ハクビシンにおける侵入可能な長方形入口の大きさの検討

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— Original Article —

Sizes of rectangular gaps large enough for masked palm civets (*Paguma larvata*) to enter

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Abstract

Masked palm civets (*Paguma larvata*) not only cause agricultural damage but also invade houses in Japan. To prevent damage to houses, in previous studies we investigated the sizes and shapes of gaps large enough for masked palm civets to enter. However, the long side of the rectangular gaps was fixed to 20 cm, although civets might be able to enter smaller rectangular gaps. In this study, we researched the sizes of rectangular gaps large enough for civets to enter by reducing the short and long sides of rectangular gaps in 1cm decrements whenever a civet successfully entered them. In addition, we investigated their exploratory behavior in front of the gaps and how they entered the gaps to consider the invasion strategy. The minimum sizes of gaps that civets could enter were the H6 × W12 cm horizontally long rectangle and H11 × W7 cm vertically long rectangle. Exploration of gaps included not only olfactory and optical contacts, but also physical contact such as insertion of the muzzle into gaps. The time spent smelling and muzzle insertion into the gaps showed significant differences between the maximum sizes of gaps entered (Max), minimum sizes of gaps entered (Min), and gaps failed to enter (FE), and these time were the longest in FE (respectively $P < 0.01$). However, the time spent on gazing in front of each gaps showed no significant difference. These suggest that civets did not decide whether to enter from the gaps using only visual information, they also decide from smelling and inserting the muzzle into the gaps and trying to enter them.

Key words : masked palm civet, behavior, rectangular gaps, damage

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Introduction

In recent years, agricultural damage and invasion of houses by masked palm civets (*Paguma larvata*) have been increasing all over Japan. The habitats of civets in Japan are highly varied, and they are able to live not only in the mountains and farmlands but also in urban areas (Abe *et al.* 2005; Torii & Miyake 1986). Although civets are fundamentally omnivorous animals that prefer fruits, they adjust their diet both spatially and temporally in response to changing food resources (Torii 1986; Zhou *et al.* 2008). The kinds and quantities of food eaten by civets may depend on the availability in each habitat and season, and they may eat garbage around houses (Ninomiya *et al.* 2003; Torii 1986, 1993). In general, masked palm civets rest in underground burrows, hollow in trees, and on tree branches (Wang & Fuller 2001; Robinowitz 1991). However, in Japan, they also use the attics of buildings such as shrines, temples, houses, and warehouses as resting and farrowing sites (Abe *et al.* 2005; Ninomiya *et al.* 2003; Torii & Miyake 1986; Torii 1993).

The invasion of houses by masked palm civets may damage the health and lives of people due to the noise they make when they run around and the smell of their excretion. In addition, it has been reported that some houses near places where agricultural damage occurs are repeatedly used by civets (Furuya 2009). Joshi *et al.* (1995) reported that the viverrids may choose rest sites near foraging areas, and masked palm civets might be similar. Moreover, providing farrowing sites promote an increase in the civet population, and might lead the serious agricultural damage in the surrounding area. These finding suggest that preventing their use of houses may also reduce agricultural damage.

However, little is known about how masked palm civets invade buildings, and there are no effective measures to prevent their invasion of houses. Pest extermination is usually done to deal with the invasion of houses by civets. The territoriality of civets is low, and several individuals share one house (Wang & Fuller 2001; Ninomiya *et al.* 2003); therefore, other civets may remain there if one is trapped. If gaps that are used as routes of invasion of the house by civets are not repaired, new individuals may invade the house. To prevent their invasion of houses, countermeasures against gaps where civets may enter are needed.

In our previous studies, we investigated the sizes and shapes of gaps large enough for masked palm civets to enter, and reported that the minimum gaps that they entered were the H6 × W20 cm horizontally long rectangle, H20 × W6 cm vertically long rectangle, 8 cm square, and 9 cm diameter circle (Kase *et al.* 2010, Kase *et al.* 2011). However, because the long side of the rectangular gaps was fixed to 20 cm, the effect of the long side on the success or failure of the invasion by civets was not clarified. Because the ventilation gaps of houses are generally rectangles, it is necessary to investigate the minimum sizes of rectangular gaps that civets can enter to control their invasion of houses. This information is necessary not only to prevent invasion of buildings, but also as parameters for protective fences on farmlands. In this study, we reduced the short and long sides of rectangular gaps in 1cm decrements whenever a civet successfully entered them to investigate the sizes and shapes of rectangular gaps large enough for civets to enter. In addition, we investigated the civet's exploratory behavior in front of the gaps to consider their invasion strategies.

Materials and Methods

1. Animals and housing conditions

Six adult masked palm civets caught in Saitama Prefecture, Japan, were used (Table 1). They were kept housed in individual cages at the Saitama Prefectural Agriculture and Forestry Research Center, Green Tea and Local Products Laboratory. The cages (W620 × D465 × H565 mm) were made of metal fencing with a sliding door. The civets were fed commercial dog food (100 g per day) and fruits (0-50 g per day) at 1700 h and had *ad libitum* access to water.

2. Materials

The experiment was conducted in an L-shaped room that was built to study the behavior of medium-sized mammals (Fig. 1). The experiment room can be divided into two rooms by partitioning the top and bottom. In this experiment, the experimental apparatus and a masked palm civet were introduced into the top part of the experiment room. The experimental apparatus used in the previous study (Kase *et al.* 2010) was used in this study. It (W880 × D900 × H220 mm) was constructed of composite boards and covered with fine metal mesh (Fig. 2). The experimental apparatus had four compartments (W220 × D900 × H220 mm) divided by composite boards. The sizes and shapes of gaps of the four entrances to the apparatus could be changed by replacing a sliding board. One of the four compartments was used in this experiment; the other three were closed with the composite boards and not used. About 3 g banana was placed as reward in the back of one compartment. In

Table 1. Details of masked palm civets used in this study

Animals	Captured day	Weight (kg)
♂A	2006/12/14	3.5
♂B	2008/4/30	3.5
♀C	2006/7/7	3.7
♀D	2008/4/30	3.8
♀E	2007/11/16	2.4
♂F	2007/11/16	2.5

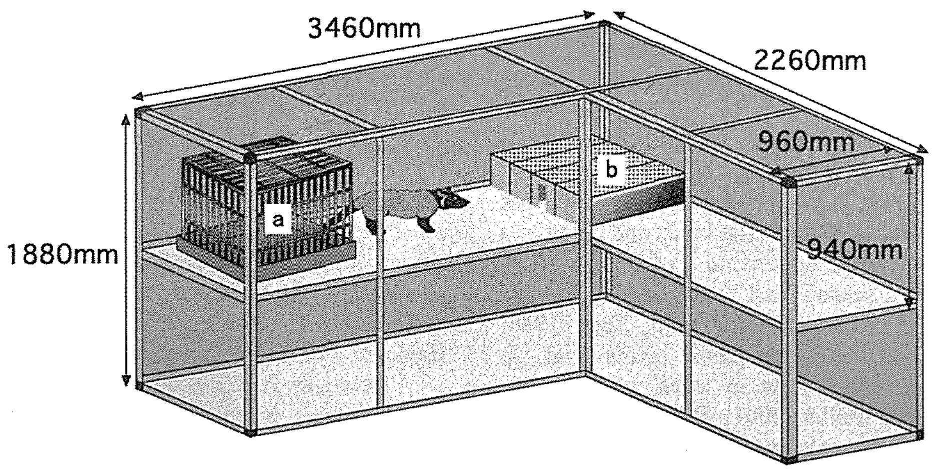

Fig. 1. Diagram of the experiment room. a: the breeding cage, b: the experimental apparatus.

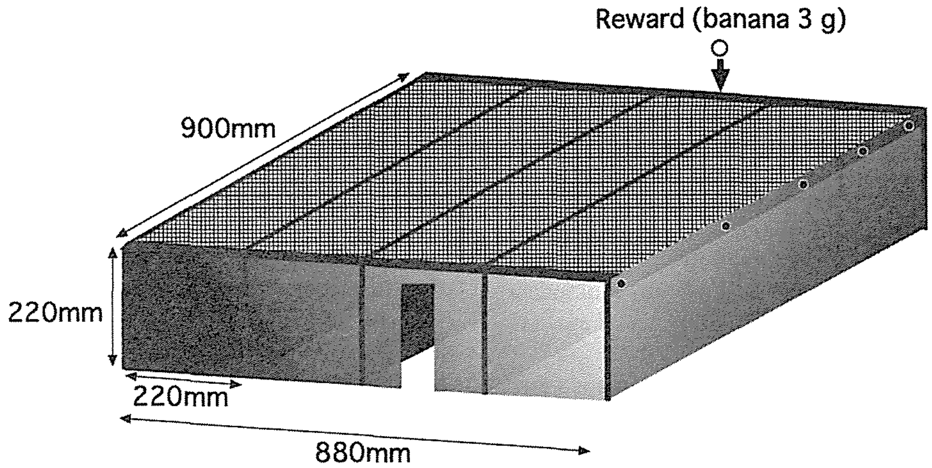

Fig. 2. Diagram of the experimental apparatus

this study, we investigated the sizes of rectangular gaps large enough for a masked palm civet to enter by changing the gap board. Based on the results of our previous studies, H8 × W20 cm horizontally long rectangular and H20 × W8 cm vertically long rectangular gaps were used. The sizes of short side and long side of the rectangular gaps were decreased in 1 cm decrements whenever a civet successfully entered.

3. Procedure

The study was conducted from September to October, 2009. A training session ahead of the test session was conducted as follows. First, the gap was not presented and civets were allowed to obtain the reward freely to habituate them to the apparatus. Next, a H8 × W20 cm horizontally long rectangular or H20 × W8 cm vertically long rectangular gap was presented, and the reward was placed in the back of the apparatus. Training was continued until an animal had entered by H8 × W20 cm and H20 × W8 cm rectangular gaps and retrieved the reward smoothly.

In the test session, the short side of the rectangular gap was decreased in 1 cm decrements whenever the civet successfully entered (short-side condition). Examination of the short-side condition was ended if the civet did not enter the gap within 30 min. If it was trying to enter the gap but could not, we judged that it was not possible to enter the gap and ended the condition. On the other hand, if motivation for the reward was obviously low and it did not try to enter the gap, the next day we presented a gap that was two ranks larger than the gap through which it did not pass. The condition was ended when a civet did not enter the gap two days in a row, and the minimum value of the short side of the rectangular gap that a civet entered (MVS) was decided. After the short side condition test, we allowed a resting period in which the entrance of the apparatus was open until the civet had retrieved the reward smoothly again. When the MVS of the rectangular gap was fixed, the long side of the rectangular gap was decreased in 2 cm decrements whenever the civet successfully entered (long-side condition). When a civet did not enter the gap, we presented a gap that was 1 cm larger than the gap through which had did not passed. The long-side condition was conducted according to a process similar to the short-side condition, and the minimum value of the long side of the rectangular gap that a civet entered (MVL) was eventually decided in 1 cm increments. To eliminate bias, the presentation order of the gap shapes was changed for every civet.

During the experiment, the behavior of the masked palm civets was recorded by a video camera (Sony DRC-TRV70, DRC-PC300). From the video tape, the success or failure of the invasion, the time spent on exploratory behavior at each gap, and the approach behavior were analyzed.

4. Data analysis

Data of two gap shapes were analyzed collectively because the results showed the same tendency. Each behavior therefore involved 12 data units in the analysis (two gap shapes × six animals). A Friedman test was used to evaluate the effects of the gap (the maximum sizes of gaps that were entered (Max), minimum sizes of gaps that were entered (Min), and gaps that were failed to enter (FE)) on the amount of time spent on exploratory behavior and the time spent on each behavior. We previously classified the behaviors of masked palm civets into seven categories (Kase *et al.* 2010).

Results

The minimum sizes of gaps that each masked palm civet entered are shown in Table 2. The minimum records in this experiment were H6 × W12 cm horizontally long rectangular and H11 × W7 cm vertically long rectangular gaps by the civet E.

The amounts of time spent on exploratory behavior in front of each gap (± SE) were 1.6 ± 0.3s at Max, 23.2 ± 6.2s at Min, and 56.5 ± 9.8s at FE, and significant differences were considered ($P < 0.01$). In each exploratory behavior, the time spent smelling ($P < 0.01$) and muzzle insertion ($P < 0.01$) in front of each gap showed significantly differences between Max, Min, and FE (Table 3). Destructive behaviors such as paw use, gnawing, and licking were hardly observed in front of the gaps that were entered.

Discussion

The minimum sizes of rectangular gaps that masked palm civets entered were the H6 × W12 cm horizontally long rectangle and H11 × W7 cm vertically long rectangle. In our previous study (Kase *et al.* 2010), we reported that civets A, B, C, and D entered the H7.5 × W20 cm horizontally long rectangular and H20 × W7.5 cm vertically long rectangular gaps. In this experiment, civets entered even smaller rectangular gaps. The walls and areas under the top layer of roofing of Japanese-style houses have many gaps to adjust to changes in humidity (Takahashi 2007). Further, installation of a ventilation opening below the floor level of the outside wall is recommended by the building code of Japan (Japan's e-Government Initiatives 2011). Ventilation openings are usually covered with wire screen to prevent invasion of animals. However, in old houses, the mesh may be rusted or broken, and civets often use such gaps as the route of the invasion of houses (Furuya 2009). There are sometimes such gaps in buildings that have been extended and rebuilt and under oriel windows set low in the wall, and civets also enter houses through these gaps (Furuya 2009).

Fences are used to prevent agricultural damage by mammals, so the gaps fences must be small enough to prevent the target species from entering. For example, the wire mesh with a 15 cm square grid that is used to keep wild boars out of farmlands will not work the smaller civet. Based on the present results, the grid of fences should be smaller than 6 × 12 cm to stop civet invasions.

As in previous studies (Kase *et al.* 2010, Kase *et al.* 2011), the head, shoulders, or pelvis was sometimes caught on the frame of gaps when they tried to enter. However, they rolled and shifted the position of the part that was caught on the frame, and were thus able to enter the gaps. Of the vertically long rectangular gaps, only civet F entered through gaps with the short side of 6 cm. Most adult civet heads are 6 cm or more wide (Kase *et al.* 2011), and even their head can not enter the W6 cm vertically long rectangular gap when they stand with all four paws on the ground. Civet F entered the W6 cm vertically long rectangular gap by turning its head 90 degrees. Civets B, C, D, and E also tried to enter the W6 cm vertically long rectangular gap in the same way as F, but they could not because their shoulders caught on the frame of the gap. This suggests that they adjust their body orientation to the shape of the gap when they try to enter it.

Kase *et al.* 2011 reported that the areas of the minimum sizes of square and circular gaps that individuals entered were approximately equal, meaning that there are the limits to the areas of gaps that civets can enter. In this experiment, the areas of the minimum sizes of horizontally and vertically long rectangular

Table 2. Minimum sizes of gaps that masked palm civets entered

Animals	Minimum sizes of gaps (H × W cm)	
	Horizontally long rectangle	Vertically long rectangle
♂A	7 × 12	12 × 7
♂B	6 × 19	12 × 7
♀C	7 × 12	12 × 7
♀D	7 × 11	11 × 7
♀E	6 × 12	11 × 7
♂F	6 × 15	14 × 6

Table 3. Time spent on each exploratory behavior (s) in front of the gaps (± SE)

	Max	Min	FE	P-value
Smelling	0.4±0.1	5.8±1.6	17.2±2.8	<0.01
Gazing	1.0±0.1	1.4±0.5	3.7±0.7	n.s.
Muzzle insertion	0.2±0.1	14.4±4.0	31.0±6.5	<0.01
Paw use	–	0.3±0.2	0.8±0.4	n.s.
Gnawing	–	0.2±0.2	2.8±1.4	n.s.
Licking	–	0.2±0.2	0.4±0.1	n.s.
Missing	–	0.9±3.3	0.6±0.4	n.s.

Max: the maximum sizes of gaps that civets could enter, Min: the minimum sizes of gaps that civets could enter, FE: gaps that civets failed to enter.

gaps that all individuals, except civet B, entered were approximately equal. In horizontally long rectangular gap, the MVS of civets A, C and D was 7 cm. However, the MVS of civet B was 6 cm even though it had about the same body weight as civets A, C, and D. Therefore, the MVL of civet B was bigger than it was in vertically long rectangular gap by physical or the psychological influence.

As expected, the smaller the gap, the longer the time spent on exploratory behavior in front of it. In each exploratory behavior, the time spent smelling and muzzle insertion in front of each gap also showed significant differences, and these were the longest in FE. However, the time spent on gazing in front of each gap showed no significant difference. Kase *et al.* 2010 reported that no significant difference in the amount of time spent on exploratory behavior in front of gaps that were successfully entered (SUE) and FE. It also reported that less time was spent smelling in SUE than in FE, but time spent in gazing and muzzle insertion in front of a gap in SUE were greater than that in FE. These results differ from the results obtained in this study due to difference in the experimental method. It means that civets intensively explored one gap in this study while they had explored four entrances at the same time in previous study. In a previous study, four different-sized but same-shaped gaps were presented at the same time, because the sizes of the gaps that civets entered were larger than others and the possibility of succeeding in the invasion was high, the time spent gazing and muzzle insertion in SUE might be long. This suggests that the visual information might be one factor used to judge the possibility of entering. On the other hand, we presented a gap one by one in this study. Therefore, gazing might be done to confirm the gap. However, in the current study as well as the previous one, exploration of gaps included not only olfactory and optical contacts, but also physical contacts such as insertion of the muzzle into the gap. While masked palm civets might recognize the sizes of the gaps by gazing, they did not decide whether to enter the gaps using only visual information.

Taken together with results of our previous study (Kase *et al.* 2011), masked palm civets could enter the H6 × W12 cm horizontally long rectangular, H11 × W7 cm vertically long rectangular, 8 cm square, and 9 cm diameter circular gaps. Consequently, it is necessary to cover these size gaps in the outside wall of buildings to prevent the invasion by civets. Furthermore, in this experiment, because slightly destructive behavior for gaps was observed, using strong materials like metal mesh is recommended to cover these gaps. However, further study is needed on the differences in the prevention effect of materials with which gaps are covered and how to cover them.

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ハクビシンにおける侵入可能な長方形入口の大きさの検討

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要　約

日本においてハクビシンは農作物被害だけでなく家屋侵入被害も引き起こしている。著者らはこれまでに家屋侵入被害を防除するため、ハクビシンが侵入可能な入口の大きさおよび形状の検討を行った。しかし実験では、長方形入口の長辺は20cmに固定しており、ハクビシンはさらに小さな入口でも侵入する可能性がある。本研究では、ハクビシンが侵入するごとに長方形入口の短辺と長辺を1cmずつ短くしていく方法で、侵入可能な長方形入口の大きさと形状を検討した。また、入口前での探査行動と侵入方法を調査し、侵入戦略に関して考察した。ハクビシンが侵入した最小の入口は、H6×W12cmの横長の長方形およびH11×W7cmの縦長の長方形であった。入口への探査行動は、嗅覚的、視覚的なものだけでなく、入口に鼻先を入れるといった物理的な接触も観察された。におい嗅ぎおよび鼻先入れの持続時間は、侵入した最大の入口、侵入した最小の入口、および侵入に失敗した入口間で有意差がみられ、侵入に失敗した入口において最長であった（それぞれ$P < 0.01$）。しかし、注視の持続時間は入口間で有意差がみられなかった。これらのことから、ハクビシンは視覚情報のみでその入口から侵入するか判断するのではなく、入口に接触して侵入の可否を判断し侵入に至ることが示唆された。

キーワード：ハクビシン，行動，長方形入口，被害

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