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Plateau pikas near roads are bold and silent when facing a potential predator

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Abstract

Human disturbance, particularly road traffic, is one of the greatest threats to wildlife. Considering the association between alerting behavior and the survival of animals, it is important to study the effects of road traffic on alerting behavior of wildlife. Previous studies assessing the short-term impact of road traffic on alerting behavior of wildlife have focused on vigilance distances. However, studies on the use of alarm calls are scarce, and it is unclear whether such behavioral responses change after repeated exposure to road traffic. We assessed the alerting behavior of plateau pikas (*Ochotona curzoniae*) who were near or far from roads when facing a potential predator. We found that pikas near roads exhibited shorter vigilance and tolerance distances, and produced fewer alarm calls than those relatively far away from roads. Furthermore, both vigilance and tolerance distances of plateau pikas were significantly positively correlated with the distance from the burrow to the road. Road traffic reduced antipredator responses and shaped alerting behavior; that is, pikas near roads were bolder and more silent compared to those far away from roads. Our findings suggest that increasing urbanization will have corresponding effects on animal behavior, which may have significant fitness effects in the future.

Key words: alarm call, flight initiation distance, plateau pika, Qinghai-Tibet Plateau, road traffic, vigilant behavior.

The expanding human footprint is affecting wildlife globally. A variety of human activities, particularly road traffic, profoundly affect wildlife (Simpson et al. 2016; Iglesias-Merchan et al. 2021). The expansion of road networks promotes economic development; however, this negatively affects wildlife and their habitats by increasing human disturbance and habitat fragmentation (Carter et al. 2020; Li et al. 2022). Even nonfatal disturbances from humans can affect an animal's behavior and physiological functions, such as disturbing hearing thresholds, communication, and foraging (Pan et al. 2011; Simpson et al. 2015; Senzaki et al. 2016; Weiperth et al. 2016; Zhang et al. 2021). Predation risk assessment and proper response are essential for the survival of prey species (Ivins and Smith 1983). Wild animals may become alert and flee in response to an approaching threat (Blumstein 2014; Shannon et al. 2014, 2016a, 2016b). Considering the direct association between alerting behavior and wildlife survival (Ivins and Smith 1983; Templeton 2005), a fundamental understanding of how road traffic influences alerting behavior of wildlife is necessary for developing conservational policies to protect wild animals (Allan et al. 2020).

With the rapid development of road construction and tourism in recent years, road traffic is having a great impact on the ecosystem of the Qinghai-Tibet Plateau. However, studies on how road traffic affects the vigilance behavior of wildlife in the Qinghai-Tibet Plateau are limited. Previous studies have primarily focused on the immediate response of animals to short-term traffic noise (Radford et al. 2016). In most cases, it is unclear whether such behavioral responses to road traffic change after repeated exposure, particularly when considering habituation (Morris-Drake et al. 2016; Kok et al. 2021). Therefore, studies on the alteration in tolerance and possible behavioral adaptations in wildlife after repeated exposure to road traffic are needed. In addition, previous studies assessing the impact of road traffic on alerting behavior have mostly focused on measuring animal vigilance distances (Li et al. 2011; Shannon et al. 2016a, 2016b); however, it is unclear whether road traffic affects alarm call usage by the wild animals.

Many studies have reported that the latency of behavioral responses in animals can be altered by human disturbance (Hasan et al. 2018; Tidau and Briffa 2019; Halfwerk and van Oers 2020). Road traffic may generate an extra peripheral stimulus (acoustic, visual, or seismic) that distracts animals from attending to key cues (e.g., an approaching predator). This is known as the distracted hypothesis, which predicts that human activities (e.g., road traffic, anthropogenic noise) may reallocate the finite attention of animals, thus preventing them from dealing with other sensory cues (Blumstein 2010, 2014; Chan and Blumstein 2011). For instance, Caribbean hermit crabs *Coenobita clypeatus* allowed a potential predator (i.e., human) to approach

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closer before they hid during boat motor playbacks than during silence (Chan et al. 2010). In contrast, the risk disturbance hypothesis states that the decreased response latency could be due to increased alertness or stress caused by traffic noise (Fernández-Juricic et al. 2003; Voellmy et al. 2014). The 3-spined stickleback *Gasterosteus aculeatus* responded significantly more quickly to the visual predatory stimulus during additional-noise playbacks than during control conditions (Voellmy et al. 2014). Despite several intriguing reports, actual evidence of the distracted hypothesis or risk disturbance hypothesis outside of the laboratory is still limited.

In this study, we explored the effect of road traffic on the vigilance behavior of a plateau mammal, the plateau pika *Ochotona curzoniae*, and its tolerance of which to human disturbance. As a small herbivorous lagomorph, plateau pikas are widely distributed on the Qinghai-Tibet Plateau at 3,200–5,300 m altitude (Qu et al. 2013, 2018). Known as a keystone species, plateau pikas live in the *Kobresia humilis* grassland (Figure 1). Their breeding season is from May to July (Qu et al. 2013, 2018). They are prey to predators (weasels, foxes, and raptors) and share their burrows with some birds (Qu et al. 2015; Speakman et al. 2021). Plateau pikas are social during the breeding season. There are strict territory boundaries between pika families, and plateau pikas have a complex social system with extensive burrows. Individuals from the same family group live mainly within their territory, while individuals from nonfamily groups are driven away. Unlike most other lagomorphs, plateau pikas have an extremely complex vocal repertoire (Smith et al. 1986); therefore, they are also called "singing mice". We measured the vigilance distance, the tolerance distance, and the proportion of alarm calls produced by plateau pikas when facing a potential predator. We predicted that plateau pikas would exhibit reduced vigilance responses after repeated exposure to road traffic, that is, habituation.

Materials and Methods

Study site and animals

Our study was conducted at the Haibei National Field Research Station of Alpine Grassland Ecosystem, located in Menyuan in Qinghai Province, China, in June 2017. A large number of plateau pikas inhabit this grassland. The study site was approximately 330 m wide, and was fenced by herdsmen with barbed wire. The grassland was divided into 3 colonies, with approximately 50 m between the colonies. Each colony was approximately 150–200 m long (Figure 2). One side of the meadow was a road, which was approximately 5 m wide. Daytime traffic flow was approximately 12 vehicles per hour during the experiment, and not many people were walking down the road. We classified plateau pikas that were <50 m away from the road as "the near-the-road group," and those that were <50 m away from the fence (far away from the road) into "the far-from-the-road group" (Figure 2).

Field observations revealed that plateau pikas tended to run close to their burrows to avoid being attacked when a potential predator approached. If the predator continued to approach, the pikas produced alarm calls (a short, monosyllabic, and high-frequency chirp) to deter the predator from hunting or immediately fled into their burrows.

Figure 1. An adult plateau pika who is producing alarm calls near the burrow (photo courtesy of Ming Zhang).

Evaluation of vigilance behavior

This experiment was conducted on adult plateau pikas since only adult pikas produce alarm calls (Smith et al. 1986). In May and June, it is easy to distinguish adult pikas from juvenile ones based on body size (Qu et al. 2013, 2018). Following Li et al. (2011) and Blumstein (2014), we measured the following 4 parameters to assess the vigilance behavior of adult plateau pikas: (1) the calling initiation distance, which is the distance from the approaching predator when a pika starts to produce alarm calls (i.e., alert distance or vigilance distance); (2) flight initiation distance, which is the distance from the approaching predator when a pika flees into the burrow (i.e., tolerance distance); (3) the corrected flight distance, which is the calling initiation distance minus the flight initiation distance, and indicates the effective distance to alert by producing alarm calls; and (4) the proportion of plateau pika groups with individuals that emit alarm calls when facing an approaching predator.

We conducted this experiment on 3 sunny days to reduce the effect of weather conditions. Two experimenters assessed 1 colony per day, wherein each experimenter randomly measured the vigilance distance of pikas close to the road or far from the road. The pikas in each colony were assessed only once. We conducted the experiment during dusk (17:00–21:00) when plateau pikas were actively foraging. Humans may be treated as predators by wildlife, and this paradigm is often used to study the antipredatory behavior of wildlife (Frid and Dill, 2002; Blumstein et al. 2004; Blumstein 2014). Considering the influence of the start distance (the distance at which the experimenter begins to approach the pikas) on the measurement of the flight initiation distance (Dumont et al. 2012; Blumstein 2014), we ensured that the start distance for focal pikas was the same before measuring the flight initiation distance. Wearing the same gray clothes, we approached the focal pikas at a consistent speed of approximately 0.5 m/s, and stopped when the pikas started to produce alarm calls or fled into the burrow (Figure 2). We then used a laser rangefinder (BOSCH GLM 30, Leinfelden-Echterdingen, Germany) to measure the distance from the burrow to the road (location distance), calling initiation distance, and flight initiation distance. In total, we measured the vigilance behavior of 234 pikas (119 near the road and 115 relatively far from the road).

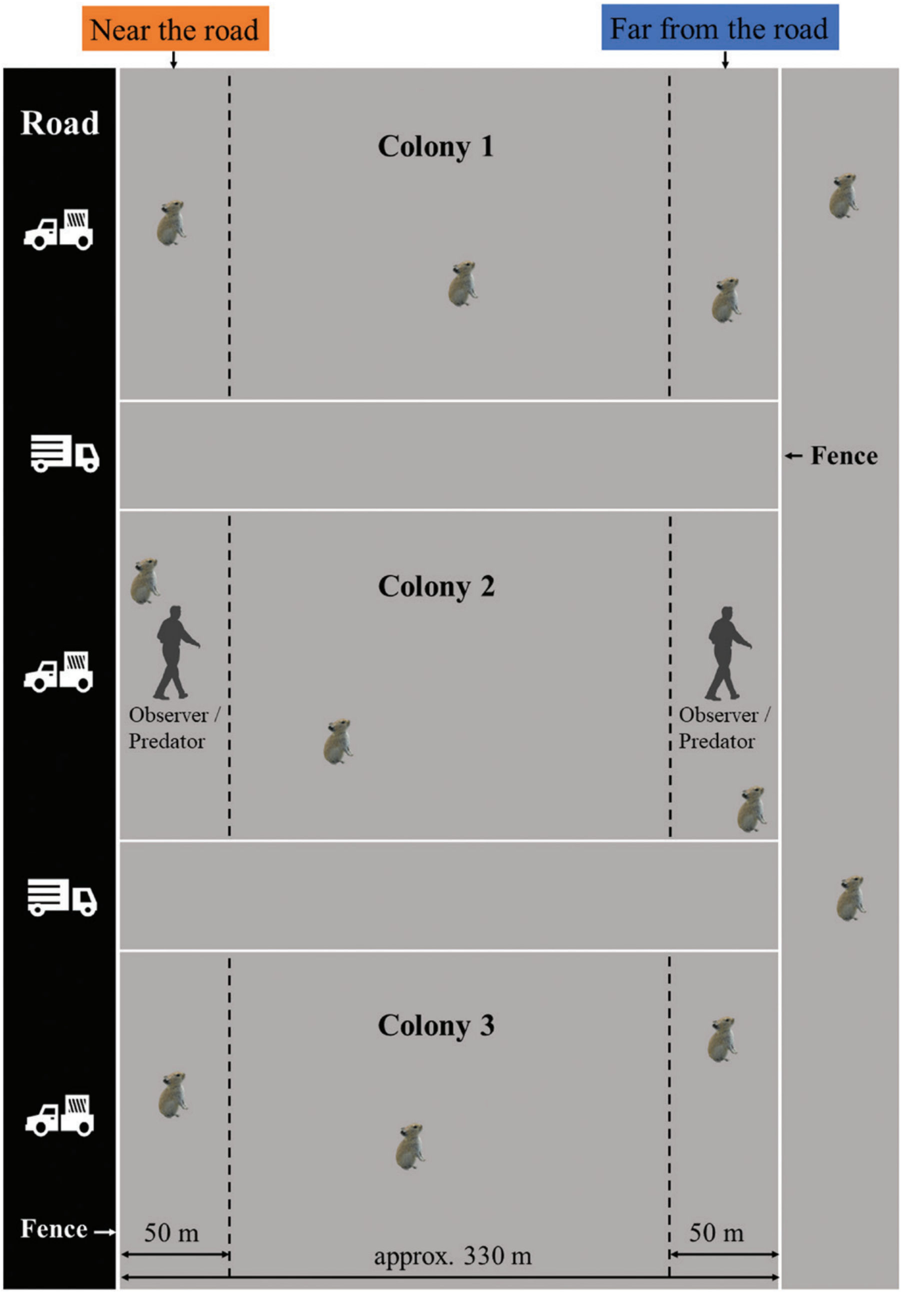

Figure 2. The diagram of the experimental colonies and procedure.

Analysis and statistics

All statistical analyses were conducted using R (v.3.6.3) (R Core Team 2020), and the statistical graphs were visualized using the packages "ggplot2" (v.3.3.3) (Wickham 2016). Spearman's correlation was used to assess whether the calling initiation distance and flight initiation distance, of plateau pikas were associated with the distance from the burrow to the road. A Mann–Whitney *U* test (Wilcoxon rank-sum test) was used to compare the alert distances and tolerance distances of plateau pikas between the 2 groups (near the road and far from the road), since the data were not normal (Shapiro–Wilk normality test; $P > 0.05$). Fisher's exact test (2-tailed) was used to compare the 2 groups in terms of the ratio of alarm calls produced by plateau pikas. As nonparametric tests were used, data were presented as medians with interquartile ranges; $P < 0.05$ was considered statistically significant.

Results

The location distances between the pikas near the road and relatively far from the road were 20 ± 7.5 and 305 ± 25 m (median ± interquartile range), respectively. The calling initiation distance of plateau pikas was significantly correlated with the distance from the burrow to the road ($r = 0.602$, $P < 0.001$, $n = 62$, Figure 3A). In addition, the flight initiation distance was significantly positively correlated with the distance from the burrow to the road ($r = 0.759$, $P < 0.001$, $n = 234$; Figure 3B).

We found that the near-the-road group had significantly shorter calling and flight initiation distances than the far-from-the-road group (Mann–Whitney *U* Test, $P < 0.001$; Figure 4 and Table 1). The calling initiation distances between the pikas near the road and relatively far from the road were 9.0 ± 2.7 and 19.5 ± 15.2 m (median ± interquartile range), respectively. The flight initiation distances

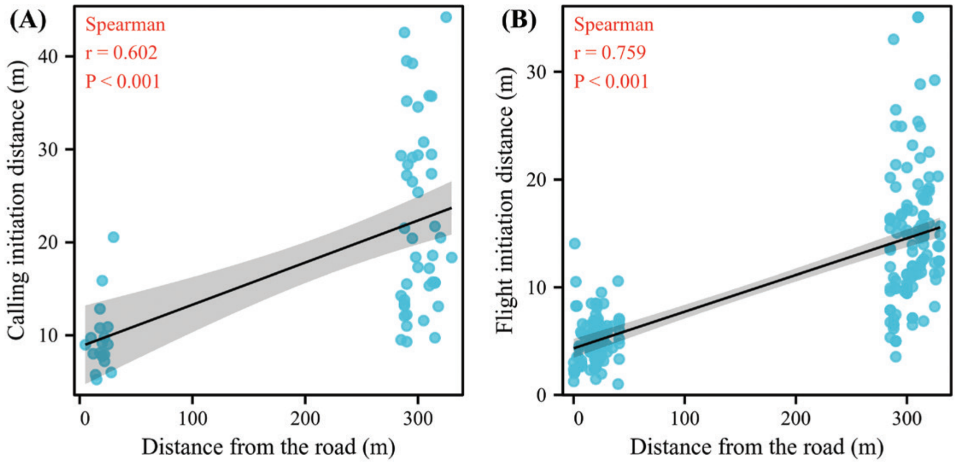

Figure 3. Spearman's correlation analyses between the location distance and alert distance of pikas. Linear correlations between distance from the burrow to the road and calling initiation distance (A), flight initiation distance (B).

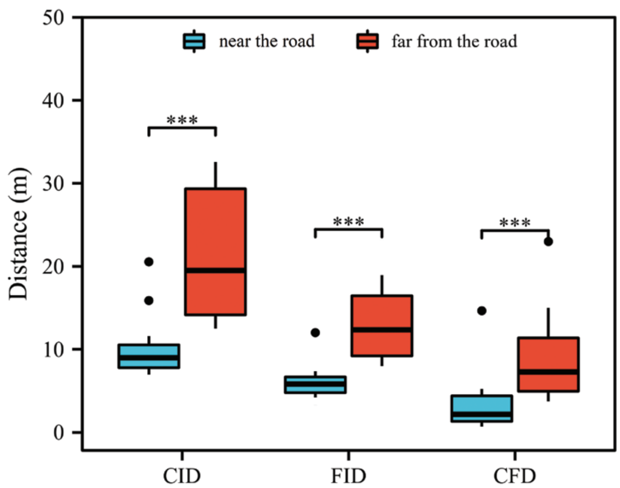

Figure 4 Comparison of alert responses between plateau pikas near the road and far from the road. CID, the calling initiation distance; FID, the flight initiation distance; CFD, the corrected flight distance. Mann–Whitney *U* Test, ****P* < 0.001.

between the pikas near the road and relatively far from the road were 4.8 ± 2.7 and 14.0 ± 6.7 m (median ± interquartile range), respectively. Interestingly, when facing a potential predator, the percentage of pikas producing alarm calls was higher in the far-from-the-road group (38.3%) than that in the near-the-road group (15.1%) (Fisher's exact test, $P < 0.001$; Figure 5). Moreover, pikas near the road also had a shorter corrected flight distance (2.2 ± 3.1 m, median ± interquartile range) than those far from the road (7.3 ± 6.4 m, median ± interquartile range; Mann–Whitney *U* Test, $P < 0.001$; Figure 4 and Table 1).

Discussion

Our results demonstrated that when facing a potential predator, plateau pikas near the road have shorter calling initiation (i.e., vigilance distance) and flight initiation (i.e., tolerance distance) distances, and produce fewer alarm calls than those relatively far from the road. In addition, both the calling and flight initiation distances of plateau pikas were significantly positively correlated with the distance from the burrow to the road (location distance).

Many studies have reported that various animals change their alerting behaviors in response to human disturbance (Li et al. 2011; Shannon et al. 2016a, 2016b; Geipel et al. 2019; Kok et al. 2021). Road traffic, which is frequently seen as a threat by wild animals, has been reported to increase vigilance distance (Meillere et al. 2015; Kern and Radford, 2016; Shannon et al. 2016a, 2016b; Sweet et al. 2022). However, we showed that the vigilance distance of plateau pikas close to the road decreased after exposure to road traffic; that is, pikas were bolder when facing an approaching risk. Our results are consistent with those of Halfwerk et al. (2019), who showed that forest male túngara frogs *Physalaemus pustulosus* ceased to call at a longer distance than that observed in urban males when a human observer approached them. To some extent, our results fit with the distracted prey hypothesis (Chan and Blumstein 2011; Blumstein 2014; Kok et al. 2021), and suggest that road traffic may potentially distract the pikas from attending to an approaching predator. As we used humans to represent a ground predator, there may be a bias for the plateau pikas to respond differently to flying predators.

Road traffic suppressed the antipredator responses of plateau pikas and shaped their alerting behavior. Among the vocal communications of adult plateau pikas, alarm calling is most frequent, particularly in females (Smith et al. 1986). We found that plateau pikas near the road produced fewer alarm calls and had shorter effective distances (i.e., the corrected flight distance) to alert by producing alarm calls than those far from the road. Our results are consistent with those of Hasan et al. (2018), who showed that the fright reaction of a freshwater fish *Pimephales promelas* was reduced after exposure to motorboat noise. Within a short distance, significant changes occurred in the vigilance pattern of plateau pikas. One possible reason is that the construction of roads reduced the number of predators (e.g., weasels and foxes) around the road, which in turn reduced predation pressure on plateau pikas near the road. Under silent circumstances, sand gobies *Pomatoschistus minutus* previously exposed to high levels of long-term boat noise retained a reduced antipredator reaction, reducing the time spent away from the nest when a predator appeared (Kok et al. 2021). Thus, the impact of road

Table 1. The vigilance responses of plateau pikas to an approaching predator.

Distance (m)	Group	Sample	Median	IQR	Lower	Upper	Mean	*SE*
LD	Near the road	119	20	7.5	15	22.5	19.217	0.905
	Far from the road	115	305	25	290	315	304.407	1.271
CID	Near the road	18	8.991	2.745	7.793	10.539	9.645	0.881
	Far from the road	44	19.507	15.189	14.148	29.337	22.382	1.488
FID	Near the road	119	4.814	2.702	3.558	6.259	5.019	0.19
	Far from the road	115	13.964	6.739	10.492	17.231	14.66	0.579
CFD	Near the road	18	2.178	3.07	1.327	4.397	3.438	0.825
	Far from the road	44	7.29	6.408	4.962	11.371	8.333	0.837

Abbreviations: LD, location distance; CID, the calling initiation distance; FID, the flight initiation distance; CFD, the corrected flight distance. IQR, interquartile range; Lower, lower quartile; Upper, upper quartile.

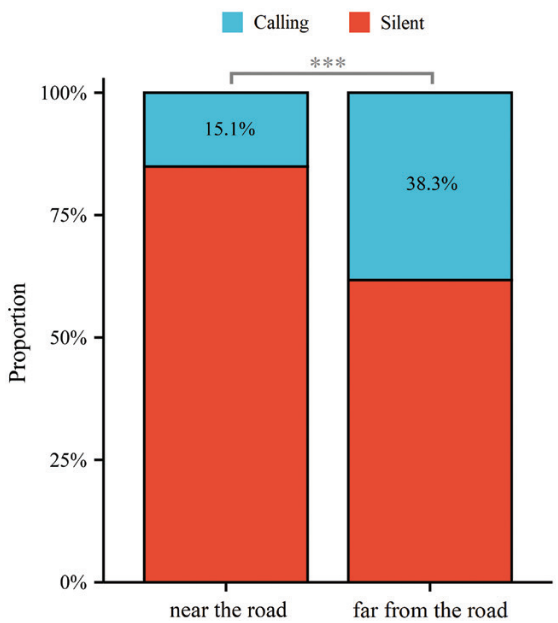

Figure 5. The proportion of alarm calls produced by plateau pikas near the road and far from the road. "Silent" means that the pikas did not produce alarm calls when a potential predator was approaching. Fisher's exact test, ***$P < 0.001$.

traffic on the vigilance behavior of pikas may remain even if road traffic is reduced. Our study indicated that road traffic may drive behavioral differentiation in wildlife.

Moreover, the closer plateau pikas were to the road, the shorter was their flight initiation distance. The reduced vigilance responses of plateau pikas near the road were likely driven by increased tolerance after repeated exposure to road traffic (i.e., habituation). Further, our field observation revealed that some plateau pikas even burrowed adjacent to roads. Samia et al. (2015) reported that disturbed populations of birds, mammals, and lizards exhibited shorter tolerance distance to humans than populations that were less disturbed. After repeated exposure, plateau pikas near the road may have learned that passing vehicles or pedestrians are not a threat; therefore, they tolerated closer approaches. This behavior is different from that of prairie dogs *Cynomys ludovicianus*, which exhibited increased responses rather than habituation during experiments involving recurrent human interference (Magle et al. 2005), and that such interspecific variation may relate to the variation in tolerance to human disturbance (Radford et al. 2016). An alternative explanation is that the timid pikas among populations near the road were eliminated (i.e., selection). However, considering that roads do not pose a lethal threat to the survival of plateau pikas, this explanation may not be appropriate here.

Road traffic suppressed the antipredator responses of plateau pikas, which may have negative ecological consequences. The disruption of this effective antipredator behavior (e.g., alarm calls) means that road traffic has the potential to increase the predation risk of the plateau pikas; that is, the likelihood of escaping from predators may be reduced (Simpson et al. 2015) and mortality may be increased (Simpson et al. 2016). Decreasing vigilance and increasing tolerance seem to be common responses for wildlife to adapt to human disturbances (Blumstein 2010; Li et al. 2011; Samia et al. 2015). However, these adaptive responses to human disturbance are thought to lead to a homogeneous community structure in disturbed environments (Cooke et al. 2020) because the taxa with relatively low tolerance to human disturbance disappear from the city. In contrast, increased vigilance response will reduce the time to invest resources for nutrition and health in the long term, although it may be an effective method to decrease predation risk and improve survival in the short term (Cresswell 2008). The reduced alert response is associated with some prospective fitness advantages (e.g., foraging). The shorter vigilance distance means less time spent on vigilance. Therefore, the bold plateau pikas will have more time for foraging than those who are always on guard (e.g., the pikas far from the road). These behavioral responses may be tuned to meet the intensity of perceived risk, allowing pikas to trade off the costs and benefits involved with decreasing or increasing vigilance responses to possible threats (Ferrari et al. 2009).

Human disturbance to animals is a key problem in wildlife management and conservation (Shamoun-Baranes et al. 2011). Analyzing animal behavioral reactions to human disturbances is a valuable tool for assessing anthropogenic influences on wildlife. Our study showed how road traffic affects the vigilance behavior of a wild mammal on the Qinghai-Tibet Plateau, which can help us in predicting the influence of increased road traffic on plateau wildlife in the future. The expanding human footprint is affecting wildlife globally, even on the Qinghai-Tibet Plateau, through various mechanisms, many of which we are only just beginning to understand. More studies should be conducted to assess the multimodal impacts of road traffic on wildlife (Cooke et al. 2020), particularly after considering that noise can affect the chemical or visual communication of animals through cross-sensory interference (Morris-Drake et al. 2016; Halfwerk and van Oers 2020; Zhu et al. 2022).

Ethics Statement

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All procedures involving animals performed in this study were in accordance with the ethical standards of the Animal Care and Use Committee of Chengdu Institute of Biology, CAS (2016008).

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Author contributions

B.Z. and J.C. conceived the original idea. B.Z. conducted the fieldwork, analyzed the data, and wrote the manuscript. J.Q. and J.C. reviewed the manuscript. All authors read and approved the final manuscript.

Conflict of interest statement

The authors declare no competing financial interests.

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