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Nicarbazin has no effect on reducing feral pigeon populations in Barcelona

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Abstract

BACKGROUND: Nicarbazin is an anti-coccidial product sometimes used as a contraceptive to reduce the size of feral pigeon populations. However, its effectiveness in reducing pigeon population size in cities has caused some controversy. Here, we evaluate its effectiveness in the city of Barcelona.

RESULTS: In 2017, the Barcelona City Council set 23 feeding stations with nicarbazin and ten with placebo (untreated corn). Censuses were undertaken before and after one year of treatment, within a 200-m radius around each feeder. We also censused 28 circles of 200 m radius distributed randomly 200 m from the feeders and 28 circles > 500 m from the feeders, which acted as controls. Population size across the whole city was also evaluated pre- and post treatment. We found that feral pigeon density did not change after one year of treatment, either in the circles around feeding stations with nicarbazin or in the areas around control stations at 200 and > 500 m from the feeders. Population size in placebo circles rose after a year by 10%. A pigeon census for the whole of Barcelona showed a 10% increase.

CONCLUSION: Overall, our results indicate that the nicarbazin treatment had no effect on feral pigeon population size, and we advise against its use as a pigeon control method, at least in large cities.

Keywords: feral pigeon; *Columba livia*; nicarbazin; contraceptives; population size control

1 INTRODUCTION

Feral pigeon (*Columba livia* var. *domestica*) is one of the many species affected positively by human activity. High reproduction rates determined by the availability of unlimited food and suitable nesting sites near humans enable feral pigeon populations to thrive in urban environments, causing problems such as a major disease risk and damage to buildings.[1–3] These issues require governments to use control methods against the species.

In Barcelona (northeast Spain), pigeons have traditionally been caught and removed from places where high densities were a public health problem.[4] However, this method was not effective in the short-term due to rapid colonization by young pigeons into areas where birds were removed.[5] After 2006, mass captures were undertaken and the population was successfully reduced,[6] but controversy surrounded the ethics of this method and pushed Barcelona Council to look for alternative and ethical methods of pigeon control.

One of these methods is the administration of an anti-fertility drug that reduces breeding success. Nicarbazin is the contraceptive product most commonly used. This ingredient was originally used to treat coccidiosis in birds.[7] Nicarbazin is an equimolar complex formed by 4,4′-dinitrocarbanilide (DNC) and 2-hydroxy-4,-6-dimethylpyrimidine (HDP). The function of the HDP is to increase absorption of the substance in the intestine, while the DNC is the active anticoccidial drug.[8, 9] Nicarbazin has the ability to reduce egg production because it interferes in cholesterol metabolism, which affects formation of the vitreous membrane, destroying the separation between egg yolk and egg white.[10, 11]

We refer to the product based on nicarbazin, used in Europe to control pigeon populations, as NP1 (see Material and Methods). NP1 consists of corn seeds covered with nicarbazin (800 ppm) and a water-repellent film. However, there has been controversy regarding its effectiveness. In studies with captive pigeons, Martelli *et al.*[12] reported a high degree of success of nicarbazin (not NP1) in reducing the fertility of pigeons under highly controlled conditions. Meanwhile, Giunchi *et al.*[13] reported very low effectiveness for NP1, which was attributed to the low palatability of the product. Results of field studies have also been unconvincing. Some studies comparing the abundance of pigeons before and after treatment found a reduction in the population.[14, 15] However, these results may not be reliable because control parcels were not considered. In addition, the two censuses were carried out at different times of the year, a factor affecting pigeon

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detectability and density.[5, 16–18] In another study in the city of Modena, control zones were not considered and restriction of nesting sites was applied over the same period.[19] This made it impossible to discern the effects of nicarbazin from those of nesting site limitation, which we know from other cities to have an effect.[20] In a study carried out in the large city of Genova, controlled areas were considered, but pigeons were counted only around feeders.[21] The reduction in pigeon numbers observed may have been due to loss of interest in the feeders or other collateral factors. In summary, the effectiveness of NP1 in reducing feral pigeon populations, especially in large cities, remains unclear.

Our aim was to use the setting by the City Council of NP1 feeders in Barcelona city to analyze the effectiveness of NP1 as a pigeon control method in a large city, where the species maintains very high densities.[4, 22] To avoid the above-mentioned methodological problems, we established different levels of study to take into account the evolution of the population over time and space. Temporary effects were tested by comparing censuses from before and after NP1 treatment. Spatial effects were analyzed by comparing censuses carried out in circles located at different distances from NP1 dispensers. An additional control treatment included feeders providing placebo food (i.e. non-treated corn), which when compared with the experimental circles, should allow us to discern the effect of nicarbazin from the effect of corn provision.

Considering that our main objective was to determine whether treatment with NP1 had an effect on the total population size of pigeons in Barcelona, a simultaneous global census was carried out before and after NP1 treatment. The census employed the same methodology and sampled the same areas as in previous years.[4, 17, 23, 24]

Our main null hypothesis was that treatment with NP1 would reduce the feral pigeon population size and density, and that this effect should be mainly seen within a radius of ∼ 200 m from NP1 dispensers, since pigeons in Barcelona generally seem to move less than this distance.[5, 25] According to this hypothesis, and in accordance with the experimental design used, we predicted that, after one year of treatment with NP1:

(1) Experimental circles with NP1 treatment should show a reduction in population size.
(2) By contrast, placebo circles baited with untreated corn should show an increase in population size.
(3) Population size decrease should be higher in experimental circles than in control circles located at increasing distances from dispensers.
(4) Global population size in the whole city of Barcelona should decline from the first to the second census.

2 MATERIALS AND METHODS

In Europe, the product based on nicarbazin is Ovistop© (ACME S.r.l., Cavriago, Italy),[26] which despite not having been approved in Europe as a biocide, is commonly used as an anti-fertility drug to control pigeon populations. We refer to it here as NP1. The American counterpart is Ovocontrol©,[27] and we refer to as NP2.

The study was carried out in Barcelona during 2017 and 2018. From March 2017 to February 2018 (treatment period), 23 feeding stations (i.e. dispensers) provided NP1 and ten provided placebo (untreated corn) in different districts of Barcelona. The company Zooethics (Odena, Spain) (previously Ambiens) installed the feeders and was in charge of the maintenance of the dispensers, and the supply and control of the consumption of the drug, following the Ovistop guidelines. The Servicio de Ecopatología de Fauna Salvaje (SEFaS -UAB) supervised technically all the operation. An unbalanced design favoring stations with treatment was chosen to increase the chances of sterilization of the population. Dispensers were located in areas of high pigeon density (Fig. 1),

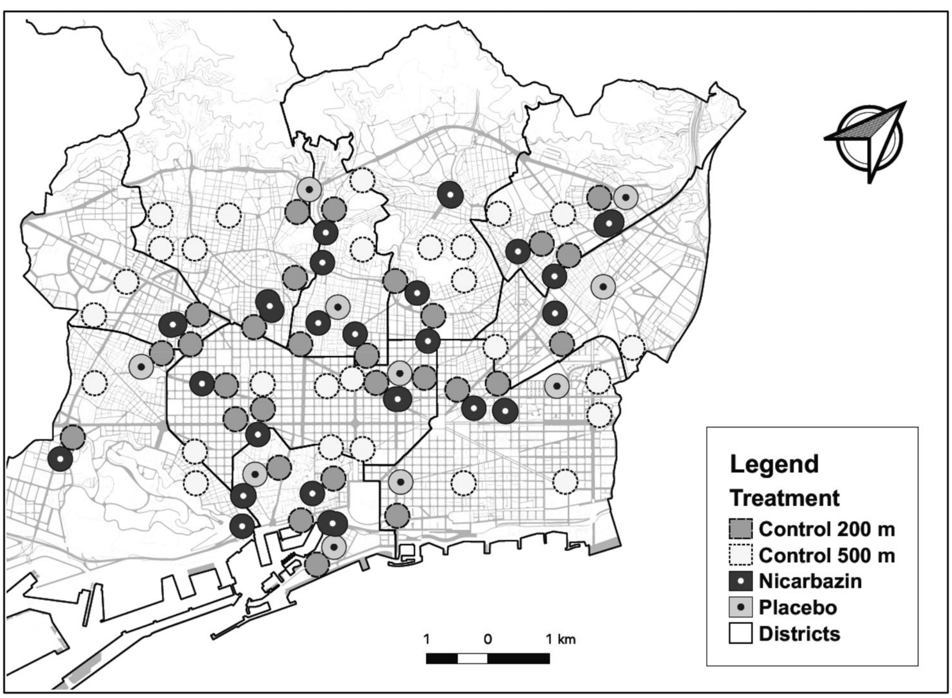

Figure 1 Map of Barcelona showing feeding stations with dispensers (black circles with white dots show nicarbazin feeders, light grey circles with black dots show placebo feeders) and the different treatment circles (solid line, area around feeders; dashed line with dark grey circles, circles 200 m from feeders; dotted line with white circles, circles > 500 m from feeders).

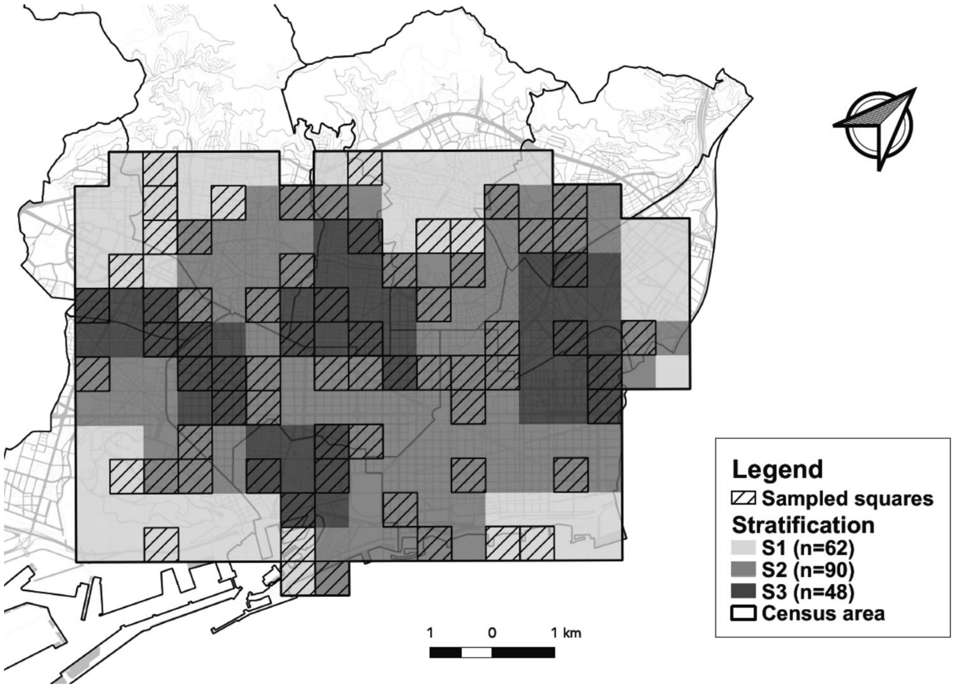

Figure 2 Map of Barcelona showing the sampled squares (striped, $N = 67$) classified in different strata according to feral pigeon density: S1, low density in light gray; S2, medium density in gray; and S3, high density in dark gray.

determined from previous knowledge on the distribution and density of pigeons in the city. Assignment of dispensers with and without (placebo) treatment was random. Dispensers were 110 cm high and 45 cm in diameter, and were shaped like a typical paper bin. Each dispenser held ~ 30 kg of corn. Dispensers automatically released ~ 1 kg of food each day, 2–3 m around the feeder. The time taken to release the food was < 5 s. Food was released at 08:00 h from March to June, and at 07:00 h in other months of the year. See Ovistop guidelines[26] and Lavín and González-Crespo[28] for more details on the dispensers and their operation. There was one feeder per feeding station, except in the case of eight NP1 feeding stations in areas with a high density of pigeons where two feeders were placed to provide a greater amount of treated food. Pigeons were baited with untreated corn from 16 February to 26 March to acclimatize them to the feeders. We estimate that during the study period ~ 9000 kg of treated corn and ~ 4000 kg of untreated corn were released into the city.

To determine the effect of NP1, we censused the pigeons inside circles located at different distances from the feeding stations, in pre- and post-treatment periods. Censuses were carried out in circles of 200 m radius around each feeder. In stations with two feeders, there were two circles centered on each feeder drawing an eight-sided polygon. The area of the circles was 12.5 ha (greater in eight-sided polygons). Hence, we censused 23 treatment circles (eight of them eight-sided) and ten placebo circles. We also censused 28 circles distributed randomly 200 m from the treatment feeders and 28 circles distributed randomly > 500 m from the treatment feeders (Fig. 1). The number of censuses was therefore 89 in 2017, and the same circles were censused in 2018. Censuses were carried out from 18 November to 15 February, a period when pigeon breeding activity is lowest.[29] SEFaS and Zooethics changed the exact location of some of the feeders just prior to the study period, to better accommodate the urban setting, with feeders moved between 5 and 184 m from their original locations. We therefore had to repeat the census in these 'new' circles, which delayed the end of censuses to 22 March. To remove any possible seasonal effect, pre- and post-treatment monitoring in each circle was carried out during the same Julian dates in 2017 and 2018.

Estimations of the total pigeon population size in Barcelona (with an urban area of 64.57 km^2) were made using the square count method,[30, 31] following the methodology used in 1991, 2007, 2011, 2015 and 2017.[4, 6, 17, 32, 33] We divided the city into 200 squares of 550×550 m[6, 17] (i.e. total census area: 60.5 km^2), excluding Collserola and Zona Franca due to their very low pigeon densities.[24] In the previous census, starting in the 1980s, we used a map of Barcelona on which the squares were drawn by hand. In this study, we took advantage of GIS and drew squares using QGIS; this resulted in one of the squares on the right side of the map being outside Barcelona, when in the past there was some overlap with the city. We chose not to exclude this square, as this would cause a mismatch in comparisons with the previous census. We should also note that the square was not actually censused, but only forms part of the layout of the city. The pre-treatment global census was carried out from 16 November 2016 to 7 February 2017 (hereafter, the 2017 census), and the post-treatment global census was carried out on the same dates of the following year (hereafter, the 2018 census). Each square was censused in the two years on the same Julian date (± 1 day) to avoid biases from seasonal or other effects. We monitored 67 randomly selected squares covering 33.5% of the total census area (Fig. 2).[24] To obtain a more accurate estimation, we followed a simple random stratified sampling[34] by classifying squares in three strata[6]: S1, peripheral areas of the city with low pigeon densities; S2, areas with medium densities; and S3, old town areas with the highest pigeon densities (Fig. 2). This method allowed us to improve the precision of our estimates.[17]

Sampled circles and squared areas were surveyed by walking along all streets, roads and parks counting all visible pigeons in the shortest time. Censuses were carried out between two hours before and two hours after noon (solar time), the time corresponding to peak pigeon activity.[24] Although this higher activity increased the likelihood of double counts, it also increased the probability of detection. To reduce the probability of counting the same pigeons (i.e. double counts), censuses were carried out by walking in one direction.[17]

To avoid underestimation caused by undetected birds, we applied to squares a correction factor of 3.5 to the sum of pigeons counted, which is a robust factor of detectability obtained in three different studies (Pavia,[20] and Barcelona in 1991[17] and 2011[33]). Pigeon density inside each square was calculated by counting the number of observations, multiplying by the correction factor and dividing by the sampled area. The area of squares was 30.25 ha (smaller in squares partially on the coast). This procedure additionally allowed us to compare current census data with values obtained from the previous census in Barcelona.[4, 17] This correction factor was not used in the case of circles, because we were only interested in relative counts.

For statistical analysis, we used the program Statistica (StatSoft Inc., DELL Inc. Round Rock, Texas, USA). The density of pigeons for all circles was compared between the different treatments (experimental, placebo, control 200 and control 500) and between the pre- and post treatment. Data were analyzed using analysis of variance (ANOVA). We compared the same circles pre- and post treatment using a paired analysis (repeated measures ANOVA). Pigeon density in 2017 and in 2018 were considered dependent variables, whereas treatment was a categorical factor. Planned comparison (PC) tests were used to test predictions related to variations in pigeon density according to different treatments (see Introduction). Data on pigeon density in the circles showed asymmetry to the right (skewness), assimilating to a Poisson distribution (distribution fitting: $X_2^2 = 25$, $P < 0.01$). Logarithm transformation over-corrected the data, which still did not fit to a normal distribution (Shapiro–Wilk test; 2017: $W = 0.973$, $P = 0.07$; 2018: $W = 0.967$, $P = 0.02$), and Levene's test for homogeneity of variances was still significant (2017: $F_{3,84} = 2.93$, $P = 0.04$; 2018: $F_{3,84} = 3.42$, $P = 0.02$). In these cases, square root transformation is advised.[35–39] The square root transformed data fit to a normal distribution and showed homogeneity of variances (Shapiro–Wilk test, 2017: $W = 0.983$, $P = 0.33$; 2018: $W = 0.979$, $P = 0.16$; Levene's test, 2017: $F_{3,84} = 0.43$, $P = 0.73$; 2018: $F_{3,84} = 0.04$, $P = 0.99$), and thus we used this transformation.

Previous work to validate the effect of NP1 used pigeon counts in the area just around each feeder.[21] At the time of our study, Lavín and González-Crespo[28] analyzed the abundance of pigeons at the feeding stations by counting the number of pigeons seen around the dispensers just before releasing the food, when the corn was released, and afterward. They used the highest these three counts as count data (see Lavín and González-Crespo[28] for more details). Initial pre-treatment counts at the different experimental and placebo feeders were carried out from 15 February to 26 March 2017, when untreated bait was distributed to acclimatize birds to the feeders (see above).[28] Final post-treatment counts were carried out from 1 to 30 November 2017. We correlated data from our census in 200-m radius circles around each feeder with counts at the feeders reported by Lavín and González-Crespo[28] for both pre- and post-treatment periods. If counts at feeders truly reflected pigeon population size, the two values should be correlated.

Total pigeon population size in Barcelona was estimated by using the average number of pigeons per square for each strata, multiplying it by the correction factor (3.5) and extrapolating it to the 200 squares into which the Barcelona urban area was divided. The density of pigeons per square was also compared between the two years of the study using repeated measures ANOVA analysis, hence using a paired analysis approach. Pigeon density in squares adjusted to a normal distribution ($X_2^2 = 3.89$, $P = 0.14$), and hence no transformation was needed.

3 RESULTS

Analyses showed that overall, and after one year of treatment, the density of pigeons in the circles slightly increased by 10% [from 7.7 ± 0.59 (SE) to 8.6 ± 0.79 (SE) individuals per ha; repeated measures ANOVA, Factor year: $F_{1,84} = 5.90$, $P = 0.02$; Treatment: $F_{3,84} = 14.28$, $P < 0.001$; Year × Treatment: $F_{3,84} = 1.97$, $P = 0.13$]. Pigeon population size in experimental circles remained the same after one year of treatment with NP1 (PC: $F_{1,84} = 1.41$, $P = 0.24$) (Fig. 3). The same was found for control circles at 200 m (PC: $F_{1,84} = 0.80$, $P = 0.37$) and at > 500 m (PC: $F_{1,84} = 0.21$, $P = 0.65$). The interaction Year × Treatment, considering these three treatments, was not significant ($F_{2,75} = 0.76$, $P = 0.47$), which means that circles treated with NP1 behaved in the same way as control circles with no treatment. However, in the placebo circles, where untreated corn was provided, pigeon population size increased by ~ 10% (PC: $F_{1,84} = 6.41$, $P = 0.01$) (Fig. 3). Pigeon density was higher in feeding station circles (nicarbazin and placebo) than in control circles (Factor Treatment, PC comparing feeding circles *versus* control circles: $F_{1,84} = 40.40$, $P < 0.001$) (Fig. 3), because feeding stations were *a priori* placed in the areas of the city with higher densities.

Pigeon counts pre- and post treatment at NP1 feeders showed a 25% reduction in the number of pigeons feeding (2017: 117 ± 12.4, 2018: 87 ± 11.2; PC from repeated measures ANOVA for NP1 feeders: $F_{1,31} = 16.22$, $P < 0.001$; data from Table 7 Lavín and González-Crespo[28]). Counts at placebo feeders did not change (2017: 97.5 ± 18.8, 2018: 100.5 ± 16.9; PC from repeated measures ANOVA for placebo feeders: $F_{1,31} = 0.03$, $P = 0.87$). However, pigeon counts obtained from census data in circles around each feeder were not correlated with count data taken immediately around each feeder, both for pre-treatment ($r = 0.10$, $t_{31} = 0.58$, $P = 0.56$) and post-treatment data ($r = 0.29$, $t_{31} = 1.67$, $P = 0.10$).

The global population size of pigeons in the city of Barcelona increased by 9.5% after one year of treatment, from 103 226 ± 14 353 individuals in 2017 to 113 048 ± 13 957 individuals in

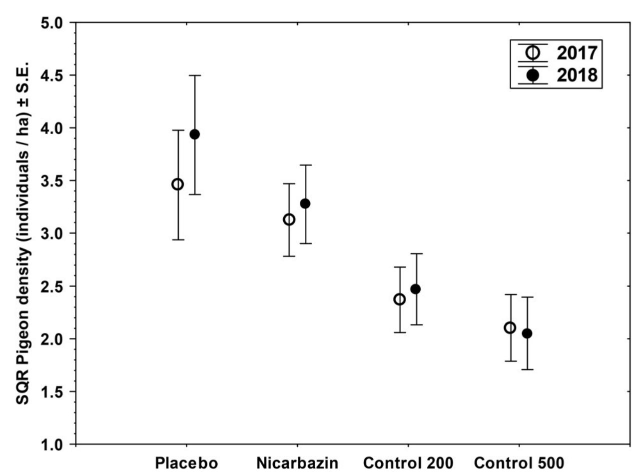

Figure 3 Mean (±SE) pigeon density, square root transformed, in circles of 200 m radius according to year of census (pre-treatment, 2017; and post treatment, 2018) and different treatments (placebo, nicarbazin, control at 200 m and control at 500 m from feeders).

2018 (95% confidence intervals). The increase in pigeon density within each square was significant (repeated measures ANOVA: $F_{1,64} = 0.09$, $P = 0.02$) and was independent of the strata (interaction Year × Strata: $F_{2,64} = 0.04$, $P = 0.96$). This latter finding is interesting, because pigeon density varied greatly according to the strata (repeated measures ANOVA: $F_{2,64} = 13.5$, $P < 0.001$), implying that the increase in pigeon density was not influenced by the initial density of pigeons and the geographical area of the city.

4 DISCUSSION

Results show that none of the predictions supporting the effectiveness of NP1 in reducing feral pigeon population size hold. One year of treatment with NP1 in experimental circles did not reduce feral pigeon density. Because experimental and control circles (at 200 and > 500 m) behaved in the same way, we can stress that NP1 had no effect on pigeon density. The global increase (9.5%) in pigeon population density over the whole of Barcelona again confirms that NP1 was ineffective in reducing pigeon density across the city. This increase, when compared with the previous increase in the population size observed from 2015 to 2017 (17%), stresses that the pigeon population size in the city increased continuously after the cessation of mass captures in 2015.[6] This increase is probably the result of high food availability in the city, in part provided by the public,[40] such that pigeon population size has not yet attained its carrying capacity. In 2006 the feral pigeon population size in Barcelona reached 256 000,[4] stressing that population size could still increase in the coming years. Here, we should also stress that pigeons living in a city are a single management unit[3, 5, 41] and thus a local reduction in density would be compensated for by incoming pigeons that will rapidly colonize the area.

Our prediction related to placebo circles, where untreated corn was provided, was upheld, because the population density increased by 10%, a similar value to the increase estimated for the pigeon population size of all Barcelona.

It could be argued that one year of treatment is not enough to detect a reduction in population density because during the first year pigeons could be attracted in the surrounding areas of the new food supply (i.e. NP1 feeders)("magnet effect").[21] However, the fact that population density behaved in the same way in experimental and control circles (with no feeders), coupled with the fact that no change in population density was found at the treatment sites, but a 10% increase in the placebo sites, makes us reject this possibility.

Pigeon counts pre- and post treatment at NP1 feeders showed a 25% reduction in the number of pigeons feeding. However, pigeon density in 200-m circles around each feeder did not correlate with counts at feeders, suggesting that they were poor density estimators. The suggestion in previous tests of NP1 that a reduction over time in bird counts at experimental feeders reflected a reduction in population size[21, 28] was therefore likely wrong. This result cautions against the use of counts at feeders to test the effectiveness of contraceptive food.

Reductions in count data at feeders could simply be measuring a decreased level of interest in the feeders among pigeons. NP1 is made of corn seeds covered with nicarbazin and coated with a water-repellent external film, which seems to make this food unpalatable to birds.[13] The finding that captive birds fed with NP1 declined in physical condition as a consequence of avoiding the food[13] supports this view. Because pre-treatment counts were carried out when providing untreated corn as bait, whereas post-treatment counts were made when providing NP1, the lower palatability of the latter product could easily explain a reduction in count data at feeders.

NP1 treatment may not have had an effect on pigeon density due to both to its unpalatability and a lack of effectiveness of the nicarbazin *per se*. This effectiveness was first evaluated in captivity by Martelli *et al.*,[12] who reported that at nicarbazin concentrations of 400 ppm, pigeon fertility declined to zero. In addition, Avery *et al.*[27] achieved a 60% reduction in the number of chicks produced by applying nicarbazin concentrations of 5000 ppm. However, Giunchi *et al.*[13] achieved only a 13% reduction with NP1 (800 ppm), whereas they achieved a 48% reduction with pellets with the same concentration of nicarbazin (but higher palatability). This indicates that nicarbazin provided with palatable food (but not with NP1) can be effective in captivity situations in which animals are forced to ingest it.

Because the lack of effects of NP1 on pigeon density in Barcelona cannot be tied to the effectiveness of nicarbazin *per se*, there may be issues related to the implementation of this product in cities. The lower palatability of NP1 compared with 'natural' food[13] could prevent females from reaching the nicarbazin blood levels needed to reduce fertility.[13] On the other hand, the timing of NP1 release in dispensers (just before sunrise) could prevent females from eating enough of this food, because in Basel females were found to remain in the nest until mid-morning.[42] Clearly, more exhaustive and individualized monitoring of the pigeon population is needed to understand in detail the effect of nicarbazin and how it should be provided. We advise, for example, an analysis of nicarbazin blood levels of male and female adult pigeons feeding at and around the feeding stations, and tracking of their movements with GPS devices.

Based on our results, we consider NP1 an inappropriate product to control the Barcelona feral pigeon population. Another antifertilizer drug like NP2 may function better given its greater palatability and higher nicarbazin dose. However, this control method is very costly because application must be permanent to be effective.[43] In some models, it was estimated that when treatment with nicarbazin is interrupted, the capacity of the population to recover is very high.[13, 44] The use of nicarbazin in urban environments could additionally entail side effects in the urban food chain if consumed by non-target species.[45]

Consequently, pigeon control methods based on reducing the carrying capacity of the urban habitat, mostly focusing on reducing the availability of food and nesting sites[1, 3, 13, 46] should be prioritized. In Barcelona, a program of public education intended to reduce the availability of food provided by humans to pigeons was carried out in 2009. After one year, the pigeon population in the experimental area was reduced by 40% compared with the control zone.[40] The same method was used in the 1990s in Basel with similar results.[47, 48] In some respects, this method works as a contraceptive because reducing food availability significantly reduces breeding success.[46] A second approach is a reduction in the presence of appropriate breeding holes for pigeons.[49] This method obtained good results in Pavia,[20] where rehabilitation programs in the oldest suburbs of the city reduced the pigeon population.[50] A combination of the two methods would therefore provide a good approach.

5 CONCLUSION

Our results suggest application of nicarbazin across a large spatial area was ineffective at controlling feral pigeon populations. Alternative ethical methods currently exist that appear to be more effective, efficient, and sustainable for controlling feral pigeon population size in large cities. However, as reviewed by Giunchi *et al.*,[3] an effective management policy for controlling feral pigeons should consider a balanced integration of different control methods, proper monitoring, and reliable modeling, with a strong emphasis on reducing the carrying capacity of the population.

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