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REPRODUCTION AND BEHAVIOR OF PLATEAU PIKAS (*OCHOTONA CURZONIAE* HODGSON) UNDER PREDATION RISK: A FIELD EXPERIMENT

ABSTRACT: The mixture of the feces and urine of the red fox *(Vulpes vulpes* Linnaeus) was used to increase the perception of predation risk of plateau pikas (*Ochotona curzoniae* Hodgson) in the field. The influence of the predation risk on the reproduction and behavior of plateau pikas was examined through comparing reproductive characteristics and five different kinds of behavior between treatment and control plots. The results showed that 1) the body weight of the pikas was not significantly different between treatment and control plots. 2) The reproductive period of the pikas extended from March to later August in both treatment and control plots. The pregnant ratio, developed testes ratio, reproductive success and sex ratio of the pikas were not significantly different between the treatment and control plots. 3) The pikas increased their observing and calling frequencies and decreased their moving and feeding frequencies when exposed to red fox's feces and urine. 4) The increased red fox's feces and urine had no influence on the behavior of the pikas when the number of their natural enemies increased; the pikas obviously increased the observing frequencies and sharply decreased the calling frequency so as to decrease the direct predation risk. 5) There were no significantly behavioral differences between males and females as well as between adults and young. 6) The results reject the hypothesis 1 that the red fox's feces and urine as indirect predation risk suppresses the reproduction of the pikas and support the hypothesis 2 that the pikas can make decision by changing behavior to avoid the predation risk they encountered whenever.

KEY WORDS: plateau pika, red fox, predation risk, reproduction, behavior

1. INTRODUCTION

The mortality within prey populations as the direct result of predation is the most obvious interaction between predators and preys (Reid *et al.* 1995). Meanwhile, indirect effects of predators on the preys have also been recognized (Lima and Dill 1990, Klemola *et al.* 1997). The predation risk has long been implicated as a major selective force in the evolution of several morphological and behavioral characteristics of preys (Norrdahl and Korpimäki 1995). It may alter numerous activities of mammalian prey, such as the use of ranges and habitats, and foraging patterns (Brown *et al.* 1988, Desy *et al.* 1990, Jędrzejewska and Jędrzejewski 1990, Jędrzejewski and Jędrzejewska 1990, 1993, Kotler *et al.* 1994, Persson *et al.* 1999). It also affects the pregnant rate, sex ratio and population structure of preys by slowing the reproduction of the preys (Longland and Jenkins

1987, Dickman *et al*. 1991). The preys will alter reproduction cycle or estrum by endocrine regulation, or restrain reproduction by reducing copulation behavior when the predation risk increases (Korpimäki *et al*. 1994, Ronkainen and Ylönen 1994, Koskela and Ylönen 1995, Klemola *et al*. 1997). Therefore, animals have the ability to assess predation risks and make decision to avoid them (Lima and Dill 1990).

The plateau pika (*Ochotona curzoniae* Hodgson), whose distribution largely coincides with the high alpine grassland of the Qinghai-Xizang (Tibetan) plateau of People's Republic of China, is one of the dominant small mammals in the alpine meadow ecosystem. It makes burrows that are the primary shelters to a wide variety of small birds and lizards, such as Hume's Groundpecker (*Pseudopodoces humilis* Hume) and Snowfinch (*Montifringilla* spp.) (Smith and Foggin 1999, 2000, Lai and Smith 2003). It creates microhabitat disturbance that results in an increase in plant species richness (Smith and Foggin 1999, 2000, Lai and Smith 2003). It serves as the principal prey for nearly all predator species, such as foxes (*Vulpes vulpes* Linnaeus, *V. ferrilata* Hodgson), alpine weasel (*Mustela altaica* Pallas), asia polecat (*M. eversmanni* Lesson), desert cat (*Felis bieti* Milne-Edwards), manul (*F. manul* Pallas), upland buzzard (*Buteo hemilasius* Temminck et Schlegel), falcons (*Falco cherrug* J.E.Gray, *F. tinnunculus* Linnaeus, *F. peregrinus* Tunstall) and owls (*Bubo bubo* Linnaeus, *Athene noctus* Scopoli, *Asio otus* Linnaeus) (Wei *et al*. 1994, Zhou and Wei 1994, 1995, Wei and Zhou 1997, Lai and Smith 2003). So the plateau pika suffers from high predation risk and has developed reproductive and behavioral adaptation to decrease the risk. The plateau pika likes to live in open area (Shi 1983). It is sensible to Asia polecat's odor (Wei 1999) and changes its feeding behavior in the laboratory condition (Bian and Zhou 1999). It forages around the holes when the risk is increased by artificially covers in the field (Bian *et al.* 1999). It obviously increases the dispersion when its natural enemies increase (Wei *et al*. 1994). Meanwhile, the plateau pika can adjust its reproduction according to its population density and environment condition. Its reproductive period, the time of birth of litter each year and litter size vary with different places and years (Fan *et al*. 1999). However, there are scarce studies about the anti-predation behavioral characteristics of plateau pika and the effect of predation risk on the behavior and reproduction of plateau pika in natural condition.

The purpose of the present study was to compare the plateau pika's behavioral variables under different predation risks, to measure the effects of feces and urine of the red fox as indirect predation risk on the plateau pika's reproduction and then to examine the hypothesis that 1) the red fox's feces and urine as indirect predation risk suppresses the reproduction of the plateau pika, and 2) the plateau pika can trade-off the predation risk and make decision by changing the behavior

2. STUDY AREA

This study was performed from April 2001 to May 2002 at the Haibei Alpine Meadow Ecosystem Research Station of the Chinese Academy of Sciences in Qinghai. The working area is located at the northeast of Tibet, a large valley in the Qilian Mountains (37°29'–37°45'N, 101°12'–101°33'E), and is characterized by large mountain ranges with steep valleys and gorges interspersed with relatively flat and wide intermountain grassland valleys. Alpine meadow, alpine shrub, and swamp meadow are major vegetation types in this region. The climate is a continental monsoon type dominated by the southeast monsoon and high pressure from Siberia and the average temperature is −1.7°, ranging from −37.1° to 27.6°. The winter is long and severe and the summer is short and cool. The average annual precipitation ranges from 426 to 860 mm, 80% of which falls in the short summer growing season from May to September. The annual average sunlight is 2462.7 hrs with 60% of total available sunshine. Except of the plateau pika and its natural enemies, other major small mammals occur in the study area like plateau zokor (*Myospalax baibily* Thomas), root vole (*Microtus oeconomus* Pallas), gansu pika (*Ochotona cansus* Lyon), long-tailed dwarf hamster (*Cricetulus lon-*

gicaudatus Milne-Edwards) and himalayan marmot (*Marmota himalayana* Hodgson) (Fan *et al*. 1999). The density of the red fox was 0.16 ind. 100 ha^{-1} according to investigation by sport-light and snow-tracking as well as by visiting the local people before setting up the research plot.

3. MATERIAL AND METHODS

3.1. Experiment design

Two sites with equal size (1 ha) and similar population density of plateau pika (65 ind. ha^{-1}), vegetation type (*Kobreisa humilis* C.A.Mey) and geographical type (flat area) were chosen as the predation risk treatment plot and control plot, respectively. The distance between them was 500 m apart. This distance could prevent the plateau pika from moving between two plots because the average home range area of this species before reproduction period is 0.13 ha and is 0.23 ha during the reproductive season (Fan *et al*. 1999). In each month, the only feces deposited by red fox in two plots were investigated because it was difficult to notice the urine of red fox. We did not find natural feces deposited by red fox in two plots during research period. This would ensure the function of artificially increasing feces and urine of red fox.

In early April 2001, all pikas on the two plots were trapped using live-traps. Newly captured animals were sexed by manually everting the cloaca and examining for a penis or clitoris, weighed at each capture to the nearest 0.5 g, and then labeled with numbered, different colored and shaped ear-tags, and toe cut-off before released at the point of capture. 68 individuals were trapped on the control plot and 61 individuals were trapped on the treatment plot. Because the adult females usually synchronously produce the litters and focused their birth on three periods in study area, all pikas including young were trapped, marked and weighed again when lots of newborn pikas began to move on the ground in each period. All pikas were trapped four times in both plots in 2001. After all pikas were trapped for first time in each year, each plot was subdivided into a 10 × 10 m grid pattern. At each intersect point of grid, we dug a small hole on the ground and enchased a plastic glass into it as a feces and urine station. In each station, 50 g mixture of thawed feces and urine of red fox was put into it in the treatment plot and 50 g pure water was put into it in control plot. The thawed feces and urine or water were replaced in each station by new one on Monday of each week until the pikas finished their reproduction in September.

In early April 2002, the same experiment was repeated in two plots. 23 individuals were trapped on the control plot and 19 individuals were trapped on the treatment plot. There were no pikas living in two plots after middle May 2002 and our study did not continue as originally designed for three years.

The feces and urine used in the experiment was collected from breeding center of the red fox in Xining city, Qinghai Province. The plastic bag was hung under the box of raising fox and the mixture of the feces and urine in box and bag was collected after 24 hr, and then frozen until it was used. Total of 20 red foxes were used to collect the samples of the feces and urine during research period.

3.2. Behavior variables and measurements

The behavior variables were described as follows. 1) *Moving*: plateau pika moving from one point to another on the grassland in a non-social context, 2) *observing*: plateau pika sitting on the grassland with neck outstretched or standing with front feet off the ground, or raising head when feeding, 3) *calling*: plateau pika uttering with long and short calling, 4) *feeding*: plateau pika either gathering or feeding vegetation, 5) *social behavior*: plateau pika interacting with each other, such as contacting, grooming, nursing, mating, chasing, fighting, and etc.

The behavioral observations in two plots were conducted at the active peaks of the plateau pika from 7:00 to 11:00 a.m. and from 4:00 to 7:00 p.m. The observer and an assistant stationed themselves on natural promontories outside the range of the pika's movements, noted the location of the observed animal according to the color and shape of the pika's ear-tags and recorded the occurring frequencies of the behavior variables by the focal animal sampling on a continuous basis for standard periods of 10 min. The frequency of each behavior variable was expressed as the number 10 min^{-1}. After one individual was observed for 10 min, new individual was observed again and each animal was observed only for 10 min per day. In 2001, the behavior of the pika in the treatment plot was observed twice each week on the first day (Monday) and fifth day (Friday) after the thawed feces and urine of the red fox were replaced in the station. The behavior of the pika in the control plot was observed once each week on one random day from Monday to Friday after the pure water was replaced in the station. In April and May 2002, the behavior of the pika in two plots was observed only once each week on the first day after the pure water or the thawed feces and urine of the red fox were replaced in the station.

3.3. The reproductive indices and the number of natural enemies of the plateau pika

The reproductive indices of the pikas were expressed as the reproductive success (RS), pregnant ratio (PR), developed testes ratio (DT), sex ratio (SR) and the reproductive period (RP). Since it was very difficult to determine the young's affiliated relationships in the family during the reproductive season, the total number of young pikas beginning to move on the ground divided by the total number of adult pikas in the same period was used to calculate RS (%). PR (%) was the number of pregnant females divided by total number of trapped adult females. The developed testes indicated that the scrotum was heavy and could be easily seen because it contains fully developed testes, DT (%) was the percent of the number of developed testes adult males in the total number of trapped adult males. SR was showed by females/(females +males) for both adults and young in the same period. RP meant a period that mating behavior could be observed, or pregnant females and developed testes males could be found.

When we observed the behavior of the pika for every day, the number and species of the natural enemies appearing on or flying over the treatment plot and control plot were separately recorded from 2001 to 2002.

3.4. The statistic methods

When the body weights of plateau pika were analyzed, the pregnant females were included into them. The body weights of plateau pika within each plot at different periods were evaluated by two-way ANOVA and one-way ANOVA was used to calculate the statistical significance of differences of body weights between two plots. Only the data about behavior variables from April to May in both 2001 and 2002 were used to analyze differences between plots, years, sexes and ages by one-way ANOVA. With the reproductive indices of plateau pika in control plot as the expected value and that in predation risk treatment plot as the observed value, we compared the expected and observed values of RS, PR, DT and SR with *Chi-Squared* statistics, respectively. The natural enemies of plateau pika were classified as mammal predators and avian predators and their numbers for every day in both treatment and control plots from April to May were combined together to compare difference between two years by one-way ANOVA. The related data were presented as mean ± SE, and the $P \leq 0.05$ level was considered statistically significant.

4. RESULTS

4.1. Body weight

Only the weights of the pika in three periods were used to compare the difference after the pure water or thawed feces and urine of red fox were placed into stations. There were no significant differences between treatment plot and control plot for the body weights of adult males ($F_{1,96} = 0.502$, $P = 0.480$) and adult females ($F_{1,139} = 1.944$, $P = 0.165$) in the whole reproductive period (Figs 1 and 2). But the body weights of adult males sharply decreased from 30th May to 25th August in both treatment plot ($F_{2,30} = 8.226$, $P = 0.001$) and control plot ($F_{2,62} = 26.420$, $P = 0.000$), and of adult females also decreased from 30th May to 25th August in both treatment plot ($F_{2,57}$

Table 1. The reproductive indices of plateau pika (*Ochotona curzoniae* Hodgson) in 2001.
PR: Pregnant ratio (%); DT: Developed testes ratio (%); RS: Reproductive success (Ind.); SR: Sex ratio.

Period	Treatment plot[1]				Control plot[2]			
	PR	DT	RS	SR	PR	DT	RS	SR
4th–15th April	40.5	87.5	/	0.61	40.0	89.3	/	0.59
30th May–3rd June	46.7	100	1.4	0.57	42.9	100	1.32	0.57
10th–24th July	26.7	40.0	2.92	0.48	23.1	42.1	2.24	0.49
19th–25th Aug.	6.7	0.0	3.4	0.47	0.0	0.0	1.88	0.52

[1] Treatment plot: the study area of 1 ha where the feces and urine of red fox were put to increase artificially the predation risk of plateau pika.
[2] Control plot: the study area of 1 ha where the pure water was put into to compare with the treatment plot.

= 46.119, P = 0.000) and control plot ($F_{2,78}$ = 57.646, P = 0.000). At the same time, the significant differences were not found between the weights of adult males and adult females in the control plot ($F_{1,57}$ = 0.928, P = 0.339) and in the treatment plot ($F_{1,41}$ = 0.076, P = 0.785) during the period from 30th May to 3rd June, while the weights of adult females were much lower than those of adult males in the control plot ($F_{1,43}$ = 7.502, P = 0.009) and in the treatment plot ($F_{1,23}$ = 4.316, P = 0.049) during the period from 10th July to 24th July, and in the control plot ($F_{1,40}$ = 26.711, P = 0.000) and in the treatment plot ($F_{1,23}$ = 41.142, P = 0.000) during the period from 19th August to 25th August.

From 30th May to 25th August, the weights of young pika sharply increased in control plot for males ($F_{2,124}$ = 162.602, P = 0.000) and females ($F_{2,128}$ = 107.598, P = 0.000), and in treatment plot for males ($F_{2,117}$ = 112.696, P = 0.000) and females ($F_{2,95}$ = 55.109, P = 0.000). But the weights did not show significant difference between treatment plot and control plot for young males ($F_{1,245}$ = 0.395, P = 0.530) and for young females ($F_{1,227}$ = 3.305, P = 0.071) in the whole reproductive period.

4.2. Reproduction indices

When all pikas were trapped for the first time in April 2001 in both plots, we did not find the young moving on the ground. In control plot, 45% of adult females had their young according to the sucked nipples, 18% of adult females were pregnant according to the weight and 23% of adult females were pregnant and also had the young, 89% of adult males obviously developed their testes. In the treatment plot, 46% of adult females had their young, 19% of adult females were pregnant and 22% of adult females were pregnant and also had the young, 88% of adult males obviously developed their testes. During the whole research period, the time of the young pikas appearing and moving on the ground had three peak periods in both plots, there were from 30th May to 3rd June, from 10th to 24th July and from 19th to 25th August.

The reproductive indices of the pikas for different periods were showed in the Table 1. The test indicated that PR, DT, RS and SR of the pikas were not significantly different between the treatment plot and the control plot (respectively, χ^2 = 0.904, P> 0.825; χ^2 = 0.141, P> 0.986; χ^2 = 1.440, P> 0.487; χ^2 = 0.006, P> 0.999). In both plots, the pikas came into estrous period at least in March. PR and DT of the pikas were higher from April to June, the pregnant pikas sharply decreased and the few pikas had developed testes in July. It was difficult to find the pregnant females and the developed testes males in later August. All pikas finished their reproduction in September. After one winter, only 15 females and 8 males in the treatment plot and 12 females and 7 males in the control plot survived in early April 2002. SR in the treatment plot was 0.65 and 0.63 in the control plot.

4.3. Behavior variation

Table 2 displayed the behavior variables of the plateau pika in both plots in 2001. When the thawed feces and urine of red fox were placed into stations, the moving and feeding frequencies of the pika in the treatment plot on the first day were much lower than those in control plot ($F_{1,116}$ = 8.448, P = 0.004; $F_{1,116}$ = 20.491, P = 0.000) the observing and calling frequencies were opposite ($F_{1,116}$ = 5.967, P = 0.016; $F_{1,116}$ = 22.361, P = 0.000) and the social behavior frequencies were not significantly different between the treatment plot on the first day and control plot ($F_{1,116}$ = 2.363, P = 0.127). Compared with frequencies of the pika on the first day in the treatment plot, on the fifth day the calling frequency significantly decreased ($F_{1,118}$ = 8.005, P = 0.006), the feeding frequency apparently increased ($F_{1,118}$ = 28.689, P = 0.000), and the moving, observing and social behavior frequencies did not show the difference ($F_{1,118}$ = 0.915, P = 0.341, $F_{1,118}$ = 0.478, P = 0.491, $F_{1,118}$ = 0.564, P = 0.454). Only calling frequency in treatment plot on fifth day was higher than that in control plot ($F_{1,124}$ = 7.659, P = 0.007) and the frequencies of other variables did not show the differences between the treatment plot on fifth day and control plot (P> 0.05).

4.4. Effect of natural enemies increase

The red fox could not be observed because it seldom moves on the ground at daytime. So the observed natural enemies of the pika in whole research period were Alpine weasel, Asia polecat, falcons and upland buzzard. According to the numbers of natural enemies observed each day from April to early May, the numbers of the natural enemies in 2002 were higher than that in 2001 (mammal: $F_{1,21}$ = 4.045, P = 0.023; avian: $F_{1,21}$ = 5.162, P = 0.017) (Fig. 3). At this situation, the differences for all behavior variable of the

Table 2. The frequencies (number 10 min^{-1}) of the behavior variables of plateau pika (*Ochotona curzoniae* Hodgson) in 2001.

Behavioural variable	Treatment plot on first day[1] (N = 56)	Treatment plot on fifth day[2] (N = 64)	Control plot[3] (N = 62)
Moving	3.6 ±0.4	4.3 ± 0.6	5.8 ± 0.6
Observing	8.4 ± 0.8	7.7 ± 0.7	5.9 ± 0.6
Calling	2.4 ± 0.4	1.1 ± 0.2	0.5 ± 0.1
Feeding	0.3 ± 0.1	2.4 ± 0.3	2.2 ± 0.4
Social	0.4 ± 0.1	0.5 ± 0.1	0.7 ± 0.2

[1] Treatment plot (see Table 1) on first day indicates that behavior variables were observed on first day after the feces and urine of red fox were replaced in the station.
[2] Treatment plot on fifth day indicates that the behavior variables were observed on fifth day after the feces and urine of red fox were replaced in the station.
[3] Control plot (see Table 1) the behavior variables were observed on one random day from first to fifth after the pure water was replaced in the station.

Table 3. The frequencies (number 10 min^{-1}) of the behavior variables of plateau pika (*Ochotona curzoniae* Hodgson) in 2002. Treatment and control plots (for explanations see Table 1).

Behavioral variable	Treatment plot (N = 19	Control plot (N = 23)	Test		
			df	*F*	*P*
Moving	3.5 ± 0.7	3.9 ± 0.7	1. 40	0.19	0.665
Observing	26.8 ± 3.4	27.4 ± 3.4	1. 40	0.01	0.913
Calling	0.4 ± 0.2	0.2 ± 0.1	1. 40	0.36	0.552
Feeding	1.7 ± 1.2	2.9 ± 1.2	1. 40	0.43	0.507
Social	0.6 ± 0.3	0.5 ± 0.2	1. 40	0.09	0.766

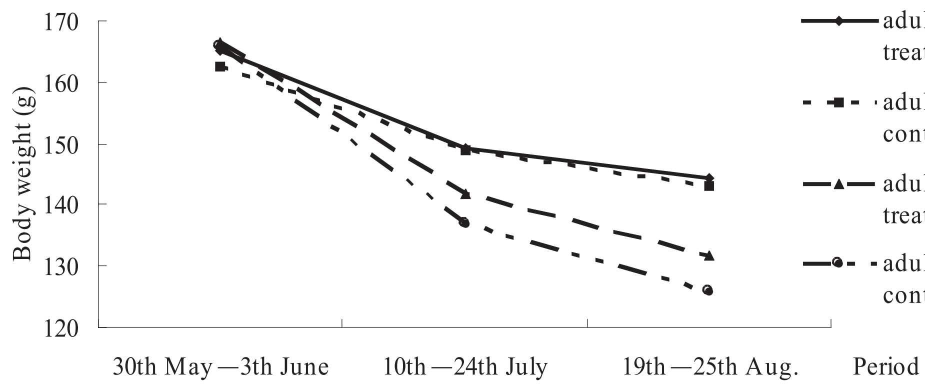

Fig. 1. The mean body weights of adult plateau pika in different periods in 2001. Treatment and control plots (for explanations see Table 1).

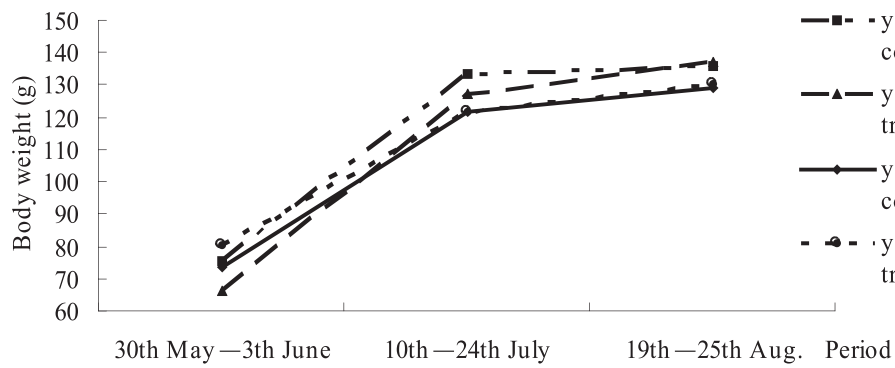

Fig. 2. The mean body weights of young plateau pika in different periods in 2001. Treatment and control plots (for explanations see Table 1).

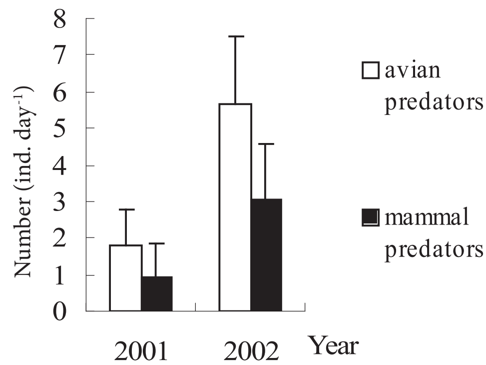

Fig. 3. The numbers of the plateau pika's predators in different years for treatment and control plots together (mean + SE). Treatment and control plots – for explanations see Table 1.

Table 4. The frequencies (number 10 min^{-1}) of the behavior variables of plateau pika (*Ochotona curzoniae* Hodgson) between males and females as well as between adults and young for treatment and control plots together in 2001

Behavior variable	Female (N = 93)	Male (N = 89)	Adult (N = 72)	Young (N = 110)
Moving	4.4 ± 0.4	4.7 ± 0.5	4.4 ± 0.5	4.7 ± 0.4
Observing	7.5 ± 0.6	6.6 ± 0.5	6.8 ± 0.6	7.2 ± 0.5
Calling	1.5 ± 0.3	1.1 ± 0.2	1.5 ± 0.3	1.2 ± 0.2
Feeding	1.6 ± 0.2	1.9 ± 0.3	1.4 ± 0.3	1. ± 0.3
Social	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1

pika were not found between the treatment and control plot when the pure water or thawed feces and urine of red fox were placed into stations (P> 0.05) (Table 3). But in the treatment plot, the observing frequency of plateau pika in 2002 was higher than that in 2001 ($F_{1,73}$ = 58.343, P = 0.000), the calling frequency significantly decreased from 2001 to 2002 ($F_{1,73}$ = 8.088, P = 0.006) and other behavior variables were not different (P> 0.05). Only the observing frequency was significantly increased ($F_{1,83}$ = 64.499, P = 0.000) and other behavior variables did not show significant differences from 2001 to 2002 in the control plot (P> 0.05).

4.5. Behavioral difference between sexes and ages

The data collected from the treatment and control plots in 2001 were combined to compare the differences between the sexes and between the ages (Table 4). The test showed that there were no significant difference in the behavior variables of males and females (P> 0.05), and of adults and young (P> 0.05); all individuals in the population had similar responses to the red fox's feces and urine.

5. DISCUSSION

Our study showed that the body weight of adult plateau pika decreased and that of young increased significantly during whole reproductive period in both predation risk treatment and control plots, but the differences of the body weights of adults or young between the two plots were not significant (Figs 1 and 2). These results indicated that the reproduction reduced the body weight of plateau pika and the feces and urine of the red fox, as indirect predation risk, could not influence the body weights of plateau pika. Meanwhile, our study also showed that reproductive success (RS), pregnant ratio (PR), developed testes ratio (DT), sex ratio (SR) and the reproductive period (RP) of the plateau pika were not influenced by the red fox's feces and urine (Table 1). So our results reject the hypothesis 1 that the red fox's feces and urine suppresses the reproduction of plateau pika. These results are inconsistent with the some reports of experimental studies as well as field observations in the deer mice *Peromyscus maniculatus* (Fairbairn 1977) and in the bank vole *Clethrionomys glareolus* (Ylönen 1989, Norrdahl 1993, Korpimäki *et al*. 1994, Ylönen and Ronkainen 1994, Koskela and Ylönen 1995) which some females can suppress breeding through influencing on the reproductive cycle, survival rate, dispersal rate, pregnancy rate, sex ratio and copulation. There are at least two apparent explanations for these differences.

Firstly, the special reproduction of plateau pika might be associated with the types and intensity of predation. Predators usually can be divided into three functional categories: resident specialist, resident generalist and nomadic specialist (Andersson and Erlinge 1977). Alpine weasel and Asia polecat are resident specialists, red fox and tibetan fox are resident generalists, and upland buzzards and falcons are nomadic specialists in study area (Wei *et al.* 1994, Zhou and Wei 1994, 1995). Although many researches have showed that avian predators influence the behavior of their preys (Brown *et al.* 1988, Kotler *et al.* 1991, Longland and Price 1991, Hakkarainen *et al.* 1992), Klemola *et al.* (1998) also found that the risk of avian predation do not have any obvious impact on pregnancy rate, mean litter size and growth rate of voles (*Clethrionomys glareolus, Microtus agrestis and M. rossiaemeridionalis*) compared with control voles studied. In our study, upland buzzards and falcons always exist in both plots and they mainly find the preys by visual cue and capture preys on the ground. The actual effect by avian predation on the behavior and reproduction of the plateau pika should have special study in the future. Small mustelids use olfactory cue to find preys and they suppress the reproduction of many preys by changing their estrous cycle (Jędrzejewska and Jędrzejewski 1990, Heikkila *et al.* 1993, Koskela and Ylönen 1995). Meanwhile, Ronkainen and Ylönen (1994) found that field vole (*Microtus agrestis*) responds to high predation pressure behaviorally decreasing the copulation times that can lead to reproductive suppression. Alpine weasel and Asia polecat mainly feed on plateau pikas and their effects on the population of the plateau pika are more significant than other predators (Wei *et al.* 1994, Zhou and Wei 1994). They use olfactory cue to search burrows (Wei 1999) and almost capture adult pikas and kill litter pikas in the burrows during reproductive period (Wei *et al.* 1994). Thus the feces and urines of weasel and polecat may have more important influence to the reproduction of the pika than that of other predators. When the red fox's feces and urine were used to increase the predation risk, the reproduction of plateau pikas were not significantly affected in the field. In fact, the red fox captures the plateau pika on the ground and the pika can depend on the complicated burrows to avoid the predation of red fox. Meanwhile the feces and urine of red fox exists all the time under natural situation and artificially increasing red fox's feces and urine in our study just was to enhance the function of the feces and urine.

Secondly, animals have formed the capacity of assessing the various risks and can adopt corresponding behavior to decrease the risks (Longland and Price 1991, Kotler *et al.* 1992, Korpimäki *et al.* 1996). In the process of assessing predation risk, chemosensory detection plays an important role in finding food and avoiding predators for preys (Jędrzejewski and Jędrzejewska 1993). When preys detects the chemical signals from their predators, many animals adjust their activities by decreasing active time, shifting active region, or using refuge to decrease the predation risk (Petranka *et al.* 1987, Keefe 1992, Cupp 1994, Hileman and Brodie 1994). Our results showed that plateau pikas reduced their moving and feeding frequencies, and increased observing and calling frequencies to decrease predation risk when the feces and urine of red fox, as an indirect predation risk, was placed in the treatment plot (Table 2). It indicates that plateau pikas can identify the type of predation risks by chemosensory detection and adopt corresponding behavioral strategy to reduce the influence of the predation. So the indirect predation risk has significantly affected the plateau pikas' behavior. The foraging behavior of plateau pikas is similar to chicken's "pecking" patterns and observing is an important component of the foraging behavior of the pika (Bian *et al.* 1999). But the increase of observing frequency does not always result in the decrease of foraging frequency. Our field observation showed that observing frequency of the pika also increased at the moment before movement began when the predation risk was increased. Bian *et al.* (1999) also reported that plateau pikas could focus on their activities near the entrances of the burrows after the cover on the ground had been increased. Therefore, the increase of observing frequency and the decrease of feeding frequency for plateau pika are mainly affected by the predation risk. Meanwhile, our results showed that the observing frequency of plateau pika was higher whether indirect or direct predation risk increased, but the calling frequency of plateau pika significantly increased after indirect predation risk was increased in 2001 and significantly decreased after direct predation risk was increased in 2002 (Table 3).

Observing is one of the main methods for animals to reduce predation risk while calling mainly has the function of communication. Animals will exhibit the calling behavior after they have detected predation risk by observing. Though calling will increase the individual's predation risk, it decreases the predation risk of whole population (Randall *et al.* 2000), so plateau pikas maybe increase their inclusive fitness by altruistic behavior to other individuals within the population when indirect predation risk increases. When the direct predation risk increases, the decrease of calling frequency of plateau pikas means to reduce the opportunities of exposing themselves to the natural enemy directly, which in turn will directly increase their own fitness and survival rate (Klemola *et al.* 1997). When the direct predation risk exceeds the tolerance, plateau pikas will reduce the pressure from predators by dispersal. In April 2001, the population densities of plateau pikas in the treatment and control plots were 61 ind. ha^{-1} and 68 ind. ha^{-1}, respectively. In March 2002, rodent control by poison method was conducted in large scale in Qinghai province except of study area of about 6 km^2. The predators of pika moved into the study area to find food and the number of predators around the study plots increased significantly (Fig. 3). We could always see 4–6 hawks sitting around the plots and 2–3 Alpine weasels and Asia polecats searching food within two plots. Sometimes Alpine weasel and Asia polecat lived within the plots. In April 2002 the population densities in both plots were apparently reduced to 19 ind. ha^{-1} and 23 ind. ha^{-1}, respectively. In the middle of May 2002, there were no plateau pikas living in the two plots. Some pikas certainly were killed by their natural enemies, some dispersed to other places. The areas, where the living pikas were not find before April, were occupied by pika and some pikas were marked in our study. This confirms that dispersal is the major way to increase the survival rate of plateau pika because it allow to wide the distribution area and to dilute the population density.

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