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Effects of fertility control in plateau pikas（*Ochotona curzoniae*）on diversity of native birds on Tibetan Plateau

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Abstract: An overabundance of plateau pika (*Ochotona curzoniae*) populations along with increased numbers of livestock was suspected to have caused degradation of the alpine meadow on the Tibetan Plateau. In April 2007, we conducted fertility control of plateau pika populations in Guoluo District, south of Qinghai Province, China. We investigated abundances of pika and bird species observed at the study sites during August and September 2007 and 2008 in order to evaluate the effects of quinestrol, levonorgestrel and EP－1 on plateau pikas, avian diversity and abundance. The results demonstrated that quinestrol reduced pika abundances significantly compared with control in the second year after delivering the baits, while bird diversity and species richness did not decline significantly. Abundances of white-rumped snowfinch were significantly lower in quinestrol group compared with control, while abundances of rufous-necked snowfinch were significantly higher in quinestrol groups compared with EP－1 group. Quinestrol reduced pika population abundances, but had limited effects on avian diversity. Therefore, it was a potential approach that could be applied in the management of plateau pika on the Tibetan Plateau.

Key words: Diversity; Plateau pika (*Ochotona curzoniae*); Richness; Snowfinch

高原鼠兔不育控制对鸟类多样性影响

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摘要：高原鼠兔种群数量过多被认为是青藏高原草地退化的主要原因之一。2007 年 4 月，在青海省果洛州大武镇开展了高原鼠兔不育控制实验。为了解 3 种不育剂（炔雌醚、左炔诺孕酮和 EP－1）对高原鼠兔和土著鸟类的影响，分别在 2007 年和 2008 年 8－9 月调查了高原鼠兔种群数量与鸟类多样性。结果表明，投药次年，炔雌醚能显著降低高原鼠兔各群数量，而对鸟类多样性和物种数均无显著影响；炔雌醚组白斑翅雪雀的数量显著低于对照组，棕颈雪雀的数量显著高于 EP－1 组。因此，炔雌醚能有效降低高原鼠兔种群数量，对土著鸟类多样性影响较小。使用炔雌醚开展不育控制是高原鼠兔种群管理的一种新途径。

关键词：多样性；高原鼠兔；丰富度；雪雀

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Native species whose densities become overabundant have negative effects on ecosystems and their abundances should be controlled (Shi *et al.*, 2002; Liu *et al.*, 2013). Traditional methods of lethal control, such as using poison or traps, often have disadvantages, such as negative environmental effects, risk to non-target species and negative welfare consequences. Fertility control has been proposed as a non-lethal alternative approach which maintains the target population at low or medium levels by reducing the birth rate (Jacob *et al.*, 2008). Mathematical models have predicted that contraception had better control effects than simple culling in the management of some wildlife populations (Zhang, 2000). Shi *et al.* (2002) confirmed

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that fertility control was more effective in reducing Brandt's vole (*Lasiopodomys brandtii*) population densities than lethal control. However, until now, it is not known whether fertility controls have any impacts on the biodiversity of local flora and fauna.

Plateau pikas (*Ochotona curzoniae*) are small native lagomorphs (Male: 130 – 180 g, female: 120 – 160 g) inhabiting the alpine meadow of the Tibetan Plateau (Smith and Xie, 2008). They are social animals with stable home ranges, each social group consists of 4 – 6 adults and their young (Qu *et al*., 2008). They breed from April to July, most adult females reproduce 1 – 3 litters per year and litter size ranges from 1 to 6 (Qu *et al*., 2012). Plateau pikas are considered as keystone species, their burrows provide nests for small birds, and they are principal prey for plateau predators (Smith and Foggin, 1999; Lai and Smith, 2003). However, when pika populations reach very high densities, they compete with domestic livestock for foraging and aggravate grassland degradation (Jing *et al*., 1991). Since the 1960s, lethal control programs using Bromadiolone or Botulin have been conducted by the local governments on the Tibetan Plateau. Although using poison reduces pika abundances rapidly to low levels (Jing *et al*., 1991), it may be hazardous to non-target species and humans, therefore has been opposed by both the public and environmental organizations.

In this paper, we used three kinds of sterilant: quinestrol, levonorgestrel and EP – 1 (the mixture of quinestrol and levonorgestrel with the ratio of 1∶2) to control the populations of plateau pika, our aims were as follows: (1) to investigate the effects of fertility control on reducing pika abundances, (2) to assess the impact of fertility control of plateau pika on avian biodiversity.

1 Materials and methods

1.1 Study site

The study was carried out in Dawu, Guoluo District, Qinghai, China (34°22′ – 34°29′ N, 100°11′ – 100°28′ E). At an average elevation of 3 857 m above sea level, the climate of this region is dry and cold. The annual mean precipitation is 440 mm, 70% of which occurs from June to August; heavy snows during the cold season are rare. The annual mean temperature is 0.9℃, and soil freezes to more than 2 m over winter. The vegetation in this area is typically alpine steppe meadow, and dominant plants are *Kobresia* spp., *Stipa* spp. and *Carex* spp. The meadow is grazed year round by livestock. The common passerines are *Montifringilla* species, such as white-rumped snowfinch (*M. taczanowskii*) and rufous-necked snowfinch (*M. ruficollis*), which nest in pika burrows and eat seeds and small insects (Arthur *et al*., 2008). Common birds of prey relying on pikas are upland buzzard (*Buteo hemilasius*), black-eared kite (*Milvus lineatus*) and large-billed crow (*Corvus macrorhynchos*) (Smith and Foggin, 1999).

We carried out fertility control of plateau pikas in April 2007. Twelve sites, each with an area of 1 km^2, were selected. The distance between adjacent sites ranged from 800 m to 5 km. These 12 sites were randomly assigned into 4 groups with 3 repeats. The 4 groups include three groups, bait of oats soaked in 0.005% solution of quinestrol, levonorgestrel, and EP – 1 respectively, and one control with plain oats as bait. An average of 10 g of bait (10 – 15 grains of oats) were placed 3 – 5 cm in front of each entrance of pika burrows within each site. Baits were delivered within the same day at each site by 30 field assistants walking parallel to each other to ensure baits were delivered to all borrow entrances. The baiting was completed within 5 days at all 12 sites.

1.2 Relative density of plateau pika

A background survey of pika densities was carried out in April 2007 before the experiment. To test the effects of fertility control on plateau pikas, tracking surveys of pika densities were performed in late July of 2007 and 2008 which was the end of breeding season. Walked transects were used to estimate the relative density of plateau pikas (Pech *et al*., 2007). To control for personal bias, each site was monitored simultaneously by two people between 08: 30 and 11: 00 am, which is the period when pikas are most active on the surface of the meadow (Zhang *et al*., 2005a). Ten non-overlapping transects of 100 m long and 20 m wide at the core area were used for the survey. Observers counted all pikas in the transects. Since the mean vegetation height of pika habitat was less than 3 cm, pikas above ground could easily be sighted and we assumed that all pikas above ground within the transect strip were counted to derive a density estimate.

1.3 Bird surveys

On the Tibetan plateau, most *Passerines* begin to reproduce in April or May and end before September (Zhang, 1982). The bird surveys were conducted in early September soon after the end of birds' breeding seasons in 2007 and 2008. The survey was carried out on a 1 km long belt transect in the core area of each site (Lai and Smith, 2003). The transects were marked with colored stones and a 30 min survey was carried out at each transect in early morning (08:00 –10:00 am), noon (12:00 – 14:00 pm) and late afternoon (16:00 – 18:00 pm) for 2 days. All small birds sighted within a 50 m width (25 m either side of the transect line) during the survey were identified and recorded. Small birds could be seen easily in the relatively flat terrain with low vegetation, we assumed all birds within the strip were counted. Additionally, after belt transect survey, we censused the abundances of birds of prey. We continually scanned for birds of prey for 15 min at each site, and recorded the species and numbers of birds of prey.

1.4 Data Analyses

A mixed-effects model with observer as a random effect was used to estimate the counts of plateau pikas. Densities were estimated using the equation $D = 10000n/(2 \times L \times W)$, where n was the number of pika recorded, L the total walked transect length, W the width on each side of the belt (Buckland *et al.*, 1993). We used ANOVA with pika densities in April 2007 and year as the covariates to test differences in plateau pika abundance under different treatments. All bird species, including the birds of prey were taken into account when analyzing the avian diversity and species richness. The Shannon index of diversity was used to express avian diversity. Data for both diversity and richness did not deviate from a normal distribution (Kolmogorov-Sminov test, $P = 0.43$). We also detected the abundances of two common *Passerine* species: white-rumped snowfinch and rufous-necked snowfinch. We conducted ANOVA in four groups (quinestrol, levonorgestrel, EP – 1 and control) with year as the covariate and used Fisher's least significant difference post-hoc tests to differentiate avian diversity, species richness and snowfinch abundances under different treatments. All statistical analyses were performed using software R 2.15.

2 Results

2.1 Pika abundance

In July 2007, after the first breeding season following the fertility treatment, densities in levonorgestrel groups were significantly higher than that in quinestrol and EP – 1 groups, while no significant differences of pikas densities were detected in quinestrol, levonorgestrel or EP – 1 groups compared with control groups ($F = 4.547$, $P = 0.004$; Fig. 1). In July 2008, pika densities in quinestrol groups were significantly lower than that in other three groups, while no significant differences of pikas densities were detected in levonorgestrel or EP – 1 groups compared with control groups ($F = 4.658$, $P = 0.004$, Fig. 1).

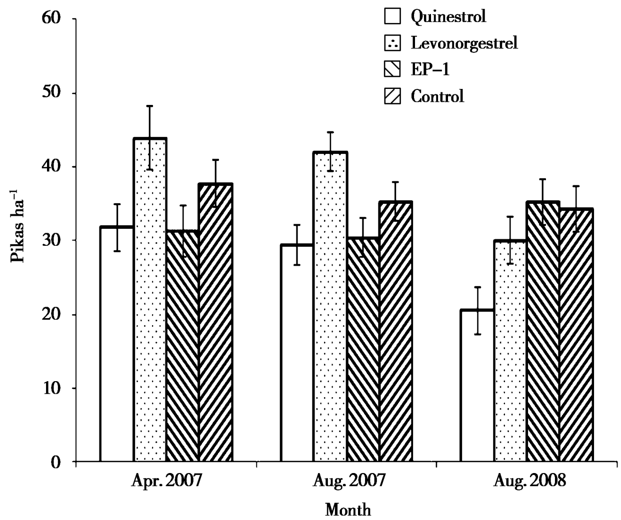

Fig. 1 Population densities of plateau pika in 2007 and 2008. Pikas were treated using four agents: quinestrol, levonorgestrel, EP – 1 and control. Results are expressed as mean ± SE

2.2 Avian censuses

In September 2007, 5 months after the treatment, there were no significant differences in either avian diversity ($F = 1.263$, $P = 0.294$; Fig. 2a) or richness ($F = 0.643$, $P = 0.590$; Fig. 2b) between the different agents.

In September 2008, avian diversity in EP – 1 groups was significantly lower than that in control groups, while no significant differences in diversity were detected between quinestrol or levonorgestrel and control groups ($F = 18.803$, $P < 0.001$; Fig. 2a); an average of 3.5 bird species were counted in each site (range from 2.9 to 4.1), and bird species richness in EP – 1 group was significantly lower than that in other three groups ($F = 4.199$, $P = 0.007$; Fig. 2b).

In September 2007, no significant differences were detected in the abundances of white-rumped snowfinch ($F = 0.927$, $P = 0.433$; Fig. 3a) and rufous-necked snowfinch ($F = 0.652$, $P = 0.585$; Fig. 3b) between the four groups.

In September 2008, densities of white-rumped snowfinch in quinestrol groups were significantly lower than that in control groups, while no significant differences of white-rumped snowfinch abundances were detected between levonorgestrel or EP-1 and control groups ($F = 2.950$, $P = 0.039$; Fig. 3a). Densities of rufous-necked snowfinch in EP-1 groups were obviously lower than that in other three groups, though the differences were not significant ($F = 2.071$, $P = 0.112$; Fig. 3b).

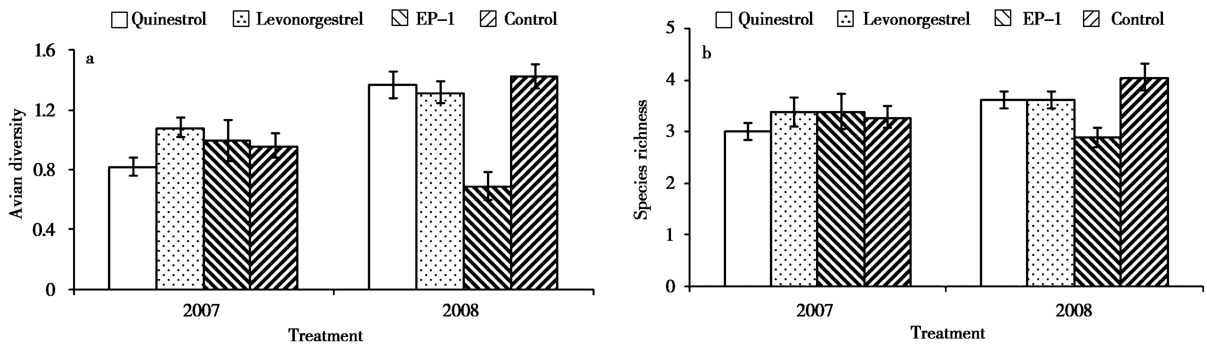

Fig. 2　Effects of fertility control of plateau pikas on avian diversity (a) and species richness (b) in September 2007 and 2008. Four agents were used: quinestrol, levonorgestrel, EP-1 and control, respectively. Results are expressed as mean ± SE

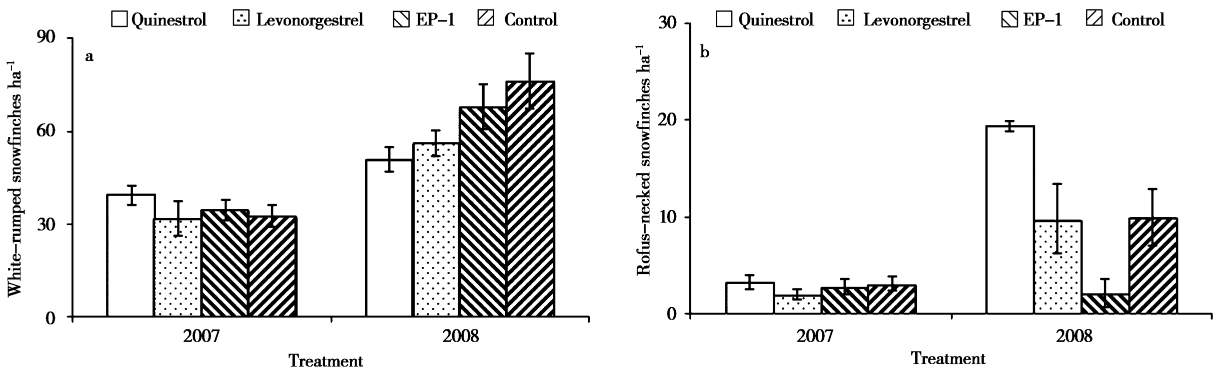

Fig. 3　Densities of two *Passerine* nesting in pika burrows: (a) white-rumped snowfinch, and (b) rufous-necked snowfinch under four different groups: quinestrol, levonorgestrel, EP-1 and control. Results are expressed as mean ± SE

Mean abundance of birds of prey ranged from 1.72 to 1.83 in 2007, and from 1.06 to 1.67 in 2008; and there were no significant differences of them between groups either in 2007 ($F = 0.031$, $P = 0.998$) or in 2008 ($F = 1.700$, $P = 0.158$).

3　Discussion

Among the three sterilizing agents tested in this study, quinestrol significantly reduced the density of plateau pika, while levonorgestrel or EP-1 had no effects on pika densities in the second breeding season after the treatment. Quinestrol caused tissue damage in the testes and epididymides, decreased sperm numbers of small mammals such as *L. brandtii* and *O. curzoniae*, the testes of adult males atrophied, and the pregnancy rate of females decreased consequently (Zhao *et al.*, 2007; Wang *et al.*, 2011; Liu *et al.*, 2012b). Males treated with quinestrol showed less aggressive compared with control, but higher level of territorial defense which resulted in the failure of successful pregnancies (Wang *et al.*, 2011; Liu *et al.*, 2012a). Lv and Shi (2011a, 2011b) found that both quinestrol and levonorgestrel had negative effects on the reproduction of *M. unguiculatus*. However, other studies suggested that levonorgestrel has no anti-fertility effects on the reproduction of small mammals (Zhao *et al.*, 2007; Wang *et al.*, 2011). Liu *et al.* (2012b) suggested that levonorgestrel had positive effects on the pregnancy ratio of plateau pika at the early period after delivering the agent. In this study, we found that pika densities were significantly higher in levonorgestrel groups than that in quinestrol or EP-1 groups in 2007, this is consistent with the results of Liu *et al.* (2012b). As a mixture of quinestrol and levonorgestrel, EP-1 was reported to be effective in reducing several rodents' reproduction (Zhang *et al.*, 2004, 2005b, 2006). However, no significant anti-fertility effects of EP-1 were detected in some other rodent species such as *L. brandtii* and *O. curzoniae* (Zhao *et al.*, 2007; Wang *et al.*, 2011; Liu *et al.*, 2012). The sterilizing effects of EP-1 on rodents might be species specific.

After lethal control, mammal populations can recover rapidly. Thus, poison practices are often less effective (Pech *et al.*, 2007). The "residue" population has access to more food and space resources, and produces more offspring successfully. An overcompensation of population growth may occur and population abundance becomes even higher than under control conditions (Ericsson, 1970). In contrast, after fertility control, the sterile males do not reproduce, but still occupy territories, and compete with normal males for mates (Wang *et al.*, 2011; Liu *et al.*, 2012a). These behaviors keep populations under high stress and restrict the reproductive compensation; as a result, the population recovers more slowly (Bomford and O'Brien, 1997). Few offspring recruited into the population after fertility control. As short-lifespan rodents, 2-year-old offspring of plateau pika were the primary reproductive individuals (Qu *et al.*, 2013). The absence of recruitment undoubtedly limited the growth of population. There was a time lag effect of fertility control on pika densities; a significant reduction of population abundances could be detected in the second year of delivering quinestrol.

Plateau pikas continually maintain their burrows (Smith and Wang, 1991). Following the poisoning of plateau pikas, the burrow systems collapse and dege nerate rapidly, the birds relying on the pika burrows for nesting and raptors depending on pikas as prey disappear (Lai and Smith, 2003). Plateau pika plays a keystone role on maintaining avian diversity on the alpine meadow ecosystem. In this study, the baits we delivered near the pika burrows disappeared quickly in 3 to 5 days, the baits were relatively big for small birds to eat, therefore, we assumed that birds did not consume the baits, an thus the agents had no direct effects on small birds. After fertility control of plateau pika, avian diversity and bird species richness did not vary significantly except EP-1 groups in 2008. The pika densities was not lower in EP-1 groups in 2008, we suggest that other factors which have not been involved in this study influenced the avian diversity and species richness in EP-1 groups.

The most common bird species are white-rumped snowfinch and rufous-necked snowfinch on Tibetan Plateau. White-rumped snowfinch mainly uses active and rufous-necked snowfinch uses inactive pika burrows (Zeng and Lu, 2009). Plateau pika maintains a limited number of burrows. After fertility control, the abundances of plateau pikas were significantly reduced in quinestrol groups, thus few pika burrows were maintained. There were less active pika burrows, but more abandoned and inactive burrows. The reduction of pika abundances led to a decrease of white-ramped snowfinch and the increase of rufous-necked snowfinch in quinestrol groups in 2008. Most of the other small birds that inhabited the meadow were seasonal migrant species (del Hoyo *et al.*, 2004), and generally existed at much lower abundances. These species do not directly interact with pika and are not likely to be affected by the density decline of pika.

Lai and Smith (2003) found that there were few raptors such as kite and upland buzzard on poisoned sites where pikas were eliminated. We did not detect significant reduction of birds of prey in this study. After fertility control, plateau pikas were reduced to lower level but not extinct in an area. Considering the large territory and strong flight ability of birds of prey, the decrease of pika abundances had limited effects on them in this study.

Since there was a significant positive relationship between pika abundance and burrow density (Pech *et al.*, 2007), reducing pika abundance to local extinction has seriously effects on local ecosystems (Lai and Smith, 2003; Arthur *et al.*, 2008). The management of pika populations should take account of the conservation of native avian biodiversity. Our study demonstrated that fertility control of plateau pika using quinestrol resulted in the reduction of pikas from an average of 36 pikas /ha to 20 pikas /ha in the second year. Such a reduction of pika density did not significantly affect avian diversity. Therefore, compared to control using toxins, quinestrol may be a more humane method for pika management and has fewer negative consequences on biodiversity of the fragile alpine ecosystem. Further study is needed to investigate the long term effect of such fertility control on pika population as well as local biodiversity.

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