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First study on domestic dog ecology, demographic structure and dynamics in Bamako, Mali

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ABSTRACT

Background: For the planning of an effective dog mass vaccination campaign against rabies in Africa, it is crucial to know more about the dog population. In this paper we describe for the first time the dog ecology, demographic structure and population dynamics of a domestic dog population in Bamako, Mali. In 2010 and 2011, we visited 2956 randomly selected compounds. Questionnaire data was collected on the compound and household level and on each dog individually. Dog-owning households were followed every six months during one (dog-owning households identified in 2011) or two years (dog-owning households identified in 2010) for the successive collection of dog demography data.
Results: We recorded 379 dogs in 279 compounds. The dog human ratio was estimated at 1:121, and the extrapolation of the domestic dog population in Bamako results in an estimate of 14 906 dogs (95% CI 13 041–17 037). The female male ratio was 1:2.8. A high proportion of young dogs was found as a result of a high turnover rate in the population. Mortality within the first year of life was high, and dogs had a life expectancy at birth of 2.5 years. Using a Leslie matrix, we estimated the annual dog population growth to be 20%. Christians were more likely to be dog owners than Muslims. Another factor favouring dog ownership was belonging to the ethnic group of *Bobo* or *Malinke*. Dogs were mainly used as watchdogs and fed with household leftovers and garbage. They were most often obtained and given away without remuneration.
Conclusions: This work contributes vital information towards planning effective and sustainable dog rabies control programmes for the district of Bamako. Due to the high turnover rate, we recommend repeated mass-vaccination campaigns of at least 70% of the owned dogs at yearly intervals. In addition, dog-owners need to be educated on good dog management.

1. Introduction

In Africa, information on the domestic dog population relevant for rabies control and other dog-mediated zoonoses have only been recorded in a few countries (Davlin and Vonville, 2012). For the planning of an effective dog mass vaccination campaign against rabies in Africa, where more than 20 000 human deaths per year due to rabies are estimated (Knobel et al., 2005; Hampson et al., 2015), it is crucial to know more about the dog population ecology characteristics such as population size, density, sex ratio, turnover, growth and the role of dogs in human societies (WHO, 1987; WHO, 1988). The work of Anyiam et al. (2016) nicely demonstrates the use of dog population estimates for the planning of dog rabies elimination on a country level for Chad. The human-dog relationship is highly diverse. Dogs can be kept as pets or working animals (e.g. watchdogs) or can be traded for food. But for cultural and religious reasons they can also be considered as unclean in a religious or hygienic sense, or they can be rejected because of diseases or the risk of bites (Frank, 1965; WHO, 1987). The World Health Organization (WHO) recommends vaccinating at least 70% of the dog population for efficient rabies control (WHO, 2013). In Bamako, Mali, rabid dogs were responsible for the majority of human cases (Dao et al., 2006) but data on dog demographics and ecology is missing to date. Mauti et al. (2017) estimated a seroprevalence of rabies virus antibodies

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in the examined domestic dog population of 24%, a coverage which is insufficient to interrupt virus transmission (Coleman and Dye, 1996). In a comparable setting in N'Djamena, Chad, it was shown that, on average, below a density of approximately 90 susceptible dogs per km^2 rabies transmission is interrupted (Zinsstag, unpublished data). Kitala et al. (2002) calculated a threshold dog density of 4.5 dogs per km^2 for the interruption of rabies transmission in Machakos District in Kenya. Generally, the proportion of dogs inaccessible for vaccination is low in Africa (WHO, 1988). In Bamako, the proportion of ownerless dogs was estimated at 8% (Muthiani et al., 2015). Given that dogs are not registered in Bamako, a way to learn more about the domestic dog population and the estimated population size is through questionnaire surveys (WHO, 1987).

In this paper we describe the dog ecology, demographic structure and population dynamics of a domestic dog population in Bamako, Mali. Furthermore, we estimated the dog human ratio and calculated the total domestic dog population in Bamako and investigated reasons for dog- and non-dog-ownership.

2. Materials and methods

2.1. Study site

A cross-sectional and longitudinal study was undertaken in Bamako, the capital of Mali, which is located in the southern part of the country. The city is divided in 6 communes with a total of 67 quarters. The national census recorded 1.8 million inhabitants in Bamako (R. G. P. H. 2009). The city has a sub-humid savannah climate with an average temperature above 30 °C each month. The total surface area of the district of Bamako is about 267 km^2 (UN-HABITAT, 2010).

2.2. Data collection

Questionnaire interviews were conducted, whenever possible with the head of the household, in all six communes of Bamako. We randomly selected 32 out of a total of 67 quarters with selection probability proportional to the size of the human population of the communes. During the first baseline survey in 2010 and the second baseline survey in 2011, compounds were selected by a geographical randomisation procedure. A compound was defined as all of the houses surrounded by a wall, which could include several households. We defined a household as an individual or a group, related or not, living within a compound under the lead of the household head. Most commonly, a household in Bamako is composed of the head of household, his spouse(s), his unmarried children and possibly other related or unrelated persons. The survey in 2010 was conducted between May and June, while the one in 2011 was between April and May. Full interviews were conducted in all households in 2010, but only in dog-owning households in 2011. The sampling method for compounds was based on a random selection approach. During the survey in 2010, five field teams, each consisting of one veterinary officer and one interviewer, started in a quarter at the household of the quarter chief, then spun a bottle and walked 200 m in the indicated direction, where they flipped a coin to select one side of the road for the inclusion of two households in two neighbouring compounds (i.e. in total one household per compound). This selection procedure was repeated until at least 38 households per quarter were enrolled and interviewed. In 2011, four field teams started at five randomly selected coordinates within the same quarters. The nearest block was then chosen, where interviews were conducted in households (only one per compound) with the team moving in a clockwise direction until at least 12 households were selected. The location of each household was recorded using a Global Positioning System (GPS). The questionnaires included questions about household characteristics (number of household members, occupation of the head of the household, religion and ethnicity of the interviewee and socioeconomics of the household), dog- and non-dog-ownership, total number of dogs, dog movement within the last six months and dog characteristics (age, sex, function, source, confinement, food source, reproductive history of females) of each owned dog older than 3 months. We defined "owned dogs" as dogs belonging to a household and which were therefore self-identified by the household. In contrast, "ownerless dogs" are dogs not belonging to a household and living in the street. Prior to the first baseline survey, meetings were held with the local chiefs of each quarter. The questionnaire was tested in a non-selected quarter. The questionnaire was in French, and questions were translated into Bambara when necessary. The dog-keeping households were followed, when possible, through telephone interviews every six months for two years (Baseline, 2010) or one year (Baseline, 2011) for the successive collection of dog demography data. If the household could not be contacted through a call, the household was visited again personally.

2.3. Data entry and statistical analysis

Data was double entered in Microsoft® Access 2010 and checked for inconsistencies using Epi Info™3.5.1. Statistical analyses were done with STATA IC 12.

To account for the clustered nature of the data, questionnaire data was analysed with generalized estimating equation models for binary distributed outcomes with a logit link function and exchangeable correlation structure. Important predictor and confounding variables for uni and multivariate analysis were pre-specified. Further exploratory analysis included potential interactions. Mean dog age was estimated by fitting the censored data to a gamma distribution using the R package 'fitdistrplus'. Dog densities per km^2 were estimated by dividing the number of dogs extrapolated for Bamako by the total size of the area. The extrapolation of the total domestic dog population of Bamako was done by means of a negative binomial model resulting in a dog per person mean. This number was then multiplied with the total human population counted during the nationwide census in 2009 (R. G. P. H. 2009). The building construction of the house roof was used for classification of the socioeconomic status, where a straw roof was considered less wealthy, steel sheet was an indicator for moderately wealthy and a roof out of cement was equated with wealthy.

By means of vertical life tables (Pianka, 1999), several life-history demographic parameters (survival, life expectancy, mortality, fecundity) of our baseline study in 2010 and 2011 could be calculated for age-specific classes (0–1, 1–2, 2–3, 3–4, 4–5, >5). Formulas are provided in this manuscript in Appendix A.

Projection of dog population growth was done by means of an age-structured population projection matrix (Leslie matrix) under the assumption that the environment remained constant and no emigration or immigration took place in the dog population. Female fecundity was in the first row of the matrix and survival (p(x)) was in the subdiagonal of the transition matrix (Vandermeer and Goldberg, 2013).

3. Results

3.1. Study population

We identified 379 dogs in 279 households/compounds during the two surveys. In total, 2956 households/compounds were visited (Fig. 1). 125 dog- and 1 017 non-dog-households were interviewed in 2010 and 154 dog-households in 2011. For 1 660