



Keystone status of plateau pikas (*Ochotona curzoniae*): effect of control on biodiversity of native birds

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Abstract. The plateau pika (*Ochotona curzoniae*) of the Qinghai–Xizang (Tibetan) plateau, People's Republic of China, has been considered a pest because it putatively competes with native livestock for forage and contributes to rangeland degradation. As a result the plateau pika has been poisoned across vast areas of the high alpine meadows of the plateau. The plateau pika has also been considered a keystone species for biodiversity on the plateau. As one test of the keystone species hypothesis, we investigated the effects of poisoning plateau pikas on avian species richness and abundance. We conducted standardized censuses of birds on a number of sites across the alpine grassland of Qinghai province on which pikas either had or had not been poisoned. Avian species richness and abundance were higher on non-poisoned sites, in particular for species that nest in pika burrows such as Hume's groundpecker (*Pseudopodoces humilis*) and six species of snowfinch (*Montifringilla* spp., *Pyrgilauda* spp.), and species that prey on pikas (upland buzzard, *Buteo hemilasius*; black-eared kite, *Milvus lineatus*). The plateau pika thus appears to be both an allogenic engineer and a keystone species. Poisoning pikas reduces biodiversity of native species on the Qinghai–Xizang plateau, therefore management decisions concerning plateau pikas should reflect caution and careful assessment.

Introduction

When native small mammals reach high densities, they are often labelled as pests and subjected to control measures. Such is the case with the plateau pika (*Ochotona curzoniae*), whose distribution largely coincides with the high alpine grasslands of the Qinghai–Xizang (Tibetan) plateau of China. For decades the pikas have been blamed for reducing forage available for domestic livestock (yak, sheep, horses), and degrading habitat (locally termed 'black sands') (Ekvall 1968; Schaller 1985; Wang et al. 1995; Fan et al. 1999). As a result of these preconceptions, and concomitant with the increasing degradation of these alpine grasslands over the past 40 years (Lang et al. 1997), the plateau pika has become the object of an extensive control effort. Poisoning of pikas and the Chinese zokor (*Myospalax fontanierii*) began in 1958 and had escalated greatly by 1962 (Fan et al. 1999). In 1964 and 1965 more than 26 667 km² in 20 counties in Qinghai province were treated with both zinc phosphate and fluoroacetate (Compound 1080; Fan et al. 1999). Fan et al. (1999)

estimate that in Qinghai from 1960 to 1990 “Cumulatively, more than 208 000 km² ... was treated with rodenticides ...”. A separate estimate by Drandui (1996) concludes that between 1986 and 1994 insect and ‘rodent’ control programs were broadcast over an area of 74 628 km² – nearly one-fifth of Qinghai’s provincial grazing lands. These massive poisoning programs are ongoing in spite of the absence of a comprehensive analysis of the role of the plateau pika in the ecosystem (Smith and Foggin 2000).

An alternative viewpoint to the perspective that common native small mammals are pests is that they may be important ecological components of the ecosystem (Dickman 1999). In many cases, small mammals are considered ‘allogenic engineers’ because their activities alter the environment by transforming living or abiotic materials from one state to another by mechanical or other means (Dickman 1999). An example would be the construction of burrows by one species that are later used by other species such as birds, reptiles, or other small mammals. In extreme cases, because of their abundance and potential ecological importance, certain small mammals can be considered ‘keystone species’. A keystone species is one whose elimination or major decimation from an ecosystem would have a greater than average effect on other species’ populations or ecosystem processes – one that has a disproportionately large influence on other species in a community (Heywood 1995; Power et al. 1996). The role of a keystone species should be unique, compared to other ecological processes or the roles of other species (Kotliar 2000).

The plateau pika has been considered a keystone species for biodiversity on the plateau, based on a review of the natural history and ecology of the pika and those species living in sympatry with it (Smith and Foggin 1999, 2000). The burrowing activity of pikas may minimize soil erosion, enhance the ability of soil to absorb precipitation, contribute to nutrient cycling, and create microhabitats resulting in increased plant species richness.

As allogenic engineers, the burrows constructed by the plateau pika function as breeding habitat for many species. Hume’s groundpecker (*Pseudopodoces humilis*) and several species of snowfinch (*Montifringilla adamsi*, *M. nivalis*, *Pyrgilauda blanfordi*, *P. davidiana*, *P. ruficollis*, *P. tacazanowskii*) nest primarily in pika burrows (Prejevalski 1876; Meyer de Schauensee 1984; Feng et al. 1986; Ma 1995; Schaller 1998; MacKinnon 2000). Similarly, small snowfinches (*P. davidiana*) and Isabelline wheatears (*Oenanthe isabellina*) regularly nest in the holes of Daurian pikas (*O. daurica*), an ecologically similar species that also occupies portions of the plateau (Smith et al. 1990).

Finally, the pika serves as the principal prey for nearly all of the plateau’s predators (Smith and Foggin 1999, 2000). The large predatory birds on the plateau may depend on the plateau pika as a food source. Schaller (1998) determined that 90% of pellets under the nest of a saker falcon (*Falco cherrug*) contained pikas, while all of the pellets beneath the nest of an upland buzzard (*Buteo hemilasius*) contained pika remains. Daurian pikas comprise the following percentages of the diet of avian predators in southeast Transbaikalia: steppe eagle (*Aquila nipalensis*), 62%; upland buzzard, 17%; Eurasian eagle owl (*Bubo bubo*), 73%; and saker falcon, 22% (Peshikov 1957, 1967). Taken together, these observations indicate that avian

species richness may be higher in areas where plateau pikas occur, as opposed to areas where they have been controlled (Ma 1995; Smith and Foggin 1999, 2000); however, there have been no direct tests of this hypothesis.

Which is the correct view? Is the plateau pika a pest or a keystone species? What will be the long-term impact if the massive poisoning of pikas is continued, or if they are instead managed to preserve the characteristic biodiversity of the Qinghai–Xizang plateau? A first step to answering these questions is to test the hypothesis that the plateau pika is a keystone species in the alpine meadow ecosystem.

To test the prediction that plateau pikas operate as a keystone species in the alpine grassland ecosystem, we examined avian species richness in relation to the presence of plateau pika populations. This study directly examines avian species richness in areas where pika populations have been drastically reduced or eliminated by poisoning, in contrast to areas harboring undisturbed populations of pikas. If pikas serve as a keystone species, then areas that have been poisoned should have lower avian species richness than areas where pikas have not been poisoned.

Methods

Study areas

Thirteen sites on the alpine grasslands of Qinghai province were chosen for sampling during summer 2000 (Figure 1) using a variety of criteria. Evidence on each site indicated current or prior presence of *Ochotona*, and areas classified as a winter pasture were selected to ensure as much consistency among sites as possible. In addition, it was essential to obtain historical information about each site from interviews with representatives of the local Animal Husbandry Bureau (AHB) and/or local pastoralists. The sites selected stretched across most of Qinghai province, occurring in four of eight provincial prefectures and in eight different counties (Figure 1), and ranged in altitude from 3200–4300 m.

At six sites plateau pikas had been extensively poisoned within the past 3–5 years, reducing their respective populations to <5% of their pre-poisoned density. These sites were characterized by abandoned and collapsed pika burrows. Seven sites had not been poisoned within the past 3–5 years, and using scan censuses we estimated they contained healthy pika populations with a minimum density of 50 pikas per ha. Two of the non-poisoned sites had been targeted for poisoning by the local AHB, but the resident pastoralists had not complied with this recommendation because of their religious beliefs.

Survey methods

At each site we established three standardized 1 km transect lines (however, only

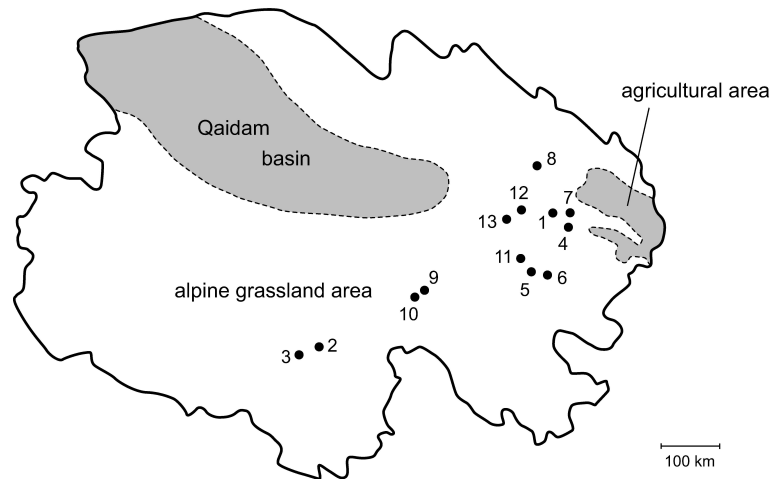


Figure 1. Map of Qinghai Province, People's Republic of China. The non-shaded portion delimits the high alpine grasslands of the Qinghai–Xizang (Tibetan) plateau. Numbered circles indicate study sites: 1–7 = sites where plateau pikas (*Ochotona curzoniae*) had not been poisoned; 8–13 = sites where plateau pikas had been poisoned.

two transects were established at Site 1) that extended for the length of each study site. The placement of these transects reflected the variability of terrain and vegetation at each site. The transects were marked with coloured flags.

An index of presence and prior presence of pikas was obtained by counting the number of fresh (open) pika burrows and/or the number of collapsed pika burrows along a 3 m wide belt centred on the transect line. Collapsed burrows were further classified as partially or fully collapsed.

An index of the presence and abundance of bird species was used to indicate biological diversity. Each transect line was censused three times each day (morning, mid-day, and afternoon) for 2 days, and each census took 1 h. The index of the presence and abundance of each bird species at each site was calculated as the number of individuals sighted per hour averaged across the three transect lines, three times of day, and two days of each census. All birds sighted during a survey were identified and tallied, and care was taken to avoid double counting. A total of 228 h was dedicated to bird censuses. Common and scientific names of bird species follow MacKinnon (2000).

Additionally, in early August 2002 we censused upland buzzards, the most common raptor on the plateau, in relation to the presence or absence of pika populations. Our census was conducted by driving a 1100 km transect north to south across the plateau. Upland buzzards often perch on power poles or the meadow and are easily spotted from a vehicle (as there are no trees or obstructions to vision). We stopped to look for pikas if they could not also be seen from the vehicle.

Results

Pika populations

Counts of fresh and collapsed pika burrows reflect the differences in population density of plateau pikas between the poisoned and non-poisoned sites. Pikas continually maintain their burrows (Smith and Wang 1991), and burrows collapse and degenerate quickly after pikas have been eliminated from an area. The average number of fresh burrows tallied along each three 1 km transect lines at the seven non-poisoned sites was 111.7 (SEM = ± 9.6), which was indicative of the high populations of pikas at these sites. In contrast, we recorded no fresh burrows along the transects at any of the six poisoned sites, and the average number of partially and fully collapsed burrows was 15.2 (SEM = ± 1.9) and 28.3 (SEM = ± 3.9), respectively. At three of the poisoned sites, pikas were encountered infrequently (an average of less than three sightings per hour), and no pikas were seen at the remaining three sites.

Avian censuses

Fourteen bird species were tallied during the walk censuses (Figure 2). Of these, one was the plateau endemic, Hume's groundpecker (*Pseudopodoces humilis*), and six species were central Asian snowfinches, forms that occur primarily on the plateau: Tibetan snowfinch (*Montifringilla adamsi*), white-winged snowfinch (*M. nivalis*), plain-backed snowfinch (*Pyrgilauda blanfordi*), small snowfinch (*P. davidiana*), rufous-necked snowfinch (*P. ruficollis*), and white-rumped snowfinch (*P. taczanowskii*). Each of these species nests primarily in burrows dug by pikas. Two other commonly encountered species nest on the meadow surface: the horned skylark (*Eremophila alpestris*), whose geographic range extends across much of Asia, Europe and North America, and the crested lark (*Galerida cristata*). The only other small bird species sighted more than once per hour was the fork-tailed swift (*Apus pacificus*), which was primarily encountered at sites near Qinghai Lake. Passerines that were sighted less than once per hour were the Eurasian tree sparrow (*Passer montanus*) and red-billed chough (*Pyrrhocorax pyrrhocorax*). Two raptors were also observed: the black-eared kite (*Milvus lineatus*) and the upland buzzard (*Buteo hemilasius*).

Overall, an average of 6.4 bird species was encountered on non-poisoned sites ($n = 7$; SEM = ± 0.3), whereas about half this number ($X = 3.7$; $n = 6$; SEM = ± 0.9) was tallied on poisoned sites. Even more striking was the difference in overall abundance, indicated by the total number of birds seen per hour at each site. Nearly five times as many birds were present on non-poisoned sites ($X = 61.2/\text{h}$; $n = 7$; SEM = ± 5.5) as on poisoned sites ($X = 12.5/\text{h}$; $n = 6$; SEM = ± 2.0).

The differences in abundance between poisoned and non-poisoned sites were largest for those species that rely on pika burrows for nest sites and cover (Figure 2). For the obligate burrow-dwellers (Hume's groundpecker and six snowfinch

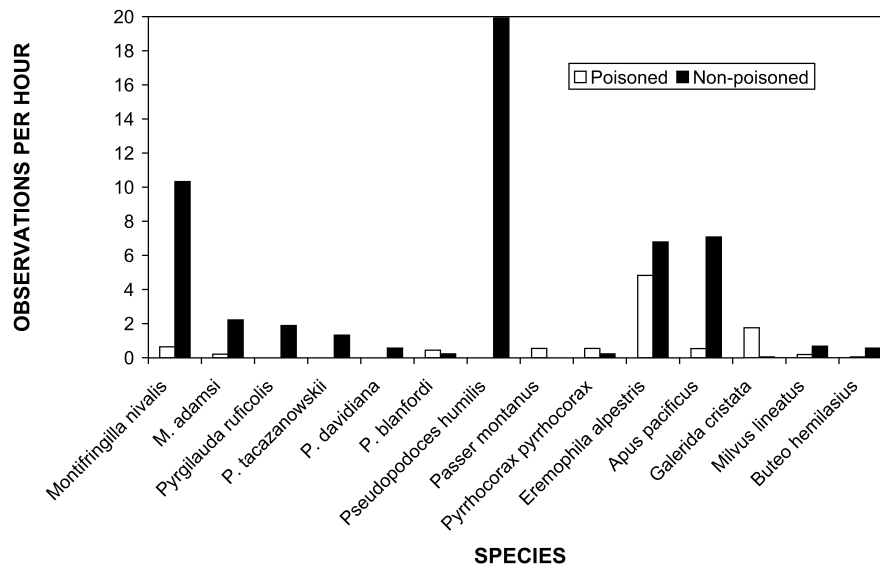


Figure 2. Observations per hour (see text for sampling regime) of 14 bird species on sites where plateau pikas (*Ochotona curzoniae*) had been poisoned (open bars) and sites that had not been poisoned (closed bars), Qinghai Province, People's Republic of China. Bird species include Tibetan snowfinch (*Montifringilla adamsi*), white-winged snowfinch (*M. nivalis*), plain-backed snowfinch (*Pyrgilauda blanfordi*), small snowfinch (*P. davidiana*), rufous-necked snowfinch (*P. ruficollis*), white-rumped snowfinch (*P. tacazanowskii*), Hume's groundpecker (*Pseudopodoces humilis*), Eurasian tree sparrow (*Passer montanus*), red-billed chough (*Pyrrhonorax pyrrhonorax*), horned skylark (*Eremophila alpestris*), fork-tailed swift (*Apus pacificus*), crested lark (*Galerida cristata*), black-eared kite (*Milvus lineatus*) and upland buzzard (*Buteo hemilasius*).

species), an average of 3.57 species ($SEM = \pm 0.3$) was found on non-poisoned sites, whereas an average of only 0.67 species ($SEM = \pm 0.3$) was found on poisoned sites.

The combined rate of sighting of all snowfinch species was significantly higher on non-poisoned than on poisoned sites (Mann-Whitney $U = 42$; $P < 0.01$), and there were almost 13 times as many snowfinches on non-poisoned sites ($X = 16.6/h$; $n = 7$; $SEM = 2.4$) than on poisoned sites ($X = 1.3/h$; $n = 6$; $SEM = 0.7$). Three of the snowfinch species were never seen on poisoned sites, and five of the six species were sighted more frequently on non-poisoned than on poisoned sites. These differences were significant for two species: white-winged snowfinch (Mann-Whitney $U = 42$; $P < 0.01$) and rufous-necked snowfinch (Mann-Whitney $U = 33$; $P < 0.01$).

Hume's groundpecker was nearly 20 times more abundant on non-poisoned sites ($X = 19.9/h$; $n = 7$; $SEM = \pm 2.3$; 2418 sightings in 120 census hours) than on poisoned sites (no sightings in 108 census hours), a difference that was significant (Mann-Whitney $U = 42$; $P < 0.01$).

The other most commonly sighted species, the horned skylark, was also seen somewhat more frequently on non-poisoned sites than on poisoned sites (6.8 vs. 4.8

sightings/h; Figure 2), even though it is not an obligate nester in pika burrows. It commonly occurred on all sites. In contrast, the other passerine birds were seen infrequently, and three of them (the crested lark, red-billed chough, and Eurasian tree sparrow) were seen more frequently on the poisoned sites (Figure 2). None of these differences, however, was significant (Mann–Whitney U tests).

Both raptor species were tallied more often on non-poisoned than on poisoned sites, but the difference was significant only for the black-eared kite (Mann–Whitney $U = 34$; $P = 0.05$). Black-eared kites and upland buzzards were seen respectively 3.6 and 11.2 times more frequently on non-poisoned than on poisoned sites. Of raptor sightings on poisoned sites, 80% occurred at the two localities (Sites 9 and 10) where remnant populations of pikas yielded censuses exceeding one sighting per hour.

Our crossplateau transect census of upland buzzards showed an almost perfect correlation between sightings of upland buzzards and active populations of plateau pikas. No upland buzzards or pikas were sighted during the first 300 km driving south from Xining, the capital of Qinghai. Our first sighting of both species occurred simultaneously, just north of the town of Wen Quan. Along some stretches with high pika populations, upland buzzards could be seen on nearly every power pole (55 upland buzzards were sighted in one day in southern Qinghai), yet interspersed with these observations were frequent stretches where neither pikas nor upland buzzards were observed.

Discussion

For approximately 2200 years the high alpine grasslands of the Qinghai–Xizang (Tibetan) plateau (extending over 2.5 million km² or approximately one-quarter the area of the People's Republic of China) have supported sustainable animal husbandry of domestic yak and other livestock by pastoralists, along with a characteristic flora and fauna adapted to the harsh conditions of intense cold and high elevation (Goldstein and Beall 1990; Zhao 1992; Miller 1995; Richard 2000). Now, this region is at a crossroads. Over the past few decades these rangelands have suffered severe degradation, and many independent research programs have concluded that the current productivity of plateau rangelands is around 30% less than that of only two decades ago (Foggin 2000). One comprehensive study sampled 111 villages in a relatively productive region of Qinghai province and found that during a 30-year period above-ground biomass decreased by over 73%, while prevalence of toxic plants increased by 5.6 times (Lang et al. 1997). Simultaneously the native fauna has been greatly reduced, and nearly every medium-to-large mammal species is now classified as threatened (Category I or Category II species under the PRC Wildlife Protection Law; MacKinnon et al. 1996; Schaller 1998). It has become increasingly clear that the alpine grassland ecosystem on the Qinghai–Xizang plateau is in danger of losing much of its native biodiversity and its ability to support sustainable pastoralism, the region's primary economic activity (Foggin 2000). Accurate data and analyses of the alpine grassland ecosystem and its ecology are necessary to

understand this trend and ensure that the next generation of environmental management decisions in the region will lead to long-term restoration of the health of the grasslands and its biodiversity.

This paper addresses one 'development' activity which has been promulgated widely on the plateau for approximately 40 years: the poisoning of plateau pikas in an attempt to increase rangeland productivity for livestock and to minimize the (putative) rangeland degradation caused by pikas (Wang et al. 1995; Fan et al. 1999). These control efforts have been extensive and are ongoing, and plateau pikas have already been eradicated from vast expanses of Qinghai's alpine grasslands. This control campaign has been executed without an examination of the ecological role of the plateau pika. What have been the effects of this widespread poisoning? Here, we evaluate the role of plateau pikas in relation to the biodiversity of native birds.

Relationship between plateau pikas and avian biodiversity

Bird species richness and overall avian abundance were greater on sites that had not been poisoned, compared with poisoned sites. Pika control on the high alpine grasslands of Qinghai province has been pursued actively for approximately 40 years. One of us (A.T.S.) has conducted field studies on the grasslands of Qinghai since 1984 and qualitatively noted vast expanses of habitat virtually devoid of birds. In this study, however, we chose sites that were poisoned relatively recently (within the past 5 years) to assess the potential for direct impact of poisoning on avian diversity. Within this short timeframe changes in the avian community were dramatic. Our long transect census of upland buzzards in 2002 further supports the facultative nature of the relationship between birds and pikas. Sightings of upland buzzards were indicative of active natural pika populations, whereas stretches through which we saw no buzzards were simultaneously devoid of pikas, presumably due to poisoning.

An important feature of biodiversity analysis is an assessment of those species that are endemic to a region. In the present study Hume's groundpecker represents a monotypic genus that is found only on the Qinghai–Xizang plateau, and four of six snowfinches (Tibetan, white-rumped, rufous-necked and plain-backed) are plateau endemics (MacKinnon 2000). Hume's groundpecker and two plateau endemic snowfinch species were observed only on non-poisoned sites, and overall species richness and abundance of these forms were higher on non-poisoned sites. Following the poisoning of plateau pikas, the burrow systems constructed by pikas degrade rapidly, and the avian forms that rely on the burrows for nesting and cover essentially disappear. Thus, the plateau pika clearly plays the role of an allogenic engineer in the alpine meadow ecosystem (*sensu* Dickman 1999). But, does this also lead to the classification of the plateau pika as a keystone species?

Plateau pika keystone species status

Controversy concerning the keystone-species concept (Power et al. 1996; Stapp

1998; Kotliar 2000; Miller et al. 2000) has led to refinement in its definition. A species is generally considered to play the role of a keystone species if: (1) it exerts a large effect on community structure and function (i.e. high overall importance); (2) these effects are disproportionately large relative to abundance (i.e. high community importance; Power et al. 1996); and (3) it provides unique functions not performed by other species or processes (Kotliar 2000).

Clearly the plateau pika meets the first of these criteria. In its functional role as an allogenic engineer, the pika provides habitat for many bird species (also lizards; Li 1989; Smith and Foggin 1999, 2000). When present at its characteristic high densities, the plateau pika serves as food for most predatory birds and mammals on the alpine grasslands (Schaller 1998; Smith and Foggin 1999, 2000). The two raptor species in this study were more abundant on areas where pikas were present than on poisoned sites. Our knowledge of the effects of plateau pikas on ecosystem-level processes, however, is indirect and extrapolated from ecologically similar species (the Daurian pika, *O. daurica*, and North American prairie dogs, genus *Cynomys*; Smith and Foggin 1999, 2000). There is a need for controlled experiments on the effect of plateau pikas on ecosystem-level processes such as nutrient cycling, disturbance, rates of erosion, etc.

Application of the second criterion has been more problematic (Kotliar 2000). Of particular concern is the issue that a species must exert an effect larger than would be predicted by their abundance. Using prairie dogs as an example, Kotliar et al. (1999) and Kotliar (2000) found that the assumption that overall importance was a linear function of abundance was invalid, and determined that community importance was sensitive to levels of abundance and issues of scale. It would be useful to examine these issues for plateau pikas. However, in our controlled examination of the effect on avian diversity and abundance caused by poisoning pika populations, the crucial dynamic was presence or absence of pikas, not gradations in their abundance. Thus, we were unable to test this criterion directly.

The third criterion for the determination of plateau pikas as a keystone species concerns their unique role in the high alpine grassland ecosystem of the Qinghai–Xizang plateau. No other mammalian species provides analogous ecological services. Among herbivorous mammals, native large grazing ungulates have been nearly eliminated from the areas in which we worked (Foggin 2000). Similarly, woolly hare (*Lepus oiostolus*) and Himalayan marmot (*Marmota himalayana*) populations have been greatly reduced across the plateau; these species are rarely sighted in the project area. Most other species of *Ochotona* in the region occupy different habitats (rocks, shrubs, or more xeric biomes; Smith et al. 1990). The Chinese zokor (*Myospalax fontanierii*) makes burrows, and thus may contribute to aspects of ecosystem-level processes, such as disturbance and nutrient cycling. But, its burrows have closed entrances which cannot function as nesting sites for Hume's groundpecker or snowfinches. One of us (A.T.S.) has conducted two long-term studies at different sites within the region of the present study (Smith et al. 1986; Wang and Smith 1988, 1989; Smith and Wang 1991; Dobson et al. 1998, 2000), and no other small herbivorous mammals have been sighted. The plateau pika is the only small burrowing mammal distributed commonly across the alpine grasslands of the

Qinghai–Xizang plateau, and this lack of ecological redundancy contributes to its classification as a keystone species.

Conservation implications

The purpose of the keystone-species concept in conservation is to identify those species whose loss would trigger a cascading effect of impoverishment in an ecosystem. We have identified the alpine grassland ecosystem of the Qinghai–Xizang plateau as being at a crossroads – the health of the land, its native biodiversity, and its ability to sustain the pastoralist economy are all at risk. We have demonstrated that eradicating populations of plateau pikas is associated with the loss of avian species richness and abundance, and in particular those forms which are most unique to the plateau ecosystem. In addition, ongoing efforts to control pikas may lead to further losses of predators and disruption of ecosystem-level processes (Smith and Foggin 1999, 2000).

It is unfortunate that in the face of ongoing degradation of the alpine grassland ecosystem, the first response by many local and provincial-level government bodies and most international aid agencies working in the region is to target poisoning of the pikas. The reasons for this response are complicated, but usually reflect the ease with which pika control can be articulated. However, the actual root causes of rangeland degradation are exceedingly complex and include overstocking, overgrazing, disruption of culturally established practices for utilizing summer and winter ranges, and climate change (Miller 1995; Foggin 2000; Richard 2000). Financial considerations are also an issue: for example, international aid and anti-poverty alleviation agencies feel compelled to spend money, and poisoning pikas is a discrete activity for which funds can be allocated easily. On the receiving side, local governments are grateful to accept funds to control pikas, as these may be their only return from the regional involvement of international aid or higher-level Chinese governmental agencies.

These decisions apparently are made without asking the broader question of the long-term effect of poisoning pikas. For example, the recently completed European Union Qinghai Livestock Development Project (Van Wageningen and Sa 2001) focuses on the role of pikas as a pest. The QLDP was initiated with the goal of finding better ways to “control of rodent – especially ‘pika’ damage” (p. 2), rather than to ask whether or not the pika contributed to grassland degradation. The QLDP claims that “Qinghai province is severely infested with rodents” (viz. pikas; p. 50); however, no criteria were established to measure infestation or potential levels of degradation by pikas. Further, the QLDP states that pikas cause “a reduction in ecosystem biodiversity” (p. 50), although no data were presented on the subject of biodiversity of native species in any context (Van Wageningen and Sa 2001). Yet, approaches such as that taken by the QLDP are used to justify ongoing poisoning campaigns.

We feel that it is time to address the role of plateau pikas in the alpine grassland ecosystem clearly and unambiguously, and without resorting to unsubstantiated claims. A precautionary approach would dictate that deliberate poisoning of a native

species, especially of the magnitude involved, should not be initiated until there is a comprehensive understanding of the ecology of these grasslands, including the interaction of animal husbandry and pikas. Our data show that poisoning pikas has a negative impact on biodiversity and some ecosystem functions. Thus, the keystone role played by plateau pikas should be considered in any future management measures designed to improve or maintain the sustainability of the sensitive alpine grassland ecosystem of the Qinghai–Xizang plateau.

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