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Relation	

The effect of communal litter box provision on the defecation behavior of free-roaming cats in old-town Onomichi, Japan

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ABSTRACT

Feces littered on the ground by free-roaming cats contain bacteria, viruses, and parasites and pose a significant health risk to humans. The purpose of this study was to examine the effect of communal litter box provision on the defecation behavior of a free-roaming cat population. The study was conducted at H temple and its graveyard in the uptown area of old-town Onomichi, Japan. Cat feces were collected and weighed once a week for 4 weeks, at five popular defecation sites in the temple precincts and graveyard, to assess the quantity of feces left by the cats. A commercial cat repellent was then applied to the ground at 11 sites, including the five popular defecation sites, and six communal litter boxes, created by filling repurposed plastic planters with cat litter, were provided at different sites. The feces in the six litter boxes and on the ground at the five defecation sites were collected and weighed once a week for 14 weeks. The behavior of the cats around the litter boxes and defecation sites was captured using trail cameras. The total weight of the feces collected from the ground before the application of the litter boxes and cat repellent was 939 g. Three adult cats were mainly responsible for the feces on the ground. The amount of feces found on the ground around the temple decreased gradually and significantly after the provision application of the litter boxes and repellent, and reached 0 g

in the final week of the study. In contrast, the average weight of the feces in the six litter boxes increased gradually and significantly, and reached 65.7 g/litter box/week in the 14th week. The results showed that the provision of litter boxes and the use of repellent is effective in changing the defecation behavior of ownerless free-roaming cats. We recommend promoting the provision of litter boxes to free-roaming cats to reduce fecal pollution in Onomichi and engaging with local cat feeders to participate in the management of the litter boxes, such as cleaning and changing the litter.

Keywords: Free-roaming cats, Defecation behavior, Feces, Communal litter box

1. Introduction

The contribution of free-roaming cats to fecal pollution has not received much attention. It was, however, reported that the free-roaming cats living in three communities in California contributed about 76.4 tons of feces to the environment annually (Dabritz et al., 2006). Cat feces pose a significant threat to human health because of the presence of bacteria, viruses, and parasites that can infect humans and their pets (Voslářvá and Passantino, 2012; Gerhold et al., 2013). For instance, cats are hosts to zoonotic parasites, such as the protozoan, *Toxoplasma* *gondii*, and the ascarid, *Toxocara cati*. Playgrounds, private gardens, and public parks contaminated by cat feces can serve as sources of infection for humans (Lee at al., 2010). Children can accidentally come into contact with *T. cati* eggs when they play in sandboxes (Despommier, 2003).

As free-roaming cat populations are increasing in urban areas around the world, controlling these populations is a pressing issue. The trap-neuter-release (TNR) program has recently been accepted as a viable tool in managing cat populations. However, Natoli et al. (2006) concluded that TNR programs alone are not sufficient for managing urban feral cat populations. In contrast, Kilgour et al. (2017) proposed that the TNR program be continued over multiple years. They suggested that controlling cat populations is a long-term project and immediate effects cannot be expected. However, zoonotic diseases from cat feces greatly concern residents in urban areas, and this problem should be handled without delay, while simultaneously attempting to control the numbers of free-roaming cats. One possible solution is to provide communal litter boxes in areas where cat defecation is frequent. However, there is no research showing that the provision of litter boxes would change the behavior of free-roaming cats from defecating on the ground to defecating in the provided litter boxes.

The objective of this study was to examine the effect of communal litter box provision on the defecation behavior of a free-roaming cat population. Our hypothesis was that free-roaming cats that defecated on the ground would change their behavior if a cat repellent was applied at sites where cat defecation was not desired and litter boxes were provided where cat defecation was preferred.

2. Material and methods

2.1. Study area

The study was conducted at an H Buddhist temple and its attached graveyard (Fig. 1) with a total area of 3,976 m^2. The temple is located in the uptown area of old-town Onomichi, Japan, which is recognized as a "town of cats" where approximately 200 free-roaming cats live (Seo and Tanida, 2018). The town consists of residential and tourist areas with many historic temples and shrines. The city office of Onomichi receives complaints from the residents of the town about cat feces soiling the paths and grass and reducing the air quality of the neighborhood. The Hiroshima prefectural animal shelter financially supports the residents and temples in the old town through a TNR program; however, the defecation behavior of the neutered cats returning to their original territory should still be controlled. The temples and shrines serve as havens for the cats because harming or killing living things conflicts with the Buddhist and Shinto doctrine.

2.2. Study procedure

The staff of the H temple identified five popular defecation sites for the free-roaming cats in the temple premises and attached graveyard (Fig. 1). Cat feces were collected at these five sites. Each piece of feces was collected with tweezers and weighed with a compact digital scale (Digital kitchen scale EM3000-PI2, Takeda Corporation, Nagoya, Japan) once a week for 4 weeks to calculate the amount of feces left by the cats. The amount of cat urine was not measured in this study. Four trail cameras (Ltl-Acorn, Ltl-6210MC, Ltl-6310MC; Zhuhai Ltl Acorn Electronics Co., Ltd., Zhuhai, China) were set up at defecation sites 1 to 4 to identify individual cats (Fig. 1). The cameras were triggered by movement and captured pictures and videos automatically for 60 s when triggered. Setting a trail camera at site 5 was not possible because the site was near a tourist trail where people often walk. The SD cards and batteries in the trail cameras were replaced weekly.

After 4 weeks of weighing cat feces, cat repellent (Cat Repellent; Technology Research Institute of Osaka Prefecture, Osaka, Japan) that primarily emitted the smell of acetic and isovaleric acids, was applied at 11 sites (the five popular defecation sites in addition to six sites where the monk of the temple did not want the cats to defecate) (Fig. 1). The effectiveness of the cat repellent has been reported in previously by Seo and Tanida (2016, 2017). Simultaneously, six roofed cat litter boxes, created from repurposed plastic planters and filled with commercially available cat litter (Woody Fresh WF-70, IRIS OHYAMA, Sendai, Japan), were placed at different sites (Fig. 1). The dimensions of the litter boxes were 18.5 × 25.0 × 65.0 cm (Fig. 2). The volume of each litter box was 19,761 cm^3 and they could hold 10 L of cat litter. The four trail cameras were positioned so that they could capture the cats defecating on the ground as well as using the litter boxes. The feces in the litter boxes and on the ground at the popular defecation sites were collected and weighed every week for 14 weeks. The cat litter was cleaned and new litter was added once a week.

2.3. Control study

We selected three sites in the town where free-roaming cats had been constantly defecating on the ground as the control sites. These were K park (1,561 m^2), U Shinto shrine (3,476 m^2), and P small park (96 m^2). Communal litter boxes were not placed at these three sites. Feces were collected and weighed every week for 18 weeks from three sites in K park, three sites in U Shinto Shrine, and two sites in P small park. Observations using trail cameras were not permitted in these areas.

2.4. Statistical analysis

Kruskal–Wallis tests with Shirley–Williams multiple comparisons were used to test weekly changes in the numbers of defecation events and the weights of the feces in the litter boxes and on the ground. The statistical package, Ekuseru-Tokei 2012 (Social Survey Research Information Co., Ltd., Tokyo, Japan), was used to conduct these tests.

3. Results

3.1. Defecation behavior before the provision of communal litter boxes

Seventeen cats were identified on the temple premises from the camera footage and human observation. Cat feeders, who were either local caretakers or tourists, were observed on the temple premises and in the surrounding neighborhood. Most of the cats were dependent on the food they supplied. Using the camera data, we confirmed that three of the 17 cats (cats A, B, and C) were responsible for defecating on the ground at the four sites with cameras (site 5 had no camera) during the 4 weeks prior to providing the litter boxes. Thus, we focused on the behavior of cats A, B, and C in this study. The three cats were tamed female feral cats. Before providing the litter boxes, the total weight of feces on the ground at the five popular defecation sites over the 4 weeks was 939 g (78.3 g/cat/week). Almost all the feces were dry when collected.

3.2. Defecation behavior after the provision of communal litter boxes

The weekly changes in the number of defecation events in the litter boxes by cats A, B, and C is presented in Fig. 3. All three cats started to use the litter boxes in the first week after they were provided, but rarely used the boxes from the third to sixth week because of the bad weather during that period. The weekly number of defecation events in the litter boxes increased over time but this change was not statistically significant.

The weekly changes in the number of defecation events on the ground at the four popular defecation sites by cats A, B, and C before and after the litter boxes were provided is presented in Fig. 4. The weekly number of defecation events on the ground by the three cats decreased significantly (Kruskal–Wallis chi squared = 25.28, $df = 14$, $P = 0.0319$) after the litter boxes were provided. The defecation rates in the litter boxes (the number of defecation events in the litter boxes/the total number of defecation events) of cats A, B, and C were 81.3%, 88.6%, and 100%, respectively.

The number of defecation events by cats A, B, and C in each litter box during the 14-week experimental period is shown in Fig. 5a. Litter box 3 was heavily utilized by all the three cats. Litter boxes 1, 2, and 3 were mainly used by cat B, whereas litter boxes 4, 5, and 6 were mainly used by cat C. The use of litter boxes by cats B and C mainly occurred between 6.00 h and 11.00 h, whereas cat A defecated randomly (Fig. 5b).

The weekly weight of feces (g/litter box/week) in the six litter boxes increased significantly (Kruskal–Wallis chi squared = 25.02, $df = 14$, $P = 0.0343$) over time and reached an average of 65.7 g/litter box/week (or 394 g/6 litter boxes/week) in the 14th week (Fig. 6a). In contrast, the weight of feces on the ground at the five popular defecation sites decreased significantly (Kruskal–Wallis chi squared = 25.48, $df = 14$, $P = 0.0301$) over time after the litter boxes were provided and reached 0 g from the 12th until the 14th week of the experiment (Fig. 6b).

3.3. Control sites

The cat feces on the ground at the control sites (where no litter boxes were provided) did not decrease over time. The feces in K park and U shrine remained the same, and the feces in P small park increased over the 18-week period (Fig. 7). The total weight of feces over the 18 weeks in K park, U shrine, and P small park were 5.4, 1.8, and 3.4 kg, respectively. Although observations using trail cameras were not permitted in these areas, we visually observed and identified 20, 1, and 11 cats in K park, U shrine, and P small park, respectively, but we could not determine which cats were responsible for the feces on the ground.

4. Discussion

Cats A, B, and C were responsible for most of the feces left on the ground in the H temple area. The other cats observed in the H temple grounds were either temporary visitors or passersby. Before providing the litter boxes, the total weight of feces produced by the three cats at the five popular defecation sites was 939 g over a 4-week period (an average of 78.3

g/cat/week). Seo and Tanida (2018) reported that approximately 200 free-roaming cats live in the old town of Onomichi. Thus, it can be estimated that the weekly weight of feces for 200 cats may reach up to 15.66 kg per week, which could have a substantial effect on the town. The negative effects of free-roaming cats on wildlife species has been shown in several studies (Ash and Adams, 2003; Dauphine and Cooper, 2009; Petersen et al., 2012), but the negative effects of the feces of free-roaming cats has not received much attention. Stray or house cats can contaminate the ground and soil with *T. gondii* oocysts and *T. cati* eggs, which are extremely resistant to the environmental (Kazacos, 2001; Dabritz and Conrad, 2010; Lee et al., 2010). Furthermore, the hookworms derived from domestic cats, such as *Uncinaria stenocephala*, *Ancylostoma tubaeforme*, *A. braziliense*, and *A. ceylanicum* can infect humans (Bowman et al., 2010; Traversa, 2012). Nagamori et al. (2018) reported that 63.9% (541/846) of the free-roaming cats in north central Oklahoma, United States were infected with at least one parasite and 24.9% (211/846) of the cats were infected with multiple parasites. Diakou et al. (2017) showed that 24% of 150 fecal samples from the free-roaming cats living in continental and insular Greece were indicative of *T. cati* infections. Nutter et al. (2004) found that the percentage of feral cats seropositive with antibodies against *B. henselae* and *T. gondii* was significantly higher than that of pet cats.

Cats A, B, and C started to use the litter boxes in the first week after placing them in the temple. No special toilet training was conducted for the cats; however, cat repellent was placed at the sites where the cats regularly defecated and where the temple staff did not want the cats to defecate. The weekly weight of feces in the six litter boxes (g/litter box/week) increased significantly ($P < 0.05$) and reached an average of 65.7 g/box/week (or 394 g/6 boxes/week) in the final (14th) week of the study. In contrast, the weekly weight of the feces on the ground at five popular defecation sites decreased significantly ($P < 0.05$) after litter box provision and reached 0 g from the 12th to the final (14th) week of the study. This indicates that the provision of the litter boxes had a positive effect on reducing feces in the temple grounds. However, the other 14 cats observed in H temple that were either temporary visitors or passersby contributed to fecal pollution elsewhere; thus, we recommend that communal cat litter boxes are provided throughout the town.

The defecation rates of cats A, B, and C in the litter boxes were 81.3%, 88.6%, and 100%, respectively, at 14 weeks, suggesting that the cats had habituated to the litter boxes. The four monitored litter boxes were shared by the cats but there was a tendency for cats B and C to appropriate the litter boxes for their own use, as was suggested by Neilson (2004). Olm and Houpt (1988) commented that cats in multi-cat households may prefer not to defecate in the same litter box as another cat or may be prevented from using the same litter box by another cat. They recommended increasing the frequency of litter box cleaning to at least once a day. The litter boxes in the H temple area were cleaned only once a week when the SD cards and camera batteries were replaced. The cooperation of volunteer caretakers to clean the litter boxes at least once a day is indispensable for the successful operation of communal litter boxes because domestic cats have the ability to differentiate between feces based on fecal odors (Nakabayashi et al., 2012).

We found that the time of litter box use varied for the three cats. This could be owing to the social ranking among cats. Therefore, we recommend that more litter boxes are used than the number of free-roaming cats to increase the use of litter box. Future studies should establish how many litter boxes are needed and how often the boxes should be cleaned to improve the litter box utilization rates.

The size of litter boxes also affects their utilization rates by cats. Guy et al. (2014) found that cats show a definite preference for larger (86 × 39 cm) over regular-sized (56 × 38 cm) litter boxes. As the boxes used in our study were repurposed plastic planters (65 × 25 cm) similar in size to the regular-sized boxes, we recommend that larger litter boxes be tested in future studies.

The amount of cat feces on the ground in the three control sites (where no cat litter boxes were provided) did not decrease over the 18 weeks. The total amounts of feces over 18 weeks in K park, U shrine, and P small park reached 5.4, 1.8, and 3.4 kg, respectively. We believe that the cat feces on the ground at the three control sites would have decreased had cat litter boxes been provided.

During the study period, we discovered cat feeders, who were either local caretakers or tourists, on the temple premises and in the surrounding neighborhood. Feeding the cats obviously encourages them to remain there. Feeding unowned free-roaming cats is common both among households that own pets and those that do not (Natoli et al., 1999; Levy et al., 2003; Finkler et al., 2011; Gunther et al., 2016; Khor et al., 2018). The presence of reliable anthropogenic food sources allows a free-roaming cat colony to thrive (Tennent et al., 2009) and reduces their home range size (Pillay et al., 2018). As the TNR program alone may not have a great affect on urban feral cat demography, as is generally predicted (Gunther et al., 2011;

Gerhold and Jessup, 2018), an effective educational campaign to reduce unplanned feeding by residents and tourists is necessary to control the free-roaming cat population in the old town of Onomichi. We recommend promoting the provision of cat litter boxes and engaging with local cat feeders to participate in the management of the litter boxes, such as cleaning and changing the litter.

5. Conclusions

This study shows that the provision of communal litter boxes and the application of cat repellent in the territory of ownerless free-roaming cats is effective in changing their defecation behavior. This will reduce the spread of zoonotic parasites by cat feces. For more effective use of communal litter boxes, the optimum number of litter boxes/cat and the necessary frequency of litter box cleaning should be investigated in future studies. We believe that providing communal litter boxes alone will be insufficient for reducing fecal pollution by free-roaming cats; thus, we propose that this be combined with an effective educational campaign directed at both residents and tourists to reduce the number of free-roaming cats in Onomichi.

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Figure legends

Fig. 1. The layout of the H temple premises in old-town Onomichi, Japan showing the popular defecation sites (DS) of free-roaming cats and sites where commercial cat repellent (CR), communal litterboxes (LB), and trail cameras (TC) were located.

Fig. 2. The design of the communal cat litter boxes, covered with a simple plastic roof, used in the experimental study.

Fig. 3. Changes in the number of cat defecation events in litter boxes (average number per week) during the 14-week experimental period following the provision of litter boxes. A Kruskal–Wallis test was used to compare the average number of defecation events between the first and last week ($P = 0.09$).

Fig. 4. Changes in the number of cat defecation events on the ground (total number per week) at four popular defecation sites before and after the provision of litter boxes over an 18-week experimental period. A Kruskal–Wallis test with Shirley–Williams multiple comparisons was

used to compare the total number of defecation events before and after the provision of litterboxes.

* represents significance at P < 0.01

Fig. 5. Changes in the a) total number of defecation events in each litter box (LB) and b) total number of defecation events per hour in litter boxes by cats A, B, and C during a 14-week experimental period.

Fig. 6. Weekly changes in the a) average weight of cat feces in litter boxes and b) average weight of cat feces on the ground, at five defecation sites following the provision of litter boxes to free-roaming cats over a 14-week experimental period. Kruskal–Wallis tests with Shirley–Williams multiple comparisons were used to compare a) the weight of feces at the start of the litter box provision period (0 g) to that during the rest of the experimental period and b) the weight of feces between the control (before the provision of litterboxes) and the rest of the experimental period (after the provision of litterboxes). * represents significance at $P \leq 0.05$

Fig. 7. Weekly changes in the total weight (g) of cat feces on the ground at control sites over 18 weeks, in a) K park; b) U shrine; and c) P small park.

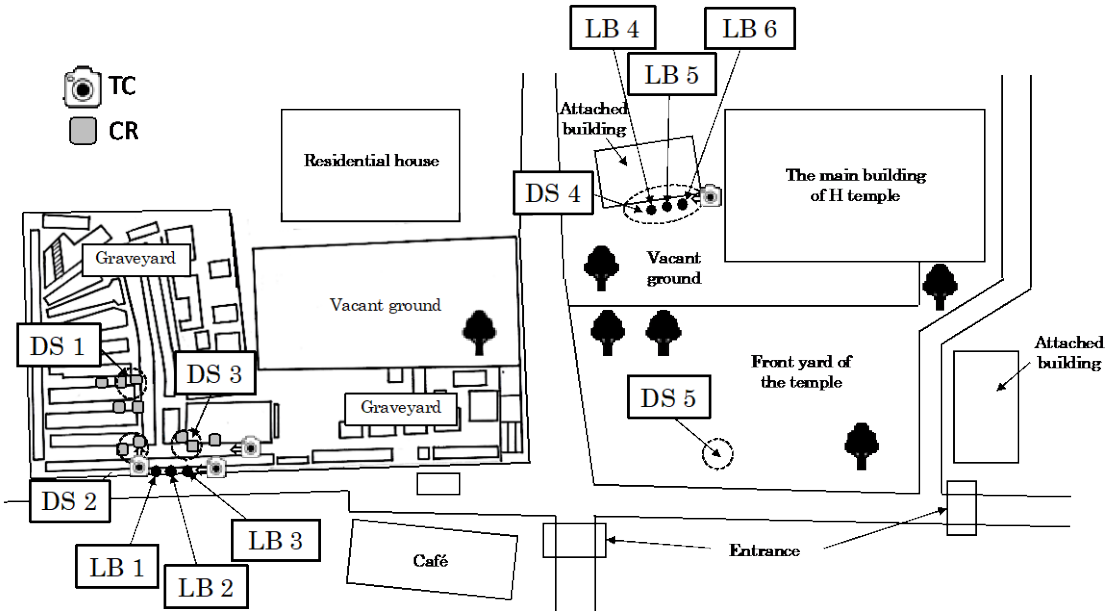


Figure 1.

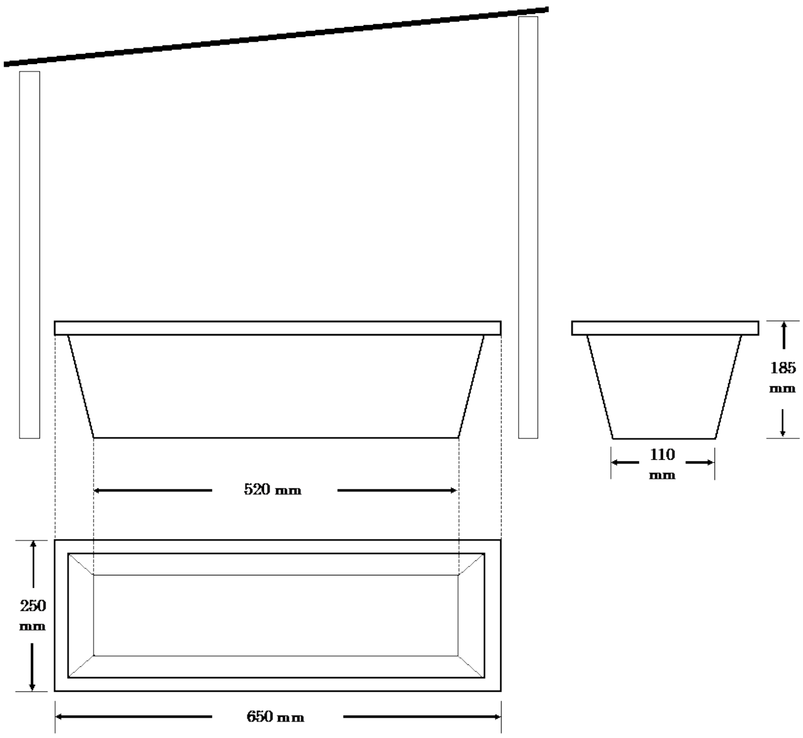


Figure 2.

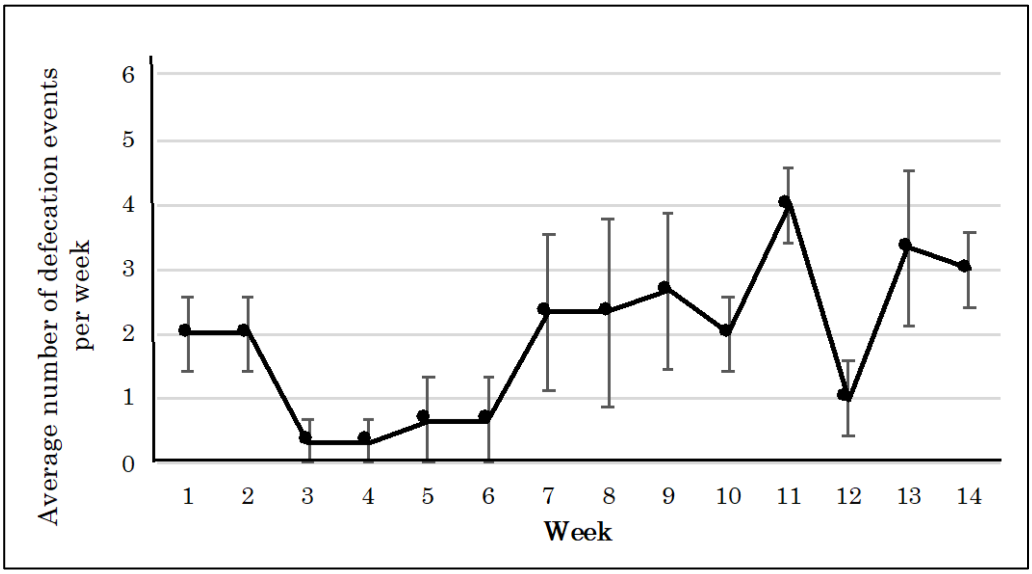


Figure 3.

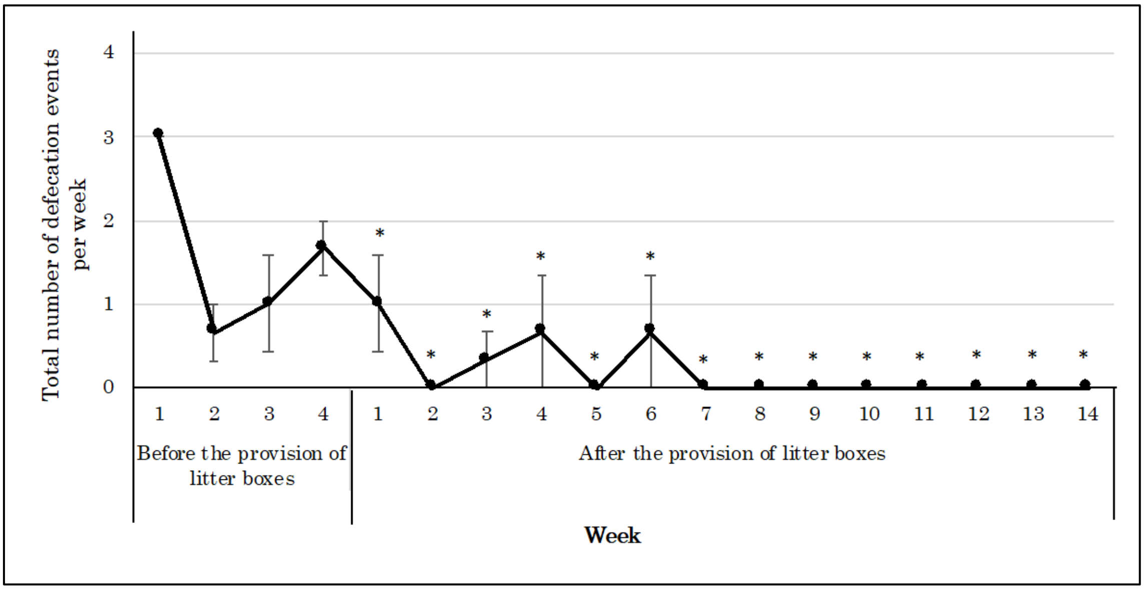
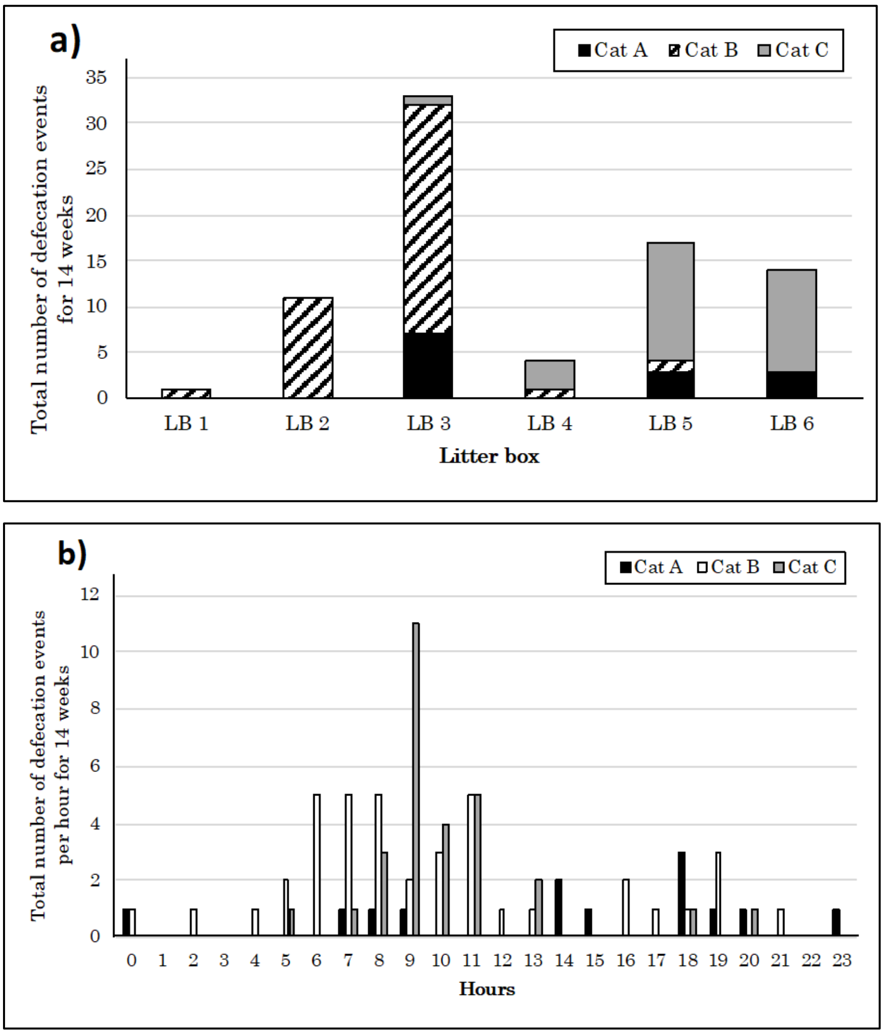
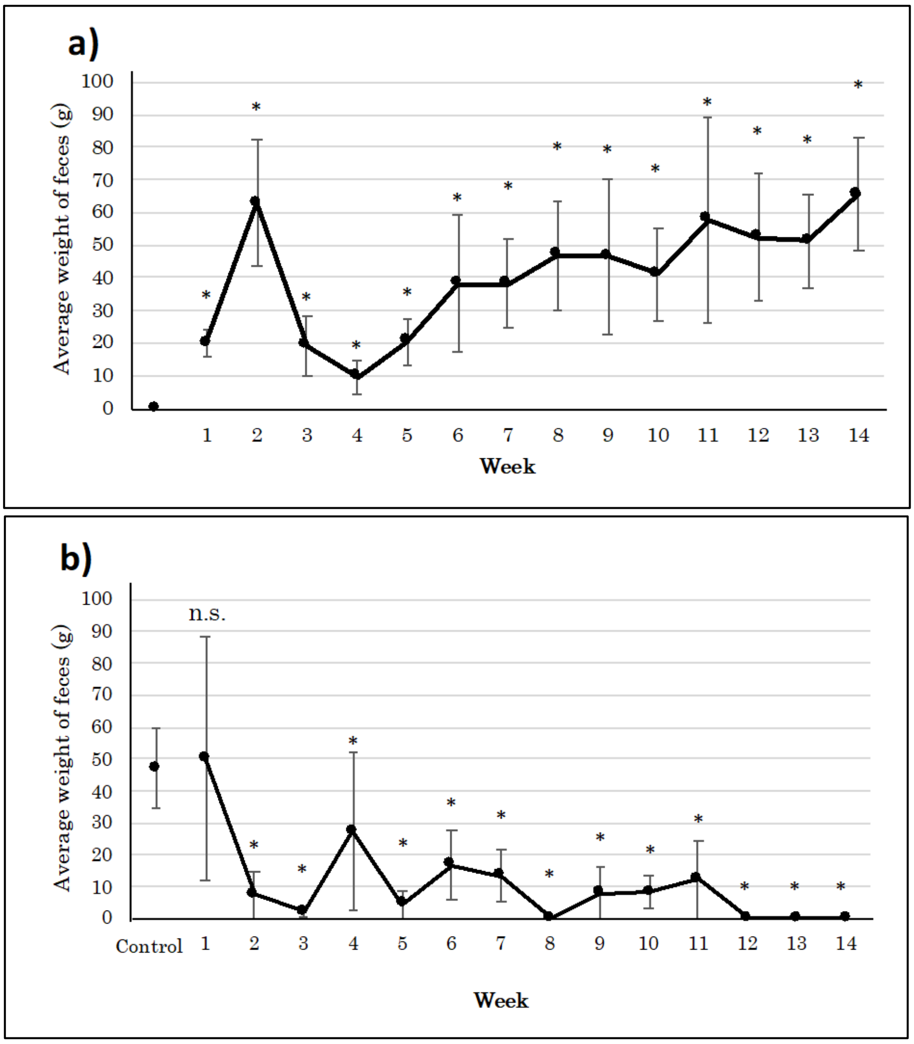


Figure 4.



a)
Cat A
Cat B
Cat C
Total number of defecation events for 14 weeks
35
30
25
20
15
10
5
0
LB 1
LB 2
LB 3
LB 4
LB 5
LB 6
Litter box
b)
Cat A
Cat B
Cat C
Total number of defecation events per hour for 14 weeks
12
10
8
6
4
2
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hours

Figure 5.



a)
Average weight of feces (g)
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Week
b)
n.s.
Average weight of feces (g)
100
90
80
70
60
50
40
30
20
10
0
Control 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Week

Figure 6.

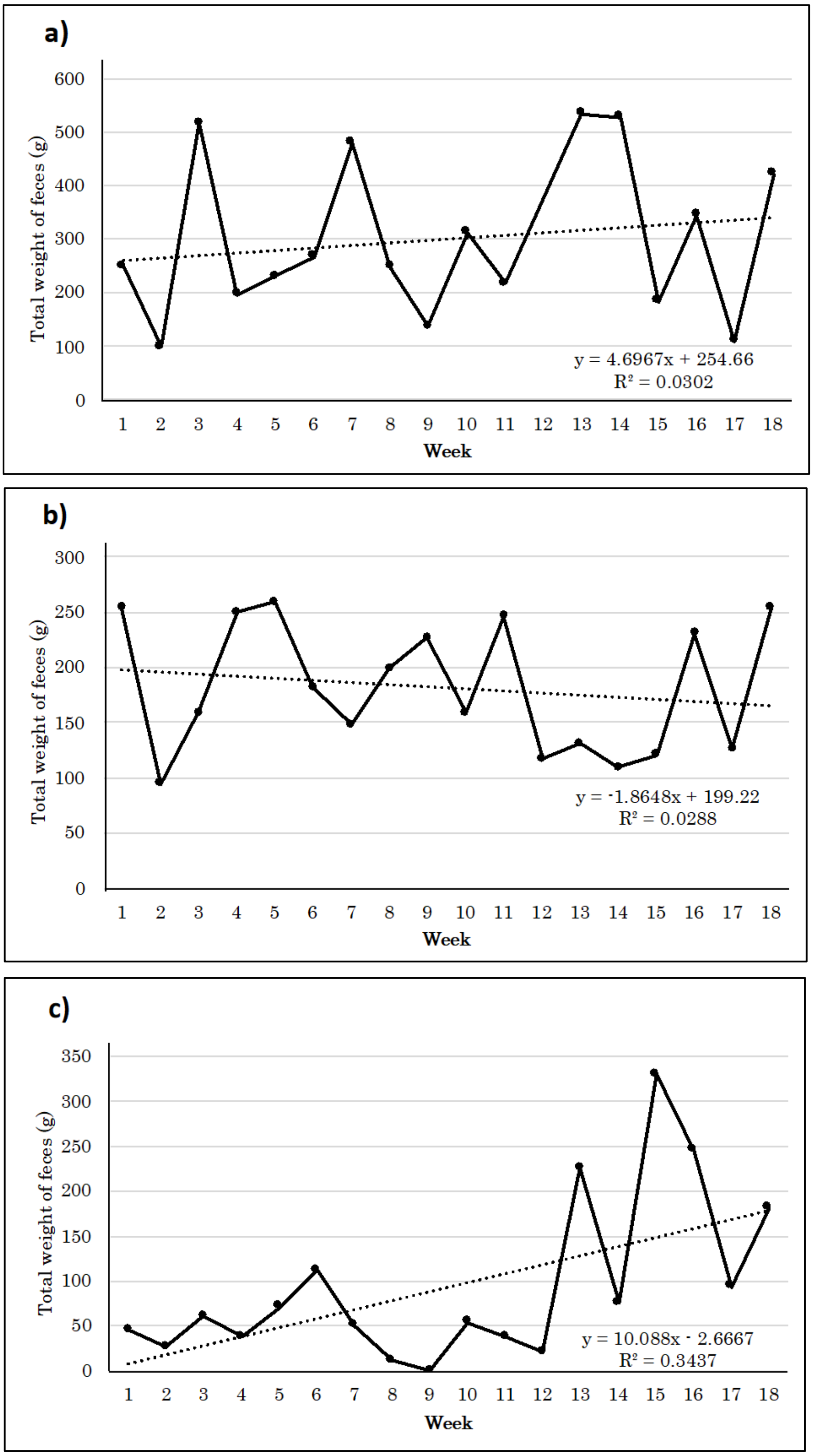

a)
Total weight of feces (g)
0
100
200
300
400
500
600
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Week
y = 4.6967x + 254.66
R² = 0.0302
b)
Total weight of feces (g)
0
50
100
150
200
250
300
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Week
y = -1.8648x + 199.22
R² = 0.0288
c)
Total weight of feces (g)
0
50
100
150
200
250
300
350
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Week
y = 10.088x - 2.6667
R² = 0.3437

Figure 7.