

**Appendix 1. Bayesian Model developed to estimate total number of owned dogs and ratio of ownerless dogs to owned dogs in N'Djaména, Chad**

This appendix correspond largely to the annex 1 of [1].

In each study zone  $i$  ( $i=1, 2$ ), data were collected in four passages  $t$  ( $t= 1, 2, 3, 4$ ) along the same transect lines, during the transect study. Let  $X_{1t}^{(i)}$  and  $X_{2t}^{(i)}$  be the number of marked owned dogs and unmarked owned dogs, respectively; and let  $Y_t^{(i)}$  be the number of ownerless (and unmarked) dogs recaptured in zone  $i$  and on transect passage  $t$ . All marked dogs were owned since ownerless dogs were not brought to the vaccination points. Unmarked dogs included not only owned but also ownerless dogs as it was not possible to distinguish them. Therefore we observed only the number of unmarked dogs  $Z_t^{(i)}$ , where  $Z_t^{(i)} = X_{2t}^{(i)} + Y_t^{(i)}$  and  $X_{2t}^{(i)}$  and  $Y_t^{(i)}$  are latent data. The total number of vaccinated (marked, owned) dogs,  $M_V^{(i)}$ , in each zone  $i$  is known from the register of each vaccination point. Let  $c_1^{(i)}$  and  $c_2^{(i)}$  be the confinement probabilities related to zone  $i$  for owned marked and owned unmarked dogs, respectively;  $M_u^{(i)}$  is the total number of unvaccinated owned dogs; and  $N^{(i)}$  is the total number of ownerless dogs in zone  $i$ . We assume that  $X_{1t}^{(i)}$ ,  $X_{2t}^{(i)}$  and  $Z_t^{(i)}$  follow binomial distributions with recapture probabilities,  $p_{t1}^{(i)}$ ,  $p_{t2}^{(i)}$  and  $p_{t3}^{(i)}$ , respectively; that is,

$$\begin{aligned} X_{1t}^{(i)} &\sim B\left((1 - c_1^{(i)})M_V^{(i)}, p_{t1}^{(i)}\right), \\ X_{2t}^{(i)} &\sim B\left((1 - c_2^{(i)})M_u^{(i)}, p_{t2}^{(i)}\right) \text{ and} \\ Z_t^{(i)} &\sim B\left((1 - c_2^{(i)})M_u^{(i)} + N^{(i)}, p_{t3}^{(i)}\right). \end{aligned}$$

To reduce the number of parameters of the model, we assumed a common recapture probability,  $p_t^{(i)}$  for all dogs (marked owned, unmarked owned, and ownerless), that is,

$$p_{t1}^{(i)} = p_{t2}^{(i)} = p_{t3}^{(i)} = p_t^{(i)}.$$

The parameters of the Bayesian model, together with their credibility intervals, were estimated with Markov Chain Monte Carlo (MCMC) simulation [2] using WinBugs (version 1.4) [3]. Data of the pilot vaccination campaign free to owners were taken from [1]. Prior information about the model parameters was obtained from the analysis of data collected during the household survey. Thus an initial estimate of the total owned dog population  $M^{(i)} = M_V^{(i)} + M_u^{(i)}$  in study zone  $i$  was taken by applying the Petersen-Bailey formula for direct sampling on captured (marked) -recaptured data

observed during the household survey, that is

$$M^{(i)} = \frac{M_V^{(i)}(n_i + 1)}{m_i + 1} \quad (1)$$

and standard error

$$SE = \sqrt{\frac{(M_V^{(i)})^2(n_i + 1)(n_i - m_i)}{(m_i + 1)^2(m_i + 2)}}, \quad (2)$$

where  $n_i$  and  $m_i$  are the numbers of recaptured dogs and recaptured marked (vaccinated) dogs in the household survey in zone  $i$ , respectively. These estimates specified the parameters of a normal prior distribution that was adopted for  $M^{(i)}$ . The parameter  $N^{(i)}$  was expressed as a fraction of the total owned dogs (in particular the mean and variance), that is  $N^{(i)} = a_i M^{(i)}$ . Uniform prior distributions were assumed for  $a_i$ ,  $a_i \sim U(0, 0.2)$  in both zones I and II with parameters based on data from the previous study [1]. The parameters of the above uniform distribution were chosen by combining the Petersen-Bailey estimate of the owned dogs with a rough estimate of the ownerless dog population per zone obtained from the household questionnaire. Uniform prior distributions were also adopted for the recapture probabilities  $p_t^{(i)}$ . The parameters of these distributions were chosen by assuming that recapture probabilities were factored in three components: the area covered by the transect line (coverage), the probability to encounter a specific dog provided the area is covered by the transect (encountering), and the probability of the observer to actually record an encountered dog (recording). For each component, uniform priors were adopted as explained below and shown in Table A1. The lower limit for the area coverage was calculated by dividing the area covered by the transect (allowing 25 m along each side of the line to include a part of the road as well as the yard of the compound next to the road) by the total area of the zone. The upper limit for the area coverage was based on the assumption that more than 50% of the total area was covered, as there was a transect in every second parallel road, most compounds are along the roads, and at intersections parallel streets could be seen. The limits of the uniform prior for the encountering component are based on our observation that many dogs gather around their compound and could therefore be seen. It is, however, a critical point in our assumption. We concluded that recording was very high by comparing the counts of dogs recorded by the three observers who moved together along each transect line. The comparison of the posterior distributions of recapture between the two campaigns (owner-charge and free-to-owners) is presented in Table A2. Finally, beta distributions were adopted for the confinement probabilities  $c_1^{(i)}$  and  $c_2^{(i)}$ . The proportion of dogs that, according to the household survey, spend in maximum half an hour outside of the compound

and were in compounds with closed doors during the survey was taken as the mean of the beta distribution. Thus we assumed that dogs spent maximum half an hour outside the compound weren't seen during the transect. The standard error of this proportion was considered equal to the standard error of the beta prior. The prior distributions of confinement probabilities are shown in Table A1 and the comparison of the posterior distributions of confinement probabilities between the two campaigns (owner-charge and free-to-owners) in Table A2.

## References

- [1] Kayali U., Mindekem R., Yemadji N., Vounatsou P., Kanninga Y., Ndoutamia A.G. and Zinsstag J. (2003) Coverage of pilot parenteral vaccination campaign against canine rabies in N'Djamena, Chad. Bull. World Health Organ. 81: 739-744.
- [2] Gelfand A.E., Smith A.F.M. (1990) Sampling-Based Approaches to Calculating Marginal Densities. Journal of the American Statistical Association 85: 398-409.
- [3] Gilks W.R., Thomas A., Spiegelhalter D.J. (1994) A Language and Program for Complex Bayesian Modeling. Statistician 43: 169-177.