

Short Communication

The Endangered Siberian marmot *Marmota sibirica* as a keystone species? Observations and implications of burrow use by corsac foxes *Vulpes corsac* in Mongolia

JAMES D. MURDOCH, TSERENDORJ MUNKHZUL, SUURI BUYANDELGER
RICHARD P. READING and CLAUDIO SILLERO-ZUBIRI

Abstract The Siberian marmot *Marmota sibirica* is a social, colonial-living rodent that ranges widely throughout northern Asia. In Mongolia the species has declined substantially in recent years due to overharvesting for fur, meat and body parts, used locally and traded illegally in international markets. The Siberian marmot is often considered a keystone species because its burrows appear to represent an important resource for a variety of taxa, including carnivores. However, few studies have quantified marmot burrow use by other species, although such use may be important for developing conservation strategies. We monitored patterns of burrow use by 10 radio-collared corsac foxes *Vulpes corsac* during a study in Mongolia during May–November 2006. Corsacs used marmot burrows regularly and at rates greater than expected by chance, suggesting that burrows represent an important resource for foxes and supporting the notion of the Siberian marmot as a keystone species. As corsacs are also declining in Mongolia we contend that targeted patrols of marmot colonies in certain areas would provide a cost-effective means of protecting both species.

Keywords Burrow, corsac fox, keystone species, *Marmota sibirica*, Mongolia, Siberian marmot, *Vulpes corsac*.

The Siberian marmot *Marmota sibirica* is a large (c. 6–8 kg), colonial-living rodent that ranges across the grassland, semi-desert, and forest steppes of northern Asia (Fig. 1; Bannikov, 1954; Mallon, 1985; Clark et al., 2006a). In Mongolia herders hunt marmots for food and body parts, used in traditional medicines, and also for fur used locally

and sold for income (Reading et al., 1998; Pratt et al., 2004; Wingard & Zahler, 2006). Millions of furs are harvested annually and many enter illegally into burgeoning markets in China and Russia (Wingard & Zahler, 2006). The impact of overharvesting has been substantial and populations have declined throughout Mongolia (Townsend & Zahler, 2006; Wingard & Zahler, 2006), from c. 40 million in 1940 (Eregdendagva, 1972) to 20 million in 1990 (Wingard & Zahler, 2006) and 5 million in 2001 (Batbold, 2002). This decline of >85% prompted the government to enact temporary hunting bans and conservationists to categorize the species as Endangered (Clark et al., 2006a; IUCN, 2008).

The decline of the Siberian marmot is of importance because it is often considered a keystone species (Zahler et al., 2004), i.e. one that exerts effects on its ecosystem that are unique and disproportionately large relative to its abundance (Power et al., 1996; Kotliar, 2000). There is therefore concern about the possible impact of the decline on other species. Marmots are important prey for some carnivores and raptors (Heptner & Naumov, 1992; Ellis et al., 1999; Gombobaatar et al., 2001) and are thought to serve key ecosystem functions through their extensive colonial burrow systems, some of which have >90 entrances (Townsend, 2006). Burrow systems may assist soil renewal (Zahler et al., 2004), influence plant community dynamics (Van Staaldunin & Werger, 2007), and provide shelter and habitat for small mammals, reptiles and insects (Adiya, 2000). The burrows may also be important habitat resources for some carnivores (Adiya, 2000). However, accounts of burrow use by carnivores remain few, unquantified, and based largely on casual sightings and reports.

The small (c. 2.5 kg), nocturnal corsac fox *Vulpes corsac* reportedly uses marmot burrows (Heptner & Naumov, 1992). Corsacs live in the grassland and semi-desert steppes of Mongolia (Murdoch et al., in press), occupying a range that overlaps with that of the Siberian marmot (Fig. 1; Clark et al., 2006b). Although details of corsac ecology are few (Poyarkov & Ovsyanikov, 2004), historical accounts suggest they rely on burrows, resting in them during daytime (Ognev, 1962; Heptner & Naumov, 1992). Most accounts, however, have been based on incidental observations. Like

JAMES D. MURDOCH (Corresponding author) and CLAUDIO SILLERO-ZUBIRI Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Tubney House, Abingdon Road, Tubney, OX13 5QL, UK. E-mail jd_murdoch@yahoo.com

TSERENDORJ MUNKHZUL Mongolian Academy of Sciences, Institute of Biology–Mammalogy Laboratory, Ulaanbaatar, Mongolia.

SUURI BUYANDELGER National University of Mongolia, Department of Biology, Ulaanbaatar, Mongolia.

RICHARD P. READING Denver Zoological Foundation, Department of Conservation Biology, Denver, USA.

Received 6 July 2008. Revision requested 14 August 2008.

Accepted 2 October 2008.

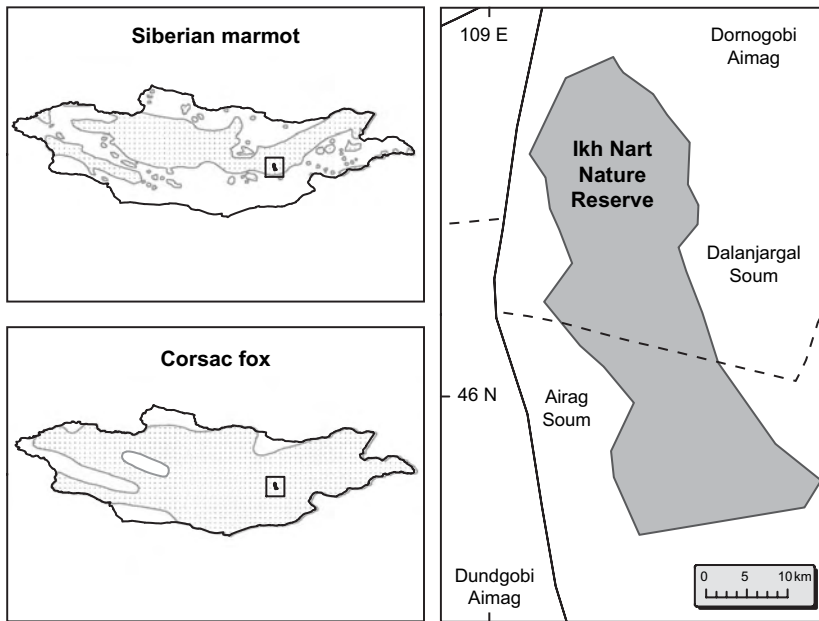


FIG. 1 Siberian marmot *Marmota sibirica* and corsac fox *Vulpes corsac* distribution in Mongolia and the location of the study site (rectangle on distribution figures) in Ikh Nart Nature Reserve relative to soum (i.e. county: dashed line) and aimag (i.e. province: solid line) boundaries. Distributions adapted from Clark et al. (2006b).

marmots, corsac populations have declined in Mongolia and there is also a similar need to identify the biological requirements of the species to inform conservation actions (Clark et al., 2006b; Wingard & Zahler, 2006).

In 2004 we began a study of the spatial ecology of corsacs in central Mongolia, during which we documented them using marmot dens on several occasions. Here, we present data on the frequency of marmot burrow use by radio-collared corsacs and evaluate the importance of burrows as a resource for the species. We also discuss the implications of burrow use and suggest a practical and cost-effective solution for protecting both species.

We studied corsacs in the Ikh Nart Nature Reserve of Dornogobi Aimag, Mongolia (Fig. 1), established in 1996 to protect argali *Ovis ammon* and the unique landscape of the region (Reading et al., 2006). Ikh Nart lies at the junction of steppe and semi-desert ecotones (Murzaev, 1948) and includes grasslands, shrublands, open plains, rocky habitats and ephemeral drainages. Siberian marmots and corsacs are sympatric there, occupying mainly grassland and shrubland areas (Murdoch et al., 2006).

Our study involved capturing, radio-collaring, and tracking the movements of 10 adult (> 1 year old) foxes. Foxes were live-captured and handled following appropriate guidelines (Gannon et al., 2007) and protocols approved by the Denver Zoological Foundation. We fitted each fox with a VHF radio-collar (c. 1.5% body weight; model-1930, ATS, Isanti, USA) and tracked them using directional antennas.

During May–November 2006 we tracked each fox weekly to its daytime resting location, and recorded whether it was inside a burrow or resting above ground, and whether the burrow used was a marmot burrow. Marmot burrows

were identified based on Townsend's (2006) criteria as having an entrance diameter of 10–30 cm, including fresh scats (< 1 month old), diggings of vegetation, and tracks near (< 3 m) an entrance, and occurring in a known colony (identified from observations of marmots and knowledge of local herders).

Of 207 daytime locations, corsacs used a subterranean burrow as a resting place on 173 (84%) occasions, greater than expected by chance ($\chi^2 = 93.34$, $df = 1$, $P < 0.001$). On other occasions corsacs rested under a shrub, in a shallow depression, ravine or the shadow of a rock. Often these above-ground resting locations were in close proximity (< 3 m) to a burrow entrance (68%; $n = 23$). Corsacs rested in marmot burrows on 53% of observations ($n = 110$), or 64% of those observations when foxes used a burrow of any kind, resulting in marmot burrows being used significantly more frequently than non-marmot burrows ($\chi^2 = 12.77$, $df = 1$, $P < 0.001$). Each fox used a mean of $6.7 \pm SE 1.1$ burrows (either marmot or otherwise; range 3–17) and $4.3 \pm SE 1.5$ marmot burrows (range 2–12).

On one occasion we observed a marmot and a corsac emerge within 2 minutes of each other from the same burrow entrance, indicating they both occupied the same burrow system. We also observed a large marmot colony ($n = 56$ burrows) go extinct, most likely due to overhunting. Corsacs regularly used burrows in this colony prior to the marmot hunting season in August–September. However, after the hunting season all of the burrows filled with sand by the end of the next winter and we did not subsequently observe corsacs using burrows or hunting in the area.

Early accounts of corsac foxes reported their regular use of marmot burrows. Heptner & Naumov (1992), summarizing studies from the Transbaikalian region of Russia and

Mongolia, even suggested that corsacs live almost exclusively in abandoned marmot burrows. Most of these studies, however, were based on incidental observations and reports. In comparison, a more recent study in eastern Mongolia noted that corsacs used marmot areas but that locations of fox sightings did not associate with colonies; the lack of association was probably due to small sample sizes that reflected substantially reduced corsac populations in the region (Townsend & Zahler, 2006).

Our observations in Ikh Nart demonstrate that burrows constitute an important resource for corsacs. Corsacs appear capable of excavating their own dens but using marmot burrows probably represents an energetically-efficient behavioural adaptation to living in arid steppe environments, where food resources fluctuate considerably. Marmot burrows probably help corsacs by providing shelter and refuges from other carnivores known to kill corsacs, such as wolves *Canis lupus*, red foxes *Vulpes vulpes* and domestic dogs (Heptner & Naumov, 1992). Our findings also suggest that the removal of marmots from an area may disrupt the ranging patterns of corsacs, which in turn may make them more vulnerable to predation.

Another implication is that the regular use of marmot burrows by corsacs may affect the transmission of plague caused by the bacterium *Yersinia pestis* (Biggins & Kosoy, 2001). Outbreaks of plague commonly occur in marmot populations in Mongolia, resulting in quarantines of affected areas and marmot eradication programmes (Batbold, 2002). Details of the transmission of plague between colonies are few but our observations suggest that it may be partly influenced by the movements of corsacs between burrows and colonies. Several fleas parasitize corsacs, including *Oropsylla silantiewi*, considered one of the main plague vectors in the Transbaikal region of Mongolia (Gratz, 1999), and corsacs may act as a vector of infected fleas by spreading them between colonies (Heptner & Naumov, 1992).

Although Siberian marmots are generally considered a keystone species, in the same way that plateau pika *Ochotona curzoniae* acts as a keystone species on the Tibetan plateau (Smith & Foggin, 1999), few studies have quantified their roles in steppe ecosystems. Similarly, we are unaware of studies quantifying the frequency of burrow use by other species, particularly carnivores. Our results support the notion that marmots act as a keystone species, as the loss of marmots from an area and the concomitant loss of their burrows would probably exert a significant effect on corsac populations. However, more detailed studies are required to assess the relationship between the population dynamics of marmots, corsacs and other burrow users.

Conservation measures are required for the protection of marmots and corsacs in Mongolia (Wingard & Zahler, 2006). Marmots have declined greatly in some areas. A 3,148 km survey in historically good marmot habitat in the eastern steppe only detected the species 68 times (130

individuals; Townsend & Zahler, 2006). Similarly, corsac declines due to hunting, and to a lesser extent poisoning, disease and habitat loss, resulted in this once common species being listed as Near Threatened on the Mongolian Red List (Clark et al., 2006b). Both species receive little protection under the Mongolian Law on Fauna (Wingard & Odgerel, 2001) but hunting quotas exist and in the past the government enacted temporary hunting bans for both species to stem declines (Clark et al., 2006a). However, enforcement of wildlife laws and regulations is weak and few large-scale strategies exist to protect these species adequately.

In Ikh Nart marmots and corsacs are hunted, even though all forms of hunting are illegal (Wingard & Odgerel, 2001) and, like many other protected areas in Mongolia, funds for conservation activities are limited. A cost-effective solution to conserving both species in Ikh Nart would be to target protection at colonies in August–September and December–January, when marmots and corsacs, respectively, are hunted. Herders mainly hunt marmots and corsacs with leghold traps set at burrow entrances, and daily checks for traps in larger colonies would probably result in a substantial reduction of poaching. Increased protection of colonies during these periods would also reduce captures of non-target species, which during our study included four corsacs, two Pallas's cats *Otocolobus manul* and a cinereous vulture *Aegypius monachus*.

Acknowledgements

We thank the Denver Zoo, Rufford Foundation, and Trust for Mutual Understanding for supporting the project. We also thank G. Otgonbayar, S. Dandarbaatar and D. Jargal-saikhan for help with radio-tracking. The project was conducted in collaboration with the Mongolian Academy of Sciences–Institute of Biology.

References

- ADIYA, Y. (2000) *Mongolian Marmots: Biology, Ecology, Conservation, and Use*. Mammalian Ecology Laboratory, Institute of Biological Sciences, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia. [in Mongolian]
- BANNIKOV, A.G. (1954) *Mammals of the Mongolian People's Republic*. Nauka Press, Moscow, Russia. [in Russian]
- BATBOLD, J. (2002) The problems of management of marmots in Mongolia. In *Holarctic Marmots as a Factor of Biodiversity, Proceedings of the Third International Conference on Marmots, Cheboksary, Russia* (eds K.B. Armitage & V.Y. Rumiantsev), pp. 68–75. ABF Publishing House, Moscow, Russia.
- BIGGINS, D.E. & KOSOY, M.Y. (2001) Influences of introduced plague on North American mammals: implications from ecology of plague in Asia. *Journal of Mammalogy*, 82, 906–916.
- CLARK, E.L., MUNKHBAT, J., DULAMT SEREN, S., BAILLIE, J.E.M., BATSAIKHAN, N., KING, S.R.B. et al. (2006a) *Summary Conservation Action Plans for Mongolian Mammals*. Zoological Society of London, London, UK.

- CLARK, E.L., MUNKHBAT, J., DULAMT SEREN, S., BAILLIE, J.E.M., BATSAIKHAN, N., SAMIYA, R. & STUBBE, M. (2006b) *Mongolian Red List of Mammals*. Regional Red List Series Vol. 1, Zoological Society of London, London, UK.
- ELLIS, D.H., TSENGEG, P., WHITLOCK, P. & ELLIS, M.H. (1999) Predators as prey at a golden eagle *Aquila chrysaetos* eyrie in Mongolia. *Ibis*, 141, 139–158.
- EREGDENDAGVA, D. (1972) Altai marmot. *Science and Life Magazine*, 3, 72–73. [in Mongolian]
- GANNON, W.L., SIKES, R.S. & ANIMAL CARE AND USE COMMITTEE OF THE AMERICAN SOCIETY OF MAMMALOGISTS (2007) Guidelines of the American Society of Mammalogists for the use of wild mammals in research. *Journal of Mammalogy*, 88, 809–823.
- GOMBOBAATAR, S., SUMIYA, D., SHAGDARSUREN, O., POTAPOV, E. & FOX, N. (2001) Diet studies of saker falcon (*Falco cherrug*) in Mongolia. In *Proceedings of the 2nd International Conference on the Saker Falcon and Houbara Bustard* (eds E. Potapov, S. Banzragch, N. Fox & N. Barton), pp. 116–127. Middle East Falcon Research Group, Ulaanbaatar, Mongolia.
- GRATZ, N. (1999) Rodent reservoirs and flea vectors of natural foci of plague. In *Plague Manual: Epidemiology, Distribution, Surveillance and Control*. World Health Organization, Geneva, Switzerland.
- HEPTNER, V.G. & NAUMOV, N.P. (eds) (1992) *Mammals of the Soviet Union*. Vol. 2, Part 1A. E.J. Brill, New York, USA.
- IUCN (2008) *2008 IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland. <http://www.redlist.org> [accessed 28 April 2009].
- KOTLIAR, N.B. (2000) Application of the new keystone-concept to prairie dogs: how well does it work? *Conservation Biology*, 14, 1715–1721.
- MALLON, D.P. (1985) The mammals of the Mongolian People's Republic. *Mammal Review*, 15, 71–102.
- MURDOCH, J.D., MUNKHZUL, T., AMGALANBAATAR, S. & READING, R.P. (2006) Checklist of mammals in Ikh Nart Nature Reserve. *Mongolian Journal of Biological Sciences*, 4, 69–74.
- MURDOCH, J.D., MUNKHZUL, T., BUYANDELGER, S. & READING, R.P. (in press) Biotope of corsac fox and red fox in Ikh Nart Nature Reserve. *Mongolian Journal of Biological Sciences*.
- MURZAEV, E.M. (1948) *The MPR: A Physio-Geographical Description*. Academy of Sciences, Moscow, Russia. [in Russian]
- OGNEV, S.I. (1962) *Mammals of Eastern Europe and Northern Asia*. Vol. 2 *Carnivora (Fissipedia)*. Israel Program for Scientific Translations, Jerusalem, Israel.
- POWER, M.E.D., TILMAN, D., ESTES, J.A., MENGE, B.A., BOND, W.J., MILLS, L.S. et al. (1996) Challenges in the quest for keystones. *BioScience*, 46, 9–20.
- POYARKOV, A. & OVSYANIKOV, N. (2004) Corsac *Vulpes corsac*. In *Canids: Foxes, Wolves, Jackals, and Dogs. Status Survey and Conservation Action Plan* (eds C. Sillero-Zubiri & D.W. Macdonald), pp. 142–148. IUCN/Species Survival Commission Canid Specialist Group, Gland, Switzerland, and Cambridge, UK.
- PRATT, D.G., MACMILLAN, D.C. & GORDON, I.J. (2004) Local community attitudes to wildlife utilization in the changing economic and social context of Mongolia. *Biodiversity and Conservation*, 13, 591–613.
- READING, R., KENNY, D., WINGARD, G., MANDAKH, B. & STEINHAEUER-BURKART, B. (2006) *Ikh Nart Nature Reserve*. ECO Nature Edition, Ulaanbaatar, Mongolia.
- READING, R.P., MIX, H., LHAGVASUREN, B. & TSEVEENMYADAG, N. (1998) The commercial harvest of wildlife in Dornod Aimag, Mongolia. *Journal of Wildlife Management*, 62, 59–71.
- SMITH, A.T. & FOGGIN, J.M. (1999) The plateau pika (*Ochotona curzoniae*) is a keystone species for biodiversity on the Tibetan plateau. *Animal Conservation*, 2, 235–240.
- TOWNSEND, S.E. (2006) Burrow cluster as a sampling unit: an approach to estimate marmot activity in the eastern steppe of Mongolia. *Mongolian Journal of Biological Sciences*, 4, 31–36.
- TOWNSEND, S.E. & ZAHLER, P. (2006) Mongolian marmot crisis: status of the Siberian marmot in the eastern steppe. *Mongolian Journal of Biological Sciences*, 4, 37–44.
- VAN STAALDUINEN, M.A. & WERGER, M.J.A. (2007) Marmot disturbances in a Mongolian steppe vegetation. *Journal of Arid Environments*, 69, 344–351.
- WINGARD, J.R. & ODGEREL, P. (2001) *Compendium of Environmental Law and Practice in Mongolia*. GTZ, Ulaanbaatar, Mongolia.
- WINGARD, J.R. & ZAHLER, P. (2006) *Silent Steppe: The Illegal Wildlife Trade Crisis in Mongolia*. Mongolia Discussion Papers. East Asia and Pacific Environment and Social Development Department, World Bank, Washington, DC, USA.
- ZAHLER, P., LKHAGVASUREN, B., READING, R.P., WINGARD, G.J., AMGALANBAATAR, S., GOMBOBAATAR, S. et al. (2004) Illegal and unsustainable wildlife hunting and trade in Mongolia. *Mongolian Journal of Biological Sciences*, 2, 23–31.

Biographical sketches

JAMES MURDOCH studies the competitive interactions between corsac and red foxes in Mongolia, and has studied other canids including kit foxes and African wild dogs. T. MUNKHZUL focuses on the population dynamics of small mammals and carnivore conservation issues. S. BUYANDELGER studies the diet of foxes and other steppe carnivores. RICHARD READING studies argali, ibex, and raptors and has been working on conservation issues in Mongolia since 1994. CLAUDIO SILLERO-ZUBIRI is Chair of the IUCN/SSC Canid Specialist Group and his interests include the conservation of threatened species, protected area management and the behavioural ecology of wild canids.