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A preliminary study of aggressive behavior in Siberian chipmunk *Eutamias sibiricus* pups: the behavioral pattern and its possible antipredator function

シベリアシマリス *Eutamias sibiricus* の幼獣で発見された攻撃的行動についての解析：行動パターンとその捕食者防衛的機能（予報）

KOBAYASHI Tomomichi
小林　朋道

Abstract：Until date, many studies have been performed to investigate antipredator behaviors in rodents. However, aggressive-defensive behaviors of very young pups have not been reported in any rodent species. I recently observed an aggressive behavior displayed by 10-day-old Siberian chipmunk（*Eutamias sibiricus*）pups whose eyes had not yet opened. In the present study, the aggressive-defensive behavior pattern of Siberian chipmunks and its possible antipredator function were investigated by preliminary experiments. The results observed were as follows:（１）the pups showed extensive, rapid body movements and made loud calls that were almost perfectly synchronized among all the pups in the nest box;（2）the aggressive behavior of the pups disappeared once they were old enough to leave the nest box and move rapidly;（3）domesticated polecats（Mustela putorius furo）retreated without biting the meat on hearing the vocalizations of the pups.

【**Keywords**】Pups of Siberian chipmunks, Antipredator behavior, Polecats, Weasels, Defensive call, Rodents

Introduction

Antipredator defensive behaviors of various animals have been well categorized by Endler（1986）. Many studies have reported different antipredator defensive behaviors of various rodents（Siberian chipmunk, Kobayashi and Watanabe, 1986; California ground squirrel *Spermophilus beecheyi* , Owings and Coss, 1977; Southern flying squirrel *Glaucomys volans*, Borgo et al., 2006; Vole, Gorman, 1984; Black-tailed prairie dog *Cynomys ludovicianus*, Loughry, 1988; Belding's ground squirrel, Robinson, 1980; Wood rat, Richardson, 1942; White rat, Griffith, 1920）. Some of these defensive behaviors of rodents have been considered to have a protective function for their litters（Sherman, 1977; Tamura, 1989; Kobayashi, 1994, 2000）.

The Siberian chipmunk *Eutamias sibiricus* is a rodent weighing 80–100 g and inhabiting Japan and northeastern areas of Eurasia. Snakes, weasels, stoats, foxes, and brown bears are known predators of the Siberian chipmunk（Snigirevskaya, 1962; Kawamichi, 1978; Kawamichi and Kawamichi, 1980; Kobayashi, 2000）. Antipredator behaviors displayed by the Siberian chipmunk are known to include fleeing, hiding, mobbing, and snake-scent application（SSA）（Kawamichi,1978; Kobayashi and Watanabe, 1981 ）. SSA（applying snake-scent to the fur）is a unique behavior that has to date only been observed in the Siberian chipmunk and California ground squirrel（Clucas et al., 2008）. This SSA behavior in the Siberian chipmunk has been considered to have a preventive function against snake attacks (Kobayashi and Watanabe, 1981, 1986).

I recently observed an aggressive behavior displayed by 10-day-old Siberian chipmunk pups on receiving some stimulus in the nest box. These pups had immature muscles, and therefore, were unable to move out of their nest. However, they showed aggressive behaviors including extensive, rapid body movements and loud calls. Such aggressive behaviors have not been previously observed in mammal pups.

This paper reports the details this newly discovered behavior and describes how it changed as the pups developed physically. In addition, the results of an experiment investigating the antipredator defensive effect of this behavior are also reported.

Ⅰ　The behavioral pattern and changes in this pattern as the pups developed physically

Materials and Methods

This study was performed under captive conditions using two litters of four and seven pups each (i.e., a total of 12 pups born in May, 2005). The pups were born from two Siberian chipmunk females (each approximately one and a half and two years old), which had been reared in an outdoor pen (1.0×1.0×0.9m) together with males for more than half a year.

When each female was pregnant, she was moved into a cage (0.4×0.4×0.35m) made of plastic and metal, and contained a wooden nest box (0.12×0.12×0.12 m). The cage was placed in a room (5.0×4.0×2.5m) with concrete walls, ceiling, and floor, and two transparent glass windows (0.8×1.0m). The daily light-dark cycle of the room was the same as that occurring outdoors because of the light coming through the window. However, the maximum value of brightness was lower in the room (approximately 600 lux) than in the outdoors. The females bred their pups in the nest box. One day after birth, the birthing cage was connected to another vacant cage of the same type via a corridor (0.1×0.1×0.25m) (Fig. 1). When the females entered the vacant cage, a barrier was installed in the center of the corridor so that the pups in the nest box were separated from their mothers. The lids of the cages and nest boxes could be easily removed, and the lids made a noise when they were removed.

At day 10 after birth, when the lids of the nest boxes were removed, the pups' behaviors were observed according to the following procedure: (1) the pups were observed once every 5–7 days between 6:00 and 8:00; (2) when the female was in the vacant cage, the barrier was quietly installed in the center of the corridor, and the number of pups that were out of the nest box was counted (the number of the pups was defined as the maximum number of pups observed during the 5 min observation period); (3) the lids of the cage and nest box were slowly removed, and the pups' responses to these stimuli were recorded for approximately 1 min using a digital video system (Sony Digital HandyCam PCR-TRU 17k, Sony Corporation); and (4) the body weight of each pup and the number of pups with open eyes were recorded.

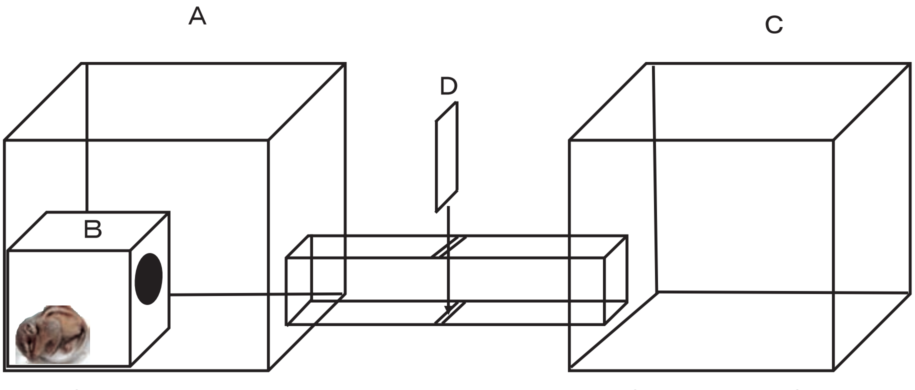

Fig.1　Setting in which the pups' behavior was observed. A and C: cages made of plastic and metal. B: wooden nest box containing pups. D: barrier being installed in the center of the corridor connecting two cages.

Kobayashi (2008) reported that pups who had begun to leave the nest box displayed SSA behavior by gnawing on pieces of snake slough. In this study, therefore, a piece of snake (*Elaphe climacophora*) slough (3×4cm) was presented to the pups outside the nest box, and their SSA behaviors in response to the snake slough were investigated between 12:00 and 13:00. These observations were also made on the same day when other observations were made. Based on these investigations, the relationship between the changes in aggressive-defensive behavior and the morphological and behavioral development of the pups was clarified.

Results

Behavior pattern

No difference was observed in the defensive behavior pattern displayed by the pups in the two litters. The defensive behavior pattern was characterized by the repeated abrupt vocalizations produced by the pups while arching their back for approximately 1 s (hereafter referred to as VAB) (Fig. 2 and 3). The VAB consisted of 10–20 short vocalizations. When the lid of the nest box was removed, one or two pups began to display VAB. Immediately after, the other pups in the nest box also began to display the same behavior and it continued. VAB was observed to be almost perfectly synchronized among all the pups during its prolonged display.

Changes in VAB as the pups developed physically

Fig. 4 shows the relationship between the observed changes in VAB and the morphological and behavioral developments of the pups (weight gain, opening of eyes, leaving the nest box, and SSA behavior). A change in VAB is expressed as the percentage of pups displaying VAB to the total number of pups present in the nest box. Weight is expressed as the average weight of the 12 pups. The number of pups with open eyes is expressed as the percentage of pups whose eyes were open to the total number of pups. The number of pups leaving the nest box is expressed as the percentage of pups that left the nest box to the total number of pups. The number of pups displaying SSA behavior is expressed as the percentage of pups displaying SSA behavior to the total number of pups that encountered a piece of snake slough placed outside the nest box.

The percentage of pups displaying VAB decreased with an increase in the weight of the pups, percentage of pups with open eyes, number of pups that left the nest box and those that displayed SSA behaviors. However, the factor influencing VAB the most was not clear.

In VAB displayed by 30-day-old pups, short vocalizations were repeated only a few times.

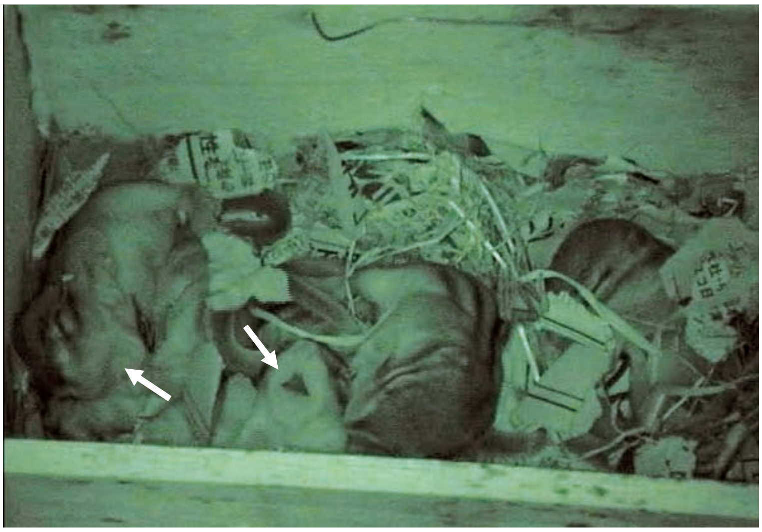

Fig. 2 Pups displaying synchronized aggressive behavior with loud calls. White arrows show the open mouths of vocalizing pups.

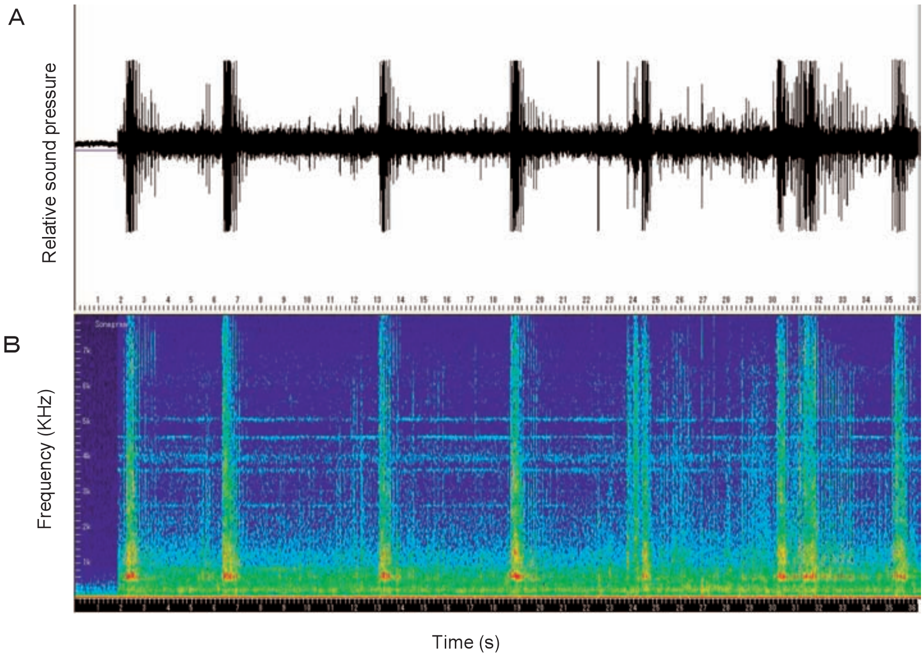

Fig. 3　Sonograms of calls emitted as part of the aggressive-defensive behavior displayed by four or five pups. Horizontal axis shows time （s）. Vertical axis in A shows relative sound pressure and in B shows frequency （kHz）.

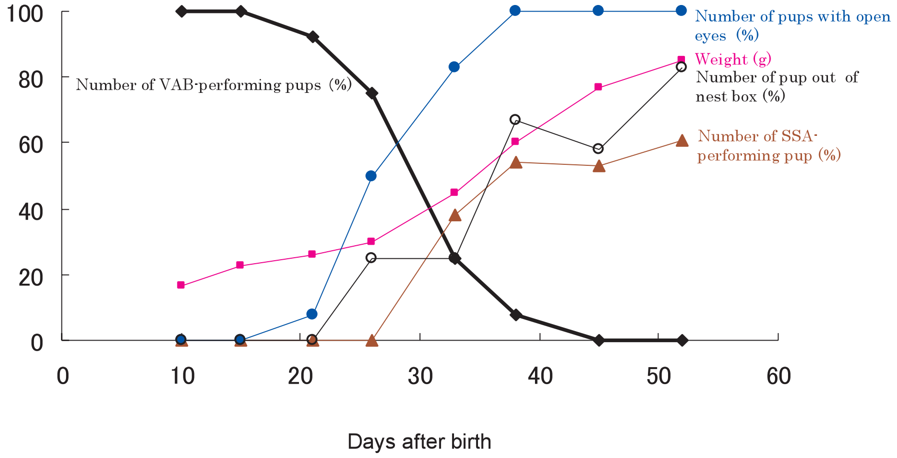

Fig. 4　Relationship between changes in VAB vocalization displayed by pups and their morphological and behavioral developments. Refer the text for the definition of numbers （%） and weight （g） in the figure.

Discussion

Synchronized vocalization and body movements displayed by almost all of the pups are important characteristics related to VAB. The functioning of VAB as an actual defensive behavior is not clear. However, synchronized VAB displayed in a dark nest is likely to be significantly effective as a defense.

Siberian chipmunks are known to construct their nests underground or in hollows in the trunks of large trees （Kawamichi, 1978; Kawamichi and Kawamichi, 1980）. Field research on Siberian chipmunks performed by Kawamichi and Kawamichi （1980） showed that the time spent by a mother chipmunk away from the nest increased after the birth of the pups and reached a maximum of approximately 10 h a day, when the pups were approximately 10-day-old （Fig. 5）. Moreover, a study by Kawamichi and Kawamichi （1980） as well as the findings of the present study suggest that pups younger than approximately 20 days seldom leave their nest. These findings imply

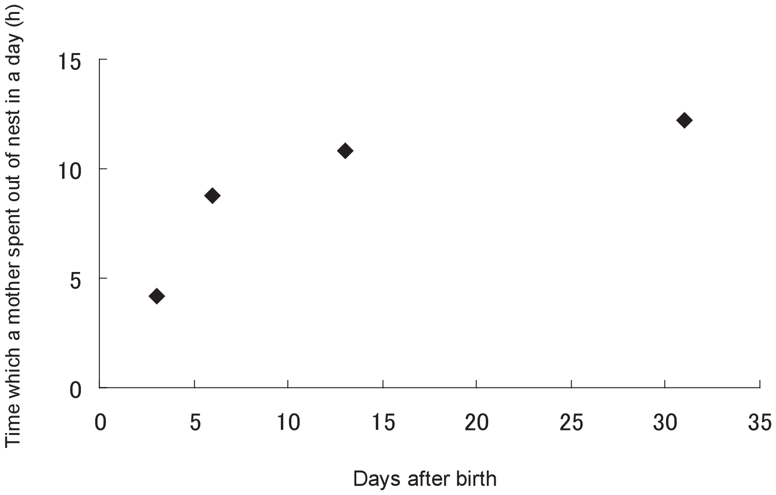

Fig. 5 Change in daily time spent away from the nest by a mother chipmunk compared with the increasing age of the pups. This plot has been constructed using the values reported by Kawamichi and Kawamichi (1980).

that, pups older than 10 days frequently encounter a predator that intrudes into their nest in the absence of their mother. Pups older than 30 days can leave the nest and hide in alternative shelters. Moreover, they also display other defensive behaviors including SSA behavior. Therefore, synchronized VAB is believed to be displayed by 10-day-old pups and decreases once they reach an age of 20 days.

In this study, the relationship between the types of stimuli and the occurrence of VAB was not investigated. However, the following were observed as stimuli to induce VAB in addition to the removal of the lid of the nest box:

(1) Noises near the nest box and (2) Direct, gentle touching of the pups by hand.

In this case, the pups performed the VAB more intensely than other stimuli.

These findings suggest that light, sound, vibration, and direct touch can induce VAB.

Ⅱ Experiment to investigate the antipredator function of VAB vocalization

Siberian chipmunks usually give birth in an underground nest, which is connected to the surface by a burrow or in the hollow of a tree trunk (Kawamichi and Kawamichi, 1980).

Weasels (*Mustela*), snakes, foxes (*Vulpes*), and owls (*Strix*) are known natural predators of Siberian chipmunks (Kawamichi, 1978). From the nature of these animals, weasels and snakes are suspected to enter the burrows leading to the chipmunk nests. In addition, these animals are able to hear the VAB vocalizations of chipmunk pups, which are emitted at a frequency of less than 7 kHz (Weasels: Hayashi, 1968; Snakes: Young, 1999). The VAB vocalizations of chipmunk pups may function as a defensive behavior against weasels and/or snakes.

In the present study, I undertook a preliminary investigation of the possibility that VAB vocalizations produced by the pups defend them against attacks by polecats or weasels.

Materials and Methods

Three ferrets (*Mustela putorius furo;* ♀ 630 g, approximately 0.5-year-old; ♀ 640 g, 0.8-year-old, ♂ 750 g, 1-year-old) obtained from an animal supplier were used for the experiment. Ferrets are known to be a domesticated form of the European polecat *Mustela putorius* retaining many wild characteristics including their hunting instinct (Hayashi, 1968; King, 1984).

The experimental apparatus was prepared as follows:

The corridor (5×5×55cm) was made of wood, except for the upper panel, which was a transparent plastic plate (Fig. 6). A speaker (ELE COM MS-77WH) was placed at one end of the corridor and the other end of corridor was left open for the ferrets to enter. The size of the entrance (6×6cm) is thought to

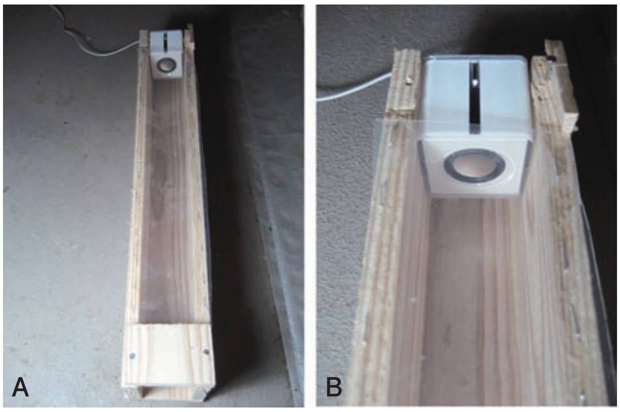

Fig. 6　Apparatus used for the experiment to investigate the effect of VAB vocalizations on ferrets. A: View of the corridor at the end of which a speaker was set up. B: Close-up of the speaker set.

be similar to that of a Siberian chipmunk burrow based on the report by Kawamichi et al. 1983.

The VAB vocalizations could be played back at any time at an amplitude of 3.5 dB at the entrance of the corridor.

The experiment proceeded as follows:

Each ferret was reared in a pen（1×1×1m）with food bought from a pet shop. The experiments were performed in a room with dimensions 5 × 4 × 2.5 m. The strength of the light in the room could be adjusted to 860, 470, 52, or 7 lux.

The pen in which the ferret was reared was placed in the room, and the door of the pen was opened to allow the ferret to exit. Then the experimental apparatus（the corridor including the speaker）was placed in the center of the room. The ferret was left to roam freely in the room one or two days（sometimes entering the corridor）under light conditions of 860 and 7 lux during the period 06:00–18:00 and 18:00–06:00, respectively. After this habituation of the ferret to the room and the apparatus, the room was darkened（52 lux）and the experimental trials began.

In the first trial, a piece of boiled chicken meat（18 g）on a plastic sheet was placed in the corridor about 3 cm in front of the speaker. Some time later, the ferret entered the corridor. I observed and recorded the behavior of the ferrets in the corridor with a Sony Digital Handycam DCR-TRU17K（set for night shooting）from the corner of the room where a chair and desk were placed. After the first trial, the apparatus was removed from the room.

The second trial begun about 30 min after the first trial and the apparatus was brought back into the room. In the second trial, the apparatus and the procedure were the same as for the first trial, except that VAB vocalizations were played back.

Some time after the second trial began, the ferret would enter the corridor. I observed and recorded the behavior of the ferret in the corridor with the handycam set for night shooting. When the ferret's nose was 10 cm from the meat, I began to play back the recorded VAB vocalizations continuously for 1 min to observe the ferrets' response.

The experiment（which consisted of both the first and second trials）was repeated two or three times for each ferret with an interval of more than two days between each experiment.

Results

The behaviors of the ferrets as they approached within 10 cm of the meat placed in the corridor could be classified into the following four categories: ① bite and eat, ② bite and carry away, ③ move back immediately, and ④ move back after approaching the meat.

Table 1 shows the results of the experiment. The three ferrets bit the meat in all eight trials in which

Table 1.　Responses of ferrets in the experiments to examine the effect of VAB vocalizations

	Experiments	1		2		3	
	Trials	first	second	first	second	first	second
Ferrets	a	②	③	②	③	②	③
	b	②	③	①	③	①	③
	c	②	③	②	③	—	

See the text for the explanation of response of ① - ③ .

VAB vocalizations were not played back. In three trials, the ferrets bit the meat and ate it in the corridor (i.e., displayed the behavior categorized as ①). In five trials, they bit the meat and withdrew from the corridor with the meat still in their mouth (i.e., displayed the behavior categorized as ②).

However, when VAB vocalization was played back, the ferrets withdrew from the corridor without biting the meat (i.e., displayed the behavior categorized as ③). In two trials, a ferret that had initially withdrawn from the corridor attempted to re-enter the corridor by only placing its head inside, but it stopped and retreated after hearing repeated VAB vocalizations.

The behavior categorized in ④ was not displayed in any of the trials.

Discussion

The results indicate that VAB vocalizations produced by Siberian chipmunk pups can suppress the attacks by ferrets. They also suggest that the predatory behavior of other *Mustela* species such as *M. nivalis, M. erminea,* and *M. itatsi,* which are biologically similar to ferrets (Hayashi, 1968), may also be curbed by such vocalizations.

Young (1999) reported that many species of snakes use a hissing sound in their interactions with predators as well as conspecifics. From the above report, it is clear that the frequency of the hissing sound of snakes overlaps with that of VAB vocalizations (for example, 0–7 kHz). Therefore, VAB vocalization may likely cause the ferrets to retreat because it resembles the hissing of snakes. Matthew et al. (1986) reported that burrowing owls *Athene cunicularia* emit a sound resembling that of rattlesnakes from inside their burrow. The report stated the possibility that the owls' hiss caused weasels to retreat from the burrow.

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