金網の特性がハクビシンの行動に及ぼす影響

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— Original Article —

Influence of the property of wire mesh on behavior in masked palm civets (*Paguma larvata*)

Chihiro KASE[1a], Yusuke EGUCHI[2*], Katsuji UETAKE[1] and Toshio TANAKA[1]

[1] School of Veterinary Medicine, Azabu University, Sagamihara 252-5201, Japan
[2] NARO Western Region Agricultural Research Center, Ohda 694-0013, Japan
[a] Present address: Chiba institute of science, Choshi 288-0025, Japan

*Corresponding author. E-mail address: eguchiy@affrc.go.jp

Abstract

To prevent masked palm civets from intruding into buildings, covering potential entry points with some obstacles is one of the best measures. In this study, we sealed up entry points with some wire mesh, and compared how they behave by differences in the mesh size and the gauge size (diameter of wire). For the wire mesh, we used Hexagonal Iron Wire Mesh (HM) (mesh size: 8 mm, 20 mm, and 40 mm; gauge size: 0.8 mm) and Welded Iron Wire Mesh (WM) (mesh size: 30 mm, 50 mm, and 75 mm; gauge size: 3.2 mm) to cover each point. All fences could block civets' intrusion in the experiments. However, they spent more time doing physical actions against the 40 mm of HM and 75 mm of WM (P <0.05) and they also took more time in biting on the 40 mm of HM (P <0.05). The results indicated that physical actions may occur linked to the mesh sizes of wire netting, and the destructive behaviors may happen linked to both the mesh and gauge sizes. Therefore we strongly recommend the choice of a smaller size of wire mesh that will lessen the chances of civets' intrusion and keep your building safer.

Key Words: intrusion prevention, masked palm civets, property of wire mesh, behavior

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Introduction

Nowadays, masked palm civets (*Paguma larvata*) have been seen across the country in Japan, however their habitats were first reported in the year of 1943 and these were dotted in a few regions only: Shizuoka Prefecture and Yamanashi Prefecture in the central region of Japan's main island and Shikoku which is an island located south west of Japan's main island (Nawa 1965). Given this distribution pattern, as there is no record of Viverridae fossil, they are considered as an introduced animal in Japan (Torii 2009). Also Masuda *et al.* (2010) determined the full mitochondrial DNA cytochrome *b* sequences of civets inhabiting in Japan and Taiwan, and reported that their results strongly indicated that civets in Japan originated in Taiwan.

Now masked palm civets have inhabited from the coast to snowy mountains including human dwellings in Japan (Torii 2009). In the southeastern area of China and Thailand, they usually rest on trees but sometimes use underground burrows that were already constructed by other animals (Rabinowitz 1991; Wang & Fuller 2001). In the daytime, civets have been seen spending time in trees in Japan but they often intrude under the floor or attics of houses to rest and reproduce (Abe *et al.* 2005; Ninomiya *et al.* 2003; Torii 1993; Torii & Miyake 1986). Once they found their favorite place to stay, they come over repeatedly. In particular, their excrements have caused damages to the houses and human health of the people living in the house. Houses intruded by civets have recently been increasing and it seriously becomes a nationwide problem. Because of the situation, effective measures to prevent civets' intrusion have to be found.

In our previous studies, we have reported the minimum sizes and shapes of entry points that allow masked palm civets to enter: a L12 × W6 cm horizontally long rectangle, a L7 × W11 cm vertically long rectangle, an 8-cm square, and a 9-cm diameter circle (Kase *et al.* 2010, 2011a, 2011b). As civets use vertical gaps on the walls as a migratory pathway, they can easily climb up and enter through inside the buildings (Kase *et al.* 2012). Therefore, it is necessary to cover potential entry points with some durable obstacles like wire netting, which has to be smaller than 8 cm, to prevent their intrusion. We hypothesize that their behavior and persistence for intrusion could be influenced by the differences in the mesh size and durability of wire nettings.

To investigate the effect and durability of wire mesh, in this study, we covered entry points with various sizes of wire mesh and compared how masked palm civets behave by differences in the mesh size, the gauge size (diameter of wire), and the positions of entry points.

Materials and Methods

1. Animals and housing conditions

Five adult masked palm civets (three males and two females) were used as test animals. They were captured for the purpose of pest extermination in Saitama Prefecture, Japan and were kept at Green Tea and Local Products Laboratory in the Saitama Prefectural Agriculture and Forestry Research Center (Table 1). They were transported in November 2010, and were kept at the National Agriculture Research Center of Western Region in Shimane Prefecture, Japan. Civets were placed separately in aluminum rearing cages (W540×D750×H525 mm).

During the experimental period, we provided civets daily care (e.g. cleaning up the rearing cages) between 0800 and 0900 h and fed them 100 g of commercial dog food per day each civet at 1700 h. They were able to access to water with *ad libitum* feeding. The rearing management and this experiment was planned and conducted according to the Guideline and the Policies Governing the Use of Live Vertebrate Animals of Azabu University.

2. Materials

The experiment was carried out in an experimental room (W960×D3460×H1880 mm) in the animal facility of the research center. The room was built to study of medium-sized mammals' behaviors. Rearing cages were placed there. The room has no windows and its temperature was kept constantly controlled by an air conditioner. For the lighting, fluorescent lamps was set and controlled by the lighting control system depends on day-length.

The frame of the experiment room was made of aluminum, two sides and the ceiling were covered with transparent acrylic boards, and the other two sides and the floor were covered with composite boards (Fig. 1). This experimental room was divided into two rooms by a plywood board with an entry point (H200×W500 mm) covered with wire mesh. The food as a reward was a commercial gummy candy (Meiji Fluid Gummy Candy with grape flavor), and was installed behind the plywood board. One gummy candy (4 g) was given at each trial. Entry points were set in two different positions: one was placed on the ground level (the ground site) and the other was above the civets' head height (the higher site). For the ground site, the entry point was installed 0 cm above the floor because we assumed civets would explore to find a food with their all four limbs on the floor. At the higher site, the entry point was installed 45 cm above the floor as we assumed they would explore standing on hind legs. For the fence, Hexagonal Iron Wire Mesh (HM) and Welded Iron Wire Mesh (WM) were placed to block over the entry points. Two kinds of wire nettings were chosen because they are commonly available products used as durable obstacles. Moreover, three different sizes of wire mesh were used: minimum, standard, and maximum size (mesh size of HM: 8 mm, 20 mm, and 40 mm; mesh size of WM: 30 mm, 50 mm, and 75 mm). Two types of the gauge size (diameter of wires) were also chosen: the thinnest size (0.8 mm) for HM and the standard size (3.2 mm) for WM.

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

Animal ID	Sex	Captured day	Weight (kg)*
A	male	2006/12/14	3.7
B	male	2008/4/30	3.0–3.2
C	male	2007/11/12	2.4–2.5
D	female	2006/7/7	2.7–2.8
E	female	2010/5/10	2.8–3.1

*: Weight of each civet changed during the experimental period though food gave the same amout

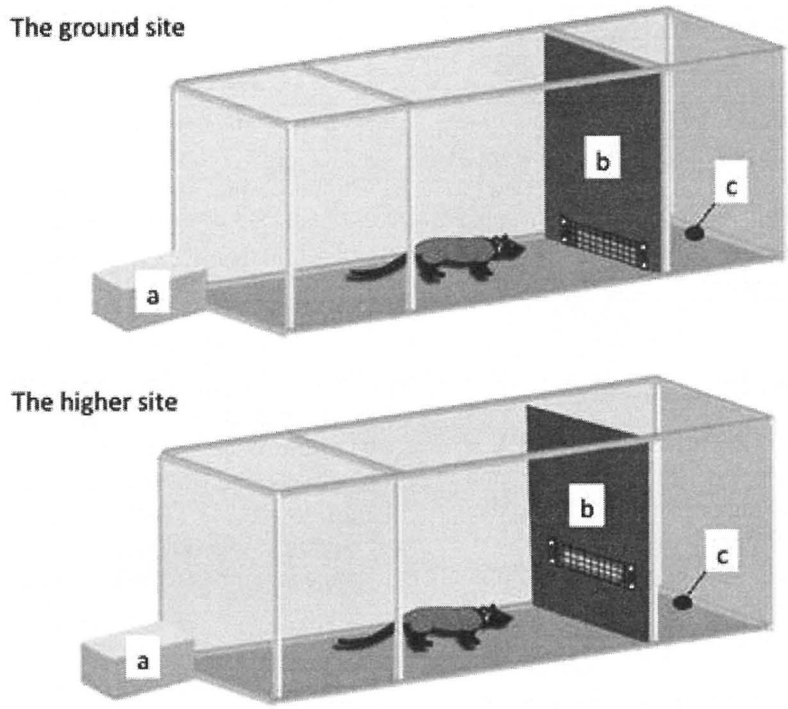

Figure 1. Diagram of the experimental room and the apparatus.
a: the rearing cage, b: the experimental apparatus, c: the food as a reward

3. Procedure

The study had been conducted between 0930 and 1400 h throughout the months of April until August in 2011. Before the tests, we habituated civets to the experiment room. For the practice, as the entry points were not covered with wire netting, they were allowed to enter and obtain rewards behind the plywood board freely. It was continued until a civet learned how to enter through the entry and retrieve rewards, and then return to the cage smoothly. For the test, the entry point was covered with the wire mesh and the duration of each trial was for 30 minutes a day each civet. Each trial with one condition has been finished when a test animal did not show any physical actions against the fence. The next condition was conducted after the rest for one day, in which the fence was removed and a civet was allowed to get rewards freely. Even if civets show their physical actions continuously, the period with one condition was not allowed to exceed five days. The trials at the ground site with HM were carried out first. To eliminate bias, the order of placing wire mesh followed the Latin square.

4. Data analysis

All tests were recorded by a video camera (Sony HDR-HC7) and civets' behaviors were successively observed. The success or failure in their intrusion, and the duration of their exploratory behaviors at the fence were analyzed. The total amount of time that each civet spent doing exploratory actions was calculated. The Wilcoxon signed-rank test was used for measuring a difference in the sum of the duration of civets' behaviors between two sites. To analyze the influence of mesh sizes, the total duration of exploratory behaviors were compared between all different types of wire nettings (HM: 8 mm vs. 20 mm vs. 40 mm; WM: 30 mm vs. 50 mm vs. 75 mm) by the Steel-Dwass procedure. The behaviors of masked palm civets were classified into four categories; Sniff, Staring, Physical actions (nuzzling, licking, putting their nose into the mesh and others) and Destructive behaviors (pushing or biting the fence) (Table 2). Data on the ground site and higher site were analyzed collectively because these results tended to be same. The durations of each behavior were also compared by the Steel-Dwass procedure. For all of analyses, a commercial statistical software "Statcel3" (OMS Publishing Inc., Tokyo, Japan) was used. For significance, a P-value of <0.05 was selected.

Table 2. Categories of observed behaviors in animals

Categories	Behaviors	Definitions
Sniff	Sniff	Sniffing the fence
Staring	Staring	Staring at the fence
Physical actions	Muzzle inserting	Putting their muzzles into the fence or nuzzling
	Licking	Licking the fence
	Pawing	Touching the fence with their paws, or putting their paws into the fence
	Others	Other than those above, and non-destructive behaviors
Destructive behaviors	Biting	Biting the fence directly, or biting pulling it up with their paws
	Pressing	Pressing or pushing the fence with their paws or heads

Results

All fences blocked civets' intrusion. At the ground site, some civets' physical actions did not continue five days in a row against the 8 mm and the 20 mm of HM, and the 30 mm of WM (Table 3). At the higher site, some civets showed physical actions against the 8 mm, 20 mm, and 40 mm of HM and the 30 mm of WM, but did not continue to show more than four days.

The total duration of their exploratory behaviors did not show any significant differences between the two sites (median ± quartile deviation; the ground site vs. the higher site; 262.0 ± 242.5 s vs. 388.5 ± 402.0 s, P =0.210) However, all civets showed their active exploring standing on their hind legs, pulling themselves up holding on to wire mesh, and climbing the fence only at the higher site.

Civets spent the longer period of time with their behaviors against the 40 mm compared to other HMs (8 mm vs. 40 mm, P <0.01; 20 mm vs. 40 mm, P <0.05) (Fig. 2), and against the 75 mm compared with other WMs (30 mm vs. 75 mm; 50 mm vs. 75 mm, respectively, P <0.01) (Fig. 3).

For the HMs, civets spent more time sniffing and staring at the 40mm than at the 8 mm (P <0.05) (Table 4). They spent the longest period of time with the physical actions at the 40 mm (P <0.05). Civets took more time in destructive behavior against the 40 mm than at the 8 mm.

For the WMs, civets spent the longest period of time sniffing and doing physical actions against the 75 mm (P <0.05) (Table 5). Destructive behavior was slightly observed against the 75 mm, but it did not happen against any other fences.

Discussion

In this experiment, all fences as an obstacle covered entry points were able to prevent masked palm civets' intrusion. However, it was also shown that they behaved differently depends on the mesh size and the gauge size.

Against both HM and WM, the total duration of exploratory behaviors tended to be long against the biggest wire netting in the mesh size. In addition, the similar tendency was shown in each behavior. It is thought that the duration of physical actions and destructive behaviors are influenced by the durability of wire nettings as civets spent the longest period of time with physical actions against the biggest one in the mesh size. It is also considered that physical actions such as putting their nose into the wire mesh occur linked to the mesh size.

Table 3. The number of testing days in each condition

Conditions			Animal ID				
			A	B	C	D	E
The ground site	Hexagonal Iron Wire Mesh (HM)	8 mm	2	4	5	2	1
		20 mm	2	5	5	3	1
		40 mm	5	5	5	5	5
	Welded Iron Wire Mesh (WM)	30 mm	5	2	1	3	2
		50 mm	5	5	5	5	5
		75 mm	5	5	5	5	5
The higher site	Hexagonal Iron Wire Mesh (HM)	8 mm	2	5	5	5	2
		20 mm	1	5	5	5	1
		40 mm	5	5	5	5	2
	Welded Iron Wire Mesh (WM)	30 mm	2	5	5	5	5
		50 mm	5	5	5	5	5
		75 mm	5	5	5	5	5

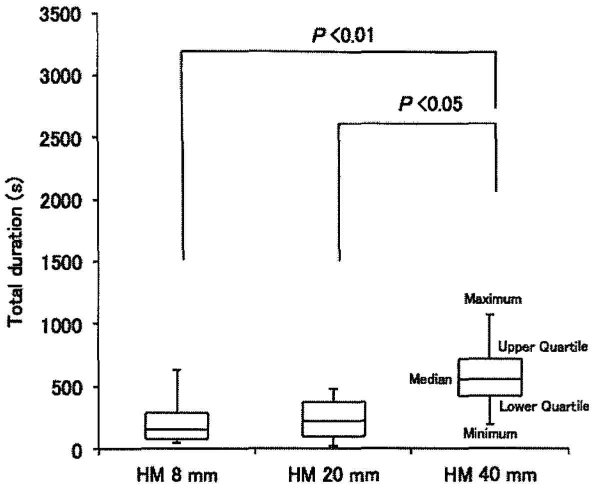

Figure 2. Total duration of exploratory behavior (s) against the Hexagonal Iron Wire Mesh (n=10).

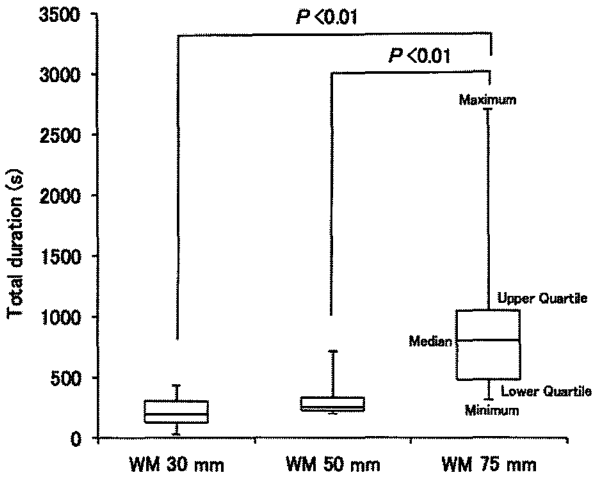

Figure 3. Total duration of exploratory behavior (s) against the Welded Iron Wire Mesh (n=10).

Table 4. Duration of each exploratory behavior (s) against the Hexagonal Iron Wire Mesh (median ± quartile deviation, n=10)

Categories	Hexagonal Iron Wire Mesh (HM)		
	8 mm	20 mm	40 mm
Sniff	143.0 ± 207.0^{a}	173.5 ± 250.0	329.5 ± 299.5^{b}
Staring	15.5 ± 15.3^{a}	28.0 ± 41.8	46.0 ± 24.0^{b}
Physical actions	0.0 ± 0.0^{a}	0.5 ± 3.3^{a}	59.0 ± 48.0^{b}
Destructive behaviors	0.0 ± 0.0^{a}	0.0 ± 0.0	3.5 ± 36.8^{b}

Between different letters: $P < 0.05$

Table 5. Duration of each exploratory behavior (s) against the Welded Iron Wire Mesh (median ± quartile deviation, n=10)

Categories	Welded Iron Wire Mesh (WM)		
	30 mm	50 mm	75 mm
Sniff	165.0 ± 183.8^{a}	189.5 ± 98.8^{a}	342.5 ± 406.8^{b}
Staring	15.0 ± 17.8^{a}	37.0 ± 24.3	64.0 ± 61.0^{b}
Physical actions	7.5 ± 11.3^{a}	43.0 ± 17.3^{b}	231.5 ± 322.5^{c}
Destructive behaviors	–	–	0.0 ± 1.0

Between different letters: $P < 0.05$

–: not observed

External measurements for 12 masked palm civets investigated by our previous study (Kase *et al.* 2011a) are as follows: the range of body weight = 2.2–3.4 kg, head width (mean ± SE) = 60.4 ± 1.0 mm, and head height (mean ± SE) = 51.3 ± 0.7 mm. Kase *et al.* (2011a) indicated a body weight of civet was positively correlated with a head width. Because civets used in this experiment weigh 2.4–3.7 kg, some of them might have a bigger head than an average head size. However, it is considered the 75 mm of wire mesh was large enough for all civets' heads to put into. Actually, civet C and E put their heads completely through the 75 mm of WM. The duration of physical actions tended to last long against the 75 mm of WM. It means that they probably get more motivated to try to put their muzzles into the wire mesh, which is big enough for their heads through.

Destructive behavior was shown against the 40 mm of HM and it was little shown against the 8 mm and 20 mm of HM. Therefore, this result indicated that destructive behaviors occurs when the mesh size is bigger. However, they did not show destructive behaviors against the 30 mm of WM and 50 mm of WM. It is because that the gauge size of WM was larger than that of HM. From these results, the destructive actions such as pushing or biting the wire mesh may happen linked to both the mesh sizes and the gauge sizes of wire netting.

Between two sites, as there was no significant difference found in the total duration of masked palm civets' responses, they might not care about the height. Because masked palm civets have great mobility in a vertical direction, they often use arboreal habitats for foraging and resting (Abe *et al.* 2005; Nowak 2005; Rabinowitz 1991). However, they showed these behaviors standing on their hind legs, pulling themselves up, or climbing the wire mesh at the higher site. It is thought that if there is an entry point covered with the wire mesh in the higher position on the external wall of the building might be more attractive and more helpful for civets to climb up and find their new path way than that in the lower level.

Although the price of wire mesh is various depends on companies, the larger mesh size and smaller gauge size of wire nettings are not generally expensive. In order to reduce the cost, inexpensive fences are often chosen at houses damaged with civets' nuisances in Japan. In this experiment, these fences were also able to stop their intrusion but the larger size of wire mesh you get, the more civets' physical actions may happen. Furthermore the smaller gauge size of wire mesh you get, the more their destructive behaviors may occur. This result strongly recommends the choice of small mesh with larger gauge fences, the smaller than the 20 mm of Hexagonal Iron Wire Mesh or smaller than the 50 mm of Welded Iron Wire Mesh that lessens the chances of civets' intrusion and keeps your building safer without expensive and time-consuming troubles.

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金網の特性がハクビシンの行動に及ぼす影響

加瀬ちひろ[1,2]・江口祐輔[1,3*]・植竹勝治[1]・田中智夫[1]

[1]麻布大学獣医学部,　相模原市中央区　252-5201
[2]現所属：千葉科学大学,　銚子市　288-0025
[3]農研機構近畿中国四国農業研究センター大田拠点,　大田市　694-0013

*Corresponding author. E-mail address: eguchiy@affrc.go.jp

要　約

ハクビシンによる家屋への侵入を防ぐには、侵入口になりうる隙間を障害物で塞ぐ必要がある。そこで本研究では、ハクビシンが侵入できる隙間を金網で覆い、目合の大きさやワイヤーの線径の違いがハクビシンの行動に及ぼす影響について検討した。障害物は、鉄製亀甲金網（目合：8 mm、20 mm、40 mm、線径：0.8 mm）、鉄製溶接金網（目合：30 mm、50 mm、75 mm、線径：3.2 mm）とした。実験の結果、どの条件でもハクビシンの侵入は防げた。しかし、目合 40 mm の亀甲金網および目合 75 mm の溶接金網に対しては接触の持続時間が長くなり ($P <0.05$)、目合 40 mm の亀甲金網に対しては噛む行動が長く発現した（$P <0.05$）。これらの結果から、接触の発現には金網の目合の大きさが、破壊的行動の発現には目合の大きさと線径が関係していることが示唆され、ハクビシンによる侵入を低減させ、家屋への侵入を防止するためには目合の小さい金網の使用が推奨される。

キーワード：侵入防止、ハクビシン、金網の特性、行動

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