Pakistan J. Zool., vol. 50(1), pp 311-316, 2018. DOI: http://dx.doi.org/10.17582/journal.pjz/2018.50.1.311.316

Architecture Characteristics of Burrow System of Plateau Pika, *Ochotona curzoniae*

Wanrong Wei and Weiguo Zhang*

State Key Laboratory of Grassland Agro-Ecosystems, College of Pastoral Agriculture Science and Technology, Lanzhou University, P.O. Box 61, Lanzhou 730020, China

ABSTRACT

Burrows serve many functions for animals by providing a place for rearing young, sleeping, hibernation, food storage, protection from predators and extreme environment, and the function of burrows varies with the degree of burrow complexity. We studied the burrow architecture (length, internal dimensions, fractal dimension of tunnel systems, number of nesting chambers and surface holes) by excavating the tunnels of 24 burrow systems of the plateau pika (*Ochotona curzoniae*). Pikas have two types of burrow systems, namely temporary and permanent burrows. The number of surface holes and length of tunnels were significantly different between the temporary and permanent burrows. Tunnel width and tunnel height were not significantly different between the temporary and permanent burrows. The permanent burrow had a nesting chamber but temporary did not have any. No hoarding chamber was found in either the permanent or the temporary burrow. The temporary burrow was used to avoid predators in emergency situations, and probably was the initial stage of construction of more complex burrows of some dispersing pikas. Permanent burrows were used for avoiding predators, resting and rearing offsprings.

Article Information
Received 03 August 2016
Revised 02 December 2016
Accepted 27 January 2017
Available online 15 January 2018

Authors' Contributions
WW and WZ designed the study and WW wrote the manuscript.

Key words
Burrow system, Burrow architecture, Plateau pika.

INTRODUCTION

Animals inhabiting frigid and temperate environments often suffer harsh environmental conditions, especially during the winter when low temperatures may impose thermoregulatory stress on animals. To adapt to these conditions, some animals hibernate and while others adjust their behavior, for instance by huddling and sun basking (West and Dublin, 1984). Another important strategy is physiological adjustment, such as the promotion of recruitment of brown adipose tissue (BAT) and improving relative metabolic rate (RMR) (Yoneshiro and Saito, 2014). In addition, animals can avoid stressful surface conditions by taking refuge in burrows (Colombini *et al*., 2013).

Burrows play an important role in the life of fossorial mammals and the function of burrow varies with the burrow complexity degree (Reichman and Smith, 1990; Hinze *et al*., 2006). Generally, a simple burrow comprises of a single nest chamber, and one or two entrance holes (Hinze *et al*., 2006), but complex burrows include several aboveground entrance holes joined to many interconnected tunnels below ground (Goyal and Ghosh, 1993; Mankin and Getz, 1994). Complex systems may contain one or more nesting, hoarding and nursery chambers, or a combination of these structures (Hoogland, 1995; Khalidas and Hansell, 1995). Burrows provide a place for protection against predators, raise offspring (Hoogland, 1995), gain access to high quality feeding sites through numerous entrance holes (Jackson, 2001) and provide a suitable microclimate for storing food (Reichman and Smith, 1990). Besides, the major advantage of burrow (Korb and Linsenmair, 1998; Burland *et al*., 2002) is to serve as a refuge and buffer against extremes in the environment (Jackson, 2000).

The plateau pika (*Ochotona curzoniae*), also called the black-lipped pika, is a small (130-195 g) nocturnal mammalian herbivores, belonging to the order Lagomorpha (Smith and Marcfoggin, 1998). It occurs naturally in large colonies in most areas above an altitude of 3300 m in the Tibetan plateau (Qu *et al*., 2012). Such a distribution restricts them to the cold, harsh sub-alpine and alpine regions (Wei *et al*., 2013). This species does not hibernate and the cold winter can cause massive mortality since it is poorly adapted physiologically (Zong *et al*., 1986). To cope with thermal stress, the pika exhibits behavioural (sun-basking, huddling), physiological (increase BAT) and morphological (dense fur) adaptations (Bai, 2015). This species excavates extensive underground burrow systems in grassland with low vegetation cover (Wei *et al*., 2013). Generally, family members were composed by 3 adult and 5-9 subadult. Pika colonies have numerous surface holes, and it is likely that the burrow system functions as a thermal buffer against climatic extremes (Wei *et al*., 2013),

* Corresponding author: wgzhang@lzu.edu.cn
0030-9923/2018/0001-0311 $ 9.00/0

since pikas retreat into burrows during the coldest and hottest times of the day (Zong and Xia, 1987). Monogamy is the basic mating system of plateau pikas, but they also exhibit other types of mating systems such as polygyny and polyandry. Dispersal of pikas occurs in a narrow window of time prior to the beginning of mating season, Yearlings were the dominant dispersers among the pikas (Choying, 2016).

Pikas are preyed upon by nearly all of the plateau's predators, but only weasels and polecats are the predators known to enter the pika burrow systems and prey on adults as well as their young (Smith and Foggin, 1999). Pikas feed primarily on grasses and forbs (Liu *et al*., 2008).

The aim of this study was to investigate and describe in detail the architecture of plateau pika's burrow system within an alpine climate in Gan-nan for the first time. To test whether temporary burrow was the initial stage of construction of more complex burrows of some dispersing pikas for saving energy.

MATERIAL AND METHODS

Study site

The research was conducted at a natural alpine meadow in Maqu County, Gansu province of northwestern China (located in the eastern part of the Qinghai-Tibetan plateau, 33°34'N; 102°15'E). The study area is a rangeland utilized by yak (*Bos grunniens*) and Tibetan sheep (*Ovis aries*) during the winter (October to mid-April) and located approximately 500 m from a main road. The plateau pikas is the only one lagomorph species in study area. The site has a typical alpine continental climate, characterised by wet and cool weather with temperatures ranging from 26°C in July to -29.8°C in January. The average annual rainfall is 643.9 mm, which falls predominantly between June and September. The growing season from June to September is about 120 days. The main soil type is alpine meadow soil. Dominant plant species are *Kobresia kansuensis*, *K. capillifolia*, *K. humilis, Elymus nutans*, *Stipa aliéna*, *Potentilla anserine*, and *Saussurea hieracioides*.

Excavation of burrow systems

Active burrow systems of the plateau pikas were identified when pika entered it. The pika burrows were found only in open areas with sparse vegetation cover.

Field work was conducted from May 2009 to October 2011. The burrow systems were carefully excavated with a spade and a small shovel to maintain the original organization and morphology of the tunnels and associated structures and not to destroy any significant marks. Released the captured pikas when excavated the burrows. A total of 24 burrow systems were excavated (15 permanent burrow systems and 9 simple burrow systems). All data were mapped horizontally and vertically. The depth from the ground surface to the top of the burrow, tunnel length, maximal depth, the height and width of the burrow were measured using a tape measure (± 0.1 cm). The number of entrance holes, dimensions, branch numbers and contents of the nesting areas and defecation sites were also recorded. The volume of all chambers was calculated using the formula $V = \text{width } 1 \times \text{width } 2 \times \text{height} \times \pi \times 1/6$ and expressed in liters (Scheibler *et al*., 2006). The excavated burrow systems were chosen at random and were not adjacent to one another. All measurements were taken with a measuring tape and rounded to the nearest centimeter.

The fractal dimension is an independent measure of burrow complexity (Le Comber *et al*., 2006). A fractal dimension is essentially a measure of the degree to which a one-dimensional structure reflects the underground environment of pikas living. A complex burrow system is characterized by the presence of numerous side branches, which run in different directions and thus has a higher fractal dimension value than that of a simple burrow with one or no side branches. The fractal dimensions for all 24 burrow systems in this study were calculated using the Fractal Dimension Calculator 1.2 program as used by Thomas *et al*. (2013), which is designed to assist with the application of the 'box counting' method, as in Le Comber *et al*. (2006), for determining the fractal dimension of burrow structure.

We identified 6 temporary burrow systems in June 2009, and used smoke bombs to identify surface all holes by plugging smoking holes with balls of paper. These burrows were then marked and the process was repeated yearly for the following two years. In order to confirm whether the number of holes used the smoking bomb method was consistent with actual number of holes then excavated them in July 2011, recorded the number of surface hole, the tunnel length, maximal depth of each burrow.

Statistical analysis

Data were presented as mean ± SE and were tested for normality and homogeneity of variance using Kolmogorov-Smirnov and Shapiro-Wilk test respectively. Mann-Whitney U-test was employed on non-normal data and independent t-test on normal data. Analyses were performed using SPSS 19.0 program and significance was measured as $p < 0.05$.

RESULTS

Our observations showed that the number of entrance holes in excavated burrows ranged from 2-9 per system. The number of tunnels varied from 2 to 9, depending on the type of the burrow system. General characteristics of burrow systems are depicted in Figure 1. The simpler type was the temporary (escape) burrow, these temporary burrows were short with no or only a few branches and low number of entrance holes (2-3). The length of the temporary tunnels was shorter compared to permanent burrows (Table I).

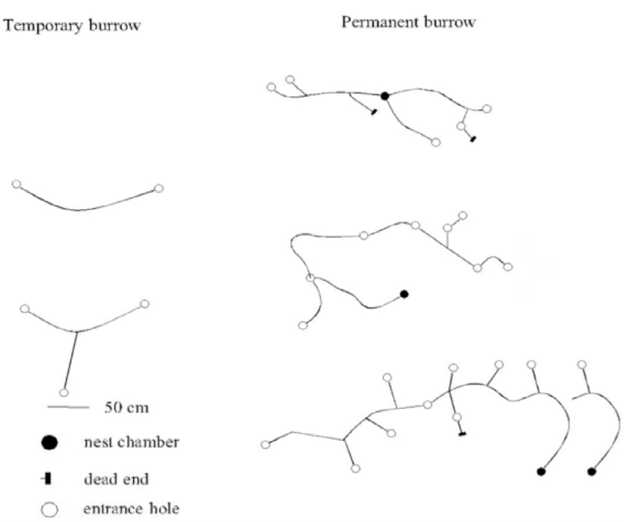

Fig. 1. Top view of burrow system types of Plateau pikas: Temporary burrow and Permanent burrow.

Table I.- Burrow features of plateau pika in permanent (*n* = 15) and temporary burrows (*n* = 9) (Means ± SD).

Features	Permanent burrow	Temporary burrow	P value
No. of entrance holes	6.6 ± 1.2	2.4 ± 0.5	0.000
Tunnel length (m)	9.4 ± 1.8	3.5 ± 0.7	0.000
Tunnel width (cm)	7.5 ± 0.8	7.4 ± 0.8	0.811
Tunnel height (cm)	7.3 ± 0.5	7.2 ± 0.5	0.856
Branch number	2.2 ± 0.7	7.4 ± 1.3	0.000
Maximal depth (cm)	55.2 ± 5.0	28.1 ± 4.9	0.000
Depth of nest (cm)	55.2 ± 5.0	—	
Volume of nest (cm^3)	284.1 ± 50.9	—	
Fractal dimension	1.025±0.004	1.004±0.005	0.000

Permanent tunnels changed direction about 30.6 ± 4.8 cm from entrances underground and the inclination changed from 18° to 31°. Permanent burrows had a nest chamber and the nest was in the deepest part of the burrows. Total length of the tunnels of each burrow system can reach 12.4 m. There was no food store chamber either in two type burrow systems. The number of entrance holes, mean length, branch number, maximal depth and the fractal dimension of two types burrow systems were statistically different ($p < 0.05$). The tunnel height ($p = 0.856$) and tunnel width ($p = 0.856$) were not significantly different.

We found the temporary and permanent burrow systems all without store chambers. The nest chamber had some dry plant material such as *Elymus nutans, K. capillifolia, K. kansuensis, Scirpus pumilus*. The volume of nest chambers of permanent burrows varied from 212.6 to 385.2 cm^3.

In June 2009, we observed only two or three surface holes in the six temporary burrow systems. We found two collapsed burrows in 2010. In July 2011, we excavated the remaining four burrows and found that two temporary burrow systems still had two or three surface holes, the tunnel lengths were 2.8 m and ± 3.3 m and the maximal depths were 24.2 cm and 22.6 cm. However, other two temporary burrow systems changed into permanent burrow systems which had a nest chamber, 6 and 8 surface holes, the tunnel lengths were 7.4 m and 8.7 m, and the maximal depth were 54.2 cm and 49.6 cm, respectively, in July 2011. The number of holes identified using the smoke bomb method, were consistent with result of excavated.

DISCUSSION

Pikas have two types of burrow systems, namely temporary and permanent burrows. Burrow architecture varies among and within species. Three types of burrows were reported for *Meriones. unguiculatus* (Scheibler *et al*., 2006) and *Allactaga. firouzi* (Saeed *et al*., 2010), including temporary, summer and winter burrows. Eygelis (1980) found 5 types of burrows of *M. persicus* in Azerbaijan, consist of temporary burrow, breeding-foraging burrows, breeding-wintering burrows, wintering burrows and complicating burrows. Shenbrot *et al*. (1997) thought that the reasonable explanation is that each animal maintains several burrows, one complex home burrow and several simple burrow systems. Because the territorary of different pika families were overlop (Wang, 1989) and we can't quantified each family has several permanent and temporary burrows, but only found pikas had two type burrow systems.

Mankin and Getz (1994) concluded that temporary (escape) burrows, that were slightly smaller than permanent burrows, had numerous (2-9) entrance holes to allow pikas rapid entry or exit. Our results were consistent with that of *Spermophilus tridecmlineatus* (Rongstad, 1965), *A. elater* and *M. unguiculatus* (Scheibler *et al*., 2006). Pikas also possess temporary burrows without a chamber and with two to three entrances, but in contrast to *A. firouzi* (Saeed *et al*., 2010), which has a nest chamber. We believe temporary burrows of pikas have the function of avoiding predators.

Ilikler (1974) and Scheibler *et al*. (2006) found that there are food storage chambers in the burrows of *M. tristrami* and *M. unguiculatus*, a feces room, a blind alley and a few feces chambers in the burrow of *M. tristrami*. Our results were consistent with the results of Liu that there was no food chamber in the burrows of pikas (Liu *et al*., 2008). Liu *et al*. (2008) demonstrated that pikas collected hay piles against an unpredictable food shortage in winter. We didn't find feces chambers, but the defecation sites were found in the abandoned holes. Wei *et al*. (2013) thought it was beneficial for the survival of the pikas when feces sites were outside of the burrow because feces can breed bacteria. There was only one nesting chamber in permanent burrows suggesting that the nest chamber was the place for reproduction and can be adequately buffered from above ground temperature conditions. Considering that pikas are social animals, we believe all individuals rest there to reduce the energy needed to keep a constant body temperature by tightly huddling and thereby reducing their surface area to volume ratio in winter (Ebensperger, 2001).

Saeed *et al*. (2010) thought temporary burrows of *A. firouzi* probably are day shelters of young dispersing individuals and the initial stages of the construction of more complex burrows for saving energy. Our observations suggested that entrance holes, tunnel length and the maximal depth of two temporary burrows changed to be similar to permanent burrows, and had a nesting chamber after 2 years. Pikas can use existing simple burrow systems and expand it to complex burrows. Considered the natural longevity of pikas is about two years (Wang, 1989), we believe that the simple burrow is probably the initial stage of construction of more complex burrows to some dispersing pikas for saving energy. According to White (2005), all burrower pikas construct their tunnels as narrow as possible in order to prevent the collapse of the walls and saving energy. Our results indicate that tunnel width was about 7.5 cm, which can allow one adult pika to pass (body width is about 5.4 cm) to two the burrow systems, which to some extent seems consistent with the results of White (2005).

CONCLUSION

Temporary burrows are thought to be used by the pikas to avoid predators in emergency situations, and are probably the initial stage of construction of more complex burrows of some dispersing pikas. Permanent burrows are used, in addition to predator avoidance, as a place for resting and rearing offsprings.

ACKNOWLEDGMENTS

We thank the help of Jun Zhang, Anwei Ma and Daihong Wei in the field work, and thank Jorge Maria K Oosthuizen for critically reading and commenting on the manuscript. This research was financially supported by the Special Fund for Agro-Scientific Research in the Public Interest (201203041).

Conflict of interest statement

Authors have no conflict of interests.

REFERENCES

Bai, Z.H., 2015. *Hypoxia and cold adaptive mechanism of Plateau Pika in Qinghai Tibetan Plateau*. Ph.D. thesis, Qinghai University, Xining, Qinghai, China.

Burland, T., Bennett, N.C., Jarvis, J.U.M. and Faulkes, C.G., 2002. Eusociality in African mole-rats: new insights from patterns of genetic relatedness in the Damaraland mole-rat (*Cryptomys damarensis*). *Proc. R. Soc. B-Biol.,* **269**: 1025-1030.

Choying, B.P., 2016. *Pikas, grasslands, and pastoralists: Understanding the roles of Plateau Pikas in a coupled social-ecological system*. Ph.D. thesis, Arizona State University, Phoenix, USA.

Colombini, I., Fallaci, M., Gagnarli, E., Rossano, C., Scapini, F. and Chelazzi, L., 2013. The behavioural ecology of two sympatric talitrid species, *Talitrus saltator* (Montagu) and *Orchestia gammarellus* (Pallas) on a Tyrrhenian sandy beach dune system. *Estura. Coast. Sh.,* **117**: 37-47. https://doi.org/10.1016/j.ecss.2012.09.016

Dearing, M.D., 1997. The function of haypiles of pikas (*ochotona princeps*). *J. Mammal.,* **78**: 1156-1163. https://doi.org/10.2307/1383058

Hoogland, J.L., 1995. *The black-tailed prairie dog: social life of a burrowing mammal*. University of Chicago Press, pp. 234-236.

Dobson, F.S., Smith, A.T. and Wang, X.G., 1998. Social and ecological influences on dispersal and philopatry in the plateau pika (*ochotona curzoniae*). *Behav. Ecol.,* **9**: 622-635. https://doi.org/10.1093/beheco/9.6.622

Ebensperger, L.A., 2001. A review of the evolutionary causes of rodent group-living. *Acta Theriol.,* **46**: 115-144. https://doi.org/10.1007/BF03192423

Eygelis, Y.K., 1980. *Rodents of Eastern Transcaucasus and the problem of sanitation of local plague foci.* Saratov University Press, Russia, pp. 132-134.

Goyal, S.P. and Ghosh, P.K., 1993. Burrow structure of two gerbil species of Thar desert, India. *Acta Theriol.,* **38**: 453-456. https://doi.org/10.4098/AT.arch.93-37

Hinze, A., Pillay, N. and Grab, S., 2006. The burrow system of the African ice rat *Otomys sloggetti robertsi*. *Mammal. Biol. Z. Säugetierk.,* **71**: 356-365.

Ilikler, I., 1974. Ege bolgesinde col faresi (*Meriones blackleri blackleri* Thomas, Rodentia-Cricetidae) nin kisa biyolojisi, Zarari ve savas metodlari uzerinde arastirmalar. *Teknik bulten*.

Jackson, T.P., 2000. Adaptation to living in an open arid environment: Leassons from the burrow structure of the two southern African whisling rats, *Paratomys brantsii* and *P. littleedalei*. *J. Arid Environ.,* **46**: 345-355. https://doi.org/10.1006/jare.2000.0683

Jackson, T.P., 2001. Factors influencing food collection behavior of Brant's whilstling rat (*Parotomys brantsii*): a central place forager. *J. Zool.,* **255**: 15-23. https://doi.org/10.1017/S0952836901001078

Khalidas, K. and Hansell, M.H., 1995. Burrowing behaviour and burrow architecture in *Apodemus sylvaticus* (Rodentia). *Z. Säugetierk.,* **60**: 246-250.

Korb, J. and Linsenmair, K.E., 1998. The effects of temperature on the architecture and distribution of *Macrotermes bellicosus* (isoptera, macrotermitinae) mounds in different habitats of a West African Guinea Savanna. *Insect Soc.,* **45**: 51-65. https://doi.org/10.1007/s000400050068

Le Comber, S.C., Seabloom, E.W. and Romanach S.S., 2006. Burrow fractal dimension and foraging success in subterranean rodent: a simulation. *Behav. Ecol.,* **17**: 188-195. https://doi.org/10.1093/beheco/arj011

Liu, W., Zhang, Y., Wang, X., Zhao, J., Xu, Q.M. and Zhou, L., 2008. Food selection by plateau pikas in different habitats during plant growing season. *Acta Theriol. Sin.,* **28**: 358-366. https://doi.org/10.2307/1382573

Mankin, P.C.and Getz, L.L., 1994. Burrow morphology as related to social organization of *Micotus ochrogaster*. *J. Mammal.,* **75**: 492-499.

Qu J., Liu, M., Zhang, Y. M. and Ji. W., 2012. Reproduction of plateau pika (*Ochotona curzoniae*) on the Qinghai–Tibetan plateau. *Eur. J. Wildl. Res.,* **58**: 269-277. https://doi.org/10.1007/s10344-011-0574-2

Reichman, O.J. and Smith S.C., 1990. Burrows and burrowing behavior by mammals. In: *Current mammalogy* (ed. H.H. Genoways), Plenum Press, New York and London, pp. 369-410.

Rongstad, O.J., 1965. A life history study of thirteen-lined ground squirrels in southern Wisconsin. *J. Mammal.,* **46**: 76-87. https://doi.org/10.2307/1377818

Saeed, M., Mohammad, K., Moahmoud, K. and Gholamreza, N., 2010. Burrow systems of Iranian jerboa (*Allactaga firouzi womochel*, 1978). *Acta Zool. Mexicana,* **26**: 457-463.

Scheibler, E., Liu, W., Weinandy, R. and Gattermann, R., 2006. Burrow systems of the Mongolian gerbil (*Meriones unguiculatus* Milne Edwards, 1867). *Mammal. Biol.,* **71**: 178-182. https://doi.org/10.1016/j.mambio.2005.11.007

Shenbrot, G.I., Krasnov, B.R. and Khokhlova, I.S., 1997. Biology of Wagner's gerbil *Gerbillus dasyurus* (Wagner, 1842) (Rodentia: Gerbillidae) in the Negev Highlands, Israel. *Mammalia,* **61**: 467-486.

Smith, A. and Marcfoggin, J., 1998. *The Plateau Pika (Ochotona Curzoniae): A keystone species for biodiversity on the Tibetan Plateau. Formation and evolution, environmental changes and sustainable development on the Tibetan Plateau*. pp. 219-221.

Smith, A.T. and Foggin, J.M., 1999. The plateau pika (*Ochotona curzoniae*) is a keystone species for biodiversity on the Tibetan plateau. *Anim. Conserv.,* **2**: 235-240. https://doi.org/10.1111/j.1469-1795.1999.tb00069.x

Thomas, H.G., Scantlebury, M., Swanepoel, D., Bateman, P.W. and Bennett, N.C., 2013. Seasonal changes in burrow geometry of the common mole-rat (Rodentia: Bathyergidae). *Naturwissenschaften,* **100**: 1023-1030. https://doi.org/10.1007/s00114-013-1105-7

Wang, X., 1989. Natural longevity of plateau pika (*ochotona curzoniae*). *Acta Theriol. Sin.,* **9**: 56-62.

Wei, W.R., Zhang, L.F., Xu, J.W. and Zhang W.G., 2013. A study on the burrow features and functions of plateau pika. *Acta Prat. Sin.,* **22**: 198-204.

West, S.D. and Dublin, H.T., 1984. Behavioral strategies of small mammals under winter conditions: solitary or social? In: *Winter ecology in small mammals* (ed. J.F. Merritt), Carnegie Museum of Natural History, Pittsburgh, pp. 293-299.

White, C.R., 2005. The allometry of burrow geometry. *J. Zool.,* **265**: 395-403. https://doi.org/10.1017/S0952836905006473

Wu, G.L., Liu, Z. H., Zhang, L., Chen, J.M. and Hu, T.M., 2010. Long-term fencing improved soil properties and soil organic carbon storage in alpine swamp meadow of Western China. *Pl. Soil,* **332**: 331-337. https://doi.org/10.1007/s11104-010-

0299-0
Yoneshiro, T. and Saito, M., 2014. Activation and recruitment of brown adipose tissue as anti-obesity regimens in humans. *Annls. Med.,* **47**: 1-9.
Zhang, Y. and Liu, W., 2005. A preliminary study of caching behavior of the plateau pika. *Zool. Res.,* **26**: 479-483.
Zong, H., Xia, W.P. and Sun, D. X., 1986. A heavy snow on the number of rodents. *Plateau Biol. Bull.,* **5**: 85-90.
Zong, H. and Xia, W.P., 1987. A study on circadian activity rhythms of plateau pika. *Acta Theriol. Sin.,* **7**: 211-223.