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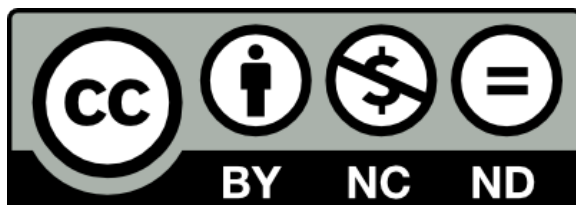
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## Size and demography pattern of the domestic dog population in Bhutan: implications for dog population management and disease control

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### Abstracts

Understanding the demography of domestic dogs is essential to plan the dog population management and rabies control program. In this study, we estimated the owned and stray dog population and the proportion of owned dogs that are free-roaming in Bhutan. For this, a cross-sectional household surveys were conducted in six districts (both urban and rural areas) and two border towns in southern Bhutan. The population estimation was done by extrapolation of the mean number of dogs per household and dogs per person, whilst mark-resight survey was conducted to estimate the proportion of owned dogs that were free-roaming. A total of 1,301 (rural: 585; urban: 716) respondents (one per household) were interviewed of which 173 households (24.4%) in urban areas owned 237 dogs whilst 238 households (40.8%) in rural areas owned 353 dogs. The mean number of dogs per dog owning household was estimated to be 1.44 (urban: 1.37 dogs; rural: 1.48 dogs) and dogs per household was estimated to be 0.45 (urban: 0.33; rural: 0.60). The dog: human ratio was 1:16.30 (0.06 dogs per person) in urban areas and 1:8.43 (0.12 dogs per person) in rural areas. The total owned dog population based on the mean number of dogs per household and dogs per person were estimated to be 65,312 and 71,245 in the country, respectively. The

male: female ratio of the owned dog was 1.31:1 in urban areas and 2.05:1 in rural areas. Majority of the dogs were local non-descript breeds in both urban (60.8%) and rural (78%) areas, and the most common source was acquisition from friends or family (44.7%). The stray dog population in Bhutan was estimated to be 48,379 (urban:22,772; rural:25,607). Of the total estimated owned dog population in the two border towns, the proportion that were found free-roaming was estimated to be 31%. The different dog population estimation methods were compared and discussed in this paper. This study generated baseline data on the demographic patterns of the owned and stray dogs in Bhutan which will be useful for planning and monitoring dog population management and rabies control program in the country.

**Key words:** Owned dog; Stray dog; Domestic dog population; dog ownership; population estimation; Bhutan

## 1. Introduction

Dogs are the first animal to be domesticated in the world; and since then have performed several useful functions to humans as companion, guide, guard, security, herding and for transport purpose depending on the socio-cultural background of the society (Coppinger and Schneider, 1995; Stafford, 2006). However, when dogs are not given proper care, they would roam the streets and become the main source of stray dogs. Large populations of stray dogs and un-supervised owned dogs can create public health threats through bites, disease transmission such as rabies and other zoonotic diseases (Robertson and Thompson, 2002; Feldman et al., 2004; WHO, 2004; Keuster et al., 2005; Zinsstag et al., 2009; Tenzin et al., 2011a; Tenzin et al., 2011b), and also pose threats to native wildlife from predation and disease transmission (Butler et al., 2003; Cleaveland et al., 2007).

Dog population control program including vaccination require data on the distribution and numbers of owned and stray dogs in the country. Thus, understanding the size and demography of dogs is a necessary first step for planning rabies prevention and control and also to plan drugs and vaccine requirement for veterinary care (Downes et al., 2013; FAO, 2014). Cross-sectional household surveys has been recommended to study the population demography of owned dogs (Downes et al., 2013). Through such surveys the proportion of households that own dogs and the mean number of dogs owned by these dog owning households can be determined to estimate the size of the owned dog population. For instance, the proportion of households that own dogs has been studied in numerous countries, including Sri Lanka (rural 57%) (Matter et al., 2000), Thailand (73.7%) (Kongkaew et al., 2004), Chile (rural 89%, towns 63% and cities 49%) (Acosta-Jamett et al., 2010), Zimbabwe (rural 62%) (Butler and Bingham, 2000) and Mexico (urban 54%) (Flores-Ibarra and Estrella-Valenzuela, 2004). These studies have also estimated the mean number of dogs per dog owning household in the range of 1.2 to 3.2. In other studies, the population of owned dogs has then been estimated by multiplying the mean number of dogs per household (obtained from household surveys) by the total number of households (obtained from national statistics) in the USA (AVMA, 2002), Zimbabwe (Butler and Bingham, 2000), Mexico (Ortega-Pacheco et al., 2007) and Italy (Slater et al., 2008).

However, no studies have been conducted to understand the demographics of owned and stray dogs in Bhutan. Therefore, the objectives of this study were to: (1) describe the pattern of dog ownership in Bhutanese households; (2) describe the demographics and estimate the size of the owned dog population; (3) estimate and compare the proportion of owned dogs that were free-roaming and conversely the proportion of free-roaming dogs that were owned; and (4) estimate the size of the stray dog population in Bhutan from the estimated population

of owned dogs. The findings from this study is expected to assist in better planning and implementation of effective population control and welfare of dogs in the country.

## **2. Materials and Methods**

### **2.1. Study area**

The Kingdom of Bhutan is situated in the eastern Himalayas, bordering People's Republic of China to the north and India to the south (Figure 1). The country is divided into 20 administrative units called Dzongkhags (districts) which are further subdivided into 205 Geogs (sub-districts). There are 127,942 households (HHs) in Bhutan of which 84,427 are rural and 43,515 urban (NSB, 2012). Bhutan has a total human population of 720,680 (rural population 466,017; urban population 254,663) (NSB, 2012). For the purpose of this study, dogs that were fed, cared-for and claimed by a household as being owned were considered as owned dogs.

### **2.2. Cross-sectional household survey**

During January to February 2012, a household survey was conducted in six Dzongkhags (Bumthang, Samtse, Samdrup Jongkhar, Trashigang, Thimphu and Tsirang – Figure 1) which covered both rural and urban areas. Households from both rural and urban settlements were selected in proportion to the population size in the relevant area/region. In the rural areas a two stage cluster sampling method was used where two villages were randomly selected from each sub-districts of the six Dzongkhags. From each selected village, five households were selected through systematic random sampling. In towns the households were chosen using a rolling sample method in which the first selected households provided information about the next available household in the area or within the building until the required number of household respondents had been interviewed in the respective study areas. The information

about the first household that owned dog was provided by the key informant—local veterinary official. One adult member of each selected household was interviewed using a face to face method to collect the information on the number of dogs owned by that particular household and their demographics.

The questionnaires consisted of two parts: a household and an individual dog characteristics. The household level questionnaire was designed to collect information about the respondents and the dog owning status of that household. For the dog survey, data were collected on the demographic characteristics of the owned dogs including their age, sex, and neuter and vaccination status. The dog owners were also asked about the source and purpose of keeping a dog as well as management aspect of their dogs. All selected households (n=1,301) were interviewed in the household survey, while only 413 households (175 urban and 238 rural) that owned dogs were included in the dog survey.

### **2.3. Estimation of the dog population**

From the household surveys the proportion of dog owning households, the mean number of dogs owned per dog owning household, the mean number of dogs for all households and the mean number of dogs per person were calculated. The size of the owned dog population was estimated by several methods which had been used in other countries (Butler and Bingham, 2000; AVMA, 2002; Slater et al., 2008; Downes et al., 2013). These involved: 1) multiplying the mean number of owned dogs per household by the number of households in the urban and rural areas, and (2) multiplying the mean number of dogs per person by the number of people in the area. We used the national household and human population data to estimate the figures (Table 1) (NSB, 2006). Using these two methods the size of the owned dog population were compared and biases for the two different methods discussed.

In Bhutan, free-roaming dog population are managed through Catch-Neuter-Vaccinate-Release (CNVR) program, wherein the dogs are captured from the street by trained dog catchers and then brought to the clinics for neutering and vaccination. The neutered dogs are given permanent identification marks by ear-notching and then released back to the place of capture. These dogs were categorized as free-roaming or stray dogs. The owned dogs are also brought to the clinic by the owners themselves for neutering and rabies vaccination and were categorized as owned dogs. This program is being implemented in all over the country, both rural and urban areas. In this study, the ratio of stray-to-owned dogs presented to the CNVR clinic from July 2011 to June 2013 was estimated (Table 1). The total number of owned dogs was then multiplied by this ratio to give an estimate of the total stray dog population. CNVR data from Thimphu Dzongkhag was not included in the estimation of the ratio of stray and owned dogs as sterilization and vaccination of the owned dogs in Thimphu city was performed by the National Animal Hospital on a weekly basis and consequently very few owned dogs were brought to the CNVR clinic. Including data of Thimphu would have resulted in an over-estimation of the mean number of stray dogs. The density of dogs in each Dzongkhag was calculated by dividing the estimated dog population (both owned and stray) by the size of the Dzongkhag (km<sup>2</sup>).

#### **2.4. Estimation of the proportion of owned dogs that were free-roaming**

A one-day free rabies vaccination campaign was organized on 28<sup>th</sup> September 2012 coinciding with World Rabies Day in two southern border town of Gelephu (Sarpang Dzongkhag) and Phuentsholing (Chukha Dzongkhag) (Figure 1). This involved setting up of 17 temporary vaccination posts (VP) at strategic locations. Each vaccinated dog was identified by placing a coloured synthetic collar around its neck. On the following day, the household surveys were conducted in the vicinity of the VP.



Households closer to the VP were initially visited and then the interview teams radiated outwards until the required number of households to be interviewed was achieved. Dog owners were asked if their dog(s) had been taken to a VP on World Rabies Day and the dogs were also checked for the presence of the identifying collars. This provided an opportunity to estimate the size of the owned dog population and their recapture probability in the area by using Lincoln Petersen's formula (Caughley, 1977). According to this formula the total population ( $N$ ) can be estimated as:

$$N = \frac{n_1 n_2}{m}$$

where  $n_1$  is the number of individuals that were captured and marked (collars attached),  $n_2$  is the number of individuals that were captured in the second capture session and  $m$  is the number of individuals in  $n_2$  that were recaptured (dogs with collars). With the same parameters, a variance estimate of  $N$  can be calculated as:

$$\text{var}(N) = \left[ \frac{(n_1 + 1)(n_2 + 1)(n_1 - m)(n_2 - m)}{(m + 1)^2(m + 2)} \right]$$

And the 95% confidence interval for  $N$  can be estimated as:

$$N \pm 1.965\sqrt{\text{var}(N)}$$

The recapture probability or the detectability rate ( $r$ ) was estimated by dividing the dogs that were captured in the second session ( $n_2$ ) by the estimated population ( $N$ ).

$$r = \frac{n_2}{N}$$

The population size of owned dogs that were found roaming was estimated by dividing the number of dogs with collars that were found (seen) roaming during the transect walk ( $m_1$ ) by the detectability rate ( $r$ ) as:

$$n = \frac{m_1}{r}$$

Thus the proportion of owned dogs that were found roaming ( $p$ ) was calculated by dividing the estimated roaming owned dog population ( $n$ ) by the total estimated owned dog population ( $N$ ).

$$p = \frac{n}{N}$$

## 2.5. Estimation of the proportion of free-roaming dogs that were owned

The mark-resight method was also undertaken in Gelephu and Phuentsholing to estimate the size of the free-roaming dog population ( $Nr$ ). A two person marking team walked through the demarcated areas following roads and settlements and sprayed vegetable coloured paints on all dogs seen without actually catching them. The transect walk was performed on the next day and the presence or absence of colour (paint) marks on all sighted dogs was recorded. The Lincoln Petersen's formula was used to estimate the free-roaming dog population in the two towns ( $Nr$ ). The proportion of free-roaming dogs that were owned was calculated by dividing the estimated number of roaming owned dogs ( $n$ ) by the estimated number of total roaming dogs ( $Nr$ ).

## 2.6. Statistical Analyses

The questionnaire data were entered into a Microsoft Access database and descriptive analyses were carried out using Microsoft Excel (Microsoft Excel 2010, Redmond, USA) and Statistical software R (R Development Core Team, 2013). ArcGIS 10.2.1 was used for area measurements and for mapping the densities of the dogs.

Descriptive analyses were performed to describe the household and demographic characteristics of the owned dogs, as well as the management practices followed by the owners. The Chi-square test of independence was used to compare the demographic

characteristics of the owned dogs between urban and rural areas. Bootstrap and Monte Carlo analyses were performed in Excel using the add-in Pop-tools version 3.2.5 (<http://www.poptools.org>) (Hood, 2010) to estimate 95% confidence intervals for the proportion of dog owning households, number of dogs owned per household, number of dogs per person or dog: human ratio and the ratio of stray to owned dogs presented to CNVR clinic. The means and 95% CI were used to estimate the dog population in the rural and urban areas with corresponding 95% CI as described previously. The beta distribution was used to estimate the proportion of owned dogs that were free-roaming and the proportion of free-roaming dogs that were owned.

### **3. Results**

#### **3.1. Household characteristics**

A total of 1,301 (rural: 585; urban: 716) respondents (one per household) were interviewed in the survey of which 173 HHs in urban areas owned 237 dogs whilst 238 HHs in rural areas owned 353 dogs. Overall, the number of dogs per dog owning household was 1.37 (95% CI 1.25 – 1.50) in urban household and 1.48 (95% CI 1.36 – 1.61) in rural household. The dog : human ratio was 1:16.30 (95% CI 1 : 13.75 – 19.38) which is equivalent to 0.06 (95% CI 0.05 – 0.07) dogs per person and 1:8.43 (95% CI 7.32 – 9.72), equivalent to 0.12 (95% CI 0.10 - 0.14) dogs per person in urban and rural areas, respectively (Table 1).

#### **3.2. Demography patterns of owned dog**

The sex ratio (male: female) of the owned dogs was 1.31: 1 and 2.05:1 in the urban and rural areas, respectively. The age of the dogs was highly skewed towards the adult age groups in

both urban (79.8%) and rural (86.3%) areas. Majority of the dogs were local non-descript breeds in both urban (60.8%) and rural (78.0%) areas. There were significant differences in the sex, breed and age of dogs between rural and urban areas ( $p < 0.05$ ). A higher proportion of dogs in rural areas were neutered (71.2%) than in urban areas (45.4%) ( $p < 0.001$ ). However, there was no significant difference in the proportion of dogs vaccinated against rabies in the urban (77.6%) and rural (78.0%) areas ( $p = 0.562$ ) (Table 2).

The most common source of dogs was acquisition from friends or family (44.7%) which were given free of cost in both urban and rural areas. The purpose of keeping a dog differed significantly between households in urban and rural areas ( $\chi^2 = 74.770$ ,  $df = 2$ ,  $p < 0.001$ ). In urban areas most dogs (62.4%) were kept as pets, whilst in rural areas they were mainly kept to guard crops, livestock and home premises (73.0%). More than 50% of the respondents indicated that their dog (s) lived either inside their house or home premises, while 39% of owners reported that their dogs were free-roaming. A significantly higher proportion of dogs in rural areas were found to be free-roaming (49.3%) than dogs in urban areas (24.3%) ( $\chi^2 = 32.360$ ,  $df = 3$ ,  $p < 0.001$ ) (Table 3). The survey also indicated that 53% of the respondents would feed stray dogs, both in urban and rural areas.

### **3.3. Estimation of owned dog population**

The total number of owned dogs in Bhutan was estimated to be 65,312 based on the mean number of dogs owned by the surveyed households. More dogs were estimated to be present in rural areas (50,909; 95% CI 44,409 – 57,579) than in urban areas (14,403; 95% CI 12,228 – 16,753) (Table 4). Using the mean number of dogs owned per person, the population of owned dogs was estimated to be 71,245 (rural: 55,456 (95% CI 48,000 – 63,844); urban: 15,789 (95% CI 13,242 – 18,336)) (Table 5). More number of owned dogs were estimated in

Thimphu, Samtse, Chhukha and Tashigang when compared to other Dzongkhags. The ratio of owned dogs-to-humans in the country was estimated to be 1:10.12.

### **3.4. Estimation of stray dog population**

The stray dog population in the country was estimated at 48,379 (urban: 22,772 (95% CI 18,667 – 27,583); rural: 25,607 (95% CI 21,433 – 30,432)) (Table 6). The ratio of stray dogs-to-humans was estimated to be 1:14.9. The overall ratio of dogs (including owned and stray) to humans was estimated to be 1:6.3.

### **3.5. Density of dogs**

The overall dog density in the country was estimated to be 2.96 dogs per km<sup>2</sup> (ranged from 0.20 to 10.12 dogs per km<sup>2</sup>). The density of owned and stray dogs was estimated to be 1.70 and 1.26 dogs per km<sup>2</sup>, respectively (Table 7). Samtse Dzongkhag had the highest owned dog density with 4.91 dogs per km<sup>2</sup>, followed by Thimphu with a density of 4.31 per km<sup>2</sup> and Tsirang (3.73 dogs per km<sup>2</sup>). Thimphu Dzongkhag had the highest stray dog density with 5.81 dogs per km<sup>2</sup>, followed by Samtse with 3.12 dogs per km<sup>2</sup> and Chhukha with 2.88 dogs per km<sup>2</sup>. Gasa had the lowest density of both owned (0.13 dogs per km<sup>2</sup>) and stray dogs (0.07 dogs per km<sup>2</sup>) (Figure 1 and Table 7). However, considering only the proportion of human settlement and arable land, the overall dog density in the country was estimated to be 42 dogs per km<sup>2</sup> (see discussion section).

### **3.6. Estimation of owned and free-roaming dogs in border towns**

The number of owned and free-roaming dogs in Gelephu and Phuentsholing towns was estimated using the Lincoln-Petersen index (Table 8). Using the recapture probability, and

based on the population estimate of free-roaming and owned dogs and the number of owned dogs that were roaming in the two towns, the proportion of owned dogs that were found roaming was estimated to be 22.6% (95% CI 18.3–27.3) in Phuentsholing and 39.3% (95% CI 33.4 – 45.4) in Gelephu. Of the total estimated free-roaming dog population, 15.6% (95% CI 12.6 – 19.4) and 16.7% (95% CI 13.8 – 19.9) were estimated to be owned dogs in Phuentsholing and Gelephu, respectively.

#### **4. Discussion**

Understanding the population size and demography of the domestic dog population is useful for planning disease control, as well as for evaluating and monitoring of effectiveness of dog population and rabies control programs. This study provides information on the size and demography of the owned and stray dog population in Bhutan. The proportion of households owning dogs in urban areas of Bhutan (24.4%) was much lower than that reported in other studies in Chile (63%), Mexico (54%) and Kenya (53%) (Kitala et al., 2001; Flores-Ibarra and Estrella-Valenzuela, 2004; Ortega-Pacheco et al., 2007; Acosta-Jamett et al., 2010). Similarly, the proportion of households owning dogs in rural area (40.8%) was also lower than that reported in Chile (89%), Kenya (53 – 81%), Sri Lanka (57%) and Zimbabwe (62%) (Butler and Bingham, 2000; Kitala et al., 2001; Acosta-Jamett et al., 2010). The low number of dog ownership in Bhutan could be due to socio-cultural practices such as strong family culture in Bhutanese society in contrast to other developed countries where people keep pets for the companionship. Higher numbers of dogs in households located in rural areas have been reported in other developing countries such as Chile, Kenya, Mexico and Sri Lanka where dogs are predominantly used for protection/guarding livestock, people or both (Matter et al., 2000; Kitala et al., 2001; Ortega-Pacheco et al., 2007; Acosta-Jamett et al., 2010).

A significantly higher proportion of dogs in rural areas were neutered than in urban areas. This could be due to an effective awareness program by livestock extension agents based in the rural areas. The livestock extension agents are responsible for providing veterinary services in the communities as well as dog population and rabies control program. Nevertheless, high rabies vaccination coverage was achieved in both urban and rural areas as a result of frequent CNVR campaigns conducted over the years. For instance, the CNVR team would make repeated visits to the previous campaign areas to increase the coverage. In some areas, the CNVR campaign was conducted for the fourth time, thus had high vaccination coverage.

This study showed that the main source of dogs were acquisition from friends or family free of cost, which is similar to that found in other countries (Kitala et al., 2001; Flores-Ibarra and Estrella-Valenzuela, 2004; Kongkaew et al., 2004; Ortega-Pacheco et al., 2007; Suzuki et al., 2008; Acosta-Jamett et al., 2010). It is also encouraging to note that a high proportion of dogs were adopted from the street in both rural (28.1%) and urban (25.6%) areas. Therefore, a planned adoption program for street dogs may further increase this rate of adoption, as well as help to reduce the size of the stray dog population in the country (ICAMC, 2007; OIE, 2010). Animal welfare organizations, in collaboration with the Department of Livestock, should initiate an adoption program for street dogs which should include the neutering, health check-up, treating for parasites and grooming of the stray dogs to encourage the adoption of these dogs by the general community. The main reason for keeping dog(s) in rural areas were for guarding crops, home premises or livestock comparing to companionship in urban areas, thus the dogs in rural areas are more likely to roam. Similar studies have reported comparable findings in other countries (Butler and Bingham, 2000; Kitala et al., 2001; Flores-Ibarra and Estrella-Valenzuela, 2004; Kongkaew et al., 2004; Suzuki et al., 2008; Acosta-Jamett et al., 2010).

The number of owned dogs estimated from the mean number of dogs per household and the mean number of dogs per person was 65,513 and 71,245, respectively. In this study the higher estimate of owned dogs using total human population may have been biased by including temporary residents in the human population count, thus estimating the dog population using dogs per household data may be more reliable. The official record of the owned dog population in Bhutan in 2014 was 24,827 (DOL, 2015) which is much lower than that estimated in the current study. The official recorded dog population figure only included owned dogs from the rural areas and do not include the figure from the municipality or the urban areas. Thus the officially recorded dog population is an underestimate and the population estimates of this study may be more realistic. Similarly, the ratio of dog-to-human based on the official data is 1:30 which is much higher than the estimate of 1:10 in the current study. The dog-to-human ratio of 1:10 is almost similar to the Asian countries estimates of 1:9.5 (Knobel et al., 2005).

The number of stray dogs in Bhutan, estimated by using the ratio of stray to owned dogs, in this study was 48,389. The ratio of stray to owned dogs was estimated from the CNVR data recorded from June 2011 to July 2013. Although this estimate may be biased, as only those owned dogs that were voluntarily brought to the CNVR clinic were counted. However, this bias may have been reduced as CNVR teams were not able to capture all stray dogs from the streets. Therefore, the reliability of the stray dog population estimate using this method is highly dependent on the number of owned dogs estimated in this study (Table 4). The stray dog population estimated by this method should be further validated by comparing with other population estimates using different techniques in selected Dzongkhags.

The overall dog density in Bhutan was estimated to be 2.96 dogs per km<sup>2</sup>, with a range from 0.20 in Gasa to 10.12 dogs in Thimphu. However, the population density estimated in this



study incorporated all areas of the country, including the forests, snow-capped mountain and water bodies which would have underestimated the density. In contrast, the dog density in the inhabited areas of Bhutan would be expected to be higher. For instance, with approximately 7% of the total areas of Bhutan being arable with human settlement, the overall dog density is estimated to be 42 dogs per km<sup>2</sup>. Therefore, the dog population management and rabies control program should be focussed in high dog density areas.

Population survey in the two border towns showed that a higher proportions of owned dogs were found roaming in Gelephu (39.3%) than in Phuentsholing (22.6%). This is likely because Gelephu is larger and more widespread area with more single storeyed buildings, as opposed to Phuentsholing where most of the people live in rented apartments in multi-storeyed buildings and hence their dogs are more likely to be confined within house most of the time. This finding is also consistent with the household survey where 38.6% (urban 24.3%; rural 49.3%) of the respondents reported their dogs were not confined at all (Table 1). This study also shows that 15.6% and 16.7% of the total free-roaming dogs were owned in Phuentsholing and Gelephu, respectively. The high proportion of owned dogs that were roaming in the streets highlights the need for good legislation on responsible dog ownership, as well as strict implementation of the law to avoid the roaming of owned dogs (WHO and WSPA, 1990; ICAMC, 2007; OIE, 2010). Although there are regulations on responsible dog ownership in Livestock Rules and Regulation of Bhutan 2008, its actual implementation in the field is poor. Therefore, it is important to educate the dog owners as well as provide adequate resources to implement the regulations.

Although, estimating the population of owned and stray dogs by extrapolating the mean number of dogs per household or the mean number of dogs per person is simple, selection bias may have been introduced during door-to-door surveys as logistical problems makes it

difficult to access some of the households. In addition, there is also possible bias while marking the dogs with paints as only the docile dogs would be marked and simultaneously the same docile dogs may be resighted later; thus underestimating the population size. Therefore, other reliable marking method such as photographic recapture method may be used to reduce the bias since there is no physical disturbance to the dogs (Punjabi et al., 2012; Belo et al., 2015).. Nevertheless, this study generated baseline data on the population of owned and stray dogs in Bhutan which will be useful for monitoring and evaluating the effectiveness of dog population and rabies control programs.

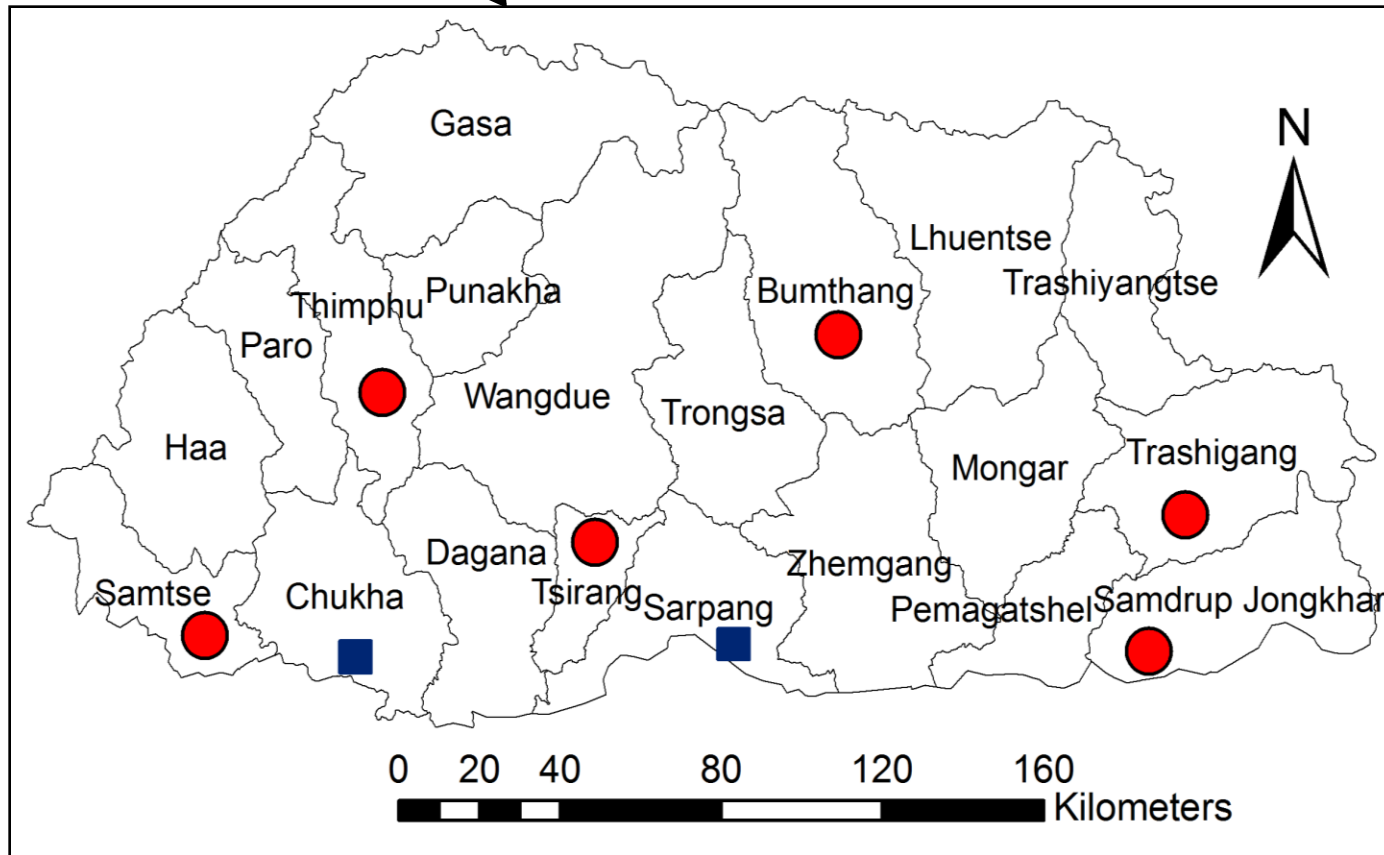
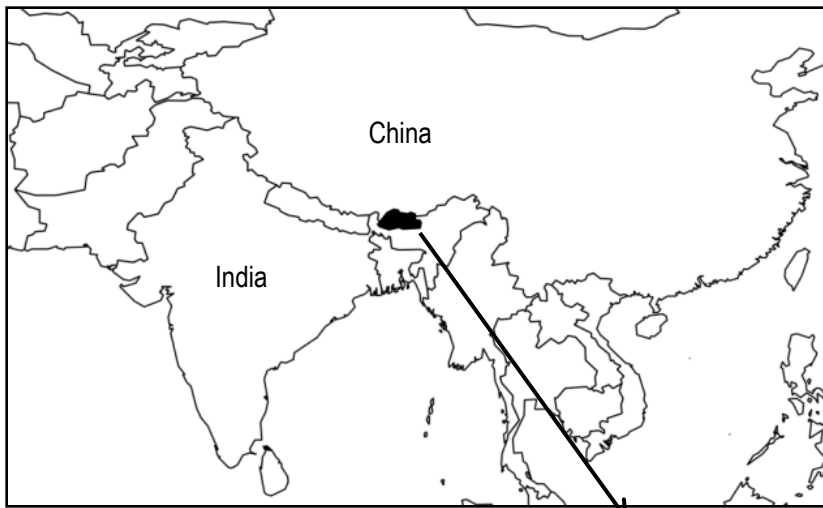
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**Figure 1: Map of Bhutan showing the study areas (red circle indicate the district selected for study and the blue square indicate the dog population survey area in two border towns of south Bhutan).**



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**Table 1: Details of dog ownership in rural and urban areas of Bhutan**

	Urban	Rural	Overall
Variables	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)
Average number of people per household <sup>a</sup>	4.56 (4.41 - 4.71)	5.14 (4.93 - 5.35)	4.83 (4.70 - 4.96)
Percentage of households owning dogs	24.18 (21.09 - 34.05)	40.66 (36.75 - 44.62)	31.59 (29.05 - 34.05)
Average number of dogs owned per household <sup>b</sup>	0.33 (0.28 - 0.39)	0.60 (0.53 - 0.68)	0.45 (0.41 - 0.50)
Average number of dogs owned per dog owning household <sup>c</sup>	1.37 (1.25 - 1.50)	1.48 (1.37 - 1.61)	1.44 (1.35 - 1.53)
Human : dog ratio <sup>d</sup>	16.30 (13.75 - 19.38)	8.43 (7.32 - 9.72)	11.12 (9.96 - 12.40)
Dogs per person	0.06 (0.05 - 0.07)	0.12 (0.10 - 0.14)	0.09 (0.08 - .010)
Stray dogs per owned dogs <sup>e</sup>	1.58 (1.30 - 1.92)	0.503 (0.42 - 0.60)	0.780 (0.70 - 0.90)

The estimates of the above parameters (<sup>a, b, c, d</sup>) were obtained from the cross-sectional household surveys of 1,301 respondents (716 urban and 585 rural). The estimate of stray dogs per owned dogs <sup>e</sup> was acquired from the CNVR records of dogs (stray and owned) presented to CNVR clinic from 01 July 2011 to 30 June 2013. 95% CI were estimated by using bootstrap and Monte Carlo analysis with 10,000 iterations.

**Table 2: Demographic characteristics of owned dogs obtained from household surveys in urban and rural areas of Bhutan (n = 590, Urban = 237, Rural = 353)**

<b>Variables</b>	<b>Overall</b>	<b>Urban</b>	<b>Rural</b>			
	<b>n (%)</b>	<b>n (%)</b>	<b>n (%)</b>	$\chi^2$	<b>Df</b>	<b>p-value</b>
<b>Sex</b>						
Female	216 (37.0)	102 (43.2)	114 (32.8)	6.604	1	0.010
Male	368 (63.0)	134 (56.8)	234 (67.2)			
Missing data	6					
<b>Age</b>						
Puppy (<6months)	46 (7.9)	26 (11.2)	20 (5.7)	6.059	2	0.048
Juvenile (6 to 12 months)	49 (8.4)	21 (9.0)	28 (8.0)			
Adult >12 months	487 (83.7)	186 (79.8)	301 (86.3)			
Missing data	8					
<b>Breed</b>						
Local (non descript)	374 (71.1)	129 (60.8)	245 (78.0)	18.172	1	<0.001
Pure bred*	152 (28.9)	83 (39.2)	69 (22.0)			
Missing data	64					
<b>Neuter status</b>						
Intact	205 (39.0)	113 (54.5)	92 (28.8)	35.000	1	<0.001
Neutered	321 (61.0)	94 (45.4)	227 (71.2)			
Missing data	64					
<b>Rabies vaccination</b>						
Yes	453 (77.8)	184 (77.6)	269 (78.0)	0.337	1	0.562
No	70 (12.0)	31 (13.1)	39 (11.3)			
Not sure	59 (10.2)	22 (9.3)	37 (10.7)			
Missing data	8					
*Includes Lhasa Apso, Tibetan Mastiff, Alsatian, Pomeranian, Dalmatian						



**Table 3: The management practices of dogs adopted by households in urban (n = 175) and rural areas (n = 238) of Bhutan**

<b>Variables</b>	<b>Overall</b>	<b>Urban</b>	<b>Rural</b>			
	<b>n (%)</b>	<b>n (%)</b>	<b>n (%)</b>	$\chi^2$	<b>Df</b>	<b>p-value</b>
<b>Source</b>						
Offspring from owned dog	61 (15.1)	19 (11.1)	42 (18.2)	13.325	4	0.009
Given by friend/ family	180 (44.7)	83 (48.2)	97 (42.0)			
Adopted from street*	109 (27.0)	44 (25.6)	65 (28.1)			
Purchased	35 (8.7)	22 (12.8)	13 (5.6)			
Other source	18 (4.5)	4 (2.3)	14 (6.1)			
Missing data	10					
<b>Purpose</b>						
Pet	154 (38.0)	106 (62.4)	48 (20.4)	74.770	2	<0.001
Guard	235 (58.0)	62 (36.5)	173 (73.6)			
Other purpose	16 (4.0)	2 (1.2)	14 (6.0)			
Missing data	8					
<b>Who feeds the dog?</b>						
Household members	394 (96.1)	165 (95.4)	229 (96.6)	0.416	1	0.519
Other person	16 (3.9)	8 (4.6)	8 (3.4)			
Missing data	3					
<b>What shelter do you provide for your dog?</b>						
Keep in dog house	40 (9.9)	17 (9.8)	23 (10.0)	32.360	3	<0.001
Live inside house with family	133 (32.9)	66 (38.2)	67 (29.0)			
Live within home premise	75 (18.6)	48 (27.7)	27 (11.7)			
Free-roaming	156 (38.6)	42 (24.3)	114 (49.3)			
Missing data	9					
<b>How often would members of your household feed a stray dog?</b>						
Daily	68 (17.2)	26 (15.2)	42 (18.6)	10.290	2	0.006
Occasionally	141 (35.6)	76 (44.4)	65 (29.0)			
Never	187 (47.2)	69 (40.4)	118 (52.4)			
Missing data	17					
*Picked up the stray dogs from the street and they looked after it.						

**Table 4: Estimated number of owned dogs based on the mean number of dogs owned by each household in different Dzongkhags of Bhutan**

Dzongkhag	Number of Households			Estimated owned dog population (95% CI)		
	Urban	Rural	Total	Urban <sup>a</sup>	Rural	Total
Bumthang	697	2130	2827	231 (196 - 268)	1284 (1120 - 1453)	1515
Chhukha	6961	5831	12792	2304 (1956 - 2680)	3516 (3067 - 3977)	5820
Dagana	626	3848	4474	207 (176 - 241)	2320 (2024 - 2624)	2528
Gasa	98	590	688	32 (28 - 38)	356 (310 - 402)	388
Haa	507	1263	1770	168 (142 - 195)	762 (664 - 861)	929
Lhuentse	275	2765	3040	91 (77 - 106)	1667 (1454 - 1886)	1758
Monggar	1480	6098	7578	490 (416 - 570)	3677 (3208 - 4159)	4167
Paro	795	6295	7090	263 (223 - 306)	3796 (3311 - 4293)	4059
Pemagatshel	579	4102	4681	192 (163 - 223)	2474 (2158 - 2798)	2665
Punakha	951	3568	4519	315 (267 - 366)	2152 (1877 - 2433)	2466
Samdrup Jongkhar	2001	5197	7198	662 (562 - 770)	3134 (2734 - 3544)	3796
Samtse	2375	9324	11699	786 (667 - 914)	5622 (4904 - 6359)	6408
Sarpang	2713	5012	7725	898 (762 - 1045)	3022 (2636 - 3418)	3920
Thimphu	17859	2692	20551	5911 (5018 - 6876)	1623 (1416 - 1836)	7534
Trashigang	1242	8933	10175	411 (349 - 478)	5387 (4699 - 6092)	5798
Trashiyangtse	560	3194	3754	185 (157 - 216)	1926 (1680 - 2178)	2111
Trongsa	575	2235	2810	190 (162 - 221)	1348 (1176 - 1524)	1538
Tsirang	372	3748	4120	123 (105 - 143)	2260 (1971 - 2556)	2383
Wangdue	2187	4779	6966	724 (615 - 842)	2882 (2514 - 3259)	3606
Zhemgang	662	2823	3485	219 (186 - 255)	1702 (1485 - 1925)	1921
Total	43,515	84,427	127,942	14,403 (12,228 - 16,753)	50,909 (44,409 - 57,579)	65,312

<sup>a</sup> Estimated owned dog population for the urban areas calculated by multiplying the mean number of dogs per household (0.331) from the survey (Table 1) by the number of households in the urban area from national statistics. For example, Bumthang urban owned dog population estimate =  $0.331 \times 697 = 231$  (lower 95% CI =  $0.281 \times 697 = 196$  & upper 95% CI =  $0.385 \times 697 = 268$ ).

**Table 5: Estimation of the number of owned dogs based on the number of dogs per person in each Dzongkhag (urban and rural) of Bhutan**

Dzongkhag	Human Population (2012)			Estimated owned dog population (95% CI)		
	Urban	Rural	Total	Urban	Rural *	Total
Bumthang	5442	12684	18126	337 (283 - 392)	1509 (1306 - 1738)	1847
Chhukha	40052	44151	84203	2483 (2083 - 2884)	5254 (4548 - 6049)	7737
Dagana	5150	20910	26060	319 (268 - 371)	2488 (2154 - 2865)	2808
Gasa	632	2890	3522	39 (33 - 46)	344 (298 - 396)	383
Haa	2595	10367	12962	161 (135 - 186)	1234 (1068 - 1420)	1395
Lhuentse	2160	14820	16980	134 (112 - 156)	1764 (1526 - 2030)	1897
Monggar	10265	31852	42117	636 (534 - 739)	3790 (3281 - 4364)	4427
Paro	6992	34182	41174	433 (364 - 503)	4068 (3521 - 4683)	4501
Pemagatshel	4151	20211	24362	257 (216 - 299)	2405 (2082 - 2769)	2662
Punakha	4001	22540	26541	248 (208 - 288)	2682 (2322 - 3088)	2930
Samdrup Jongkhar	13215	25493	38708	819 (687 - 951)	3034 (2626 - 3493)	3853
Samtse	15498	52027	67525	961 (806 - 1116)	6191 (5359 - 7128)	7152
Sarpang	16027	27015	43042	994 (833 - 1154)	3215 (2783 - 3701)	4208
Thimphu	93270	15663	108933	5783 (4850 - 6715)	1864 (1613 - 2146)	7647
Trashigang	9353	44683	54036	580 (486 - 673)	5317 (4602 - 6122)	5897
Trashiyangtse	4276	15675	19951	265 (222 - 308)	1865 (1615 - 2147)	2130

Trongsa	3902	11338	15240	242 (203 - 281)	1349 (1168 - 1553)	1591
Tsirang	2793	18101	20894	173 (145 - 201)	2154 (1864 - 2480)	2327
Wangdue	10456	25176	35632	648 (544 - 753)	2996 (2593 - 3449)	3644
Zhemgang	4435	16237	20672	275 (231 - 319)	1932 (1672 - 2224)	2207
Total	254,663	466,017	720,680	15,789 (13,242 - 18,336)	55,456 (48,000 - 63,844)	71,245

\* Estimated owned dog population for the rural areas calculated by multiplying the mean number of dogs per person (0.119) from the survey (Table 1) by the human population in the urban area from national statistics.

**Table 6: Estimation of the number of stray dogs in different Dzongkhags in Bhutan (urban and rural)**

Dzongkhag	Owned dog population			Estimated stray dog population* (95% CI)		
	Urban	Rural	Total	Urban	Rural	Total
Bumthang	231	1284	1515	365 (299 - 442)	646 (541 - 765)	1011
Chhukha	2304	3516	5820	3643 (2986 - 4412)	1769 (1480 - 2096)	5411
Dagana	207	2320	2528	328 (269 - 397)	1167 (977 - 1383)	1495
Gasa	32	356	388	51 (42 - 62)	179 (150 - 212)	230
Haa	168	762	929	265 (217 - 321)	383 (321 - 454)	648
Lhuentse	91	1667	1758	144 (118 - 174)	839 (702 - 994)	983
Monggar	490	3677	4167	775 (635 - 938)	1850 (1548 - 2192)	2624
Paro	263	3796	4059	416 (341 - 504)	1909 (1598 - 2262)	2325
Pemagatshel	192	2474	2665	303 (248 - 367)	1244 (1041 - 1474)	1547
Punakha	315	2152	2466	498 (408 - 603)	1082 (906 - 1282)	1580
Samdrup Jongkhar	662	3134	3796	1047 (858 - 1268)	1576 (1319 - 1868)	2623
Samtse	786	5622	6408	1243 (1019 - 1505)	2828 (2367 - 3351)	4071
Sarpang	898	3022	3920	1420 (1164 - 1720)	1520 (1272 - 1801)	2940
Thimphu	5911	1623	7535	9346 (7661 - 11320)	817 (683 - 967)	10162
Trashigang	411	5387	5798	650 (533 - 787)	2709 (2268 - 3210)	3359
Trashiyangtse	185	1926	2111	293 (240 - 355)	969 (811 - 1148)	1262
Trongsa	190	1348	1538	301 (247 - 364)	678 (567 - 803)	979
Tsirang	123	2260	2383	195 (160 - 236)	1137 (951 - 1347)	1331
Wangdue	724	2882	3606	1144 (938 - 1386)	1450 (1213 - 1718)	2594
Zhemgang	219	1702	1921	346 (284 - 420)	856 (717 - 1015)	1203
<b>Total</b>	<b>14,403</b>	<b>50,909</b>	<b>65,313</b>	<b>22,772 (18,667 - 27,583)</b>	<b>25,607 (21,433 - 30,342)</b>	<b>48,379</b>

\* Estimated stray dog population: This is calculated by multiplying the estimated owned dog population (Table 4) by the ratio of stray to owned dogs presented to the CNVR clinic from July 2011 to June 2013 (Table 1).

**Table 7: Dzongkhag wise density of owned and stray dogs in Bhutan**

District	Total area (Sq. km)	Dog population			Density of dogs per sq. km.		
		Owned	Stray	Total	Owned	Stray	Total
Bumthang	2668	1515	1011	2526	0.57	0.38	0.95
Chhukha	1879	5820	5411	11232	3.10	2.88	5.98
Dagana	1723	2528	1495	4022	1.47	0.87	2.33
Gasa	3073	388	230	618	0.13	0.07	0.20
Haa	1865	929	648	1578	0.50	0.35	0.85
Lhuentse	2809	1758	983	2741	0.63	0.35	0.98
Monggar	1945	4167	2624	6791	2.14	1.35	3.49
Paro	1251	4059	2325	6384	3.24	1.86	5.10
Pemagatshel	1023	2665	1547	4212	2.61	1.51	4.12
Punakha	1110	2466	1580	4046	2.22	1.42	3.65
Samdrup Jongkhar	1878	3796	2623	6420	2.02	1.40	3.42
Samtse	1305	6408	4071	10479	4.91	3.12	8.03
Sarpang	1666	3920	2940	6860	2.35	1.76	4.12
Thimphu	1749	7534	10162	17696	4.31	5.81	10.12
Trashigang	2204	5798	3359	9157	2.63	1.52	4.15
Trashiyangtse	1449	2111	1262	3373	1.46	0.87	2.33
Trongsa	1822	1538	979	2517	0.84	0.54	1.38
Tsirang	639	2383	1331	3715	3.73	2.08	5.81
Wangdue	3920	3606	2594	6200	0.92	0.66	1.58
Zhemgang	2416	1921	1203	3124	0.80	0.50	1.29
Total	38394	65,312	48,379	113,692	1.70	1.26	2.96

Note: Considering approximately 7% of the total area of Bhutan is arable with human settlement, the overall dog density is estimated to be 42 dogs per km<sup>2</sup>

**Table 8: Estimates of the number of owned and free-roaming dogs in Gelephu and Phuentsholing town using the Lincoln-Petersen index, estimate of roaming owned dog population size and the proportion of owned dogs that are roaming and proportion of roaming dogs that are owned.**

Area	No. marked dogs ( $n_1$ )	Total dogs counted ( $n_2$ )	Resight marked dogs ( $m$ )	Population estimate N (95% CI)	Recapture rate ( $r$ )	Marked owned dog roaming ( $m_1$ )	Estimated owned dog roaming ( $n$ )	Proportion owned dog roaming ( $p$ ) - (95% CI)
<b><i>Owned dogs</i></b>								
Phuentsholing	148	44	18	362 (271 - 546)	0.12 (0.09 - 0.16)	10	82	22.6 (18.4 – 27.3) <sup>a</sup>
Gelephu	171	71	45	270 (234 - 320)	0.26 (0.21 - 0.32)	28	106	39.3 (3.34 – 4.54) <sup>a</sup>
<b><i>Stray dogs</i></b>								
Phuentsholing	267	244	124	525 (481 - 579)	0.46 (0.42 - 0.51)	10	82	15.6 (12.6 – 19.0) <sup>b</sup>
Gelephu	323	303	160	612 (568 - 663)	0.49 (0.45 - 0.54)	28	106	16.7 (13.8 – 19.9) <sup>b</sup>

$n_1$  = number of marked dogs (collar for the owned and colour paints for the free-roaming dogs)

$n_2$  = total number of dogs counted during the household visits for the owned dogs and transect walk for the free-roaming dogs.

$m$  = Number of marked dogs resighted during the household visits and during the transect walk for owned and free-roaming dogs.

$N$  = Total population size estimated using Lincoln-Petersen index ( $n_1 n_2/m$ )

$r$  = recapture probability  $n_2/N$ .

$m_1$  = Number of owned dogs with the mark (collar) that were found roaming during the transect walk.

$n$  = Estimated owned dog population that were found roaming ( $m_1/r$ ).

$p$  = Proportion of owned dogs that were found roaming<sup>a</sup> and proportion of roaming dogs that are owned<sup>b</sup>.