorpha*. Plateau pikas are mainly distributed in areas with altitudes of 3200~5300 m on the QTP and live in groups(Koju et al. 2017; Smith et al. 2010). A family of plateau pikas consists of 2~6 adult pikas and their offspring(PAN and MIGMAR 2016; Smith and Gao 1991). Due to their strong survival and reproductive ability, they are widely distributed in the QTP and their population density can reach more than 300 individuals/ha. Plateau pikas burrow and dig soil, gnaw grass and roots, and destroy the grass layer. In addition, long-term overgrazing creates favorable conditions for plateau pika invasion, thus, accelerating grassland degradation(Bai et al. 2002). According to Fan et al.'s study(Fan 1999), the annual consumption of forage caused by plateau pikas is approximately 150×106 t, equivalent to the grazing of 150×106 sheep a year. Therefore, it is important to control the number of pikas to reduce grassland degradation.

Population density is the key to animal management and protection(Karels and Boonstra 2000; Qu et al. 2017). The population density of rodents is directly related to the degree of grassland damage; a higher number of rodents results in more serious damage. In addition, plateau pikas are a key species on the QTP and play an irreplaceable role in maintaining the balance and stability of grassland ecosystems(Smith and Foggin 1999). Controlling the population of plateau pikas is the fundamental way to implement grassland protection, which is helped by understanding the distribution and behavior pattern of plateau pikas. Many relevant studies have been completed. Qu et al.(Qu et al. 2017) found that the population of plateau pikas has almost no inter-year changes, reaching a peak in June and then decreasing continuously.

Wei et al.(Wei et al. 2003) indicated that the population of plateau pikas was significantly different on grasslands with varying degrees of degradation, and increased

with the aggravation of grassland degradation; in addition, the population in moderately degraded grasslands was the highest and decreased in severely degraded grasslands due to a lack of food. Wangdwei (Wangdwei 2019)used the Poisson regression analysis method to analyze the effects of yaks and different land uses on plateau pika behavior; they indicated that the frequency of plateau pika foraging behavior was higher than that of warning behavior in winter but was opposite in summer, and vegetation coverage was inversely proportional to the foraging frequency.

In this study, a one-week field observation was conducted in the southeastern QTP from August [12] to 18, 2019. Based on the photos and videos, the random encounter model (REM) established by Rowcliffe et al.(Rowcliffe et al. 2008) was used to estimate the population density of plateau pikas, and the frequency of different behaviors was counted. The effects of water source distance and terrain on the distribution of plateau pikas were investigated. In addition, the frequency of different behaviors of plateau pikas under different population densities was also explored. This study supplements and improves the ecological theory of plateau pikas and provides a reference for the control of plateau pikas.

Methodology

Study area

The source area of the Yellow River is located in the southern portion of Qinghai Province, with a total area of 137.7×10^3 km^2, of which, the grassland area accounts for 81.2%. Alpine grassland and alpine meadows are typical vegetation types in the source region of the Yellow River(Li et al. 2016). The source area of the Yellow River has been the habitat of many wild animals and the grazing area of livestock for a long time. However, in recent decades, due to changes in the natural environment including rodent and human activities and other adverse factors, the ecological environment of the Yellow River source area is deteriorating, resulting in serious grassland degradation.

Dari County is located in the southern portion of the Yellow River source area (98□15′29"~ 100□32′41" E, 32□36′42"~ 34□15′20" N). The average altitude of the county is 4426 m, which belongs to an alpine semihumid climate. Except for the cold and warm seasons, there is no obvious division of the four seasons. There are cold monsoons and heavy snow in winter lasting for up to 7-8 months. The warm season is humid, but lasts for only 4-5 months. The average temperature of the county is between -0.1□ ~ -3.5□. The annual precipitation is approximately 560 mm and mostly occurs from June to September. The grassland type is relatively single, most of which are alpine meadow grasslands. The grassland begins to turn green in the middle of May every year and the annual growth period is only 120 days.

There are 1.402 million hectares of natural grassland in Dari County, accounting for 94% of the total land area of the county, and 1.117 million hectares of usable grassland, accounting for 80% of the total natural grassland area. In recent decades, the grassland

in Dari County has been continuously degraded, and the area of moderately degraded grassland has reached 50% - 60% of the total usable grassland area(Zhang et al. 2011). The area of the "black soil beach" with an extremely low utilization value is expanding, rodent infestation is rampant, and vegetation patches are serious; therefore, Dari County has become the county with the most serious grassland degradation in the source region of the Yellow River(Liu et al. 2008). Due to its significance, Dari County was selected as the study area.

Field observation

Camera trap technology has been widely used in wildlife population density estimation and behavior observation due to its low labor cost, small interference with the environment and strong adaptability. The camera used in this study is the foresafe H885 field infrared camera, as shown in Fig. 1. In the layout, the camera was adjusted so that the lens was basically parallel to the ground to avoid direct sunlight on the lens. The front view of the camera was clear without occlusion. After the installation of the camera, the scene was cleaned up, and the scene environment was restored. The deployment time and other local information, such as GPS sites, were recorded. Six cameras numbered #1 to #6 were arranged at six different locations considering the water source and terrain difference. According to the actual situation of the sample area, camera #1 was installed at the floodplain; cameras #2, #3 and #4 were placed 100 m, 300 m and 600 m away from the river channel, respectively; and cameras #5 and #6 were placed at the steep slope and gentle slope, respectively, as shown in Fig. 1.

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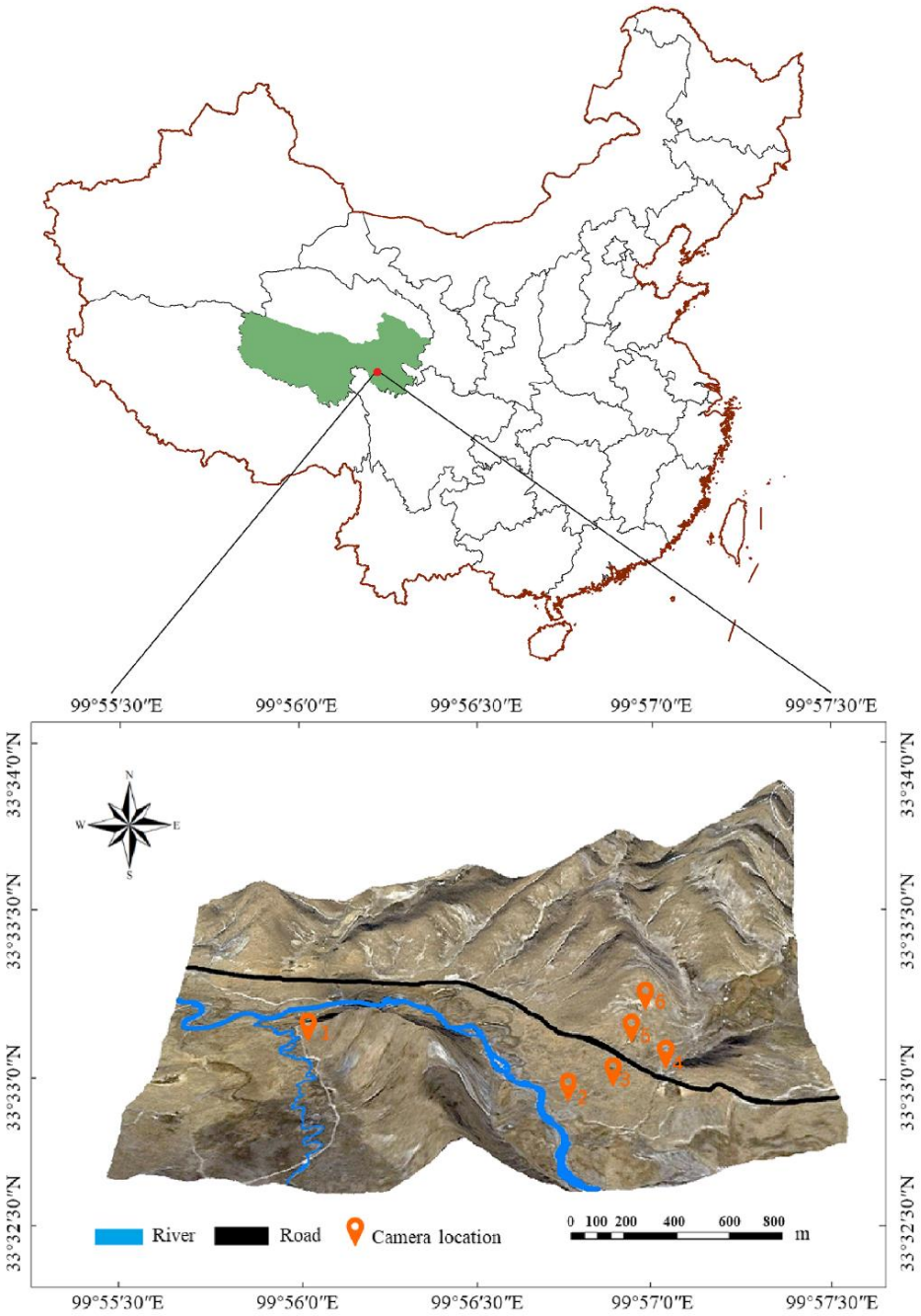

Figure 1. Infrared camera locations.

The cameras were installed from August 12 to August 18, 2019. The sensor on the camera can actively detect the sudden change in animal heat and infrared energy in the area, thus triggering the camera to work. The camera works 24 hours a day in photo and video mode, and the video recording time was set to 30 seconds. Once triggered, the camera takes a picture, records a video within 30 seconds, and then returns to standby mode. The time, temperature and other information are recorded on the photos and videos and stored in the memory card in sequence.

To reduce the autocorrelation of photos in the field observation, two photos are considered to be independent of each other if the time interval between them is more

than two minutes. The camera trigger time, temperature, behavior frequency of plateau pika and other data in the videos collected by six cameras were recorded.

Estimation of population density

The random encounter model (REM) proposed by Rowcliffe et al.(Rowcliffe et al. 2008) in 2008 is adopted in this study to estimate population density based on camera trap data, which does not require individual recognition of animals. Since it was proposed, REM has been applied to estimate the population density of many animal species(Anile et al. 2014; Caravaggi et al. 2016; Manzo et al. 2012), as shown in Eq. (1):

$$D = \frac{y}{t}\frac{\pi}{vr(2+\theta)} \quad (1)$$

D is the population density; y is the number of independent pictures; t is the number of days the camera was installed; v is the daily moving speed of animals; r is the radius of the camera detection area; and θ is the camera detection angle, as shown in Fig. 2.

Derived from preliminary experiments, the installation information of the camera is r=8 m and θ=55 □ =0.96 rad). According to the research of Zhang et al.(Zhang et al. 2013), the daily moving distance of plateau pikas was approximately 300 m, and, thus, v was set to 0.3 km/d. The total number of independent photos (y) was obtained by counting the pictures taken by the cameras.

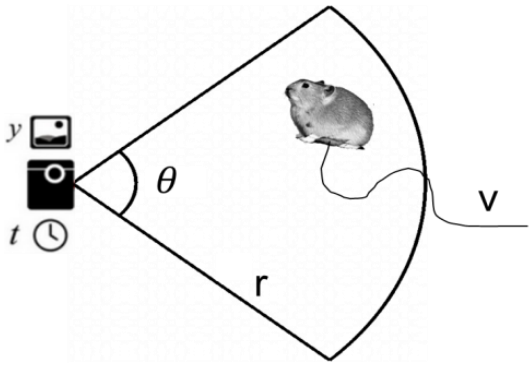

Figure 2. Schematic diagram of the REM.

Classification of pika behavior

According to the related literature and observed video data, the behavior of plateau pikas was classified into five types: foraging, running, vigilance, combing hair and fighting, as illustrated in Table 1 and Fig. 3.

Table 1. Classification of plateau pika behavior

Behavior	Description
Foraging	Stay in place to chew food or take food while moving
Running	Move quickly from one place to another
Vigilance	Sit on the ground with stretched neck or stand with forefoot off the ground

Fighting	More than two pikas grab and bite each other aggressively
Combing hair	Clean the body with paws or mouth

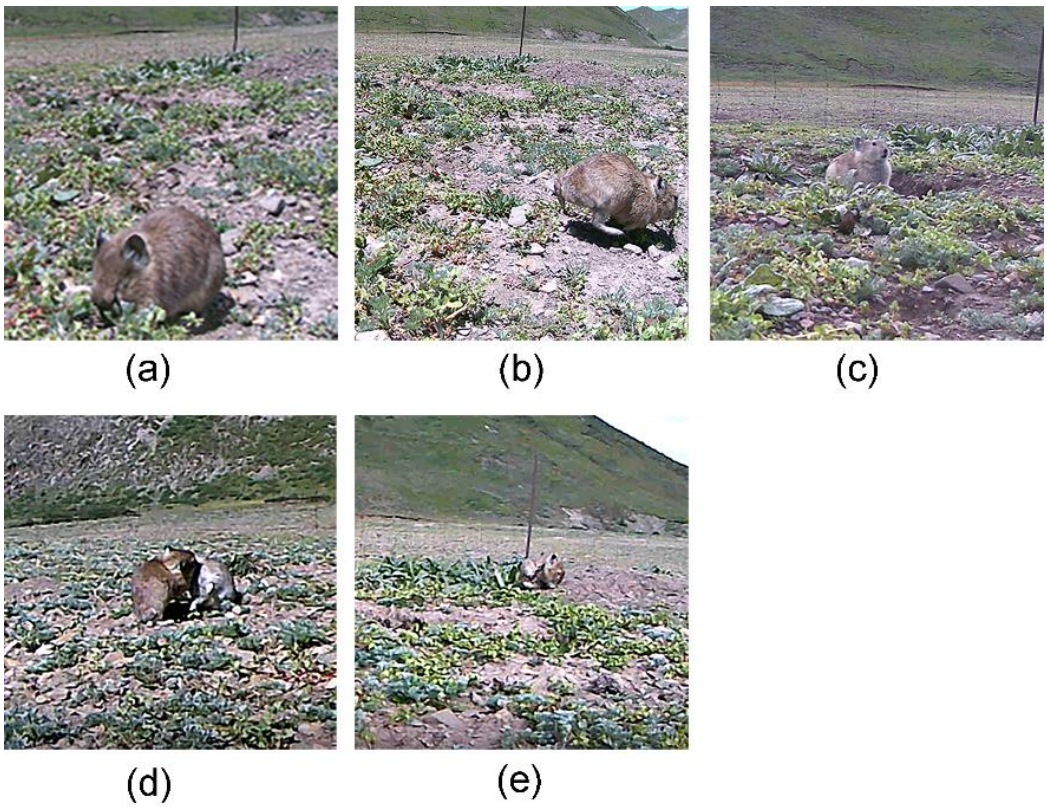

Figure 3. Classification of the plateau pika behavior: (a) foraging; (b) running; (c) vigilance; (d) fighting; and (e) combing hair.

Results

Population density

During the field observation lasting for one week, a few cameras did not work normally on some days due to overturning and other reasons. A total of 1138 independent photos were obtained. The working days of cameras at each position, the total number of independent photos taken, and the population density of plateau pikas were estimated by the REM in Eq. (1) and are shown in Table 2. The results show that the average density of plateau pikas in the study area was 144 per hectare, the highest density was 200 per hectare at 100 m along the riverbank, and the lowest density was 77 per hectare at the steep slope on the sunny side.

The location of the water source had a high impact on the density of plateau pikas, which was highest at 100 m along the riverbank, followed by the location 300 m along the riverbank, 600 m along the riverbank, and lastly the beach location. In addition, the

density of plateau pikas was significantly higher on sunny gentle slopes than on steep slopes.

Table 2. Population density of plateau pikas estimated by REM at different locations.

Location	Number of camera working days	Number of independent photos	Number of plateau pikas per hm^2
Beach	5	161	142
100 m from the riverbank	6	271	200
300 m from the riverbank	7	270	171
600 m from the riverbank	4	130	144
Sunny side of gentle slope	7	201	127
Sunny side of steep slope	6	105	77

Note: the average population density of plateau pikas in the study area is 144/hm^2 derived from REM.

Occurrence frequency of different behaviors at different locations

From August 15 to August 18, all six cameras worked normally. The occurrence frequencies of the five behaviors defined in Table 1 and Fig. 3 in different locations are shown in Fig. 4.

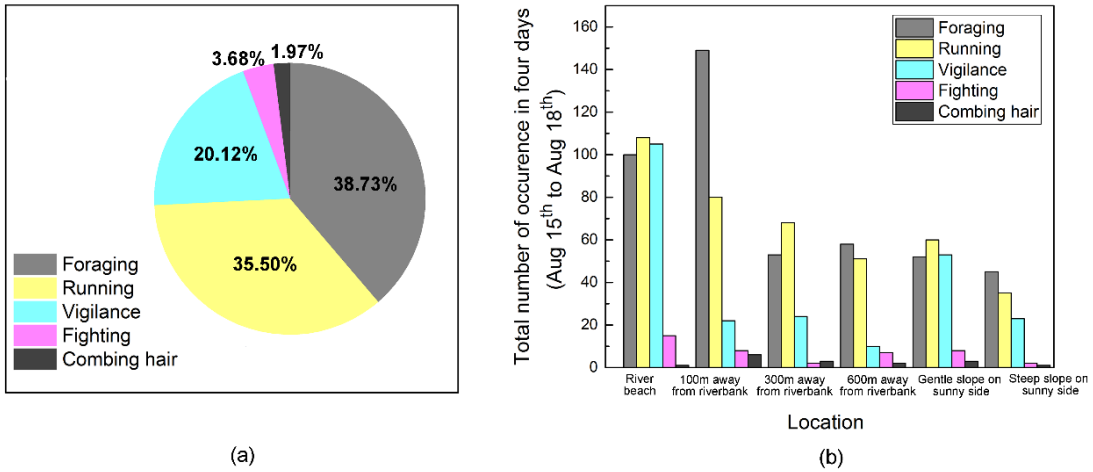

Figure 4. Occurrence frequency of five behaviors defined in Table 1 and Fig. 3: (a) percentage of the occurrence of different behaviors; and (b) total occurrence number of different behaviors in different locations.

As shown in Fig. 4(a), foraging and running behaviors accounted for the largest proportion of plateau pika behavior, with percentages of 38.72% and 35.5%, respectively; vigilance behavior accounted for 20.12% and fighting and combining hair accounted for only 4% and 2%, respectively. Fig. 4(b) indicates that the frequency of foraging behavior was highest 100 m away from the riverbank, and the frequency of vigilance and running behavior were highest at the river beach. Compared with the river beach, the frequency of vigilance behavior at other locations decreased significantly,

and the frequency of all behaviors at the steep slope on the sunny side was lower than those at the gentle slope on the sunny side.

Occurrence frequency of different behaviors during different periods

To investigate the behavior differences during different time periods, the occurrence frequencies of different behaviors during time periods of 6:00-7:00, 7:00-8:00,…., 19:00-20:00 were counted, as shown in Fig. 5. Fig. 5 shows that there are two peaks of foraging behavior, which occur during 8:00-9:00 and 17:00-18:00. During 6:00-9:00, foraging, vigilance and running behaviors increased gradually, and after 18:00, foraging and vigilance behaviors decreased significantly. The Pearson correlation analysis showed that there was a significant positive correlation between foraging behavior and vigilance behavior ($r = 0.734$, $P = 0.003$).

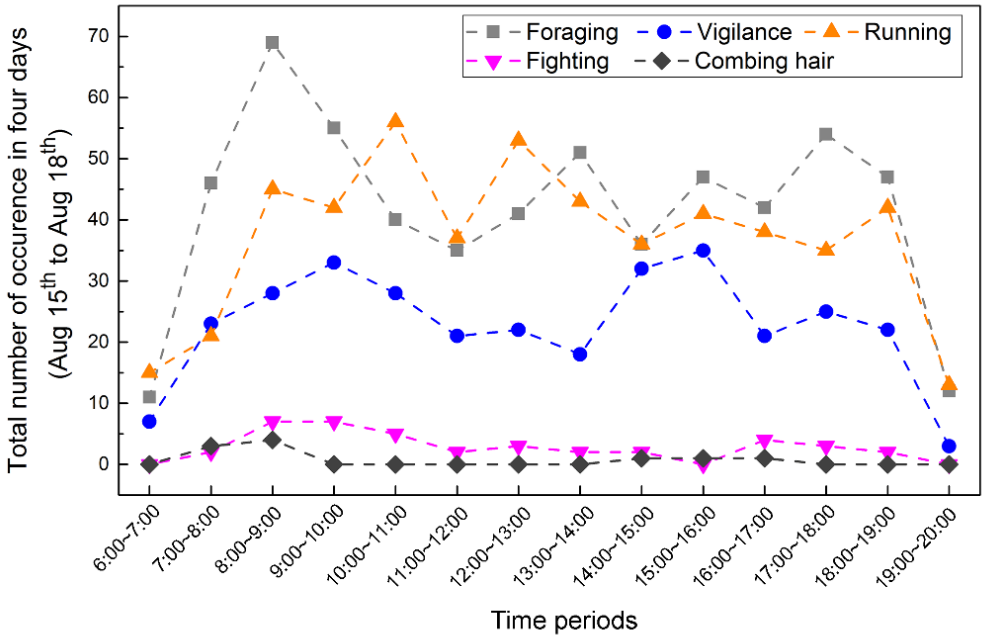

Figure 5. Total occurrence number of different behaviors during different time periods.

The highest surface temperature recorded by the infrared cameras was 48□, and the surface temperature was above 0□ during the observation period. The frequency of each behavior under different temperature gradients is shown in Fig. 6. With increasing temperature, the frequency of foraging, vigilance and running behavior of plateau pikas increased gradually and then decreased significantly above 35 □.

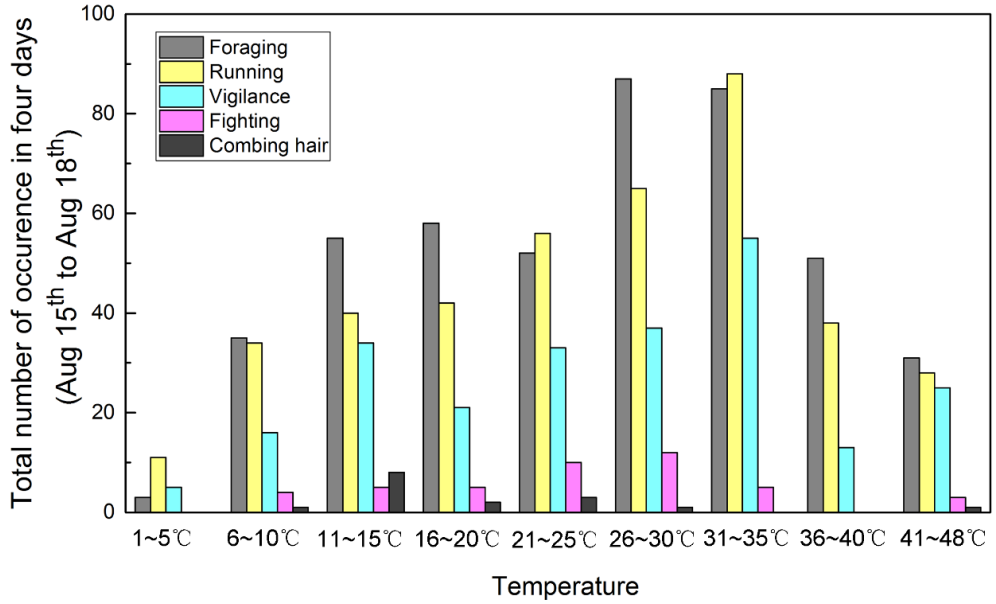

Figure 6. Total occurrence number of different behaviors under different temperature gradients.

Discussion and conclusion

Distribution of plateau pikas

The breeding peak of plateau pikas appears in May and June, and pikas do not breed in middle and late August. Resulting from the slow reproduction of pikas, coupled with interspecies competition, increased precipitation and other factors, the mortality of pikas increased and the population decreased in July and August. The field observations in this study were completed in mid-August, and the average population density of pikas in the study area was estimated to be 144/ha. During the breeding peak of pikas, the average density of pikas in the area could be much higher than 144/ha.

Plateau pikas were distributed more in the environment near the water source and in the relatively gentle terrain. This may be due to the following reasons: (1) the vegetation near the water source grows better; (2) it is beneficial to shorten the drinking distance of pikas; and (3) it is beneficial to reduce the energy consumption and the risk of predation when drinking water. However, the highest distribution did not appear at the river beach, which is nearest to the water source. This may be due to flooding of the river in the summer rainy season, which increases the risk of rat burrows being submerged, and predator drinking water activities are also frequent. The highest population density of pikas appears 100 m from the riverbank, followed by 300 m from the riverbank. The growth of vegetation on sunny steep slopes is poor, and it is not conducive for pikas to escape when encountering natural enemies, which may be the reason why the density of pikas on sunny gentle slopes is significantly higher than that

on sunny steep slopes.

Behavioral characteristics of plateau pikas

In the area with a higher population density of pikas (100 m and 300 m away from the riverbank), plateau pikas have relatively low vigilance times; whereas, in the area with a low population density (sunny gentle slope and sunny steep slope), they alert each other more frequently. This may be due to the high individual safety in the area with high population density. The occurrence number of runs and vigilance is highest at the river beach, as predators drink water frequently and, thus, pikas increase their vigilance and running times to avoid the risk of predation.

The plateau pika is a diurnal animal and its foraging behavior has two peaks: 8:00~9:00 and 17:00~18:00. Plateau pikas forage frequently in the early morning and dusk to reduce the risk of predation and energy consumption. In Dari County, the sunshine is sufficient. When the ground temperature is high, the activity of pikas is reduced to reduce energy consumption.

Correlation between plateau pikas and barren patches

According to Ma's study, plateau pikas tend to live in open habitats with low vegetation. Moderate degraded grassland with sparse vegetation is conducive to the survival of pikas. Studies have shown that moderately degraded grasslands have the highest population density of pikas. With the increase in the pika population, the vegetation in the habitat gradually decreases, and the proportion of bare land area increases, which leads to more serious grassland degradation.

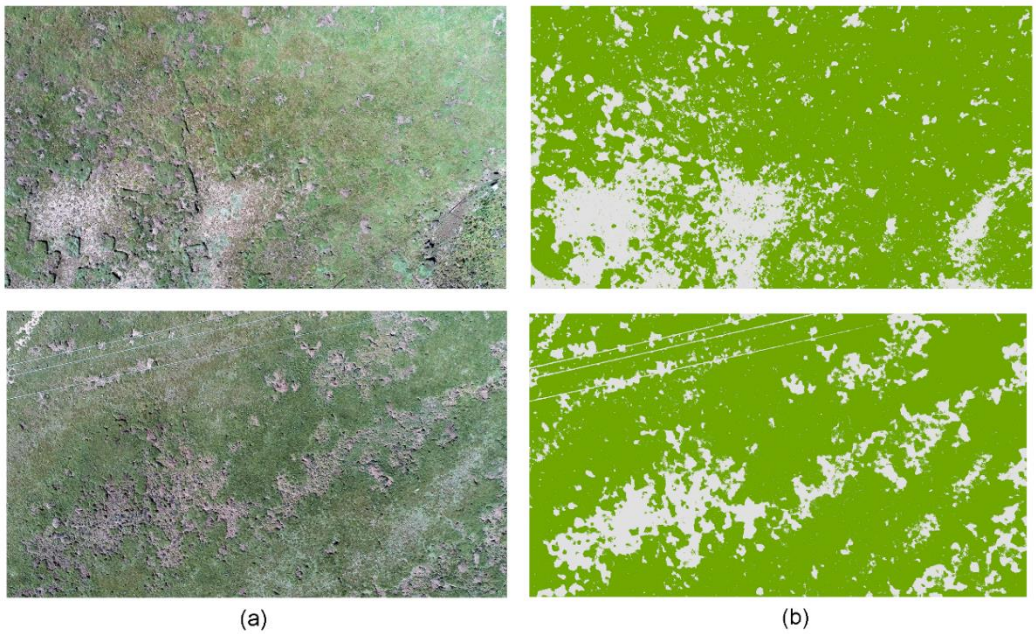

Figure 7. The area of barren land in the study area: (a) original remote sensing images of the study area; and (b) picture processing to identify the barren land.

To verify this conclusion, ArcGIS software was used to classify the barren land and grassland and calculate the area of barren land in the study area. The results are shown in Fig. 7. The percentage of bald patch area is 18.2% ~ 30.1%, with an average percentage of 23.3%. According to the bare patch area proportion and the classification criteria proposed by Ma (2006), the grassland in the study area has reached a moderate degradation level.

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