Nicarbazin has no effect on reducing feral pigeon populations in Barcelona

Juan Carlos Senar[1], Helena Navalpotro[1], Jordi Pascual[1,2] and Tomás Montalvo[2].

[1] *Museu de Ciències Naturals de Barcelona, Castell dels Tres Dragons, Parc Ciutadella, Pº Picasso s/n, 08003 Barcelona, Spain*

[2] *Agencia de Salut Publica de Barcelona, and CIBER de Epidemiología y Salud Pública, Av.Príncep d'Astúries 63, 3r.2a, 08012 Barcelona, Spain*

Corresponding author: Juan Carlos Senar. +34.616737695, jcsenar@bcn.cat

Juan Carlos Senar: jcsenar@bcn.cat https://orcid.org/0000-0001-9955-3892
Helena Navalpotro: helena.navalpotro@gmail.com
Jordi Pascual: jpascualsala@gmail.com
Tomas Montalvo: tmontal@aspb.cat

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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 generated some controversy. Here, we evaluate its effectiveness in Barcelona city.

RESULTS: We set 23 feeding stations in which we provided nicarbazin and 10 feeding stations with a placebo (untreated corn). Censuses were carried out before and after one year of treatment, in radii of 200 m around each feeder. We additionally censused 28 circles of 200 m of radius distributed randomly 200 m away from the feeders and 28 circles distributed >500 m away 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 distributed at 200 and >500 m from the feeders. Population size in placebo circles rose after a year by 10%. The pigeon census for the whole city of Barcelona showed a 10% increase.

CONCLUSION: Overall, our results indicate that the nicarbazin treatment had no effect on the 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 activities. High reproduction rates determined by availability of unlimited food and suitable nesting sites near humans enable feral pigeon populations to thrive in urban environments, causing problems such as major disease risk and building damage [1–3]. These issues require governments to undertake control methods against the species.

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

One of these methods is the administration of an anti-fertility drug, which reduces breeding success. Nicarbazin is the contraceptive product most commonly used. This ingredient was originally employed 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 the absorption of the material in the intestine, while the DNC is the active anticoccidial drug [8, 9]. Nicarbazin has the ability to reduce the production of eggs because it interferes in cholesterol metabolism, which affects the formation of the vitreous membrane breaking 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 section). NP1 consists of corn seeds covered with nicarbazin (800 ppm) and with a water-repellent film. However, its effectiveness has generated some controversy. In studies conducted with captive pigeons, Martelli et al. [12] reported a high success of a different nicarbazin product (not NP1) in in reducing the fertility of pigeons in highly controlled situations. Meanwhile, Giunchi et al. [13] reported a very low effectiveness of NP1, which was attributed to the low palatability of the product. Field studies have also provided unconvincing results. Some studies comparing the abundance of pigeons before and after the treatment found a reduction in the population [14, 15]. Nevertheless, the results may not be reliable since control parcels were not considered. In addition, the two censuses were carried out at different times of year, a factor affecting pigeon detectability and density [5, 16–18]. In another study in the city of Modena, control zones were not considered and a restriction of the nesting sites was simultaneously applied in the same period [19]. This made it impossible to discern the effects of nicarbazin from 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 the feeders [21]. The reduction of pigeons observed may have been due to a loss of interest in the feeders or to other collateral factors. In summary, the effectiveness of NP1 in reducing feral pigeon populations, especially in large cities, remains unclear.

Our aim was to analyze the effectiveness of NP1 as a pigeon control method in a large city, namely Barcelona, where the species maintains very high densities [4, 22]. To avoid the methodological problems already mentioned, we established different levels of study to take into account the evolution of population over time and space. Temporary effects were tested by comparing censuses both before and after NP1 treatment. Spatial effects were analyzed by comparing censuses carried out in circles located at different distances from NP1 dispensers. We established an additional control treatment by providing placebo (i.e. non-treated corn) in some of the dispensers, 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 the treatment with NP1 had an effect on the total population size of pigeons in Barcelona, a global census was carried out simultaneously before and after the NP1 treatment. The census employed the same methodology and the same sampled areas as in previous years [4, 17, 23, 24].

Our main null hypothesis was that the treatment with NP1 would reduce the feral pigeon population size and density, and that this effect should be mainly seen within a radius of about 200 m from NP1 dispensers, since pigeons in Barcelona city generally seem to move less than this distance [5, 25]. According to this hypothesis, and according to 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). On the contrary, 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; and 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 © [26], which in spite of not having been approved in Europe as a biocide, is commonly used as an anti-fertility drug to control pigeon populations. We will refer to it as NP1. The American counterpart is Ovocontrol © [27], and we will refer to it as NP2.

The study was carried out in Barcelona city during 2017 and 2018. From March 2017 to February 2018 (treatment period), 23 feeding stations (i.e. dispensers) provided NP1 and 10 feeding stations provided placebo (untreated corn) in different districts of

Barcelona. We chose an unbalanced design to favour stations with treatment and thus increase the chances of sterilization of the population. Dispensers were settled in areas of high pigeon density (Figure 1), determined from previous knowledge on the distribution and density of pigeons in the city. The assignment of dispensers with and without (placebo) treatment was determined at random. Dispensers measured 110 cm high and 45 cm in diameter, and had the shape of a typical paper bin. Each dispenser held about 30 kg of corn. Dispensers released automatically about one kg of food each day, 2-3 m around the feeder. The time to release the food was <5 sec. Food was released at 8:00h from March to June, and at 7:00h in other months of the year. See Ovistop guidelines [26] and Lavín & González-Crespo [28] for more details on the dispensers and their operation. We placed one feeder per feeding station, except in the case of 8 NP1 feeding stations in areas with a high density of pigeons where we placed two feeders to provide a greater amount of treated food. Pigeons were baited with untreated corn from 16th February to 26th March to acclimate them to the feeders. We estimate that during the study period about 9,000 kg of treated corn and about 4,000 kg of untreated corn were released into the city. The company Zooethics (previously Ambiens) installed the feeders and was in charge of the entire operation, including maintenance of the dispensers as well as the supply and control of the consumption of the drug, following the Ovistop guidelines.

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 feeding stations with two feeders, we had two circles centered on each feeder drawing an eight-shaped polygon. The area of circles was 12.5 ha (greater in eight-shaped polygons). Hence, we censused 23 treatment circles (8 of them eight-shaped) and 10 placebo circles. We also censused 28 circles distributed randomly 200 m away and 28 circles distributed randomly >500 m away from the treatment feeders (Figure 1). The number of censuses was therefore 89 in 2017, and the same circles were censused in 2018. Censuses were carried out from 18th November to 15th February, a period when pigeon breeding activity is lowest [29]. 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 from 5 to 184m 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, the pre- and post-treatment monitoring at each circle was carried out during the same Julian dates in 2017 and 2018

Estimations of the total pigeon population size in the city of Barcelona (with an urban area of 64.57 km^2) were made using the square count method [30, 31] , following the same methodology as in 1991, 2007, 2011, 2015 and 2017 [4, 6, 17, 32, 33]. We divided the city into 200 squares of 550 x 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 1980’s, we used a map of Barcelona where the squares were drawn by hand. Now, we have taken advantage of GIS and drawn squares using QGIS; this resulted in one of the squares on the right side of the map to be outside of 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 with comparisons to 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 16th November 2016 to 7th 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 to cover 33.5% of the total census area ([24]; Figure 2). To obtain a more accurate estimation, we followed a simple random stratified sampling [34] by classifying the 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 (Figure 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), corresponding to the 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]). Density of pigeons 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 the squares partially on the coast). This procedure additionally allowed us to compare current census data to values obtained from the previous census in Barcelona [4, 17] . This correction factor was not used in the case of circles, since here we were only interested in relative counts.

For the statistical analysis, we used the program Statistica (Statsoft, Inc). 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-treatments. Data were analyzed using an ANOVA. We compared the same circles pre-treatment and post-treatment using a paired analysis (Repeated Measures ANOVA). The variables pigeon density in 2017 and pigeon density in 2018 were considered dependent variables while the treatment was a categorical factor. Planed comparison tests (PC) 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, the 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 same time that we were carrying out our study, Lavín & 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 as count data the higher figure from these three counts (see [28] for more details). Initial pre-treatment counts at the different experimental and placebo feeders were carried out from 15th February to 26th March 2017, just when the feeders distributed untreated bait to acclimate the birds to the feeders (see above) [28]. Final post-treatment counts were carried out from 1st to 30th November 2017. We correlated data from our census at 200 m radius circles around each feeder with the counts at the feeders by Lavín & González-Crespo [28], for both preand post-treatment periods. If counts at feeders truly reflected pigeon population size, the two counts should be correlated.

The estimation of the total pigeon population size in the city of Barcelona was calculated by using the average number of pigeons per square for each strata, multiplying it by the correction factor (i.e. 3.5) and extrapolating it to the 200 squares in which the Barcelona urban area was divided. The density of pigeons per square was also compared between the two years of study using a Repeated Measures ANOVA analysis, hence using a paired analysis approach. Pigeon density in the 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 x 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; Figure 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 x 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 about a 10% (PC: $F_{1,84}= 6.41$, p=0.01; Figure 3). Pigeon density was higher in feeding station circles (nicarbazin and placebo) than in control circles (Factor Treatment, PC comparing feeding circles *vs.* control circles: $F_{1,84}= 40.40$, p<0.001; Figure 3), since 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 reduction in the number of pigeons feeding of a 25% (2017: 117±12.4 SE, 2018: 87±11.2 SE pigeons; PC from RM ANOVA for NP1 feeders: $F_{1,31}$= 16.22, p< 0.001; data from Table 7 in [28]). Counts at placebo feeders did not change (2017: 97.5±18.8 SE, 2018: 100.5±16.9 pigeons; PC from RM ANOVA for placebo feeders: $F_{1,31}$= 0.03, p= 0.87). However, pigeon counts obtained from census data in circles around each feeder was 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 2018 (95% CI). The increase in density of pigeons within each square was significant (Repeated Measures ANOVA: $F_{1,64}$= .09, p=0.02) and was independent of the strata (interaction Year x Strata: $F_{2,64}$ = 0.04, p= 0.96). This latter finding is interesting, since pigeon density highly varied 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 to reduce feral pigeon population size hold. One year of treatment with NP1 in experimental circles did not reduce the feral pigeon density. Since 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 in the whole city of Barcelona again confirms that NP1 was ineffective in reducing pigeon density across the city. This increase, when compared to the previous increase in the population size observed from 2015 to 2017 (a 17%), stresses that the pigeon population size in the city increased continuously after the cessation of the massive captures in 2015 [6]. This increase is probably the result of a high availability of food in the city, in part provided by the public [40], such that pigeon population size has not yet attained its carrying capacity. The fact that in 2006 the feral pigeon population size in Barcelona reached 256,000 pigeons [4], stresses 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 of density would be compensated for by dispersing pigeons that will rapidly colonize the area.

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

Pigeon counts pre- and post-treatment at NP1 feeders showed a reduction in the number of pigeons feeding of a 25%. However, pigeon density in 200-m-radius circles around each feeder did not correlate with these pigeon counts at the feeders, implying that they were poor density estimators. The suggestion in previous tests of NP1 that a reduction with 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 the feeders could simply be measuring a decreasing 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 the 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. Since pre-treatment counts were carried out when providing untreated corn as bait, while post-treatment counts were made when providing NP1, the lower palatability of this 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 to a lack of effectiveness of the nicarbazin *per se*. This effectiveness was first evaluated in captivity by Martelli et al. [12], who reported that in 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] only achieved a 13% reduction with NP1 (800 ppm), while they achieved a 48% reduction with pellets with the same concentration of nicarbazin (but with a higher palatability). This indicates that nicarbazin provided with palatable food (but not with NP1) can be effective in captivity situations where animals are forced to ingest it.

Since 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 to “natural” food [13] could prevent females from reaching the necessary nicarbazin blood levels 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, since in Basel they were found to remain in the nest until mid-morning [42]. Clearly, more exhaustive and individualized monitoring of the population of pigeons is necessary 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 to be an inappropriate product to control the Barcelona feral pigeon population. Another anti-fertilizer drug like NP2 may function better given its greater palatability and higher nicarbazin dose. However, this control method is very costly because its application must be permanent to be effective [43]. In some models, it was estimated that when the 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 population of these birds in the experimental area was reduced by 40% compared to the control zone [40]. The same method had been used in the 1990's in the city of Basel with similar results [47, 48]. In some respects, this method works as a contraceptive method since 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 the city of Pavia [20], where rehabilitation programs in the oldest suburbs of the city reduced the pigeon population [50]. The combination of the two methods should therefore provide a good approach.

5. Conclusion

Our results suggest the application of nicarbazin across a large spatial extent 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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Figures

Figure 1. Map of Barcelona city showing the feeding stations with dispensers (dots show nicarbazin feeders, triangles show placebo feeders) and the different treatment circles (straight line for the area around feeders, discontinuous line for circles 200 m away from feeders and dotted line for circles >500 m away from feeders).

Figure 2. Map of Barcelona city showing the sampled squares (stripped, 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.

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

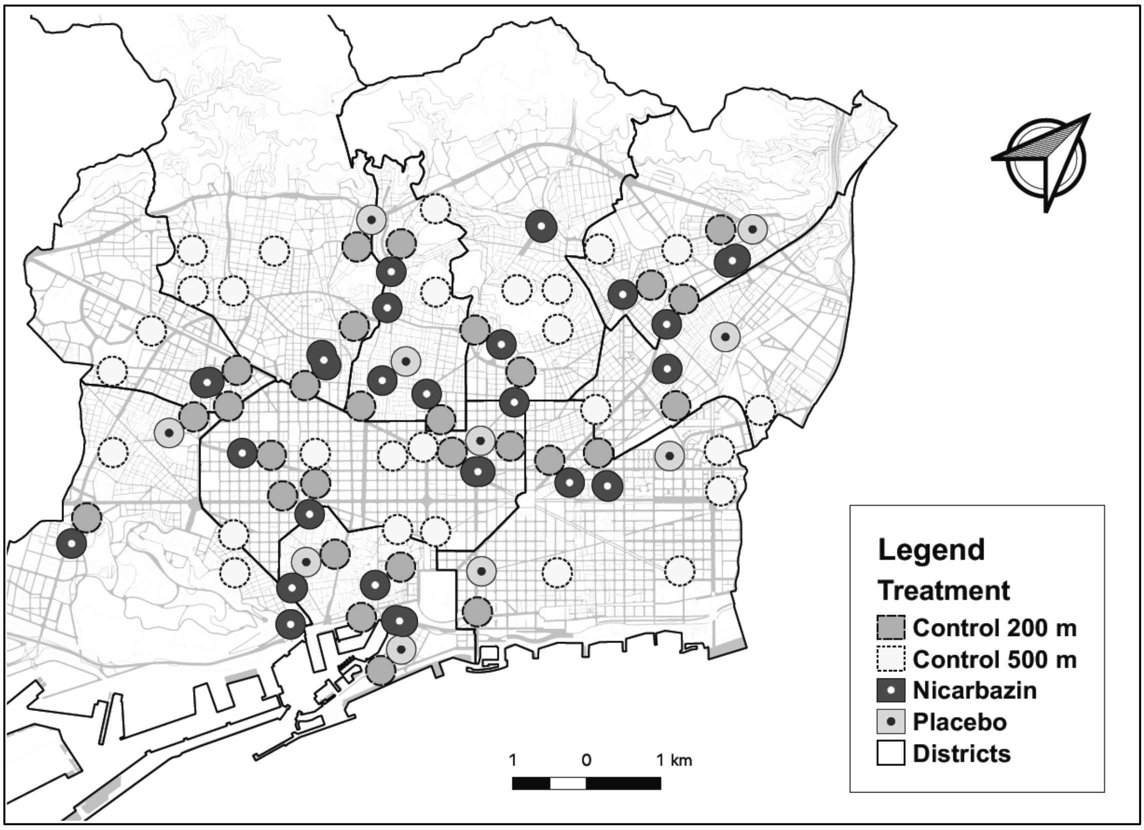
Legend
Treatment
Control 200 m
Control 500 m
Nicarbazin
Placebo
Districts
1
0
1 km

Figure 1.

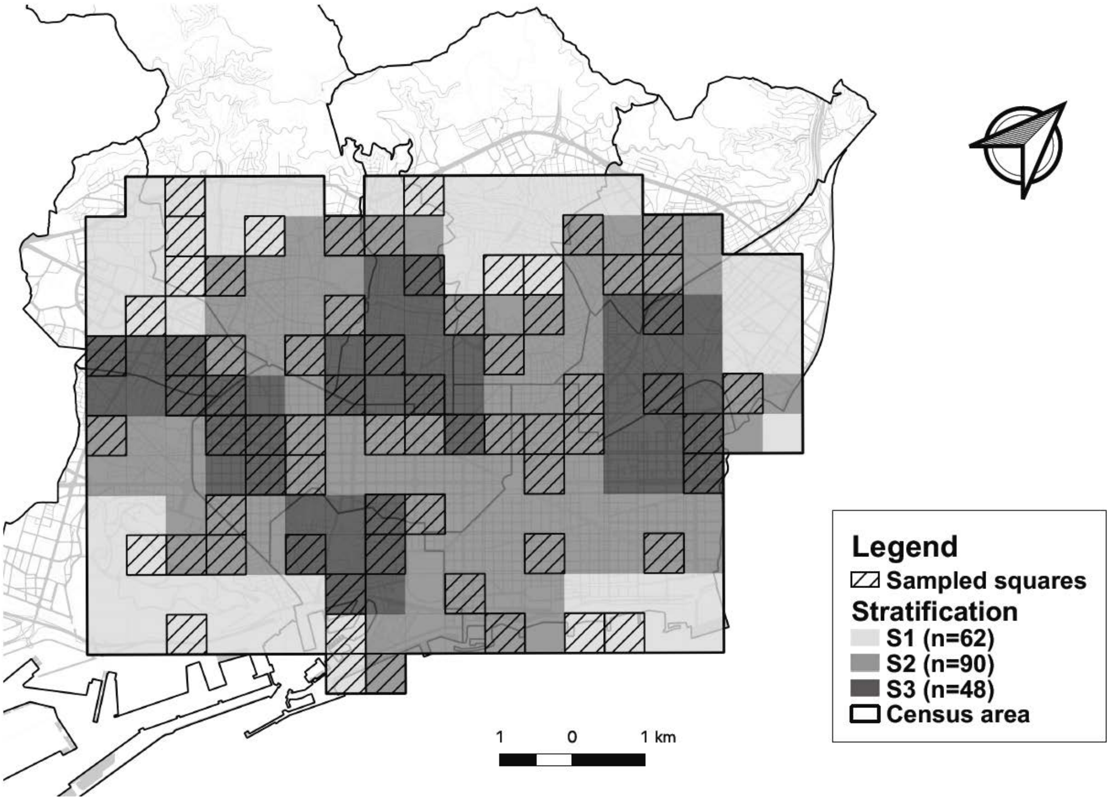
Legend
▨ Sampled squares
Stratification
S1 (n=62)
S2 (n=90)
S3 (n=48)
Census area
1
0
1 km

Figure 2.

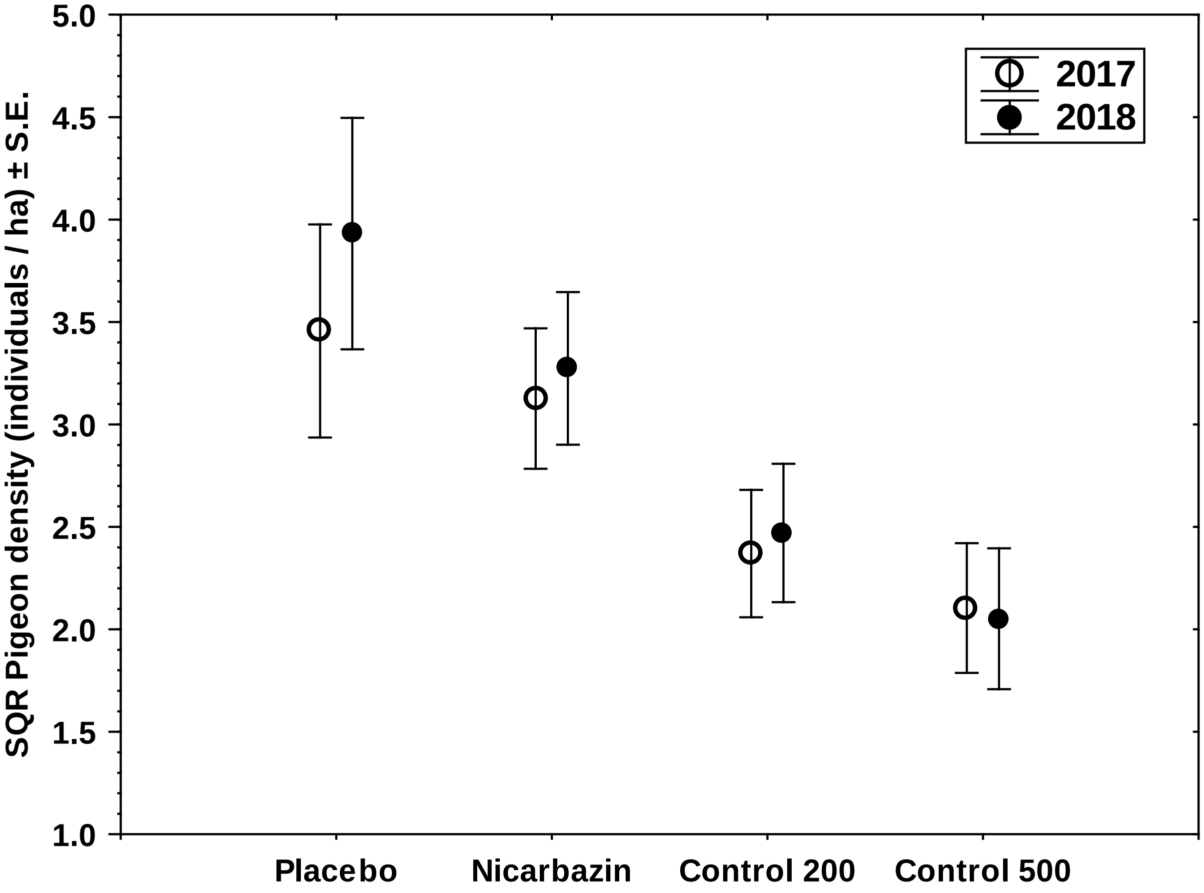
SQR Pigeon density (individuals / ha) ± S.E.
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Placebo
Nicarbazin
Control 200
Control 500
2017
2018

Figure 3.