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Demography of domestic dog population and its implications for stray dog abundance: a case study of Omsk, Russia

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Abstract In cities of Russia, stray dog populations have been conserved for a long time, despite natural mortality and constant catching. We suggested that the overpopulation of owned dogs and their subsequent transition into stray dogs is a primary reason for the increase in the number of stray dogs. Information on owned dogs was obtained through a cross-sectional household survey of dogs owners in Omsk, Russia. Analysis of a vertical life table showed that the maximum mortality of owned dogs under 1 year of age was 53 %; in other age classes, the mortality was, on average, 5.6 %. Analysis of fecundity showed that 81 % of the owners do not mate their dogs; consequently, only 36 % of the adult females whelped at least once. Analysis of the Leslie matrix showed that the growth rate of the population of owned dogs was 1 % per year. This result shows minimum overpopulation. Previous dogs escaped or were lost or vanished in rare cases (approximately 0.5 %). However, in a megalopolis, even such low frequencies are significant (95 % CI: 1433–5473 individuals). Analyses of the demographic processes in a population of owned dogs showed that a transition from owned dogs to stray dogs exists. Overpopulation is not the key reason for the transition, but different accidents are: that is, pets are lost, run away, etc. The frequency of such events is small, but, because of the size of the city, the number of such dogs might be 10–39 % of the total number of stray dogs.

Keywords Demography of domestic dogs · Stray dogs · Owned dogs · Fecundity · Mortality

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Introduction

Russian urban dogs There are several publications in the Russian-language scientific literature devoted to the study of dogs living in large Russian cities. Some authors classify urban dogs into several ecological groups (Ivanter and Sedova 2008; Berezina 2002; Snigirev and Mister 2010). From the different classifications, three ecological groups of dogs can be generally identified in large Russian cities, including, owned dogs, free-roaming owned dogs, as well as stray dogs.

Owned dogs, indicate dogs that have owners who feed them, walk them and control their reproduction and behavior. In terms of the WHO (1990), this group corresponds to 'Restricted or Supervised dogs', in that, they are fully dependent, and fully restricted or supervised.

The free-roaming owned dogs, represent dogs that have owners who sometimes feed them but do not always do so. The dogs are able to leave the household freely, unaccompanied by their owners. In WHO classification (WHO 1990), this group corresponds to 'Neighbourhood dogs'. They are largely semi-dependent, semi-restricted or unrestricted.

The stray dogs, represent dogs that live outdoor and typically have no owners. According to the WHO (1990), such dogs are classified as 'Feral dogs', since they are mostly independent and unrestricted. It is important to note that in Russia, these dogs live not only in cities but also in the Wild. They live far away from settlements and avoid contact with the people. Therefore, to avoid confusion, we use the term 'Feral dogs' to refer to dogs living in the Wild, and 'Stray dogs' to indicate un-owned dogs within the cities.

The majority of authors studied the number of stray dog populations, sex structure, behaviour, diseases (Berezina 2002; Zaloznykh and Ponomarenko 2006; Ivanter and Sedova 2008; Snigirev and Mister 2010; Zolina 2011; Poyarkov et al. 2011b;. Makenov and Kassal 2014). The reproduction of the stray dog population is not investigated.

Stray dogs apparently come from the following sources:

- *Breeding.* In studies, the reproduction of stray dogs was described for different Russian cities. The research examined 20 litters of stray dogs in Petrozavodsk between 2004 and 2007 (Ivanter and Sedova 2008), and 78 litters in Omsk during 2002–2006 (Makenov and Kassal 2014). In Moscow, it was found that puppies accounted for 20 % of the population (Poyarkov et al. 2011b). The breeding success has not been studied.
- *Lost dogs.* At times, some owned dogs get lost while walking or traveling. Some also run away from home to join a stray dog group and do not come back home. Owners usually have slim possibilities of finding and returning their pets, because urban animal control service is poorly developed. This service captures free-roaming dogs at different times, and kill captured animals quickly.
- *Abandoned pets.* The dog owner has a very limited option of where to place his (her) pet in case he (she) decides to abandon the dog. For example, there is only one shelter in Omsk, which is very small and usually overcrowded. Besides, the shelter takes abandoned dogs with certain requirements (vaccination, sterilisation), and not every owner is willing to comply with these requirements. Therefore, many owners who decide to abandon the pet give the dog to friends, colleagues, relatives (in the city or in the village) or just throw them away. Thus, there is very limited study on the number of abandoned dogs in Russian cities. Authors that study stray dogs have found that purebred dogs occur among stray dogs (Makenov 2007; Snigirev and Mister 2010). This fact implicitly confirms that some un-owned dogs may be from previously lost dogs.

The hypothesis The number of stray dogs is very high in the cities of Russia: approximately 26,000 in Moscow (Poyarkov et al. 2011b), 4000 to 5000 in St. Petersburg (Batsanov et al. 1998), 4600 in Nizhny Novgorod (Zaloznykh and Ponomarenko 2006) and 10,000 in Omsk (Berezina 2002). These populations have existed for a long time. For example, A. Poyarkov studied the behaviour of stray dogs in the late 1970s in Moscow (Poyarkov 1991). A. Poyarkov reported that before the start of the XXII Summer Olympic Games in 1980, the city authorities performed a mass destruction of stray animals in the city (Poyarkov 1991). Despite these measures, the population of dogs in Moscow recovered, and the population density in 1997 was 24.5 individuals/km^2 (Poyarkov et al. 2011a).

According to archival documents, municipal services in Omsk have been organized to capture stray animals since 1960; each year, several thousand dogs on the streets are caught and disposed (Makenov and Mihaylova 2013). Despite these measures, the number of stray dogs in the city is estimated to be about 10,000–14,000 (Berezina 2002; Makenov and Kassal 2014).

The density of dog populations in cities of Russia is very high: 21 individuals/km^2 in Penza (Zolina 2011), 28 individuals/km^2 in Barnaul (Snigirev and Mister 2010) and 58 individuals/km^2 in Petrozavodsk (Ivanter and Sedova 2008).

Thus, on the one hand we have a constant mortality (diseases, accidents, etc.) and the permanent capture of stray dogs, and on the other hand we are face with the high number of stray dogs. The question is how the population of stray dogs remain high. We assumed that owned dogs are the one of the main source of replenishment for the stray dog population.

According to our hypothesis, in large cities, reproduction of owned dogs exceeds the demand, resulting in overpopulation. Simultaneously, phenomena such as free walking of dogs and deliberately «throwing out» pups and adults can serve as the mechanism underlying the regular replenishment of the stray dog population.

In this study, we aim to determine whether overpopulation of owned of dogs occurs in Omsk and evaluate the conversion of owned dogs to stray ones.

Methods

Study area

The study was conducted in Omsk (Russia) between May and August 2014. Omsk is a regional centre with a population of 1,173,000 people, and it is located south of Western Siberia.

We carried out the study by households. Households were defined as communities of persons living in the same compound.

Owners housing condition largely determines the practice of dog keeping. We divided the residential part of Omsk into two categories: multi-storey buildings and single-storey buildings. In multi-storey buildings, dog care presents certain difficulties, and it reflects in the everyday practices of dog keeping, especially with regard to pets and their role in the family. Housing conditions in single-storey buildings differ a lot. It is possible to keep the dog in a private courtyard and there is no need to walk the pet every day. In which case, dogs start to play other roles.

Besides, we took into account such parameter as, the distance from the centre of the city, because it may have an impact on the decision to buy a dog or not, as well as dog keeping practices.

Taking into account the above, we divided each area into three zones.

1. Centre: the central part of the city with the most expensive housing, high concentration of office, commercial, social and political buildings and high traffic roads. Single-storey buildings of this area are represented by cottage settlements.
2. Middle of the city: it is the transition between the central part of the city and the outskirts, characterised by reduced density, less number of public buildings and the bustling traffic.
3. Periphery: it is a residential area adjacent to undeveloped territories and parkland that surrounds the city.

The number of households in each zone was determined using Remote sensing technique and open GIS sources. We count households in single-storey area by Russian open GIS source (2GIS). Multi-storey houses in Omsk are built on standard projects. We identified the type of building in multi-storey area using remotely sensed images, and determined the number of households in each multi-storey building. As a result, we obtained the GIS database with the number of households in each apartment building and the base of separate houses for each zone. We verified our database selectively visiting different areas of the city.

In sum, we estimated the total number of households in Omsk to be, 471,794 households, including 442,694 in multi-storey buildings and 29,100 in single-storey buildings.

Study design

Information on owned dogs was obtained through a cross-sectional household survey of dog owners.

The first step of the research The sample of the first step was created based on the total number of households. We formed separate subsamples for multi-storey and single-storey areas. The first sample consisted of 1583 households: 1260 households in the multi-storey area, and 323 households in the single-storey area.

A stratified two-stage random sample was established. We divided each zone into equal sections – 60 households per section. Then each section was numbered for subsequent random selection procedure. The questionnaire survey was carried out by sections, which were selected through a random number generator. In each section we use systematic sampling with random start to select households.

In this step, we estimated the number of households with dogs, the number of dogs, sex and age structure of the pets. The questionnaire also had questions about reproductive history of female dogs, including:

- number of litters in lifetime as well as in 2013;
- size of each litter;
- sex ratio in the last litter;
- the fate of pups (i.e. kept, sold, given away or died) and age of pups at that event.

Furthermore, we studied the previous dogs according to sex, age, fate (lost, ran away, died, given away etc.), and date of that event. We suggested this questions to all respondents (both in dog-owning households and in non-dog owning households).

The second step of the research As a result of the first step survey, we estimated the total number of households with dogs. It allowed us to build the second step sample, which covered only households with dogs. The second sample size was 321 dog-owning households. At this step, we also selected sections by the random number generator, and then we questioned in the selected sections only dog-owning households.

The main goal of this step was to examine the dog keeping practices (not published yet). In this study, we used from the second step of research the data about breeding control.

Data analysis

We used the data which were obtained during the earlier indicated survey to construct the life table, evaluating breeding control, dog population growth rate, and migration of dogs from owned to stray.

Life table

We collected data for the age structure of the owned dogs in 2013 to build a vertical (static) life table. The questionnaire of first step survey was compiled in such a way that we could evaluate:

1) Sex and age composition of owned dogs that were alive on January 1, 2013, and during the survey;
2) Sex and age composition of owned dogs that were alive on January 1, 2013, but did not live in the household (died/lost/was taken to a village) during the survey;
3) Sex composition and number of puppies born in 2013.

This information was collected not only during the survey of households with dogs but also households that had no live dogs during the survey to avoid bias.

We created a vertical life table, relying on the number of a_x individuals of each age x class. We calculated survival l_x as the ratio of individuals of age class x to individuals of first age class x_1:

$$l_x = \frac{a_x}{a_{x_1}}.$$

Mortality denoted as d_x represents the probability of death in the age interval of x up to $x + 1$ and was calculated as a difference between 2 successive values of l_x.

Age-specific mortality q_x characterizes a share of animals in the age of x that died before reaching age $x + 1$:

$$q_x = \frac{d_x}{l_x}.$$

The parameters were calculated under the assumption that the population had a stable age structure, and the population size was, or nearly, stationary.

In the received age distribution, not all the subsequent age classes were numerically less than the previous ones. Thus, d_x mortality in the age classes 3–4, 8–9, 12–13 and 15–16 years had negative values. We applied the procedure «of smoothing» for the interval from 2 to 3 years to 18–19 years to achieve a monotonous decrease in the age classes. We used the polynomial approximation with the following regression equation:

$$y = 64,36 + 0,25x^2 - 7,68x,$$

where the coefficient of determination is $R^2 = 0.90$. We carried out further calculations of mortality and specific mortality by using a «smoothed» age structure.

Breeding control

We used the answers of second step survey to study breeding control. The sample covered data for 164 females, from which we excluded the individuals under the age of 1 year and spayed females. Twenty-seven respondents had difficulties with their answers. Therefore, we used data on the reproductive history of 107 females for the analysis.

Leslie matrix

We used the Leslie matrix to calculate finite growth rate λ, basic reproduction ratio R_0 and exponential growth rate r of the population. The first row of this matrix contains data on the fecundity of the age classes, and the main diagonal presents data on the survival of individuals in each age class (Caswell 2001).

We used only data of the females; the males were excluded from the analysis. Fecundity was calculated using data on the birth of pups in only 2013. The data were collected during the first step of the survey (both in dog-owning households and in non dog-owning households), and contain information about age structure and reproductive history of 253 female dogs. We conducted a projection of the population growth on the basis of the assumption that the environmental conditions were steady, age structure and fecundity remained unchanged, and there were no restrictions on population size.

We determined finite growth rate λ when reaching a stable age structure as the dominant eigenvalue. We determined reproductive number as the left eigenvector of the matrix. We carried out the elasticity analysis by using the package «popdemo» in the R-environment (Stott et al. 2014).

Migration

We used information on previous dogs and considered all cases in which the respondents answered that their pets «ran away» and were «lost» as transition to stray dogs. The data were collected in first step survey and contain information both dog-owning households and non dog-owning households.

We cannot say that all lost dogs will become members of the stray dog population. Lost or abandoned dogs have in general three outcomes, someone will pick them up, they will die, or become stray. The study design does not allow us to estimate the probability of a particular outcome. We can only estimate how many dogs had migrated from 'owned' to 'stray'. We did not consider the success of the migration. Obviously, this approach entails biases and overestimations. Nevertheless, this estimate provides the upper limit of the number of migrating dogs.

Results

Vertical life table and mortality

We created a vertical life table to determine specific mortality on the basis of the age groups. In 2013, the population of owned dogs in Omsk consisted of 18 age classes; the median age was 3.0 years, and the most numerous age class consisted of individuals under 1 year (24 %). Maximum mortality (53 %) was recorded at this age; for other age classes, the mortality was 5.6 % (SE = 1.4, range = 0.0–14.0 %; calculated on the basis of unadjusted mortality with the exception of negative values). By 11 years, the cumulative mortality was 90 % (Table 1).

Causes of death

Information on previous dogs was obtained from dog owners as well as respondents who at the time of the survey did not have dogs. We divided the causes of death of the previous pets into 5 groups (Table 2). Almost half of the respondents (48.5 %) noted «old age» as the cause of death, and the average age at the time of death of such pets was 12.9 years (SD = 3.3; range: 7–22 years).

Table 1 Vertical life table for the owned dog population

Age class	Number of individuals sampled per age class	Cumulative survival	Smoothed values		
			Cumulative survival	Mortality	Age-specific mortality
x	a_x	l_x	l_x	d_x	q_x
0–1	136	1.00	1.00	0.53	0.53
1–2	64	0.47	0.47	0.05	0.11
2–3	61	0.45	0.42	0.05	0.12
3–4	42	0.31	0.37	0.04	0.12
4–5	52	0.38	0.32	0.04	0.14
5–6	35	0.26	0.28	0.04	0.16
6–7	33	0.24	0.24	0.04	0.16
7–8	22	0.16	0.20	0.03	0.15
8–9	14	0.10	0.17	0.03	0.17
9–10	32	0.24	0.14	0.02	0.16
10–11	14	0.10	0.12	0.02	0.19
11–12	13	0.10	0.10	0.02	0.23
12–13	9	0.07	0.07	0.01	0.20
13–14	10	0.07	0.06	0.01	0.13
14–15	10	0.07	0.05	0.01	0.14
15–16	2	0.01	0.04	0.00	0.00
16–17	8	0.06	0.04	0.00	0.00
17–18	4	0.03	0.04	0.04	1.00

Table 2 Causes of owned dog death in different zones of Omsk

Cause of death	Multi-storey building zone		Single-storey building zone		Total	
	Value	%	Value	%	Value	%
Old age	61	43.6	56	55.4	117	48.5
Accident	46	32.9	20	19.8	66	27.4
Disease	12	8.6	14	13.9	26	10.8
Euthanized	5	3.6	6	5.9	11	4.6
Unknown	16	11.4	5	5.0	21	8.7
Total	140	100.0	101	100.0	241	100.0

About 27.4 % of the dogs died in accidents, and this group includes dogs that died under the wheels of cars, fights with other dogs, poisoning, etc.

According to dog owners, 10.8 % of the dogs died because of a disease. Most owners did not know which disease, and in a few cases, they indicated «after tick bite», «a stroke» or «hereditary disease».

Breeding control

Based on all lifetime reproduction history we found that 36.4 % females older than 1 year pupped at least once. Mean litter size was 4.5 pups (SE = 0.3), the reproductive period of the owned female dogs in Omsk lasted from 1 year to 9 years (inclusive).

We also investigated how the owners of female dogs control the reproduction of their pets. Only 9.8 % of all the female dogs were sterilized. In other cases, only 15.4 % of the owners do nothing during the oestrus of the dog; 3.1 %, allow for the mating of the dog, but with a pre-selected male and 80.8 %, do not allow reproduction by using special medicines or limiting contact with male dogs (Table 3).

Table 3 Control of reproduction in female dogs

Method of control	Multi-storey building zone		Single-storey building zone		Total	
	Value	%	Value	%	Value	%
Sterilized[a]	12	10.0	4	9,1	16	9,8
Controlled reproduction[b]	3	3.2	1	2.7	4	3.1
Medicines	6	6.5	1	2.7	7	5.4
Limit contact	73	78.5	25	67.6	98	75.4
Do nothing	12	12.9	8	21.6	20	15.4

[a] Proportion of sterilized females calculated separately from the total number of females in each zone and the entire city

[b] Allow mating with a pre-selected male

Projection of population growth

Leslie matrix model

A Leslie matrix based on a table that presents age-related changes in the survival and fecundity of owned female dogs in 2013 (Table 4) was constructed. The survival rate of females in the first year of life was only 43 %. In 2013 fecundity was sharply limited: breeding females in 5 age classes (2–7 years of age), and in most of them, fecundity was less than 1; it was 1.13 only in the age class 2–3 years.

Table 5 presents the main results of the projection of population growth. Finite growth rate λ was calculated when a stable age structure was achieved in the 13th iteration ($\lambda = 1.01$). The intrinsic rate of increase was $r = 0.01$, and the net reproductive rate was $R_0 = 1.03$. The reproductive number reaches maximum values in age classes 1 to 2 years, 2 to 3 years and 3 to 4 years (27.3 %, 27.5 % and 18.7 %, respectively; Table 5).

Elasticity analysis

Elasticity analysis of the Leslie matrix showed that the first 3 age classes provide maximum proportional effect on the change of the dominant eigenvalue λ: for each of them, *e* was 0.26.

Influence of fecundity on the growth rate of the population was relatively small; it was maximum for the age class 2–3 years, where $e = 0.12$ (Fig. 1). Survival of dogs belonging to

Table 4 Survival and fecundity of owned female dogs

Age class	Number of individuals sampled per age class	«Smoothed» number of individuals sampled per age class	Age-specific mortality	Fecundity
x	a_x	a'_x	P_x	F_x
0–1	63	63	0.43	0.00
1–2	27	27	1.00	0.00
2–3	27	27	0.78	1.13
3–4	21	21	0.86	0.76
4–5	20	18	0.89	0.83
5–6	12	16	0.88	0.11
6–7	18	14	0.86	0.09
7–8	9	12	0.92	0.00
8–9	7	11	0.82	0.00
9–10	15	9	0.89	0.00
10–11	7	8	0.75	0.00
11–12	9	6	0.83	0.00
12–13	6	5	0.80	0.00
13–14	3	4	0.75	0.00
14–15	3	3	1.00	0.00
15–16	0	3	0.67	0.00
16–17	4	2	0.50	0.00
17–18	2	1	1.00	0.00

Table 5 Estimated age structure and population parameters

Age class	Stable age distribution, %	Reproductive value, %	Parameters
0–1	25.4	11.7	λ = 1,01 r = 0,01 R_0 = 1,03
1–2	10.8	27.3	
2–3	10.7	27.5	
3–4	8.3	18.7	
4–5	7.1	11.6	
5–6	6.3	2.2	
6–7	5.5	1.1	
7–8	4.7	0.0	
8–9	4.2	0.0	
9–10	3.5	0.0	
10–11	3.1	0.0	
11–12	2.7	0.0	
12–13	2.3	0.0	
13–14	1.5	0.0	
14–15	1.5	0.0	
15–16	1.1	0.0	
16–17	0.7	0.0	
17–18	0.4	0.0	
18–19	0.4	0.0	

age classes 0–1 year and 1–2 years had the greatest influence on λ (elasticity =0.26). In subsequent age classes, the role of survival decreased (Fig. 1).

Migration

We asked all respondents (both in dog-owning households and in non dog-owning households) whether had they a dog in 2013, and, if they did, what happened to the dog. Answers of the respondents were classified into 4 groups (Table 6):

1. Non dog-owning households – 2013. This group includes answers of the non dog-owning households respondents that did not have a dog in 2013 and answers of the owners in dog-

Fig. 1 Results of the elasticity analysis of the Leslie matrix

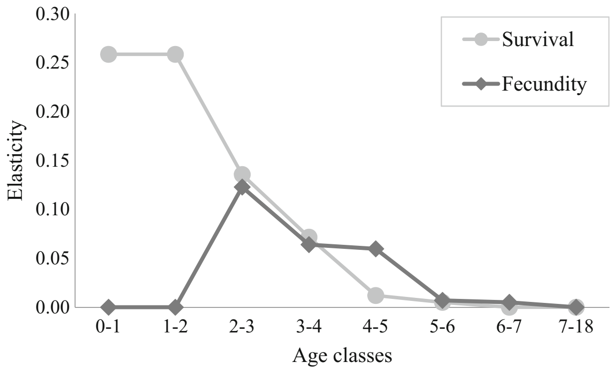

Table 6 Fate of previous dogs according to the data for 2013

Group	Number of households		
	Sample		Extrapolated
	Value	% (95 % CI)	Individuals (95 % CI)
Non dog-owning households – 2013	1442	93,5 (92,1–94,6)	440,912 (434,537–446,492)
Migration to stray dogs	10	0,6 (0,3–1,2)	3058 (1468–5608)
Migration in the country	8	0,5 (0,2–1,0)	2446 (1057–4808)
Other	83	5,4 (4,3–6,3)	25,378 (20,320–31,256)

owning households that, in addition to having a live pet at the time of the survey did not have another dog in 2013.

2. Migration to stray dogs. This group includes answers of respondents (both in dog-owning households and in non dog-owning households) who had a dog, but it got lost/ran away in 2013.
3. Migration in the country. This group includes answers of respondents who had a dog, but in 2013, it was taken to a village/given to relatives in a village.
4. Other. This group includes answers of respondents who had a dog, but in 2013, they lost the dog; either the dog died or it was given to other owners within the city.

Dogs that have transitioned from owned to stray, are, in relative terms, few, less than 1 % (0.6 %); however, in a megapolis with more than 470,000 households, even this small number can be significant in absolute terms. We extrapolated the obtained frequency to all households in the city and revealed that in 2013 about 3000 dogs got lost/ran away (Table 6). The interval estimation shows that with 95 % probability, the number of such dogs is 1433–5473 (Table 6).

In the study of the fate of previous dogs, we established that some dog owners give them away to family/friends in a village; such instances are few (0.5 %; 95 % CI: 0.2–1 %; Table 6).

It is important to note that, we projected the population growth using Leslie matrix approach. This approach is performed under the assumptions that there is no migration in population. Nevertheless, the study design allowed us to estimate the migration. In total, the number of emigrants was extremely low – 1.1 % (Table 6). Taking into account such small percentage of the migration rate, we can consider migration as not significant for the growth rate estimation.

Discussion

In this study, we obtained important results that verify our hypothesis on the role of overpopulation of dogs in Omsk in the replenishment of stray dog populations. Unfortunately, similar studies in other cities of Russia have not been performed, so we can compare our results with only data obtained from studies conducted in other countries.

Analysis of the age structure and construction of a survival table allowed us to obtain an estimate of the mortality for each age class. We found that the mortality of individuals under the age of 1 year was 53 %, and for subsequent age classes, the percentage decreased and did not exceed 14 %. Similar values for first-year mortality were obtained in N'Djaména (Chad) – 57 % (Mindekem et al. 2004) and Machakos District (Kenia) – 52 % (Kitala et al. 2001). Higher mortality of pups was noted in Iringa (Tanzania) – 72 % (Gsell et al. 2012) and Zimbabwean communal lands – 72 % (Butler and Bingham 2000). J. Acosta-Jamett et al. (2010) showed that the mortality of dogs under the age of 1 year was significantly lower in large cities of Chile (about 20 %) than in small towns (40 %). It is also interesting to compare our results with the survival of feral dogs in Italy; according to Boitani and Ciucci (1995), only 5 % survived the age of 1 year. The comparison shows that although about half of all puppies of domestic dogs in Omsk do not survive to 1 year, this rate is relatively low.

In this study, about half (48.5 %) of all dog owners in Omsk reported that their previous pets died of old age. Further analysis showed that this estimate is, most likely, inflated and includes dogs that died due to diseases. Thus, some respondents chose this answer as the cause of death, even in cases when the pet was 7–9 years of age at the time of the death. For comparison, respondents in cities of Chile chose old age as the cause of death for dogs in only 12 % of the cases (Acosta-Jamett et al. 2010). In Chile, accidents (under the wheels of cars, poisoning, etc.) are the cause of death for 41 % of the dogs (Acosta-Jamett et al. 2010), whereas in Omsk, accidents are the cause of death for about 27 % of the dogs. The number of deaths because of disease also varies greatly: 11 % in Omsk, 13 % in the city of Merida (Mexico) (Ortega-Pacheco et al. 2007) and 35 % in cities of Chile (Acosta-Jamett et al. 2010).

The structure of mortality largely characterizes the living conditions of dogs. The relatively low percentage of deaths due to disease and accidents and a high proportion of deaths due to old age indicate good conditions for dogs and the availability and development of veterinary services.

Analysis of breeding control showed that that the owners of female dogs in Omsk significantly restrict the reproductive function of their pets: 81 % of the owners do not allow the mating of their dogs; consequently, only 36 % of the adult females pupped a minimum of 1 time. For comparison, in the cities of Chile, 47 % of female dogs had reproductive experience (Acosta-Jamett et al. 2010) and in Kenya, 85 % (Kitala et al. 2001). Mean litter size in Omsk is not significantly different from the values recorded in urban Zimbabwe, Kenya, Chile and Tanzania (Butler and Bingham 2000; Kitala et al. 2001; Acosta-Jamett et al. 2010; Gsell et al. 2012).

In this study, we tested the hypothesis that overpopulation of owned dogs in the city is one of the main sources of replenishment of stray dog populations; therefore, results of the projection of population growth are of interest. The growth rate of the population of owned dogs in Omsk was 1 % per year. If we assume that the demand for dogs remained unchanged, then the finite rate of increase in the population characterizes the overpopulation of dogs. Thus, overpopulation is insignificant and only 1 % per year. The growth rate of dog populations is high in other countries: 7 % in Zimbabwe (communal lands) (Butler and Bingham 2000), 9 % in Kenya (Machakos District) (Kitala et al. 2001), 19–20 % in the cities of Chile (Acosta-Jamett et al. 2010) and 10 % in Tanzania (Gsell et al. 2012).

Analysis of the elasticity of the Leslie matrix showed that the survival of dogs in the first 2 years of life is the most important factor that influences the rate of growth. This result is consistent with the conclusions of A. Gsell et al. (2012), who studied dog populations in Iringa (Tanzania).

The projection of population growth is based on an assumption about the stability of external factors, age structure, fecundity rate and survival rate; therefore, this model does not include migration between populations of owned and stray dogs. We considered migration processes separately. We found that there are 2 main migration flows: to stray dogs and to households of rural settlements. The power of these flows is approximately the same and amounts to approximately 0.5–0.6 % of the total number of households in the city. This value is smaller than the standard error of our sample, so in this case, it is most appropriate to use the interval estimate: The 95 % confidence interval for estimating the number of dogs that migrated from owned to stray was 1433 to 5473 individuals. If we consider data obtained in the previous study (Makenov and Kassal 2014), then in 2013, the proportion of migrants from owned dogs among the stray dogs ranges from 10 % to 39 %. Although the scope of this assessment is large, we can conclude that the «lost» and «runaway» dogs are a significant source of the annual replenishment of stray dog populations.

Conclusion

We found high mortality of puppies under the age of 1 year, as well as control of reproduction by dog owners to minimize the rate of growth of the population of domestic dogs. Thus, overpopulation is minimal, and «throwing out» and «abandonment» may not be the main cause of replenishment of the number of stray dogs.

Analysis of the processes of migration showed that the transition from owned dogs to stray dogs exists. The cause of such transitions is not overpopulation but accidents: pets are lost, run away, etc. The frequency of such events is small (0.3–1.2 %), but because of the size of the city, the number of such dogs may be 1433–5473 individuals per year in absolute terms.

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