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Owned dog ecology and demography in Villa de Tezontepec, Hidalgo, Mexico

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ABSTRACT

Dog overpopulation in developing countries has negative implications for the health and safety of people, including the transmission of zoonotic diseases, physical attacks and intimidation to humans and animals, as well as impacts on canine welfare. Understanding the ecology and demographic characteristics of a dog population can help in the planning and monitoring of canine population control programs. Little data exist regarding demography and dynamics of domestic dog populations in semi-urban areas in Mexico. A cross-sectional study was carried out between October 21 and November 7, 2015, to characterize the dog ecology and demography in Villa de Tezontepec, Hidalgo, Mexico. A face-to-face survey was used to collect data from randomly selected households in four contiguous communities using stratified two-stage cluster sampling. Within each household, adults answered questions related to their dogs and their experiences with dog bites and aggression. A total of 328 households were interviewed, representing a participation rate of 90.9% (328/361) and 1,450 people. Approximately 65.2% of the households owned one or more dogs, with a mean of 1.3 (SD = 1.5) and 2.0 (SD = 1.5) owned dogs in all participant households and dog-owning households, respectively. The human: owned dog ratio for all participant households was 3.4:1 (1450/428), and for the dog-owning households was 2.3:1 (984/428). The owned dog male: female ratio was 1.4:1 (249/179). Approximately 74.4% (95.0% CI = 69.8% – 78.7%) of the owned dogs were older than one year (mean age: 2.9 years; SD = 2.5). The mean age of owned female dogs at first litter was 1.9 years (SD = 1.2) and the mean litter size was 4.2 puppies (SD = 2.1). Approximately 36.9% (95.0% CI = 31.8% – 46.4%) of the females were spayed, and 14.1% (95.0% CI = 10.7% – 19.7%) of the males were neutered. Only 44.9% (95.0% CI = 40.1% – 49.7%) were always confined when unsupervised. Approximately 84.4% (95.0% CI = 80.6% – 87.7%) were reported to have been vaccinated against rabies in 2015. The knowledge of owned dog demography and ecology provided by this study can inform local government planning of dog population control interventions, and could serve as a baseline for the development of agent-based models to evaluate the effects of different dog population control strategies on dog demography.

1. Introduction

Inadequate control of dog populations can have grave consequences for public health and the welfare of dogs (Stafford, 2007). Dogs can transmit several important zoonotic diseases to humans, including rabies, leishmaniasis and echinococcosis (Garde et al., 2013). Dogs also remain the main reservoir and vector of rabies to humans worldwide (Wunner and Briggs, 2010; Chomel and Arzt, 2013). It is estimated that canine rabies is responsible for

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55,000 human deaths worldwide every year (Knobel et al., 2005). In Mexico, there have been no reported cases of human rabies transmitted by domestic dogs since 2006 (Secretaria de Salud, 2015c); however, 12 cases of canine rabies were confirmed during 2012 (Dyer et al., 2014), therefore the threat for rabies transmission to humans remains. Even in the absence of disease, dog bites are a major public health problem in Mexico, with 116,832 reported cases of dog-to-human bites in 2007 (Arroyo, 2009). Dogs can also cause other problems including physical aggression and intimidation towards humans, noise and fouling, livestock predation, wildlife endangerment, and road traffic accidents (ICAM, 2008; Hiby, 2013; Pulczer et al., 2013).

It is estimated that the global abundance of domestic dogs is 700 million and 75.0% of these may be free-roaming dogs (Hughes and Macdonald, 2013). Government efforts to reduce dog population density in developing countries tend to focus on culling (Beran and Frith 1988; Windiyaningsih et al., 2004) and sterilization (Reece and Chawla 2006; WHO, 2013). New approaches to non-surgical sterilization, such as chemical castration in males, have also been tested and continue to be investigated (Jana and Kumar, 2007; Levy et al., 2008; Oliveira et al., 2012).

An understanding of dog demography, ecology and dog ownership practices and behaviors can help inform the planning, implementation and monitoring of appropriate dog population management and zoonotic disease control programs (WHO, 1987; WHO/WSPA, 1990; Perry, 1993; Patronek and Rowan, 1995; Acosta-Jamett et al., 2010; Morters et al., 2014) and estimates of dog abundance can help project the cost and resources needed for population control interventions (Wandeler, 1985). This is especially important when resources are limited. Data collected in dog demography and ecology studies can also serve as a baseline against which comparisons can be made after an intervention has been implemented to measure its effectiveness (ICAM, 2015). Information on dog population dynamics such as birth and mortality rates and demographic data such as age and sex distributions can also be used to inform mathematical models that can be used to simulate population growth and control activities and help quantify the expected effects of interventions (Coleman, 1997).

Limited data currently exist regarding domestic dog population demography and dynamics in semi-urban areas in Mexico. There have been only a few studies on dog demography in urban and rural areas; these include Mexico City, (Romero-Lopez et al., 2008), Mexicali, Baja California (Flores-Ibarra and Estrella-Valenzuela, 2004), Merida, Yucatan (Ortega-Pacheco et al., 2007) Atlixco, Puebla (Fishbein et al., 1992) and Miacatlan, Morelos (Orihuela and Solano, 1995). To the authors' knowledge, there have not been any published studies focused on semi-urban communities (i.e. areas with 10,000 to less than 15,000 residents) in Mexico (INAP, 2009). Currently there are 262 semi-urban municipalities in Mexico (INFDM, 2010a) which are typically characterized by a lack of infrastructure for the provision of public services (INAP, 2009) including animal control services. Therefore, it is important to understand dog ecology and demography in semi-urban communities in Mexico because this knowledge will inform strategic investment of resources and use of limited infrastructure for more effective dog population control programs.

Villa de Tezontepec is one of the 84 municipalities in the state of Hidalgo, located in central-eastern Mexico. The municipality covers an area of 133.6 km^2 and has an estimated human population of 11,746 based on the 2010 National Institute of Statistics and Geography (INEGI) census (INEGI, 2010). The municipal government of Villa de Tezontepec estimates that every weekend over 2000 people come to eat Baracoa, the regional dish (sheep slow-cooked in a hole dug in the ground covered with Agave leaves); these weekly events may increase the contact between people and the free-roaming dog population of this community, raising the potential risk of dog bites and transmission of zoonotic diseases. The municipal government of Villa de Tezontepec consulted with the Ministry of Health regarding their dog overpopulation concerns. The present study was conducted to better understand the local situation. The specific objective of this study was to characterize the ecology and demography of the owned dog population in a Villa de Tezontepec, Hidalgo, Mexico.

2. Materials and methods

A cross-sectional study was conducted in Villa de Tezontepec, Hidalgo, Mexico, between October 21 and November 7, 2015. The University of Guelph Research Ethics Board approved the involvement of human participants in this study (Protocol #15JL005).

2.1. Questionnaire survey design

A household questionnaire was designed and modified from Pulczer et al. (2013) and the Guide to Monitoring and Evaluating Dog Population Management Interventions (ICAM, 2015 pp. 115–120). Part A of the questionnaire focused on household information, including questions about the age and gender of household members, number of dogs owned per household, number of dogs that died or left the household in past 12 months, reasons for dog ownership status, and plans to acquire a dog. Part B of the questionnaire focused on individual owned dog information and included questions about each dog's age and sex, sterilization (i.e. spay or neuter), vaccination and confinement statuses, sources of the dog, reasons for owning the dog, female dog reproductive history, and whether a dog had ever bitten a person or another dog. An "owned" dog was defined as a dog for which a person, during the household questionnaire administration, stated that they owned and could answer questions about the dog's sex and age, as well as provide knowledge of the dog's life. No formal pre-testing of the questionnaire was conducted for the present study; however pre-testing was done for questionnaire that was used in Guatemala (Pulczer et al., 2013) and served as the basis of the questionnaire used here. The questionnaire was written in English and then translated into Spanish by the principal author, who is a native Spanish speaker; local government collaborators also reviewed the Spanish translation of the questionnaire prior its use. A copy of the questionnaire in English and Spanish is included in the Supplementary materials.

2.2. Study region and neighborhood selection

The municipality of Villa de Tezontepec lies between latitudes 19° 53′ north latitude and 98° 49′ west longitude, at an altitude of 2.3 m above the sea (INFDM, 2010b). Tezontepec, the capital and center of day-to-day activities in the municipality of Villa de Tezontepec, and three contiguous neighborhoods (Colonia Morelos, Colonia Benito Juarez, and Chamberluco) were selected as the study region, as they were located next to the capital. Other neighborhoods were excluded from the study region because they were either relatively far from the capital (range: 1.9–8.6 km) or because the number of households was relatively small (range: 5–288 households).

2.3. Household selection

A sample size of 328 households was calculated for this study, based on an expected prevalence of 50.0% (households owning at least one dog), 5.0% allowable error and 95.0% confidence (Flores-Ibarra and Estrella-Valenzuela, 2004; Ortega-Pacheco et al., 2007; Romero-Lopez et al., 2008). Anticipating 10.0% refusal to participate, this sample size was increased to 361 households out of

Table 1
Number of people categorized by age, median number of people per household, median age of people per household, and male to female ratio in 328 households in 4 neighborhoods surveyed in Villa de Tezontepec, Hidalgo, Mexico, 2015[a].

Neighborhood	Children < 5	Children 5–9	Children 10–17	Adults 18–50	Adults ≥ 50	Median # of people per household	Median age	Male to Female Ratio
Tezontepec	41 (5.2)	58 (7.3)	108(13.7)	415 (52.5)	168 (21.3)	4.0	36	0.9:1.0
Morelos	17 (8.4)	13 (6.4)	41 (20.3)	99 (49.0)	32 (15.8)	4.0	32	1.0:1.0
Benito Juarez	27 (7.2)	40 (10.7)	60 (16.1)	183 (49.1)	63 (16.9)	5.0	27	1.1:1.0
Chamberluco	1 (3.6)	4 (14.3)	3 (10.7)	8 (28.6)	12 (42.9)	3.5	48	1.2:1.0
TOTAL	86 (6.2)	115 (8.3)	212(15.2)	705 (50.6)	275 (19.7)	4.0	32	1.0:1.0

[a] The table does not include missing age data for 57 people.

the total 2249 occupied households reported in the 2010 national census (INEGI, 2010), the most recent census available.

Multistage sampling was used, where the primary sampling unit was blocks within neighborhoods, and the secondary sampling unit was households within blocks.

The probability proportional to size sampling (PPS) technique described by Inner City Fund (ICF) International (2012) was used at the first stage to randomly select a sample of blocks within each neighborhood. Blocks were defined as "a geographical space of polygonal shape and variable surface, comprised of one or more households, shops, or vacant lots" (INEGI, 2007).

The required number of blocks was calculated by dividing the required sample size (n = 361 households) by a fixed number of households to be surveyed per block, agreed to be 8 households, based on study logistics and the perceived maximum number of households a questionnaire administrator could reasonably interview in a day. A total of 46 blocks was required. We used information from the national household inventory from the INEGI to construct the sampling frame (total of 174 blocks). All blocks in the sampling frame were listed and numbered sequentially based on a geographic pattern, starting from west to east and moving north to south, and the total number of households in each block was recorded. A list of the cumulative number of households per block was then created, producing a total 2249 households. A sampling interval (49) was calculated by dividing the total cumulative number of households (n = 2249 households) by the primary sampling unit (n = 46 blocks). A random number equal to or less than the calculated sampling interval (49) was selected using a computer random number generator (www.random.org). This randomly chosen number was then located within the list of cumulative households and the identified block was determined to be the first block selected. Every 49th household in the cumulative household list was sequentially selected thereafter to randomly select blocks until all the 46 blocks were selected.

For sampling in the second stage, eight households per block were selected using simple random selection and the random number generator. The household selection started at the southeast corner of the block then moved counterclockwise around the block for all the blocks. If a randomly selected household was a business or was unoccupied, the neighboring occupied household on the right was selected.

2.4. Door-to-door household survey

The study was promoted in Villa de Tezontepec several days before the survey began, via printed posters and social media networks to encourage participation. Both dog-owning and non-dog-owning households were included in the study. Within each sampled household, the person (18 years of age or older) at home and most able to answer questions related to dogs and their care (if the household owned dogs) was asked to participate in the survey. If no one was home at a selected household, it was revisited twice more on different days and at a different times of day. If no one was home on these subsequent visits, the household was considered a refused household.

Survey administrators attended a 3-h training session on the survey methodology. Survey administrators included 25 students from the Veterinary College of the Autonomous University of the State of Hidalgo and 5 students from the National College of Professional Technical Education, 5 local volunteers, and 4 members of the Ministry of Health Zoonosis and Rabies Prevention Program in Tizayuca.

The household questionnaires were administered orally in Spanish. Informed oral consent was obtained from all participants prior to starting the questionnaire. Data were recorded by the survey administrators directly on individual hard copies of the questionnaire. At the end of each data collection day, the survey administrators gave the questionnaires to the lead author to be entered in an electronic database.

2.5. Owned dog density

The area of the study region and the area for each neighborhood were calculated in square kilometers using the polygon tool in Google Earth Pro for Mac (Google Inc., 2015) by drawing a perimeter connecting the most external households in each neighborhood (Belsare and Gompper, 2013). The predicted owned dog abundance for the study region and for each neighborhood was calculated by multiplying the number of households in each area by the proportion of dog-owning household and then by the mean number of owned dogs per area. The dog population density was calculated by dividing the predicted owned dog abundance in the study region and per each neighborhood by its calculated area, respectively.

2.6. Data analysis

Collected questionnaire data were entered into a custom-made online database made in ODK (Open Data Kit) Collect version 1.3, and uploaded into Formhub (Modi Research Group, Columbia University, NY). Data entry was validated by visually comparing the data against the original questionnaire responses for accuracy. All entered data were then uploaded into an Excel® file (Microsoft Corporation, 2010). Descriptive statistics (means, standard deviations, medians, ranges, proportions and 95.0% confidence intervals) and Fisher's exact chi-square statistics to compare proportions were performed using STATA/SE for Mac (StataCorp LP, 2015).

3. Results

3.1. Survey participation and household characteristics

Individuals residing in 328 households were interviewed in the study region (15.0% of the total identified households across the four selected neighborhoods), representing a household participation rate of 90.9% (328/361; 95.0% CI = 87.4%–93.6%) and a total of 1450 household residents. Out of all the respondents

Table 2
Mean, median and range of number of dogs per dog owning household, the human to owned dog ratio, the estimated total number of owned dogs and the estimated absolute owned dog density for four neighborhoods surveyed in Villa de Tezontepec, Hidalgo, Mexico, 2015.

Neighborhood	# Owned Dogs	Percent of all households that owned dogs	Mean # Owned dogs among Dog-owning Households (SD)	Owned dogs per Dog-owning Households Median (range)	# People	Human to Owned dog ratio	Number of Households	Area (km^2)	Predicted Owned Dogs Abundance	Estimated Owned Dog Density (# Owned Dogs/km^2)
Tezontepec	248	64.6 (126/195)	2.0 (SD = 1.5)	1 (1–8)	827	3.3:1.0	1270	3.6	1651	465
Morelos	44	51.1 (24/47)	1.8 (SD = 1.6)	1 (1–8)	211	4.8:1.0	307	0.1	359	2566
Benito Juarez	127	73.1 (57/78)	2.3 (SD = 1.4)	1 (1–7)	384	3.0:1.0	613	0.6	915	1666
Chamberluco	9	87.5 (7/8)	1.3 (SD = 0.8)	1 (1–3)	28	3.1:1.0	59	0.5	50	111
Overall	428	65.2 (214/328)	2.0 (SD = 1.5)	1 (1–8)	1450	3.4:1.0	2249	4.7	2924	623

asked to participate, female participation (73.0%; 239/328; 95.0% CI = 66.8%–77.4%) was higher than male participation. Details on participating household characteristics are described in Table 1.

3.2. Dog ownership

Approximately two-thirds of households (65.2%; 214/328; 95.0% CI = 60.0%–70.2%) reported owning one or more dogs, for a total of 428 dogs. The calculated surface area for the study region was 4.69 km^2; therefore, the estimated absolute owned dog density was 623 owned dogs/km^2. Details on the number of owned dogs, human: owned dog ratios and estimated absolute density per neighborhood are described in Table 2.

Of the 114 participating households that did not own dogs, 31.6% (36/114; 95.0% CI = 23.2%–40.9%) reported that they did not own a dog because they did not like dogs, 39.5% (45/114; 95.0% CI = 30.4%–49.1%) did not have space for a dog, and 22.8% (26/114; 95.0% CI = 15.5–31.6%) indicated that a dog required too much time, work, and/or money (multiple reason allowed per participant). One hundred thirteen non-dog owning households answered a question of whether they planned on acquiring a dog in the next 12 months; 87.6% (99/113; 95.0% CI = 80.0%–92.6%) reported they had no such plans.

3.3. Owned dog demographics

3.3.1. Age, sex and spay/neuter status

Of 428 owned dogs, 58.2% (249/428; 95.0% CI = 53.4%–62.8%) were male, producing a male to female ratio of 1.4:1 (249/179). The age and sex structure of the owned dog population is listed in Table 3, and displayed in an age pyramid Fig. 1. The majority (94.7%) of dogs were 3 months of age or older, and 74.4% (294/395; 95.0% CI = 69.8%–78.7%) were older than one year. The mean age of owned dogs was 2.9 years (SD = 2.5; median: 2 years, range: newborn to 15 years). Only 14.1% (35/249; 95.0% CI = 10.7%–19.7%) of the males were reported as neutered and 36.9% (66/170; 95.0% CI = 31.8%–46.4%) of the females were reported as spayed (Table 3, Fig. 1). Female dogs were significantly more likely to have been sterilized than male dogs (Fisher's exact test, $p < 0.0001$). Out of all reported surgically altered dogs, 80.0% (76/95; 95.0% CI = 70.6%–87.0%) were sterilized during subsidized government spay/neuter clinics, 16.8% (16/95; 95.0% CI = 10.5%–26.0%) were sterilized by private veterinarians; three owners reported not knowing where their dog was spayed or neutered. Reasons reported by dog owners for not spaying or neutering their dogs are listed in Table 4.

3.4. Owned dog mortality

A total of 36 dogs from all dog-owning households were reported to have died or have been killed in the 12 months prior to the survey; reasons included old age, disease, hit by a car, killed by someone, starvation, and intentional poisoning. The proportion of males and females among dogs that died was the same (18 and 18, respectively) and the mean age of was 3.9 years (SD = 4.3; median: 2 years; range 0.2 years–13 years).

3.5. Reproductive indices and litter survivorship

Among the owned female dogs, 5.4% (9/167 responses; 95.0% CI = 2.8%–10.1%) were pregnant at the time of the survey, and 26.4% (37/140 responses; 95.0% CI = 19.7%–34.4%) had been pregnant in the previous 12 months. Among female dogs that had been pregnant in the previous 12 months, 73.0% (27/37; 95.0% CI = 55.8%–85.3%) had 1 litter, 5.4% (2/37; 95.0% CI = 1.3%–20.3%) had 2 litters, and 21.6% (8/37; 95.0% CI = 10.8%–38.5%) did not

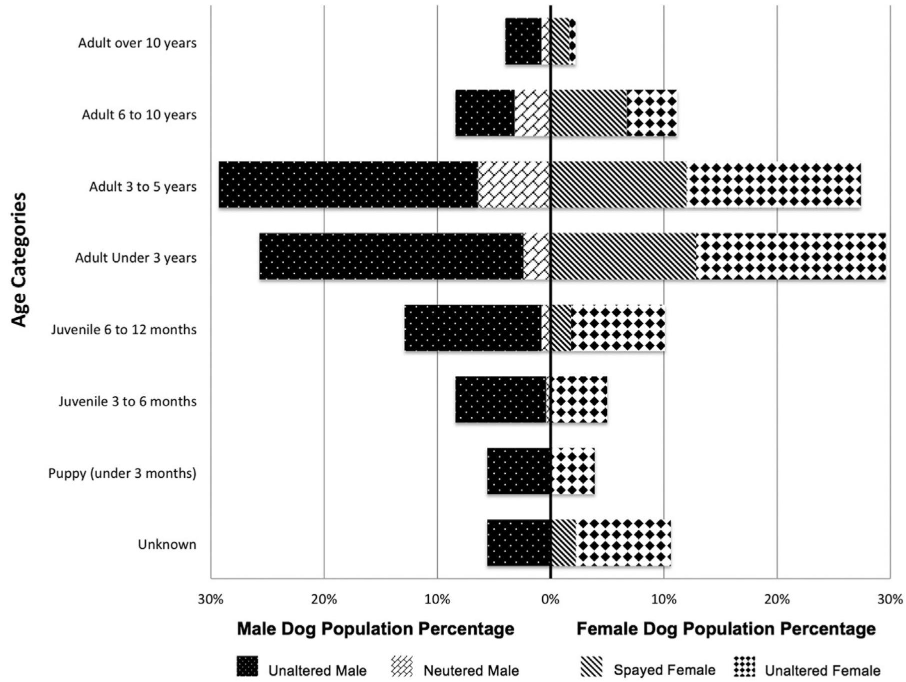

Fig. 1. Age population pyramid of owned dogs, in Villa de Tezontepec, Hidalgo, Mexico, 2015.

provide information regarding the number of litters during this time. More than half (58.0%; 21/37; 95.0% CI = 39.5%–72.9%) of owned female dogs that had been pregnant in the past 12 months were bred intentionally. The reasons reported by dog-owning households for intentionally breeding their female dog(s) included: wanting to sell the puppies (50.0%; 6/16; 95.0% CI = 25.0%–75.0%), "For my dog's health and needs" (31.1%; 5/16; 95.0% CI = 12.2%–59.8%), wanting more dogs (12.5%; 2/16; 95.0% CI = 2.6%–43.0%), and wanting a male dog (6.3%; 1/16; 95.0% CI = 0.7%–39.3%). Five households did not provide reasons for intentionally breeding their female dog.

The mean age of an owned female dog at first litter was 1.9 years (SD = 1.2; median: 1.5 years; range 0.7 years to 6 years). The mean number of live pups born per owned female dog was 4.3 (SD = 2.0; median: 4; range: 1–9). Information obtained on last litter revealed a total of 97 puppies, of which 5 puppies from 2 different litters were stillborn, yielding a stillborn risk of 5.2% (5/97; 95.0% CI = 1.7%–11.6%). The overall mean number of litters in the past 12 months reported per female was 0.22 (SD = 0.45; median: 0; range 0–2). The litter male to female ratio was 1:1.

3.6. Owned dog ownership patterns

Of 411 owned dogs for which we had data, 26.5% (109/411; 95.0% CI = 22.5%–31.1%) had been acquired in the past 12 months. The sources of dogs reported by dog-owning households are described in Table 5 and included: gift (having someone give the household a dog at no cost), adopted (from a dog rescue organization or an animal shelter), pup of owned dog, bought, found (on the street), and other sources. The mean age of a dog when it was acquired was 0.4 years (SD = 0.7; median: 0.3 years; 0 years to 6 years).

Of the 428 reported owned dogs for which reasons for ownership were provided (multiple responses per participant were allowed), approximately two-thirds (68.9%; 295/428; 95.0% CI = 64.3%–73.3%) were owned for companionship as pets, 30.1% (129/428; 95.0% CI = 25.8%–34.7%) for guarding, 2.1% (9/428; 95.0% CI = 1.0%–4.0%) for breeding, 1.4% (6/428; 95.0% CI = 0.5%–3.0%) for herding/protecting livestock, 0.2% (1/428; 95.0% CI = 0.0%–0.2%) for pest control; one dog was reported as having "arrived by himself".

3.7. Dog management and handling practices

Almost half (44.9%; 184/410; 95.0% CI = 40.1%–49.7%) of the owned dogs were described as "always confined" when unsupervised; the remainder were allowed to roam free unsupervised during all or part of the day (Table 6). Only 35.4% (101/285; 29.9%–41.3%) of the reported intact owned dogs (both female and male over 6 months) were described as "confined" at all times.

More than half (58.3%; 238/408; 95.0% CI = 53.5%–63.0%) of the owned dogs were reported to be walked by their owners; of these, roughly one-third (34.7%; 74/213; 28.4%–41.5%) were reported to be walked on a leash. Almost all (97.8%; CI = 95.8%–98.9%) of the owned dogs were fed at least once a day.

The proportion of owned dogs reported to have ever bitten a person or another dog was 3.4% (14/409; 95.0% CI = 2.0%–5.7%) and 12.5% (51/408; 95.0% CI = 9.6%–16.1%), respectively. Approximately 84.4% (342/405; 95.0% CI = 80.6%–87.7%) of all owned dogs were reported to have been vaccinated against rabies in 2015. The rabies vaccination male to female ratio was 1.4:1 (199:143, respectively). The proportion of vaccinated male dogs was not significantly different than vaccinated female dogs ($X^2 = 1.5$, $p = 0.5$). The proportion of owned dogs reported to have been dewormed in the past 12 months was 67.9% (275/405; 95.0% CI = 63.2%–72.3%).

4. Discussion

This study describes the dog ecology and demography of the owned dog population in Villa de Tezontepec, Hidalgo, Mexico. This information can be used in the effective design of targeted humane dog population programs in Mexico and potentially, other developing countries. It could serve the local government as a baseline against which comparisons can be made after an intervention has been implemented to measure intervention effectiveness (ICAM, 2015). This information could also be used to inform mathematical models for the simulation of population control activities that

Table 3
Age, sex and spay/neuter structure of the owned dog population, in Villa de Tezontepec, Hidalgo, Mexico, 2015. (n = 428 dogs).

Age Group	Total Owned Dogs # (%)	Male Owned Dogs # (%)	Female Owned Dogs # (%)	Neutered Male Owned Dogs # (%)	Spayed Female Owned Dogs # (%)
Unknown	33 (7.7)	14 (5.6)	19 (10.6)	0 (0.0)	4 (21.1)
Puppy (under 3 months)	21 (4.9)	14 (5.6)	7 (3.9)	0 (0.0)	0 (0.0)
Juvenile 3–6 months	30 (7.0)	21 (8.4)	9 (5.0)	1 (4.8)	0 (0.0)
Juvenile 6–12 months	50 (11.7)	32 (12.9)	18 (10.1)	2 (6.3)	3 (17.7)
Adult Under 3 years	117 (27.3)	64 (25.7)	53 (29.6)	6 (9.4)	23 (43.4)
Adult 3–5 years	122 (28.5)	73 (29.3)	49 (27.4)	16 (21.9)	21 (43.8)
Adult 6–10 years	41 (9.6)	21 (8.4)	20 (11.2)	8 (38.1)	12 (60.0)
Adult over 10 years	14 (3.3)	10 (4.0)	4 (2.2)	2 (20.0)	3 (75.0)
TOTAL	428 (100.0)	249 (100.0)	179 (100.0)	35 (14.1)	66 (36.9)

Table 4
Reasons reported by dog owners for not spaying or neutering their owned dogs, in Villa de Tezontepec, Hidalgo, Mexico, 2015.

Reasons for Not Spaying/Neutering Owned Dog(s)	Percent of Owner Responses # (%)[a]
"Do not know"	38 (17.9)
Do not know what is involved or how to get it done	31 (14.6)
Want to breed to sell offspring	27 (12.7)
Transportation/scheduling problems	26 (12.3)
"To keep it in good health"	25 (11.8)
Risk of the surgery/suffering of dogs	25 (11.8)
Too expensive/do not have the money right now	13 (6.1)
Other[b]	27 (12.7)
TOTAL	212 (100.0)

[a] Calculated as: number responses per particular reason/total number of reasons provided.
[b] Other owner-reported reasons include: 1) Too young (48.5%; 16/33), 2) Dog does not go out (12.1%; 4/33), 3) There is no spay/neuter campaign (6.1%;2/33), 4) I have not done it (6.1%; 2/33), 5) He/she does not need it (6.1%; 2/33), 6) I have not thought about it (3.0%; 1/33), 7) Carelessness (3.0%;1/33), 8) There was a campaign but she was pregnant (3.0%;1/33), 9) I do not want it (3.0%; 1/33), 10) I want him to be a dad (3.0%; 1/33), 11) I want a male dog (3.0%; 1/33), 12) I want him to mate (3.0%; 1/33).

Table 5
Sources of owned dogs in Villa de Tezontepec, Hidalgo, Mexico, 2015. (n = 411 dogs)[a].

Source of Owned Dog	Percent of Owned Dogs # (%)[b]
Gift from inside Villa de Tezontepec	138 (33.6)
Adopted	59 (14.4)
Gift from outside Villa de Tezontepec	58 (14.1)
Pup of owned Dog	52 (12.7)
Bought from outside Villa de Tezontepec	39 (9.5)
Bought from owner inside Villa de Tezontepec	32 (7.8)
Found	24 (5.8)
Bought from a store inside Villa de Tezontepec	4 (1.0)
Other[c]	5 (1.2)
TOTAL	411 (100.0)

[a] Table does not include 17 missing responses.
[b] Calculated as: number of owned dogs in a type of source/total number of owned dogs reported.
[c] Other sources include, 1) Veterinary Clinic 6.7% (1/6) and 2) Do not know 83.3% (5/6).

Table 6
Percent of owned dogs by confinement frequency category, in Villa de Tezontepec, Hidalgo, Mexico, 2015. (n = 410dogs)[a].

Time of Confinement	Percent of Owned Dogs Confined # (%)[b]
Always	184 (44.9)
Never	143 (34.9)
Night	36 (8.8)
Daylight	29 (7.1)
"Sometimes"	17 (4.2)
"Do not know"	1 (0.2)
TOTAL	410 (100.0)

[a] Table does not include 18 missing responses.
[b] Calculated as: number of owned dogs in a confinement frequency category/total number of owned dogs reported.

can help quantify the expected impact of an intervention (Coleman, 1997).

Dogs are very popular pets in Mexico (Ortega-Pacheco et al., 2007). Several studies in developing countries (e.g. Guatemala, Brazil, Chile, Peru) report that dog-owning households account for half or more of all the households studied (Davlin and VonVille, 2012). The proportion of dog–owning households reported in this study was 65.2% and is comparable with other studies performed in Mexico: 42.7%–56.4% in Mexico City (Romero-Lopez et al., 2008); 54.0% in Mexicali, Baja California (Flores-Ibarra and Estrella-Valenzuela, 2004); 73.0% in Merida, Yucatan (Ortega-Pacheco et al., 2007); 73.9% in Atlixco, Puebla (Fishbein et al., 1992) and Central and South America: 51.0% in Guatemala (Pulczer et al., 2013); 52.5% in São Paulo, Brazil (Alves et al., 2005); 57.0% in Villa del Mar, Chile (Morales et al., 2009); 58.2% in San Martin de Porres, Lima-Peru (Arauco et al., 2014). Knowledge of the size of the owned dog population can be used to help determine the number of resources that might be required for reproduction control interventions within communities.

Similarly, the human: owned dog ratio in our study (3.4:1) is comparable to ratios reported in other Mexican studies, in both urban and rural communities: 2.6:1 in Miacatlan, Morelos (Orihuela and Solano, 1995); 3.4:1 in Atlixco, Puebla (Fishbein et al., 1992); 3.4:1 in Merida, Yucatan (Ortega-Pacheco et al., 2007); 4.0–6.0:1 in Mexico City (Romero-Lopez et al., 2008); and 4.3:1 in Mexicali, Baja California (Flores-Ibarra and Estrella-Valenzuela, 2004). It should be noted that several of these studies either did not provide, or used different definitions of “owned dog” than the present study; this has implications for direct comparisons of study results. Our definition was very restrictive and therefore might have underestimated the number of owned dogs compared to studies that used a less restrictive definition. In the present study, the interviewed households with dogs reported having 1 to 8 dogs, with a mean in dog-owning households of 2 dogs. This is also consistent with reports in Guatemala (1.6) (Pulczer et al., 2013), Brazil (1.6) (Alves et al., 2005), Peru (1.6) (Arauco et al., 2014), and Mexico (1.6–2.1), (Orihuela and Solano, 1995; Ortega-Pacheco et al., 2007).

The mean age of owned dogs in our study was 2.9 years, which is consistent with previous reports: 2.7 years in San Martin de Porres, Lima-Peru (Arauco et al., 2014); and 3.1 years in Merida, Yucatan, Mexico (Ortega-Pacheco et al., 2007); but notably lower than the mean age of 4.6 years reported in Villa del Mar, Chile (Morales et al., 2009). Age is one of the most impactful characteristics in population modeling, as individuals have different reproduction and survival characteristics at different ages (Li and Brauer, 2008), and sterilization of dogs at different ages has different affects on the dog population growth (Di Nardo et al., 2007).

Dog ecology studies in developing countries, have commonly reported that the sex ratio favors male dogs (Orihuela and Solano, 1995; Kongkaew, et al., 2004; Suzuki et al., 2008; Arauco et al., 2014). Our study is not the exception, with a male: female dog ratio of 1.4:1. Dog owners may believe that male dogs make better guard dogs (Kitala et al., 2001), and in contrast, that female dogs tend to attract free-roaming males during estrus, as well as produce unwanted puppies (Hsu et al., 2003). We speculate that born unwanted female dogs might be abandoned on the streets, sold or given away, but we are unable to confirm this. Intact free-roaming female dogs abandoned or otherwise, are likely to impact the dog population dynamics and they should be the focus of the dog population control programs (Jackman and Rowan, 2007).

Surgical sterilization (neutering of males and spaying of females) has been generally accepted as a vital part of humane population control programs (Leney and Remfry, 2000). Female dogs (36.9%) in our study had a significantly higher proportion of sterilization than male dogs (14.1%). The relatively high proportion of sterilized dogs and the higher proportion of sterilized females over males described by our study are comparable with estimates previously reported in Italy (8.0% males; 30.0% females) (Slater et al., 2008) and Brazil (17.0% males; 23.0% females) (Baquero et al., 2015); but differ from estimates reported in Bolivia (26.0% males; 7.0% females)(Suzuki et al., 2008); Mexico (5.8% males; 3.8% females) (Orihuela and Solano, 1995); Kenya (15.0% males; 0.0% females) (Kitala et al., 2001); and Guatemala (9.2% males; 0.0% females) (Pulczer et al., 2013). One of the reasons for observing a lower proportion of sterilized males dogs compared to females dogs could be due to owners' attitudes against male dog castration. In Mexico “virility is a cultural symbol” (Stevens, 1965) characterized by the ideology that males should have valor, strength and courage, as well as sexual potency beyond normal levels (Stevens, 1965; Andrade, 1992). These beliefs remain strong especially in more rural communities. Male dogs may be less likely to be sterilized because male owners of male dogs may experience “anthropomorphic empathy regarding emasculation” and fear that protective behaviors in male dogs might be removed or decreased by castration (Blackshaw and Day, 1994; Martins-Soto et al., 2005; Levy et al., 2008). However, lack of knowledge regarding the benefits of male dog sterilization and the availability of male dog sterilization services could also result in lower numbers of male dogs being sterilized. For example, a spay and neuter program conducted in El Paso County along the US-Mexico border reported almost equal numbers of male and female dogs being sterilized. Several factors influenced the increase in pet owners participation in that program, including promotional and educational activities prior to the sterilization event, as well as affordability and accessibility of the services. Hence, education of male dog owner regarding benefits of sterilization may have led to increased uptake of the sterilization services (Poss and Bader, 2008). Dog reproduction control approaches need to be evaluated during the planning stages to ensure they are socially and culturally accepted by the community before they are implemented (Massei and Miller, 2013). For example, educational efforts focused on altering negative attitudes towards male sterilization could be implemented prior to an intervention. These efforts increase the likelihood that the proposed intervention will succeed (Fielding et al., 2002).

Approximately 80.0% of dogs in this study were reported to have been sterilized during government subsidized spay/neuter clinics. The reason for the higher proportion of altered dogs seen in our study compared to the others studies, may be due to government subsidized services of pet sterilization offered in the State of Hidalgo and all its municipalities, including Villa de Tezontepec. The Ministry of Health in Mexico provides spay and neuter services at no cost for both male and female dogs and cats, from 6 weeks of age (Secretaria de Salud, 2015b). Despite high uptake overall, only a small proportion of owned dogs younger than 6 months were spayed or neutered (2.9% (1/35) males, 0.0% females). This may be due to a lack of awareness among dog owners of the availability and benefits of early age sterilization (i.e. between the ages of 6 and 16 weeks), including the reduction of reproductive behaviors such as roaming, urine marking, sexual aggression, and the decreased risk of mammary tumors and pyometra in female dogs and testicular tumors in male dogs (Root-Kustritz, 2014). Despite the availability of early spay and neuter services in the study area, this service appears to have been under-utilized.

In our study, 26.4% of the non-spayed female dogs were bred in the past 12 months, which is lower than reported elsewhere (for example, 37.5% in Merida, Yucatan, Mexico (Ortega-Pacheco et al., 2007); 50.9% in Antananarivo, Madagascar (Ratsitorahina et al., 2009); and 54.0% in the Machakos District, Kenya (Kitala et al., 2001)). Out of female dogs that were bred, 58.3% were bred intentionally and the most common reason for this decision as described by their owners was that they would like to sell the offspring (50.0%). The mean litter size per owned female dog was 4.2 puppies, which is consistent with other studies (for example, 3.7 pups per litter was reported in Antananarivo, Madagascar (Ratsitorahina et al., 2009), 5.0 in Villa del Mar, Chile (Morales et al., 2009), and 5.2 in the Machakos District, Kenya (Kitala et al., 2001)). Dog owners that obtain a financial gain from breeding their dogs, even if the gain is small, will be less likely to participate in dog reproduction control initiatives such as spay and neuter initiatives (Fielding, 2010). Unregulated backyard breeding of dogs plays an important role in the overpopulation of dogs (Fielding and Plumridge, 2005). Knowledge of the proportion of female dogs that are intentionally bred and that might not participate in dog reproduction control initiatives can be used to assess the potential effectiveness of dog population interventions in the long term. Further research is needed regarding the economic and cultural motivation of backyard breeding in this community. Investing in educational interventions to create public awareness on the dog overpopulation problem should also be considered.

In our study, only 18.2% of owned dogs were purchased either from internal or external sources such as dog owners, stores, markets, and veterinary clinics. Almost half (47.7%) of the owned dogs in our study were acquired as a gift (i.e. given to the dog-owning households from households within or outside the study region at no cost). This finding is similar to other studies in developing countries (for example, 36.0% in Antananarivo, Madagascar (Ratsitorahina et al., 2009); 56.0% in the Machakos District, Kenya, (Kitala et al., 2001); and 57.2% in Merida, Yucatan (Ortega-Pacheco et al., 2007)). In the present study, the questionnaire did not distinguish "gifts" (i.e. just being given to someone at no cost) versus "true gifts" (i.e. given to someone as a surprise or to celebrate a birthday or holiday). When dogs are given to someone at no charge, they can end up with owners that lack a genuine interest in caring responsibly for them, and such dogs could eventually be relinquished or abandoned on the street (New et al., 2000; Fielding, 2010). However, studies have reported that dogs received as "true gifts" have a lower risk of relinquishment compared to dogs acquired from other sources (Weiss et al., 2013). Having a dog for companionship was the main reason (68.9%) reported for dog ownership in this study; this is similar to what has been reported in Mexico City (55.4%–69.8%) (Romero-Lopez et al., 2008). In contrast, our result is higher than that reported in dog ecology studies in Chile (42.4%) (Morales et al., 2009) and Merida, Yucatan (49.4%) (Ortega-Pacheco et al., 2007) Dogs can be an emotional and social support to their owners (Ramírez et al., 2014), and an alternative to human affection, especially for older adults (Lagoni et al., 1994; Kurdek, 2008; Ramírez et al., 2014). A high proportion of dogs owned for companionship may be associated with a high number of older adults in the population. When planning for dog reproduction control interventions such as spay and neuter services, consideration should be given to make sure these services are accessible to older adults and their pets.

The percentage of owned dogs kept confined varies between developing countries. Our study revealed that 44.9% of dog-owning households kept their dogs confined at all times when unsupervised. This is lower than Mexico City, Mexico (54.6% and 58.3%) (Romero-Lopez et al., 2008), Brazil (60.7%) (Alves et al., 2005), Guatemala (68.5%) (Pulczer et al., 2013), and Villa del Mar, Chile (77.5%) (Morales et al., 2009). A high number of owned free-roaming dogs could have a negative impact on human health and safety, including the potential transmission of zoonotic diseases, physical aggression towards humans, fouling, livestock predation, wildlife endangerment, and road traffic accidents (ICAM, 2008; Hiby, 2013). Further, unaltered owned dogs that are allowed to roam free, could contribute to dog overpopulation as a result of unplanned pregnancies and unwanted litters (Fielding, 2010). Further research is warranted to understand the reasons dogs are allowed to roam free in this community. This may help in the development of applicable and enforceable responsible pet ownership legislation.

The World Health Organization (WHO) recommends that at least 70.0% of the dog population be vaccinated against rabies and that the vaccination status be maintained to achieve control and eventual elimination of canine rabies (Coleman and Dye, 1996; Cleaveland et al., 2003; WHO, 2013). In Latin America, in 2005, the mean rabies vaccination coverage was reported to be 68.0% (OPS, 2005). In Mexico, the rabies vaccination coverage reported between 2001 and 2003 was higher than 80.0% in most parts of the country (OPS, 2005). Other studies in Mexico report different levels of vaccine coverage, for example in Miacatlan, Morelos (90.6%) (Orihuela and Solano, 1995); in Merida, Yucatan (90.1%) (Ortega-Pacheco et al., 2007); in Mexicali, Baja California (73.0%) (Flores-Ibarra and Estrella-Valenzuela, 2004) and in Mexico City (39.8–47.4%) (Romero-Lopez et al., 2008). Our study shows that in Villa de Tezontepec, 84.4% of the owned dog(s) were vaccinated against rabies during the government anti-rabies vaccination campaign in 2015. The Ministry of Health carries out a rabies vaccination campaign each year in the months of March and September. Each campaign has a duration of seven days. During each event, owned cats and dogs receive a rabies vaccine from trained personnel and volunteers. Vaccines are given to pets either as a part of a door-to-door campaign or in fixed vaccination booths at no cost to pet owners (Secretaria de Salud, 2015a). Our study data were collected during the months of October and November; therefore, we are reporting the government anti-rabies vaccination coverage for 2015. Subsidized dog rabies vaccination programs increase vaccine coverage rates (Durr et al., 2009). A limitation of the government vaccination program is that it may only be owned dogs that are vaccinated (Secretaria de Salud, 2015a); high proportions of owned dogs vaccinated against rabies might not indicate that the level of control and protection against rabies have been reached as non-owned, unvaccinated, free roaming dogs still pose a risk for the transmission of canine-mediated rabies. Further studies to estimate the abundance of non-owned, unvaccinated, free-roaming dogs is necessary to better assess the total dog population vaccination coverage level in this community.

5. Limitations

Several limitations of the study should be noted. Owned dog demography studies only play a partial role in the true understanding of the "total dog population" ecology and demography; information on the non-owned dog population would be useful, but was not possible in the present study. The four neighborhoods included in the study were sampled based on their proximity to the capital. These neighborhoods may be more highly populated and have higher household density than the other neighborhoods in Villa de Tezontepec. As stated earlier, the questionnaire was translated from English to Spanish by native Spanish speakers. However, we noticed during survey administration that a few words may have been misinterpreted by the respondents during the survey application. For example, we noticed that the proportion of dogs reported as "adopted" was unexpectedly high (14.4%), suggesting that adoption as the source for owned dogs may have been chosen by the respondent over other options also presented on the questionnaire. The word 'adoption' was intended to describe dogs that were adopted from a humane society or similar institution, but local people may have understood that adoption meant getting a dog from the street (found on the street, an option provided in the questionnaire), or getting a dog from another household owner (received as a gift, also an option provided in the questionnaire). As a result, we may have underestimated the proportion of dogs acquired as gifts and found stray on the street. Another example where a word could have been misinterpreted is the word "gift", as described above. As a result, we may have overestimated the number of dogs that may be at a higher risk of relinquishment.

6. Conclusions

In conclusion, more than half (65.2%) of the households in Villa de Tezontepec owned dogs. The majority (84.4%) of owned dogs were vaccinated against rabies in 2015, less than half (44.9%) of these dogs were kept confined when unsupervised and only a small proportion were spayed or neutered. The knowledge of owned dog demography provided by this study allows for the description of demographic indicators that could be used by the local government for the planning, implementation and monitoring of effective dog population control interventions. The data collected in this study could serve the local government as a baseline against which comparison can be made after an intervention has been implemented to measure intervention effectiveness. These data can also be used to build a dog population agent-based computer simulation model to assess the potential impact of different control programs in this, and similar, populations.

Conflict of interest statement

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.prevetmed.2016.10.021.

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