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DANKMAR BÖHNING

İSMAYİL SAFA GÜRCAN

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Estimation of stray dog and cat populations in metropolitan Ankara, Turkey

Doğukan ÖZEN^{1*}, Dankmar BÖHNING², İsmayil Safa GÜRCAN¹

¹Department of Biostatistics, Division of Animal Husbandry and Animal Nutrition, Faculty of Veterinary Medicine, Ankara University, Ankara, Turkey

²School of Mathematics & Southampton Statistical Sciences Research Institute, University of Southampton, Southampton, United Kingdom

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Abstract: Stray dogs and cats contribute to serious health problems in human societies around the world. Before any necessary interventions to control the stray dogs and cats, an accurate estimate of their populations should be attained. Yet, there is a very limited number of methods for an estimation. Some of them depend on the identification of marked or counted animals. However, problems arise when it is not possible to identify a previously captured animal. In this paper, we used a different approach to estimate the lower bound for the total number of dogs and cats in consecutively visited settlements that might be useful for future studies internationally. It was estimated that there were 17,839 (95% CI: 14,862–20,816) stray dogs and 10,191 (95% CI: 8439–11,942) stray cats in Ankara, Turkey. The results highlight the need for a science-based policy to control and manage the stray dog and cat populations in Ankara.

Key words: Stray cat, stray dog, identification probability, population estimation

1. Introduction

Cats and dogs have a very important role in many countries in the world in terms of human health and social benefits. On the other hand, they also pose potential health risks to human society, such as viral, bacterial, rickettsial, parasitic, and fungal zoonotic diseases. It is known that more than 100 zoonotic diseases are transmitted from cats and dogs to humans (1,2).

The control of stray dog and cat populations is vital for the reduction of zoonoses and other perceived nuisances such as dog bites, noise, and road accidents. It is also important for the welfare of these animals. Rabies is the most common and well known among the zoonoses. Although vaccination is the core strategy to eliminate rabies, population control might also contribute to addressing the problem. Rabies is present on all continents and endemic in most African and Asian countries (3). Turkey is unique in that it is the only European country in which the principle vector for rabies is the domestic dog (*Canis familiaris*) rather than the fox (*Vulpes vulpes*). Considering the fact that in Turkey over 70% of the cases are recorded in dogs, followed by cats and ruminants (4), studies that might help control the number of stray animals are particularly important.

Animal population size estimates are essential prior to any interventions to control the population effectively, to

plan and monitor disease-control programs, or to assess the economic need for any necessary actions. In the literature, there are more international studies on stray dogs than on cats, mainly because dogs are of primary importance in rabies control in about half of the countries in the world (5,6). The present study differs in this aspect since one of its primary goals was to estimate the population of stray cats in addition to that of stray dogs.

The population density of dogs and cats is dependent on many factors, including habitats, cultures, and the social strata of resident populations (7). The population density can even be highly variable among different districts of a city (8). One of the popular ways to estimate the total animal population is to use methods based on recapturing of marked animals. It is effective when there is an animal control campaign in which dogs or cats are collected, vaccinated, marked in an appropriate way, and then released back into their habitats. However, problems arise when it is not possible to identify a previously captured animal due to degradation in the applied marking, or when it is simply not possible to recapture a subset of the released animals. The aim of the present study was to estimate the lower bound (a certain plausible minimum number) for the true population size using a novel statistical approach, which may assist future studies when there are marking or identification difficulties, in

* Correspondence: dogukanozen@yahoo.com

concordance with the guidelines provided by the World Health Organization (WHO) and the World Society for the Protection of Animals (WSPA) (7,9).

2. Materials and Methods

2.1. Study design and data collection

Metropolitan Ankara is divided hierarchically into districts and settlements, with each settlement consisting of neighborhoods and villages. Although the city has 25 districts, only 16 of those are considered part of the Municipality of Metropolitan Ankara. The present study was conducted in those 16 districts, which consist of 701 settlements (10).

Prior to the study, random sampling was conducted in which the settlements were considered as sampling units in accordance with the guidelines of the WSPA (9). Considering the limited resources, 67 of the 701 settlements were randomly selected to be visited.

Twenty internship veterinary students were employed and assigned to 10 teams. A car and a camera were provided to each team to be used in the counting process. The students were instructed to take photos of dogs and cats that do not have owners or caretakers (independent of human control) in their area of assignment after undergoing a 1-day field course. Unfortunately there is no clear information in the literature on specific time intervals to count the maximum number of dogs and cats living around a settlement. However, WSPA guidelines (9) suggest visiting the settlements before garbage collection times. In Ankara, almost every district has a different schedule for garbage collection, which makes it difficult to plan proper visiting time intervals. As a result, the randomly selected settlements were visited at three different times: in the early morning, in the evening, and at night. To prevent any possible bias, the teams were reorganized after each visit so that each settlement was visited by different teams. Teams were asked to take photos of each dog and cat in order to mark and reidentify the animal at each visit; the photo could also be considered as proof of a count. The study was conducted for 3 months (from October to December 2013) to decrease any possible effects of animal movement. The supervision of the students was guaranteed over the entire study period.

2.2. Statistical approach

Our statistical approach to estimate the total number of dogs and cats is based on the identification probability of each dog and cat seen in each visit. Let X_{ij} denote the number of dogs (or cats) seen in site i at visit j where $j = 1, 2, 3$. We assume that each dog (or cat) is identified in each site with probability p and that these identifications occur independently. Let N_i denote the total number of dogs (cats) in site i and $M_i = \max_j\{X_{ij}\}$ the maximum number seen in site i . Evidently, $N_i - M_i$ remains unseen. The issue is to estimate N_i .

With the above assumptions, each X_{ij} follows a binomial distribution:

$$P(X_{ij} = x) = \binom{N_i}{x} p^x(1-p)^{N_i - x},$$

so that the likelihood of N_i is given as the following binomial likelihood:

$$L(N_i) = \prod_{j=1}^3 \binom{N_i}{x_{ij}} p^{x_{ij}} (1-p)^{N_i - x_{ij}}.$$

For the time being, we assume that p is known. Then $L(N_i)$ can be maximized in the site population size N_i . An example is provided in the Figure for $x_{i1} = 3, x_{i2} = 5$, and $x_{i3} = 7$. Clearly, there is no closed-form analytical solution for finding the maximum likelihood estimator of N_i , but a computational solution is possible by calculating $L(N_i)$ for $N_i = M_i$ and then increasing N_i in steps of 1; $N_i = M_i + 1, N_i = M_i + 2 \dots$, until no further increase in the likelihood is observed (see again Figure). Here the maximum likelihood estimate of N_i is 10, assuming that we are able to identify half of the population ($p = 0.5$).

2.2.1. Estimating p

In the above, we assumed that p is known, which in fact is not the case. Hence, we need to come up with some way of estimating it. Let us assume that there is an infinite sequence of observational visits at site i : X_{i1}, X_{i2}, \dots . Then it is reasonable to assume that $p_i = E(X_{i1}) / \max_j X_{ij}$ where the maximum is taking over the infinite series X_{i1}, X_{i2}, \dots . We estimate this as $\hat{p}_i = \bar{x}_i / M_i$ where $\bar{x}_i = (x_{i1} + x_{i2} + x_{i3})/3$. Since we assume that the identification probability is constant across sites, we use a Mantel-Haenszel type estimator:

$$\hat{p} = \frac{\sum_i \bar{x}_i}{\sum_i M_i}.$$

Note that this is a weighted estimator $\frac{\sum_i \omega_i \bar{x}_i / M_i}{\sum_i \omega_i}$

of the site-specific identification probabilities using the Mantel-Haenszel weights of $w_i = M_i$.

2.2.2. Extrapolating from the sample to the population

Using the estimated population sizes of each randomly selected settlement, we can estimate the total population size of dogs (cats) in Ankara with the following:

$$\hat{N}_{ANKARA} = \hat{N}_{TOTAL} / f,$$

where f denotes the sampling fraction (the number of visited settlements/the total number of settlements) and \hat{N}_{TOTAL} is the estimated population of each settlement

$$\left(\sum_{i=1}^{67} \bar{x}_i / p \right)$$

Before calculating the 95% confidence interval for the population estimate, we need to know the variance of \hat{N}_{TOTAL} , which can be calculated by the following:

$$VAR(\hat{N}_{TOTAL}) = \frac{\sum_{i=1}^{67} \left(\bar{x}_i / p - \hat{N}_{TOTAL} / SampleSize \right)^2}{SampleSize}$$

where p denotes the estimated identification probability for the animals and $SampleSize$ denotes the number of visited settlements. Since the standard deviation (Std) of the \hat{N}_{TOTAL} equals to $\sqrt{VAR(\hat{N}_{TOTAL})}$, the standard deviation for the average number of dogs and cats counted can be calculated by dividing it by the square root of the sample size. Then it is reasonable to estimate the standard deviation of \hat{N}_{ANKARA} by multiplying the standard deviation of the mean by the total number of settlements.

Using the above formulation, we can estimate the 95% confidence interval (CI) with the following equation:

$$95\% \text{ CI} = \hat{N}_{ANKARA} \pm 1.96 \times Std(\hat{N}_{ANKARA})$$

2.2.3. Other methods

Descriptive statistics of all data were calculated for each block. Correlations between the human and estimated dog (cat) populations were performed using Pearson’s correlation analysis. All data were analyzed using R environment, version 2.15.3 (11) and $P < 0.05$ was considered significant.

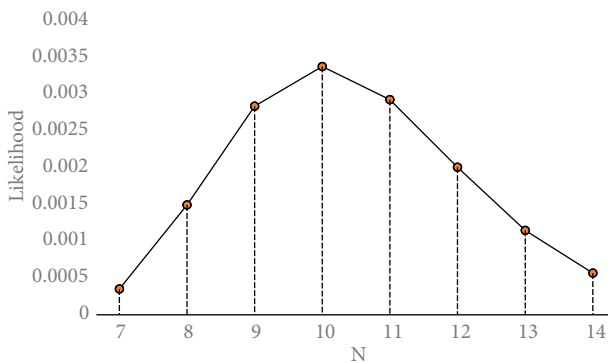


Figure. Likelihood as a function of the unknown population size N for $x_{11} = 3$, $x_{12} = 5$, and $x_{13} = 7$, assuming that we are able to identify half of the population ($p = 0.5$).

3. Results

3.1. Settlement characteristics

During the study a total of 67 settlements were visited in the 16 districts under the management of the Major Municipality of Metropolitan Ankara. Table 1 shows the number of settlements and the accumulative human population of those settlements for each district. Considering the total number of settlements (701), the coverage ratio was 9.6% and the human population coverage was 15% according to the 2012 human population census data taken from the Turkish Statistical Institute (10).

3.2. Estimation of stray dog and cat populations

To estimate the populations of stray dogs and cats in each visited settlement, the identification probabilities of dogs and cats were first calculated separately using the formula $\hat{p} = \sum_i \bar{x}_i / \sum_i M_i$. The identification probability of dogs was 0.606 and the identification probability of cats was 0.605, i.e. almost identical for the 2 species.

To estimate the dog and cat populations for each visited settlement, methods described above were used. A summary of the estimations for the visited settlements is given in Table 2.

Table 1. The number of selected settlements and the accumulative human population among districts.

	District	N	Population
1.	Akyurt	2	2147
2.	Altındağ	10	106,969
3.	Ayaş	1	581
4.	Bala	2	1665
5.	Çankaya	12	92,405
6.	Çubuk	3	36,179
7.	Elmadağ	2	8053
8.	Etimesgut	3	38,761
9.	Gölbaşı	3	17,240
10.	Kalecik	1	873
11.	Kazan	2	4001
12.	Keçiören	5	129,079
13.	Mamak	6	59,870
14.	Pursaklar	1	2713
15.	Sincan	5	61,588
16.	Yenimahalle	9	125,457
Total		67	687,581

Table 2. Descriptive statistics of the estimated number of dogs and cats in the visited settlements.

	N	Mean ± std. error	Std. deviation	Quartiles (Q ₁ ; Q ₂ ; Q ₃)	Sum
Dogs	67	25 ± 2.18	17.7	14; 22; 32	1705
Cats	67	15 ± 1.28	10.51	7; 13; 21	974

Considering the human population and the estimated number of dogs (cats) of the visited settlements, it was found that the human/dog ratio was 10,000/25, while the human/cat ratio was 10,000/14. Using the estimated numbers of stray dogs and cats in each visited settlement, the population estimates for all 16 districts with 95% confidence intervals were estimated (Table 3).

There was no significant correlation between the estimated number of cats or dogs and the human population in the settlements ($P > 0.05$). Moreover, there was no significant correlation between the estimated numbers of stray dogs and stray cats seen in the visited settlements ($P > 0.05$) (Table 4).

4. Discussion

The estimation of dog or cat populations is not an easy task, especially in countries where the registration and licensing of these animals are not obligatory. In the literature, there are many methods such as questionnaire surveys (12–14), mark-resight (recapture) studies (15–18), and counts of randomly selected city blocks (9) used for the estimation of stray animal populations. Using a combination of two or more of these methods can give a more accurate estimation;

however, that would require time, money, and well-trained staff. In order to get a reliable population size estimate, we planned a counting in a randomly selected city block based on recapturing. However, because of the marking problems encountered during the study, we proposed an approach based on identification probabilities of dogs (cats) seen in each site, and used this information to give at least a minimum number for the actual population size. We think that this proposed approach might be a cost-effective, time-saving, and practical way to provide data about the true population size where there is no marking of animals.

A possible limitation of the present study involves the validation of the described methodology. In order to explain more about how the presented method compares in terms of accuracy with more validated methods (such as the capture–recapture method), a comparative study using both methodologies needs to be done with data collected from the same selected area in a specific time interval. In the present study, the collected data were not appropriate for using in a capture–recapture methodology since it was not possible to reidentify the animals due to the low quality of the photos taken in the dark and the

Table 3. Population estimates for the Major Municipality of Metropolitan Ankara.

Species	Estimation	95% confidence interval	
		Lower bound	Upper bound
Dogs	17,839	14,862	20,816
Cats	10,191	8439	11,942

Table 4. Correlation matrix of the estimated stray cats and dogs in visited settlements (n = 67).

		Human population	Estimated dog population	Estimated cat population
Human population	<i>r</i>	<i>1</i>	0.06 (NS)	0.17 (NS)
Estimated dog population	<i>r</i>		<i>1</i>	0.12 (NS)
Estimated cat population	<i>r</i>			<i>1</i>

r: Pearson's correlation coefficient; NS: not significant ($P > 0.05$).

fact that the majority of the dogs and cats look almost the same. However, it should be noted that this approach aims to give only the lower bound for the true population size since all calculations depend on the maximum number of observations and the identification probability, assuming an infinite sequence of observational visits to settlements. Therefore, an increase in the number of visits might give the capturing probability of all the animals living in the block and a better estimation of the true population size. Hiby (19) estimated that about one third of the dogs were missed during a single survey of sample blocks in Cairo, Egypt.

The populations of stray cats and dogs, like other populations, depend on the availability of resources such as food, water, and shelter (20). This information might suggest the idea that most dog (cat) populations depend in some way on the referral households (21). Moreover, Butler and Bingham (22) indicated that canine population density was positively associated with human population density. However, in the present study, no significant correlation was found between the human populations and the dog (cat) populations among the visited settlements. This evidence suggests that other important factors like urbanization, local culture, local waste management, or social strata of the residential population should also be taken into consideration in addition to residential population.

To quantify the dog and cat population size, some studies use a ratio of animals to humans (23), while others give an animal density per household (22) or per km² (13,15). A canine population dynamics study in Manhattan, the United States, reported a 1:4 dog to human ratio, since the free roaming animals in 1 year represented 12% of the total dog population, of which 36% were stray and the rest were owned (24). A study to estimate the stray dog population in Kathmandu and Shimotsui determined the ratio of humans to stray dogs as 1:4.7 and 1:5.2, respectively (23). Knobel et al. (25) reported the mean humans per dog ratio as 7.4–21.2 (rural–urban) in a region in Africa, and 7.5–14.3 (rural–urban) in a region in Asia, respectively. Some researchers (26,27) report a ratio of cats to humans between 1:8 to 1:16. The results of the present study showed that the estimated human to dog ratio of 10,000:25 and human to cat ratio of 10,000:14 from the visited settlements seem one of the lowest ratios

among what has been reported elsewhere in developing countries. Yet, it should be noted that neither owned dog (cat) populations nor the dogs (cats) in the local shelters were taken into consideration for these estimates. Unfortunately, there is no clear information about the number of unowned cats and dogs in local shelters and there is no study on the estimation of the population size of owned dogs and cats in Ankara.

There are many potential risk factors associated with an increase in the number of stray dogs and cats, including unplanned urbanization, waste disposal management problems, irresponsible pet owners, insufficient regulations, and local culture (28). Worldwide data on the population size of stray dogs and cats are still limited and data collection needs to be extended. Although the estimated number in the current paper was only a lower bound for the true population size, the presented methodology might provide a cheaper and simpler way to give a population size estimate where there is no marking of animals.

This study focused on the estimation of the stray dog (cat) population, excluding owned dogs (cats), in the central districts (16 of 25) of Ankara for the first time and showed that stray dogs and cats are common on the streets. There is no doubt that those animals suffer from diseases and fare poorly with limited access to vaccination. Although the necessary steps that should be taken are beyond the scope of this paper, providing baseline information about the numbers of stray dogs and cats might be useful for authorities to evaluate the success of any recent or future intervention to control zoonotic diseases and to improve the welfare of the animals.

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