

European Journal of Wildlife Research

An experimental study on the effectiveness of a gel repellent on feral pigeons

--Manuscript Draft--

Manuscript Number:	EJWR-D-19-00239R1	
Full Title:	An experimental study on the effectiveness of a gel repellent on feral pigeons	
Article Type:	Original Article	
Keywords:	feral pigeons; peppermint; repellent; UV light	
Corresponding Author:	Anna Gagliardo Universita degli Studi di Pisa Pisa, ITALY	
Corresponding Author Secondary Information:		
Corresponding Author's Institution:	Universita degli Studi di Pisa	
Corresponding Author's Secondary Institution:		
First Author:	Anna Gagliardo	
First Author Secondary Information:		
Order of Authors:	Anna Gagliardo	
	Enrica Pollonara	
	Lorenzo Vanni	
	Dimitri Giunchi	
Order of Authors Secondary Information:		
Funding Information:	University of Pisa (PRA_2018_15)	Dr Anna Gagliardo
Abstract:	<p>The presence of feral pigeons (<i>Columba livia</i>) in anthropic environments often has a negative impact on human activities, public health and historic buildings. A number of different kind of dissuading devices, including gel repellents, are on the market. However, their efficacy has been rarely rigorously tested. We reported the effect of a recent multi-cue gel formulation (Bird Free®) on free living feral pigeons. In order to assess the efficacy of this product in discouraging the birds from occupying buildings, we conducted tests on both a night and a day roost. In addition, we performed a test on sites potentially suitable for nesting, in order to assess how pigeons reacted to the installation of the product just on the small area that can be occupied by a single nest. The tested product totally abolished the presence of feral pigeons at the night roost, and significantly reduced for at least one year their presence on the day roost area, compared to the control treatment. In addition, we observed that pigeons are discouraged from building their nests on sites treated with Bird Free® for at least three months. Our results indicate that Bird Free® is an effective method for reducing the location-specific impact of pigeons on buildings. The local effect of the product, strictly limited to the treated area, makes Bird Free® not suitable for large scale pigeon management programs aimed at reducing the carrying capacity of urban environment by lowering nest and roost sites availability.</p>	

An experimental study on the effectiveness of a gel repellent on feral pigeons

Anna Gagliardo, Enrica Pollonara, Lorenzo Vanni, Dimitri Giunchi

Department of Biology, University of Pisa, Via Volta 6, 56126 Pisa, Italy

Corresponding author: Anna Gagliardo, anna.gagliardo@unipi.it

ABSTRACT The presence of feral pigeons (*Columba livia*) in anthropic environments often has a negative impact on human activities, public health and historic buildings. A number of different kind of dissuading devices, including gel repellents, are on the market. However, their efficacy has been rarely rigorously tested. We reported the effect of a recent multi-cue gel formulation (Bird Free®) on free living feral pigeons. In order to assess the efficacy of this product in discouraging the birds from occupying buildings, we conducted tests on both a night and a day roost. In addition, we performed a test on sites potentially suitable for nesting, in order to assess how pigeons reacted to the installation of the product just on the small area that can be occupied by a single nest. The tested product totally abolished the presence of feral pigeons at the night roost, and significantly reduced for at least one year their presence on the day roost area, compared to the control treatment. In addition, we observed that pigeons are discouraged from building their nests on sites treated with Bird Free® for at least three months. Our results indicate that Bird Free® is an effective method for reducing the location-specific impact of pigeons on buildings. The local effect of the product, strictly limited to the treated area, makes Bird Free® not suitable for large scale pigeon management programs aimed at reducing the carrying capacity of urban environment by lowering nest and roost sites availability.

KEY WORDS feral pigeons, peppermint, repellent, UV light

Introduction

Feral pigeons (*Columba livia*) are distributed worldwide in urban habitats and their population density significantly increased especially during the second half of the last century (Johnston and Janiga 1995; Giunchi et al. 2012). This resulted in an increased negative impact of feral pigeon populations on human life and activities, such as public health, preservation of infrastructures, and resource exploitation (see Giunchi et al. 2012 for a review). Recently several management strategies for feral pigeons became available, mainly aimed at decreasing birds' survival rate, reproductive output, or resource availability (Giunchi et al. 2012; Skandrani et al. 2018). Experimental evidence (Haag-Wackernagel 1995; Dobeic et al. 2011; Giunchi et al. 2012; Senar et al. 2017) and population models (Giunchi et al. 2007, 2012) indicated that significant and long-lasting effects on feral pigeon populations can be obtained only by lowering the carrying capacity of the urban environment, that is by restricting the availability of food and nest/roost sites. This management policy can be integrated with other approaches (e.g. chemosterilization) according to the characteristics of both the city and pigeon population (Giunchi et al. 2012).

Several systems to exclude or repel pigeons from buildings have been proposed in recent years. These systems are designed to decrease the impact of pigeons on urban structures (Spennemann et al. 2017a, b; Balogh et al. 2019) and human exposure to zoonotic diseases (Haag-Wackernagel and Moch 2004; Haag-Wackernagel and Bircher 2010), but they could also be effective in controlling pigeon populations by reducing the availability of nest/roost sites. Although deterring/excluding pigeons from buildings is beneficial (Haag-Wackernagel and Geigenfeind 2008), this option is often dismissed because of the high costs of installation (e.g. electrical deterrents) and/or the visual impact of the devices (e.g., nets) especially on historic buildings. A variety of less costly and inconspicuous repelling methods are now available (Clark 1998; Stock and Haag-Wackernagel 2014; Harris et al. 2016), but their efficacy has been rarely rigorously tested (e.g. Haag-Wackernagel 2000; Jenni-Eiermann et al. 2014).

1 Gel repellents have been on the market for several years. The oldest formulations were based on
2 tactile aversion (contact gel), while recent products are mainly based on a combination of visual and
3
4 olfactory effects. Stock and Haag-Wackernagel (2014) tested the efficacy of two gel formulations
5
6 and found a significant and quite strong repellent effect of both gel types. However, Stock and Haag-
7
8 Wackernagel (2014) did not recommend these products for pigeon management. Their main concerns
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10 were: 1) although both gels significantly reduced the number of landings and the time spent by
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12 pigeons on the treated shelf, the presence of pigeons was not completely eliminated (100% reduction);
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14 2) the authors had the impression, although not statistically supported, that the repelling effect was
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16 transient; 3) both gels were very sticky, posing both aesthetical problems and concern for animal
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18 welfare due to the possible gluing of target birds and not target birds, although no bird turned out to
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20 be harmed by the repellents during the study (Stock and Haag-Wackernagel 2014).
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27 In this paper, we reported a test on the efficacy to repel free living feral pigeons of a recent multi-cue
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29 gel formulation, different from the product tested in previous experiments (Stock and Haag-
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31 Wackernagel 2014). In order to assess the efficacy of this new product (Bird Free®) in discouraging
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33 feral pigeons from occupying buildings, we conducted a test on both night and day roosts. In addition,
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35 we conducted a test on sites potentially suitable for nesting, in order to assess how pigeons reacted to
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37 the installation of the product just on the small area that can be occupied by a single nest.
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46 **METHODS**

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48 The tests were conducted at the Ospedale Didattico Veterinario (ODV) of the University of Pisa in
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50 San Piero a Grado (Pisa, Italy). The ODV is located in the open countryside near the small rural
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52 village of San Piero a Grado, ca. 6 km from the city of Pisa. The ODV consists of a big main building,
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54 several small buildings and horse and donkey stables. Pigeons could be observed on the roofs of the
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56 buildings and stables in variable numbers during the day. Each stable had windows and access to
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58 paddocks through which pigeons could freely enter.
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1 The repelling product (Bird Free®; EZFlexCo., Ltd., Korea) is a non-drying highly viscous (viscosity:
2 543500 mPa·s) gel supplied in pre-dosed PET dishes (diameter: 65 mm; height: 8 mm). The gel
3
4 contains: peppermint oil (0.52-0.55%) as bird repellent, citronellal as insect repellent (0.40-0.44%),
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6 beeswax (16-17%) and polybutene (72-73%) as fillers, and polydimethylsiloxanes (10-11%)
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8 reflecting ultraviolet light.
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11 12 13 14 15 16 **Experiment 1: Night roost**

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18 The night roost study was conducted on the two lower pitches of the roof of the building housing a
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20 heating equipment, which expelled hot air through vents below the roof on either side of the building
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22 (Figure S1, Online Resource). The warm air blown out from the vents during cold months created an
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24 ideal night roost for pigeons in winter. However, pigeons used this night roost all the year round. The
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26 south roof (dimension 9.09 x 4.15 m; a 29.2 cm wide metal cladding on either side of the roof was
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28 present; the width of the tiled section of the roof, where roosting occurred was about 8.5 x 0.5 m) was
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30 treated with Bird Free® (BF-roof); the north roof, (same dimensions as the south roof, but containing
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32 a chimney approximately half way down the roof on the east side, see Figure S1 (Online Resource);
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34 dimension of the area where roosting occurs are about the same as the BFN-roof) was treated with
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36 Empty PET Dishes (EDN-roof). In order to document the presence of the birds before and after the
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38 treatment one video-camera for each pitch of the roof was installed about one week before the
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40 beginning of the experiment. Each camera (BFN-roof, video-camera CAM01; EDN-roof video-
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42 camera CAM04) recorded a picture every second. Prior to the installation of the dishes (either
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44 containing Bird Free® or empty dishes) the guano was manually removed, and the roof was washed
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46 and disinfected with Lysoform®. When the roof to be treated was dry, the dishes (either Bird Free®
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48 or empty dishes) were fixed on the tiles with silicone adhesive at a distance (centre to centre) of 20
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50 cm from each other. However, the dishes fixed on the apex of the bent tiles turned out to be distant
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52 28 cm from the dishes fixed on the shingle. the installation the presence of the roof, closest to the warm
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air ducts, the dishes were placed at 14 cm from each other centre. An additional row of dishes was placed on the edges of the higher roof above the experimental roofs at 25 cm centre to centre. The installation of Bird Free® dishes occurred on the morning of 29th March 2017, while the installation of the Empty Dishes took place on the morning of the 30th March 2017. The treated area on each of the two roofs was approximately 9.0 x 1.8 m.

In the data analysis we considered Day 0 the day of the installation of the dishes. We counted the number of pigeons visible in the image recorded by the video-cameras at sunrise, 12.00, and sunset for each experimental Day (Day -3, Day -2, Day -1, Day 1, Day 2, Day 3, Day 7, Day 14, Day 30, Day 60, Day 90, 1 year later). For each experimental day we considered the highest number of birds recorded from among three images. The ratio between the highest number of birds present in each experimental day after the treatment and the median number of birds counted before the treatment was compared between BFN and EDN-roofs by means of the one tailed paired t-test.

Experiment 2: Day roost

The day roost study was conducted on the south-facing roof of a horse stable, on where pigeons roosted and displayed social activities during the day. In order to document the presence of the birds before and after treatments one video-camera was installed at the western, and one at the eastern side of the roof a few days before the treatment. Each camera recorded a picture every second. On the 16th May 2017 the eastern side roof (BFD-roof, Figure S2, Online Resource) was treated with Bird Free® (CAM01), while the western side of the roof (EDD-roof, Figure S2, Online Resource) was treated with empty PET dishes (CAM04) as a control. The sections of the corrugated roof to be treated were first cleaned with a power washer, and once dried the dishes were fixed with silicone on the apexes of the corrugations, which were 18.5 cm apart. Dishes fixed on the same corrugation were placed at a distance of 25 cm centre to centre. The section of the roof treated with Bird Free® was about 270 cm east/west, and 300 cm north/south on the west side of the treated area, tapering to 225 cm on the

east edge. The section of the roof treated with Empty Dishes was about of the same size as the area treated with Bird Free®, but with a specular shape (see Figure S2, Online Resource).

The day of the installation of the dishes was designated Day 0. The data collected during each experimental Day (Day -3, Day -2, Day -1, Day 1, Day 2, Day 3, Day 7, Day 14, Day 30, Day 60, Day 90, 1 year later Day 1, 1 year later Day 2, 1 year later Day 3) were included in the data analysis.

After viewing the videos, it emerged that in the period of the experiment the roof of the horse stable was used by the birds for courtship rather than for roosting most of the day. While courting, two or more pigeons walked on the roof mostly moving within a small area, and flew onto and off the roof within a short time. Consequently, the highest number of pigeons simultaneously sitting on the roof was not a good indicator for assessing the occupancy of the experimental areas by the birds, as in most cases very few pigeons (2-3) were present at the same time in the experimental areas. The Total Time (TT) each experimental area was occupied by at least one pigeon on each experimental day was used to test the efficacy of Bird Free® in repelling the birds. The considered parameter (TT) was log-transformed and modelled by means of a Linear Mixed Model (LMM) using the R-package *lme4* 1.11-19 (Bates et al. 2015). The fixed effects considered in the model were the experimental group (BF-roof and ED-roof), the stage (before and after installation of the dishes) and their interaction, while the experimental day was included as random intercept. Significance of fixed effects was tested using the type-III ANOVA with the Kenward-Roger approximation for degrees of freedom, using function *mixed* in the R-package *afex* 0.22-1 (Singmann et al. 2018). *Post hoc* comparisons were performed by adjusting the p-value using the Tukey method by means of the R-package *emmeans* 1.3.0 (Lenth 2018).

Experiment 3: Nest sites

This experiment was performed in a donkey stable, consisting of 6 cubicles with access to paddocks, 4 of which were occupied by donkeys. Pigeons used roosted throughout the donkey stable, and nested

1 on the floor of the rooms not occupied by donkeys and on the partition walls. The stable was
2 continuously monitored, so that when a nest was vacated by the fledged young pigeons, the nest site
3 was included in the experiment, and systematically assigned either to the experimental (BF, treated
4 with Bird Free®) or the control group (ED, treated with empty PET dishes). In total 16 sites were
5 treated (BF: n = 8; ED: n = 8). Each site was cleaned and disinfected before the application of either
6 Bird Free® or empty PET dishes. The dishes were fixed with silicone adhesive with their centre at
7 15 cm from the centre of the nesting site (Figure S3, Online Resource). In all but one case four dishes
8 of either BF or ED were fixed to each site. In one case, where a nest site was located in a particularly
9 sheltered location behind a piece of equipment, six dishes of BF were fixed to the nesting site. The
10 positions of the sites on the map of the stable are reported in Figure S4 (Online Resource). Each
11 treated site was monitored for three months after the installation of the dishes.

12 We photographed each nest on the day of the installation immediately after treatment (Day 0), and
13 on each experimental day: Day 1, Day 2, Day 3, Day 7, Day 15, Day 30, Day 60, Day 90. Considering
14 the subsequent stages through which a potential nest site may pass, at each nest a score was attributed
15 relative to the latest stage of the reproductive cycle reached. Where a second reproductive cycle
16 occurred, the highest score was considered in the analysis. The scores attributed to each site are as
17 follows (Figure S5, Online Resource): 0, no new material such as straw, feathers, egg or squabs; 1,
18 unstructured material (as the stable was full of straw, material such as straw or feather could
19 accidentally cover the dishes without being part of a structured nest, in particular for the nesting sites
20 located on the ground); 2, structured nest without egg or egg without nest; 3, eggs on structured nest;
21 4, squabs on nest; 5, fledglings on nest. The scores 0 and 1 indicate no nesting activity, while scores
22 ranging from 2 to 5 indicate either an attempt of or a successful reproduction. The Total Score of the
23 nests treated with BF and ED were compared with the Mann-Whitney U-test. The proportion of BF-
24 and ED-nests producing at least one fledgling was compared with the Fisher's exact test.

RESULTS

Experiment 1: Effect on a night roost

After the installation of Bird Free® not one single bird was observed to roost at night in the BFN-roof, while many birds regularly continued to roost on the EDN-roof. The number of pigeons observed on each roof on the experimental days at the established times are reported in Table 1 (Online Resource). The highest number of pigeons counted in each experimental day on the BFN-roof and on the EDN-roof is reported in Figure 1. The ratio between the highest number of pigeons observed after the installation and the median number of birds recorded in the three days immediately before the installation of the dishes was highly significantly different between treatments ($t_8 = 17.7$, $p < 0.001$, paired t-test). Visual evidence of the effect of the treatment is the accumulation of bird dropping on the tiles of the EDN-roof, but no accumulation of bird dropping on the BFN-roof one year after the installation (Fig. 1).

Experiment 2: Effect on a day roost

The Linear Mixed Model highlighted a significant effect of the stage ($F_{1,12} = 11.99$, $p = 0.005$), of the treatment ($F_{1,12} = 7.01$, $p = 0.02$) and of their interaction ($F_{1,12} = 8.57$, $p = 0.01$) on TT (Total Time each experimental area was occupied by at least one pigeon on each experimental day) (Table 2 Online Resource; Figure 2). The Tukey test did not reveal any significant difference between the two roofs before the installation of the dishes ($t_{12,0} = -0.16$, $p = 1$). The installation of Empty Dishes did not significantly affect the time spent by the birds on the roof ($t_{23,5} = 0.72$, $p = 0.89$), while the installation of Bird Free® strongly reduced the time spent by the birds on the roof compared to the stage before any installation ($t_{23,5} = 4.53$, $p < 0.001$). A significant difference between experimental groups emerged after the installation of the dishes ($t_{12,0} = 6.02$, $p < 0.001$), as TT was significantly greater on EDD-roof compared to BFD-roof. After one year the effect of Bird Free® on TT persisted without variation.

Experiment 3. Effect on nesting sites of feral pigeons.

The Fisher's exact test revealed a significant difference between the two treatments ($p = 0.001$). All the nest sites treated with Bird Free® were never used to reproduce or even attempting to reproduce (laying an egg in absence of a structured nest, or making a structured nest without egg; Fig. 3). By contrast, in all but one site treated with Empty Dishes pigeons made a new attempt to breed. There was a significant difference between the treatments (median score: BF, 1; ED, 3.5; Mann Whitney U test, $U = 7$, $p = 0.005$; see Fig. 4). It is worth noting that the nests on the partition walls (Figure 4) remained clean of feathers and hay, unless a structured nest was made or eggs were laid, as for the ED treated nest sites. By contrast, all nest sites on the floor, even if not re-occupied by breeding birds, such as the BF-treated nests, were dirty with hay, feathers and droppings after 90 days from the installation of the dishes. As the nests on the floor were next to the partition walls, birds sitting on top of these walls dropped on the floor, including to the BF- treated sites. Since the experiment took place during the moulting period of the pigeons, the down feathers accumulating on the floor were blown all over the stable, including onto the BF-treated nest sites. Since during the experimental observations the workers attending the donkeys were requested not to clean the rooms where treated nest sites were, hay blown from a big pile placed nearby the entrance of the two experimental rooms accumulated on the floor including on the unoccupied treated sites. Nevertheless, even the BF-treated sites on the floor, that were more likely to get dirty, were not occupied by the pigeons.

DISCUSSION

The data reported showed the efficacy of Bird Free® in repelling feral pigeons in three different contexts, characterised by a different motivational state of the birds: a night roost, a site where pigeons mainly gathered during the day for social activities, and a breeding area. We found Bird Free® immediately and totally dissuaded feral pigeons from roosting in the treated area of the night roost.

1 Interestingly, the repelling effect of the product did not diminish after one year from its installation,
2 even though a few dishes were blown away during a winter storm (see the bottom right picture in
3 Figure 1). It is probable that the birds continued to be discouraged by the product because the Bird
4 Free® dishes placed on the section of the roof close to the warm air vents, where the birds used to
5 roost, were still present.
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11 The Day Roost site was mainly used for short time intervals by small flocks of pigeons at a time,
12 which in many cases displayed courting behaviour. Based on the total time (TT) the areas were
13 occupied by at least one pigeon, Bird Free® appeared to significantly reduce the presence of pigeons
14 in the treated area compared to the control area. In fact, soon after the installation, the presence of the
15 birds on the BFD-roof dropped to near zero, and did not increase even one year later. By contrast the
16 TT in the EDD-area did not significantly diminish after installation of the dishes. However, there was
17 a fluctuation in the presence of birds on the roof of the horse stable, possibly reflecting the
18 reproductive activity of the pigeons, as many of them were engaged in incubating eggs and attending
19 the chicks, and/or a seasonal fluctuation in local pigeon numbers. In fact, in August (90 days after the
20 installation of Bird Free® and empty dishes) the attendance of the pigeons on the EDD-treated side
21 of the roof drastically dropped. Nevertheless, the repelling efficacy of Bird Free® is clearly shown
22 by the dramatic difference in the presence of pigeons in the two experimental areas after one year. In
23 fact, in the following spring the time spent by pigeons on the BFD-roof remained almost zero, while
24 the activity of the birds on the EDD-roof increased to a level comparable to that recorded before the
25 installation of the dishes.
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50 None of the nest sites treated with Bird Free® were subsequently used for nesting, despite the fact
51 that some material (feathers, straw) accidentally fell on the nest sites located on the floor of the donkey
52 stable. By contrast, among the ED-treated control sites five sites were occupied by nests for a
53 successful reproduction, at two sites attempts at reproduction occurred, and only one site was totally
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1 abandoned. It is worth noting that the repelling effect of BF was limited to the treated local area, and
2 pigeons continued to frequent the donkey stable.
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5 To the best of our knowledge only one previous paper reported a test on the efficacy of a multi-cues
6 gel product allegedly repelling pigeons (Stock and Haag-Wackernagel 2014). This product, however,
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8 was different from Bird Free®; the latter was put on the market later. For this reason, it is difficult to
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10 compare the results of the present experiment with Stock and Haag-Wackernagel's (2014)
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12 experiment, although some issues need to be discussed. Stock and Haag-Wackernagel (2014) reported
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14 that the gel tested by them was significantly effective in repelling pigeons, but they attributed this
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16 effect to a neophobia. However, it is unclear how much of the observed effect reported in Stock and
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18 Haag-Wackernagel (2014) was due to neophobia, because a control group was not included in their
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20 experiment, and their observation period lasted less than 30 days after the installation. In our
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22 experiment the neophobic component of the pigeons' response turned out to be marginal, while the
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24 repellent effect of Bird Free® was still evident a year after its installation. In addition, the installation
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26 of the dishes *per se* (Empty PET Dishes) did not repel pigeons in any of the experiments performed.
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28 Stock and Haag-Wackernagel (2014) reported that the gel used in their experiment was sticky and
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30 resulted in gluing insects and birds' feathers. By comparison, we never observed insects or feathers
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32 glued on the Bird Free® gel even after one year. The presence of citronellal is likely to discourage
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34 insects from approaching the dishes (Tamares et al. 2018), and the high viscosity of the Bird Free®
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36 gel makes the product not sticky enough to glue feathers, even when hay or down feathers were blown
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38 onto the dishes, as occurred with the sites on the floor of the donkey stable. Further, we never
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40 observed any pigeons pecking the gel dishes or any signs of feathers glued on the gel.
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52 The goal of our work was to assess the behavioural response of feral pigeons to installation of a
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54 repellent gel, without testing the mechanism and the sensory systems involved in the avoidance
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56 response. According to the manufacturer, Bird Free® combines olfactory (citronellal and peppermint)
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58 and visual (gel reflecting UV light) stimuli. Previous studies have shown that some chemicals at high
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1 concentration, including those contained in mint plant derivatives, act as primary bird repellents. They
2 have been shown to induce aversion in birds due to both odour quality and irritation sensed by the
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4 olfactory and trigeminal systems, respectively (Mason et al. 1989; Mason 1990; Avery et al. 1996;
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6 Day et al. 2003; Orr-Walker et al. 2012). On the basis of previous literature on chemical repellents
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8 for birds, it is likely that the effect of Bird Free® is based mainly on the olfactory stimuli, in particular
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10 the compounds contained in the peppermint oil. To the best of our knowledge citronellal acts
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12 essentially as an insect repellent (Tamares et al 2018).
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17 Ultraviolet sensitivity is well documented in pigeons (Emmertson and Delius 1980; Vos Hzn et al.
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19 1994), although a repellent effect of UV light stimuli on birds has never been clearly shown
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21 (Habberfield and St Clair 2016). However, it has been shown that the efficacy of post ingestive
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23 anthraquinone-based repellents is enhanced if the food ingestion by birds occurs from feeders
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25 provided with UV light stimuli (Werner et al. 2014). Consistently to what reported by Werner et al.
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27 (2014), the UV light reflected by the gel of Bird Free® may have enhanced the repellent effect of the
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29 odorants in the peppermint oil.
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35 In general, Bird Free® seems to be effective in repelling feral pigeons from their habitual roosts and
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37 from discouraging them to nest at suitable nesting sites. However, its efficacy is strictly limited to the
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39 treated area, so that application to buildings requires that all the surfaces potentially used by pigeons
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41 are treated with the product. In fact, the videos recorded during Experiment 2 on the horse stable roof
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43 showed that pigeons, although only marginally and shortly entering the BFD-area (see Figure 2),
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45 often landed on the untreated part of the roof contiguous to the treated area (see Figure S6, Online
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47 Resource). This observation, together with the results of the nest sites experiment, is evidence that
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49 the repellent effect of Bird Free® is limited to the local site to which it is applied. Our results showed
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51 that the efficacy of Bird Free® lasted at least one year after the installation of the dishes in the night
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53 and day roosts. Unfortunately, we were not able to monitor the night and day roosts from the period
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55 from 90 days and 1 year after the installation for logistic reasons. We are aware that observations in
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1 this period in particular for the day roost would have provided useful data, potentially documenting
2 the variability in the number of pigeons using the empty dish-treated roof. However, it is very unlikely
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4 that such an observation changed the statistical results. It follows from the observations above that
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6 Bird Free® is probably not suitable for large scale pigeon management programs aimed at reducing
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8 the carrying capacity of urban environment by lowering nest and roost sites availability, given the
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10 high cost of installation of the product on a city-wide scale and to its as-yet-unknown durability.
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12 However, due to the relative low conspicuousness of the gel dishes, this product could be useful for
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14 protecting historic buildings, monuments, workplaces and private houses from pigeons' impact.
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23 **ACKNOWLEDGEMENTS**

24
25 We thank Prof. Grazia Guidi, Prof Micaela Sgorbini and Prof. Francesco Camillo for allowing us to
26
27 conduct the experiments in the ODV of the University of Pisa. We thank Stefano Benedettini, Andrea
28
29 Guidi, Resi Mencacci, Fabio Chini, Giorgio Boccone and Lorenzo Galletta for their help in the
30
31 organization of the experiment. We are grateful to Daniele Santerini for his help in the preparation of
32
33 the figures. This research was commissioned by EZFlex Co. Ltd. (South Korea), and partially
34
35 supported by PRA_2018_15.
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Figure captions

Figure 1. Experiment 1. The diagram reports the highest number of pigeons observed before and after the installation of the dishes on the night roost sites, for each experimental day. The pictures below show the condition of BF and ED treated roofs a year after the installation of the dishes.

Figure 2. Experiment 2. Total time (TT) each experimental area (BF and ED treated roof) was occupied by at least one pigeon in each experimental day.

Figure 3. Experiment 3. Each picture shows the condition of each nest at its highest score (see Material and methods for details).

Figure 4. Experiment 3. Each dot represent the score assigned to each nests treated with Bird Free® or Empty Dishes.

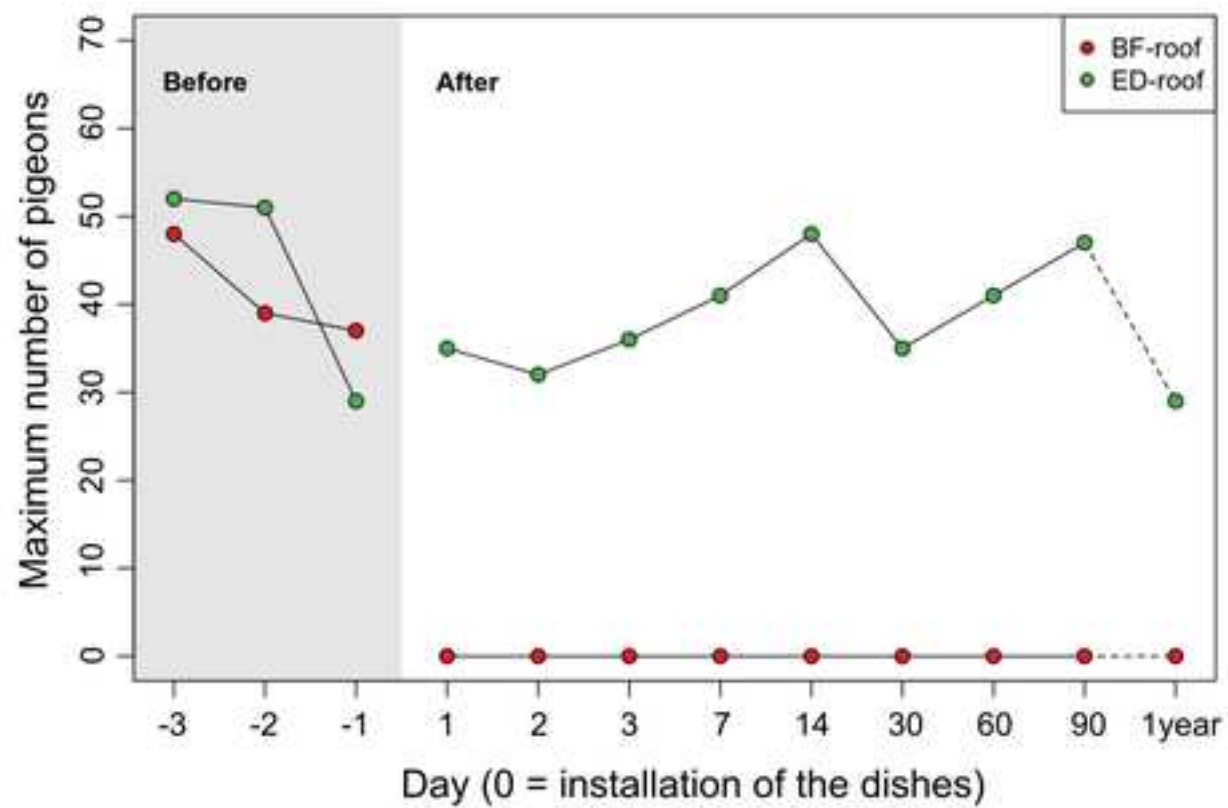
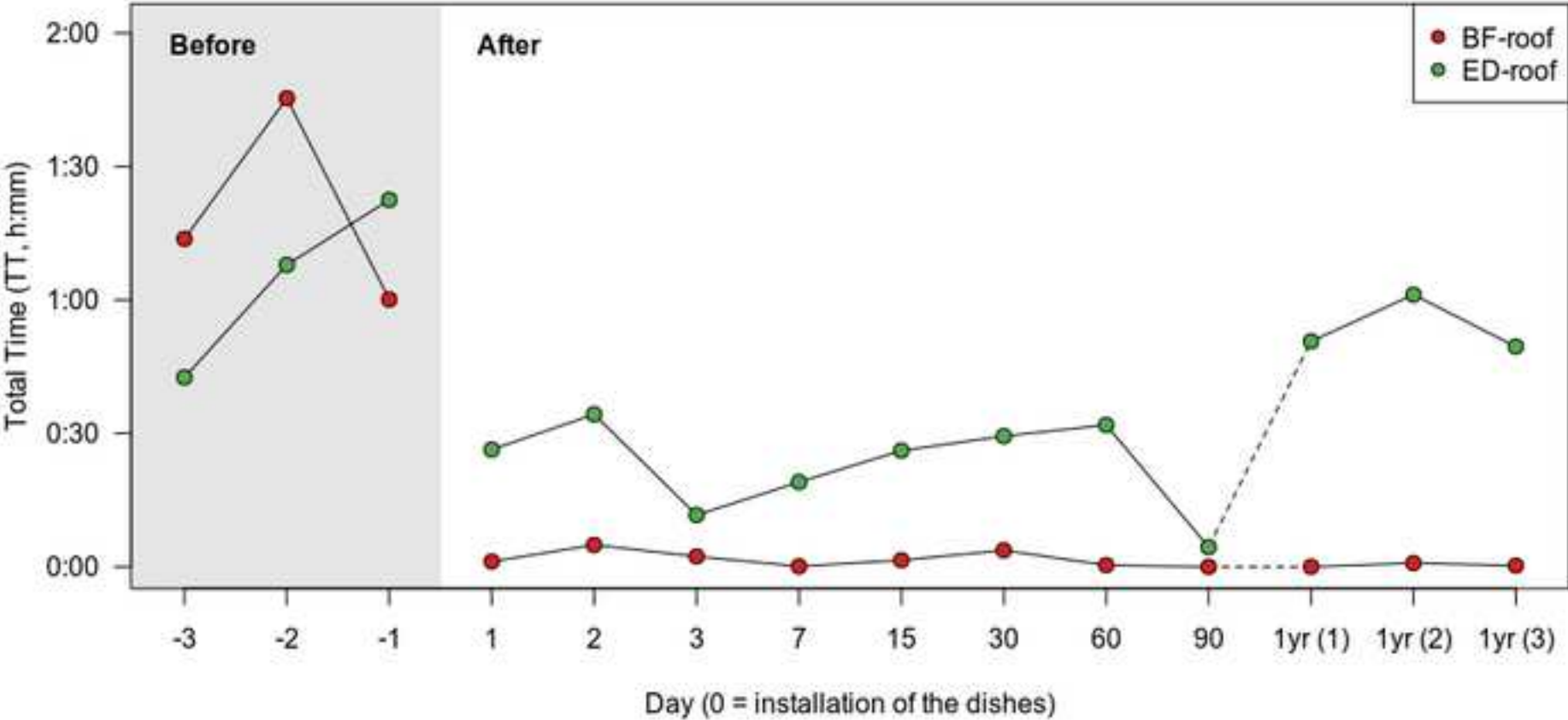


Figure 2



Nests on top of the partition walls

ED-nests

Nest E1
(Day 60)



Nest E2
(Day 30)



Nest E3
(Day 60)



Nest E4
(Day 60)



Nest E9
(Day 30)



BF-nests

Nest G1
(Day 90)



Nest G2
(Day 90)



Nest G7
(Day 90)



Nests on the floor

ED-nests

Nest E5
(Day 30)



Nest E6
(Day 90)



Nest E7
(Day 60)



BF-nests

Nest G3
(Day 90)



Nest G4
(Day 90)



Nest G5
(Day 90)



Nest G6
(Day 90)



Nest G8
(Day 90)



Figure 4

