THE BURROWING BEHAVIOR OF MYOSPALAX BAILEY AND ITS RELATION TO SOIL HARDNESS*

WANG Quanye ZHOU Wenyang WEI Wanhong ZHANG Yanming
(*Northwest Plateau Institute of Biology, the Chinese Academy of Sciences, Xining*, 810001)
FAN Naichang
(*Department of Biology, Zhejiang Normal University, Jinhua*, 321004)

Abstract: Burrowing behaviors of the plateau zokors (*Myospalax bailely*) in relation to soil hardness were investigated by using radio-telemetry at Haibei Alpine Meadow Ecosystem Research Station, Qinghai, China. The results showed that there were no differences of burrowing behaviors and the efficiencies of the excavating segment between male and female, except the digging duration of the male was longer than that of the female in the same soil. With increase of soil hardness, digging duration in incisors significantly increased, but dried soil mass dug out by the zokors in each bout reduced. Meanwhile the field investigation also showed that soil hardness affected the distribution of the zokor.

Key words: Plateau zokor (*Myospalax bailey*); Burrowing behavior; Soil hardness
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Plateau zokor (*Myospalax bailey*) is one species of the four genera in Cricetidae which are entirely fossorial herbivores. It is one of the most important rodents in China and widely distributed in the Qinghai-Tibetan Plateau[1,2]. Plateau zokor uses its strong foreclaws to excavate subterranean tunnels, which are not only acted as shelters but also as paths to underground plant parts[3]. In winter, zokors reduce their digging activities significantly, but in spring, they increase the digging activities because of moderate temperature and for reproduction. It has been estimated that, in one year, a single individual can push 1 024 kg of dry soil to the ground surface, the soil can form 242 mounds and cover 22.53 square meters of alpine meadow during the period of 228 days of mound-building[3,4]. Despite that people have conducted many studies on zokor, little is known about its burrowing behavior because its activities occur in burrow systems. Radio-tracking is a potential method to detect the activities and location of fossorial animals[5~7], but we still can not know how animals excavate. Therefore, glass burrow system for observing the burrowing behavior of zokor was invented[8~10].

The objective of our study was to present a new radiotelemetry to determine how the zokors allocate their time during excavation, how much soil could be dug out in unit time, as

* **Biography:** WANG Quanye (1953-), male, associate professor, be engaged chiefly in animal ecology, and pest control and management research.
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well as burrowing behavioral display in the habitats of different soil hardness, and sexual dimorphism of digging behaviors.

1 STUDY AREAS AND METHODS

Study area: The study was carried out at the Haibei Alpine Meadow Ecosystem Station, the Chinese Academy of Sciences (37°29′～37°45′N, 101°12′～101°33′E). The area is characterized by the alpine continental climate, only the cold and warm seasons can be recognized during a year. The annual mean temperatures is about - 2℃ and the precipitation is 530 mm[11]. The zokor mostly distributed in areas with meadow vegetation dominated by dense *Kobresa humilis*, *Potentilla anserina*, *Ajania tenuifolis*, *Elymus nutans*, *Ranunculus pulchells*, and *Carex* sp., its density significantly decreased with increase of the biomass and density of grasses and sedges[2].

Data collection: The zokors used in present study were captured with live traps from study area[12]. Then they were weighed, sexed, placed individually in hardware cloth cages in an animal room in which the temperature was kept between 15～20 ℃and fed on a variety of forbs roots and carrots.

A radio-transmitter (made in the department of rodent behavior and management of our Institute) was encapsulated in vinyl, it weights 7.2 g and was fastened around the neck of the zokor. A new receiver[7] was connected to Yokogawa 3 057 portable inking recorder. The paper was moved at 200 mm/minute. 2 ×2 square meters plots were selected at each study area. A ditch (200 mm wide, 400 cm deep) surrounding the plot was dug out to make sure there were no tunnel and abandoned burrow. Meanwhile, we dug out a gap (150～200 mm deep of the underground) to lure zokor to dig. Once an animal began to burrow, its activity was automatically recorded by the receiver. After a segment was burrowed about 500 mm long, we rapidly dug along one end of the burrow to expose it entirely and the animal was recaptured by hand, unfixed the transmitter, and placed in the cage. The length, diameter and slope of the segment were measured. Soil hardness was measured along tunnel wall at intervals 5 cm by soil hardness measurer made in Zhejiang Agriculture University. Soil density and moisture was also determined to calculate burrowing efficiency in an unit time.

Data analysis: Burrowing behavior of animal was categorized as digging, kicking loosened soil backward, pushing loosened soil to deposit site, arching soil and other movements (walking, turning around, grooming, eating, and motionless)[13]. The drawing patterns of these actions were recognized depending on the background drawing, which the observer sit at the recorder equipment to watch on the animal and made marks at the drawing whenever an action was changed during burrowing until the animal disappeared from sight. The time spending on each action was quantified from measuring the length of drawing pattern of the action.

2 RESULTS

The burrowing patterns were compared between male and female to determine whether

males were more competent for excavating tunnels (Table 1). Although the body weights of males (average 283.25 ±42.53 g, $N = 8$) were higher than that of females (average 231.86 ±22.9 g, $N = 7$; t = 2.28, $P < 0.05$), there were no significant differences between them in dried soil mass dug out ($t = 0.08$, $P > 0.05$), frequency of animals kicking loosed soil away ($t = 0.29$, $P > 0.05$), the duration of transporting soil ($t = 0.45$, $P > 0.05$) and the percentage time spending on digging ($t = 0.37$, $P > 0.05$) or transporting soil. However, the male had longer digging duration than the female ($t = 2.09$, $P < 0.05$).

Table 1　Comparison of burrowing behavior between females and males under the same soil hardness (3.99 ±0.79 kg/cm^3)

Behavior pattern	Females ($N = 7$)	Males ($N = 8$)	t - test
Mass of soil dug (g/sec.)	4.20 ±2.01	4.13 ±1.30	$t = 0.077$, $P > 0.05$
Digging duration (sec./bout)	29.68 ±4.46	40.15 ±12.51	$t = 2.093$, $P < 0.05$
Kicking loosed soil backward (Times/min.)	15.75 ±4.93	16.32 ±2.41	$t = 0.291$, $P > 0.05$
Duration of soil transportation (sec./bout)	8.68 ±3.43	9.57 ±4.15	$t = 0.449$, $P > 0.05$
Percentage of digging time	85.87 ±8.74	84.22 ±8.50	$t = 0.369$, $P > 0.05$
Percentage of transporting time	14.13 ±8.74	15.78 ±8.50	$t = 0.369$, $P > 0.05$

Plateau zokors tended to increase the digging time with the increase of the soil hardness, except in the plot where soil hardness was over 35.56 kg/cube centimeter, the absolute time spent by zokor on digging was reduced as more time spent on indistinguishable and self-grooming activities (Table 2).

Table 2　Frequency of behavior under different soil hardness

Behavior (%)	Soil hardness (kg/cm^3) ($N = 4$)				
	3.40 ±0.20	4.39 ±0.31	9.84 ±2.19	26.07 ±1.00	35.56 ±2.79
Digging	76.27 ±9.78	80.07 ±11.60	80.98 ±7.90	90.44 ±7.43	84.33 ±7.04
Pushing	16.56 ±6.22	12.64 ±6.61	4.42 ±0.12	4.20 ±2.83	1.84 ±0.57
Selfgrooming	0.00 ±0.00	0.00 ±0.00	0.77 ±0.37	1.69 ±1.32	
Other	0.26 ±0.26	2.50 ±1.32	4.68 ±1.89	0.67 ±0.36	1.25 ±1.13
Undistinguished	6.91 ±6.91	4.79 ±4.23	9.92 ±6.41	3.92 ±3.66	10.88 ±5.16

Fig. 1 showed that the time the zokor spent on digging soil was longer than on transporting soil, meanwhile the harder the soil, the longer the digging duration and shorter the transporting time ($df = 3$, $r = 0.987\,6$, $P < 0.01$).

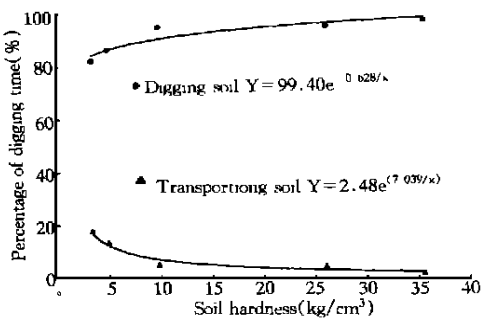

Fig. 1　Relationship between burrowing time and soil hardness

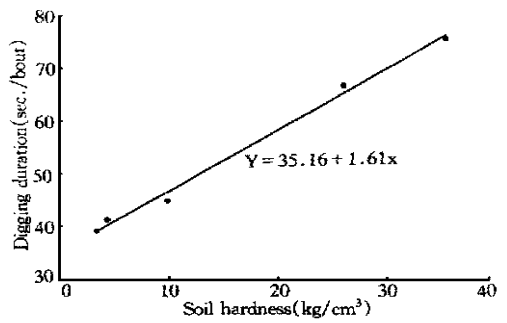

Fig. 2 Relationship between digging duration and soil hardness

A significant correlation between the digging duration and soil hardness ($df = 3$, $r = 0.997\,1$, $P < 0.01$ suggested that the increase of time in burrowing resulted from the in-

crease of digging duration per bout (Fig. 2). Though plateau zokors dug much longer while soil is harder, the dry soil amount dug out per bout by animal was significantly reduced ($df = 3$, $r = 0.965\ 2$, $P < 0.01$) (Fig. 3). Meanwhile dry soil mass dug out in a second decreased significantly with increase of hardness ($df = 3$, $r = 0.994$, $P < 0.01$) (Fig. 4) and frequency of kicking loosened soil away in a minute was also significantly related to soil hardness ($df = 3$, $r = 0.988$, $P < 0.01$) (Fig. 5).

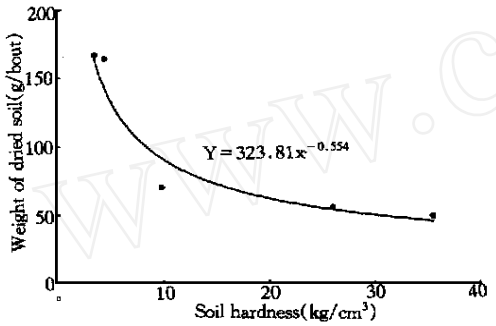

Fig. 3 Soil mass dug out by the zokor for one bout

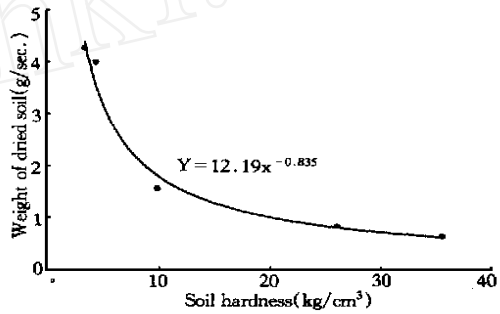

Fig. 4 Soil mass dug out by the zokor for one second

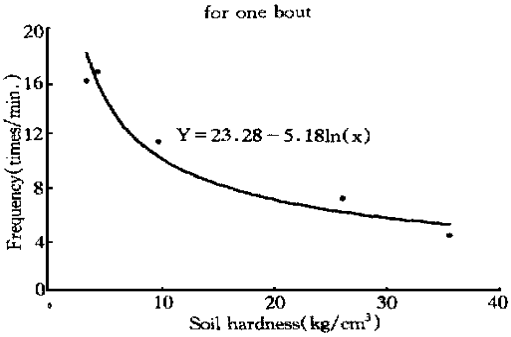

Fig. 5 Frequency of zokor kicking soil away in minute

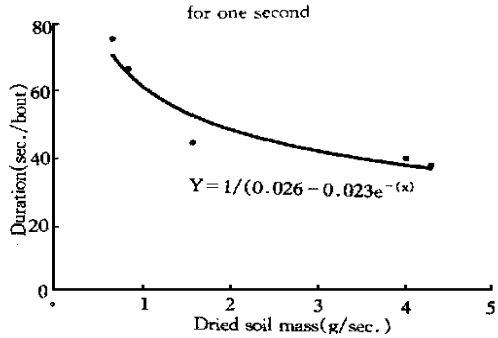

Fig. 6 Relationship between the digging duration and soil mass dug out by the zokor

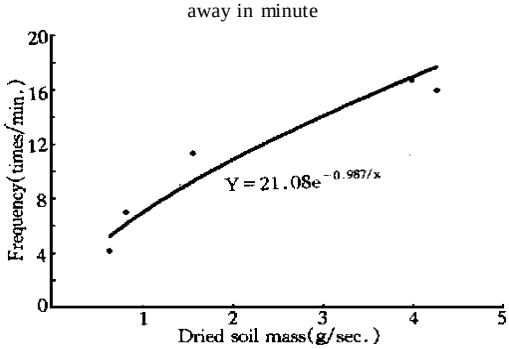

Fig. 7 Relationship between the frequency and soil mass dug out by the zokor

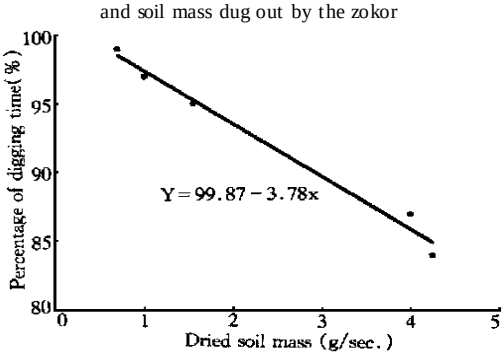

Fig. 8 Relationship between the digging time and the soil mass dug out by the zokor

In addition, the dry soil mass dug out by animal in a second had a significant negative correlation with digging duration ($df = 3$, $r = 0.986$, $P < 0.01$) (Fig. 6) and a positive

correlation with the frequency of kicking loosened soil away per minute ($df = 3$, $r = 0.993$, $P < 0.01$) (Fig. 7) . Thus , the digging time within burrow decreased with the increasing of digging effectiveness ($df = 3$, $r = 0.979$, $P < 0.01$) (Fig. 8) . The more effective animals burrowed , the shorter time spent in digging duration , this was more remarkable when animals faced harder soil.

3 DISCUSSION

It is very difficult to quantify the plateau zokor's burrowing activities. However the method used in this paper made it possible. For the whole year , the burrowing activities had close relation with season for both plateau zokor[3] and valley pocket gopher[14]. Meanwhile , plateau zokor favored burrowing on a mild or fine rainy day , digging may even go on until the next day[3]. It was suggested that rains soften the hard and dried soil , bring about favorable digging condition. Cox and Hunt also noted that moist condition favored activity only indirectly , probably creating moist conditions favored to digging for pocket gopher[14]. Our observations of burrowing behavior confirm that plateau zokor favored burrowing in soft soil conditions which were related to soil moist. For example , the burrowing processes happened in such an order: that is searching digging point , digging , kicking loosed soil backward , turning around , pushing loosed soil to a deposition site , and turning back to dig in soil conditions bellowed 10 kg/ cm^3[13] , but the order was interfered when the soil hardness was increased over 10 kg/ cm^3 , and the acts such as selfgrooming , turning around , and pausing occurred. Plateau zokor is a species different from Vleck's pocket gopher , but same result was found , that is , soil type or soil hardness largely affected the labor efficiency of burrowing as described by Vleck and in this study[9,15].

Table 3　Relationship between zokor density and soil hardness

Soil hardness (kg/ cm^3) ($N = 10$)		Zokor density (ind. / hm^2)
Ground surface	Underground 15～20 cm	
3.11 ±0.91	2.64 ±0.91	25.82
3.65 ±1.26	2.42 ±0.51	26.08
3.89 ±2.02	4.24 ±1.31	8.43
4.00 ±1.61	4.20 ±1.83	7.42
4.33 ±1.29	4.28 ±1.92	2.49
5.69 ±1.33	3.44 ±2.08	0.91
5.77 ±1.31	5.11 ±2.84	3.59
6.31 ±1.65	4.62 ±1.28	6.89
6.75 ±6.65	3.84 ±1.76	8.70
9.36 ±5.58	5.86 ±2.82	6.56
10.02 ±8.05	5.35 ±2.81	0.18
15.54 ±13.59	9.27 ±3.77	0.72
16.26 ±8.49	3.42 ±1.49	0.00

Plateau zokors prefer to the habitats where soil was disturbed or softened that favorite forbes were relative abundant (Table 3) . An animal could dig out 15.4 kg dried soil per hour in favorite habitat where soil hardness is about 4 kg/ cm^3 , the population density was

over 70 individuals/ hm^2. Before zokors were controlled in 1987[16], which was about 5 times high than that of the harder areas where soil hardness is over 26 kg/ cm^3. It is one of reasons why forage efficiency was improved along with decrease of the energy cost for burrowing.

When Lessa and Thaeler[17] reassessed the morphological specializations for digging soil in pocket gophers, they described that claw diggers are restricted to sandy soil, whereas modification for tooth digging allow exploitation of a broad range of soil types. The plateau zokors inhabit alpine meadow soil[18] and occasionally used the incisors cutting roots in the most hard soil, they usually use claw to dig, this was different from the description of Lessa and Thaeler.

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中　文　摘　要

高原鼢鼠的挖掘行为及其与土壤硬度的关系

王权业　周文扬　魏万红　张堰铭

(中国科学院西北高原生物研究所，西宁，810001)

樊乃昌

(浙江师范大学生物系，金华，321004)

采用无线电遥测法在中国科学院海北高寒草甸生态系统定位站对高原鼢鼠的挖掘行为及其与土壤硬度的关系进行了研究。结果表明，在相同的硬度条件下，雌雄动物的挖掘行为格局和挖掘效率基本相同，但是雄性动物挖掘所持续的时间明显高于雌性动物。随着土壤硬度的增加，高原鼢鼠挖掘的时间及每次挖掘时持续的时间明显增加，而每次的掘土量显著减少。野外调查也表明土壤硬度是影响高原鼢鼠对栖息地选择的一个重要因素，高原鼢鼠明显选择土壤硬度较小、而杂草类生物量较高的地方栖息。

关键词：高原鼢鼠；挖掘行为；土壤硬度