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Research article

Owned and free-roaming dogs in the North West of Tunisia: estimation, characteristics and application for the control of dog rabies

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ABSTRACT

Understanding the structure of dog population and the evaluation of the accessibility of dogs to vaccination is essential to succeed in the fight against dog rabies and to adapt the strategy of its control. We studied the characteristics of the unowned and owned dogs using the beck method during a rabies vaccination campaign in randomly selected sectors (urban and rural sites) in the North West of Tunisia. During a door-to-door investigation of households, data on owned dogs were collected to describe the owned population dog. A photographic-recapture method was used to characterize and estimate the size of the unowned dogs. A total of 1432 households accounting for 5403 inhabitants were interviewed during the survey (1298 (90.6%) in the urban site and 134 (9.3%) in the rural site). The dog-owning households were significantly higher in the rural site (76.1% (102/134)) compared to the urban site (17.8% (231/1298)) ($P < 0.000000$). Of the 17.8% dog-owning households in urban site, 58.4% owned one dog and 9% between 4 and 8 dogs. While, of the 76.1% dog-owning households in rural site, 24.5% owned one dog and 32.3% owned between 4 and 10 dogs. The dog: human ratio was 1:11 in the urban site and 1:1.6 in the rural site. The dog population density was estimated at 16 dogs/km2 and 4 dogs/km2 in the urban and rural sites, respectively. The confinement practices varied significantly among the urban and rural sites ($P < 0.000000$). The percentage of free-roaming owned dogs was 51.1% in the rural site and 31.4% in the urban site. More than 60.0% of the owned dogs in the urban site were confined. The majority of dogs in the rural site were born in the house, although, a high percentage (56.7%) of owned dogs in the urban site was adopted from neighbours, others sectors, or countries. The vaccination coverage findings indicated that 77.8% and 84.2% of the owned dog were vaccinated in the urban and rural sites, respectively. The estimated size of the free-roaming dogs was 72 dogs in the urban site (Kalaat Senan) and 16 dogs in the rural site (Sod el Khir).

1. Introduction

Rabies is a fatal disease and continues to be considered as a major public health concern despite the availability of efficient vaccines and post-exposure prophylaxis (PEP). More than 95% of human rabies cases are recorded in Asia and Africa, and in 99% of these cases, dogs are responsible for the transmission of the disease (Bourhy et al., 2010). The number of deaths in the African countries where rabies is endemic, is estimated to be 23,700 deaths (Expert Consultation on Rabies and Weltgesundheits organisation, 2013). In the North African countries, it is a neglected disease with high incidences of dog rabies (Nel, 2013; Ripani et al., 2017).

In Tunisia, rabies was first reported in 1870 and its rapid progression appears to be associated with the increasing immigration of Europeans (Néfissa et al., 2007). The recent history of rabies in Tunisia can be subdivided into five periods characterized by variations in the observed incidences of the disease. During the first period, from 1960 to 1981, the annual average of rabies cases was 207 in animals and 18 in humans. This period is characterized by the absence of national campaigns of mass vaccination of dogs. The second period, from 1982 to 1987, is characterized by the introduction of the national program for rabies control (Osman and Haddad, 1988). Three ministries are involved in this program; the ministry of agriculture is in charge of dog mass vaccination, surveillance, and management of rabies outbreaks. The national rabies

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control program is principally based on the prevention of the disease in dogs, the reservoir and vector, through annual vaccination at fixed vaccination posts in urban, and sub-urban areas and house-to-house campaigns are organized in rural areas. In the private sector, vaccination is carried out by private veterinarians. In the public sector, the regional veterinary services conducted an annual mass vaccination campaign for owned dogs. According to the Tunisian regulation, vaccination against rabies is free and obligatory and all owned dogs over 3 months of age must be vaccinated. A vaccination certificate is issued to the owner of the vaccinated animal without any marking tools (Kalthoum et al., 2021; Le Programme National de Lutte Antirabique). The Ministry of Public Health is responsible for post-exposure prophylaxis; finally, the control and the management of stray dogs attributed to the Interior Ministry, is mainly based on the mass killing of unowned dogs (Lahmar et al., 2017) (Kalthoum et al., 2021; Bouslama et al., 2020) and sterilisation of stray dogs is starting to be applied but it is very limited. In this period, the averages reported rabies cases dropped to 91 and 5, in animals and humans, respectively. The third period ranged from 1988 to 1992, in which the average annual rabies cases increased to 281 in animals and 10 fatalities in humans, reaching a peak, in 1992, with 581 animal rabies cases (350 in dogs) and 25 human rabies cases (FAO, 2009; Ripani et al., 2017; Seghaier et al., 1999), indicating a resurgence of the disease following the cessation of mass vaccination of dogs. The fourth period (from 1993 to 2011) is characterized by the resumption of the dog vaccination campaigns resulting in a decrease in the annual number of animal rabies to 148 cases and that of humans to 3 victims, with fluctuations ranging from 0 to 6 victims per year. Finally, the fifth period coincides with the Tunisian revolution of 2011 to the present day. It is characterized by a recrudescence of the disease with average animal rabies cases of 377 (Kalthoum et al., 2021). The control of rabies in Tunisia depends on the logistic and the targeted population which are owned but have free-roaming behaviour. Thus, legally, imported dogs do not pose a risk as they are subjected to regulatory procedures and are controlled and registered.

Studying dog ecology allows good estimates of the size and characteristics of a dog population and the obtained data will help to evaluate the already implemented rabies control measures. Studies of dog populations in Tunisia had been conducted in the eighties of the last century. The first study was conducted in 1986 in the northeast of Tunisia (governorate of Zaghouan) and revealed that an average of one dog per 6.8 inhabitants was estimated in rural areas. The sex ratio was 2.75 males per one female (Artois et al., 1986). From 1986 to 1990, dog populations in five rural and eight urban or suburban sites (North and centre of Tunisia) were studied. The density of dogs in the rural area ranged between 7 and 30 dogs per km^2 (one dog per 3–5.5 inhabitants). Although, in urban and suburban areas, the density of dogs was very high (700–1000 dog/km^2). High turnover rates were observed with 23%, 30%, and 40% in rural, suburban and, urban areas, respectively. Free-roaming dogs exceeded 10% of the whole population (Wandeler et al., 1993). From 1993 onwards, dog population has never been investigated again despite the recrudescence of the disease especially after the revolution of 2011. An increase in household landfills could have contributed to the proliferation of stray dog populations allowing the increase of rabies transmission between dogs (Kalthoum et al., 2021, Belkhiria, 2018). The limited knowledge on the ecology of the dog population can explain the failure of the control of rabies in Tunisia (Hassine et al., 2021). Dog population estimation is fundamentally based on a model taking into account the human population size and the categorization of the sector into three categories (rural, urban and semi-urban) (Wandeler et al., 1993). The categorisation of sectors may have varied over time and an updated model taking into account changes in categories could improve the precision of the results (Bouslama et al., 2020). The high economic burden of rabies surveillance and control measures estimated at 5.2 million US Dollars in five years (Aicha, 2019; Baccar, 2018), stresses the need for dog population analysis and update in order to optimize the outcomes.

The main objectives of this study are to estimate the owned and free-roaming dog population sizes in urban and rural areas and to study their demographic characteristics; In addition, we investigated the vaccination coverage and to assess the accessibility of dogs for parenteral vaccination; Furthermore, we evaluated the impact of the human factor in the long distances movements of dogs which increases the risk of rabies transmission in different regions of the country. Data generated from this study will provide key elements for a more effective control strategy of dog rabies and can be used for modelling the spread and persistence of the disease in the owned and unowned dog populations.

2. Methodology

2.1. Study area

This study was conducted among households in the district of Kalaat Senan (35° 45′ 54″ north, 8° 20′ 43″ east) in the governorate of Kef (Northwest of Tunisia) (Figure 1). This district is bordered in the West by Algeria and is well known by the agricultural activities. Two sectors were randomly selected from 9 sectors. Kalaat Senan and Sed el Khir are classified as urban and rural areas, respectively and considered as high risk areas for the introduction of rabies from Algeria due to the uncontrolled movement of dogs at the borders. The population in the study areas is estimated to be 9704 inhabitants (Census, 2014). The study area is 123.1 km^2 (23.9% of the district of Kalaat Senan).

2.2. Study design and data collection

A cross-sectional study was conducted in the urban and rural sites during the vaccination campaign in order to investigate dog demography and management practices. An exhaustive household-level census was carried out in the two sites through a face-to-face questionnaire from December 2019 to March 2020, during the door-to-door vaccination campaign. Both dog-owning households and non-dog owning households were interviewed. If no person was present at the household at the time of the visit, the investigator programmed another visit. In each dog-owning household, we interviewed the dog owner, vaccinated, and marked all accessible dogs found in the house by a multicolour collar (red, yellow, and green). The collars were bounded by a metal clip with serial numbers (Figure 2). Each interview with the dog's owners was completed within 20 min. Puppies were not marked due to their small size and in order to prevent unnecessary stress of manipulation. To avoid owners' refusal and non-acceptance of collars, local veterinarians in the study areas conducted a prior-survey awareness campaign to educate dog owners about the importance of the collar and vaccination against rabies. Data were collected using a structured questionnaire with different categories of questions (multiple-choice, closed-ended and, open-ended questions) that was designed based on the World Health Organization Guidelines (Bögel et al., 1990). The questionnaire was modified after piloting it with several dog-owning households in the sector of Kalaat Senan. The data collected from the pilot trial were included in the data analysis of the study. The questionnaire described the owned dogs (age, gender, breed, dog use, and, confinement status), their vaccination histories and their management (Figure 3). The source of the dog (born in the house, found, gifted, adopted), the type of feeding (homemade, commercial). Information about household characteristics included: the number of family members, the number of children, and type of housing…) and the presence of free-roaming dogs. Owners were also asked about the eventual death of their dogs during the past 12 months. For female dogs, information about the number of litters per year per female, the number of puppies born in the previous 12 months, season of birth and, number of survived puppies were collected. Data on owners was not published.

Free-roaming dogs (Figure 4) are defined as any dogs are not under human control and unmarked dogs during the survey. This term encompasses ownerless dogs. To estimate the free-roaming dog populations

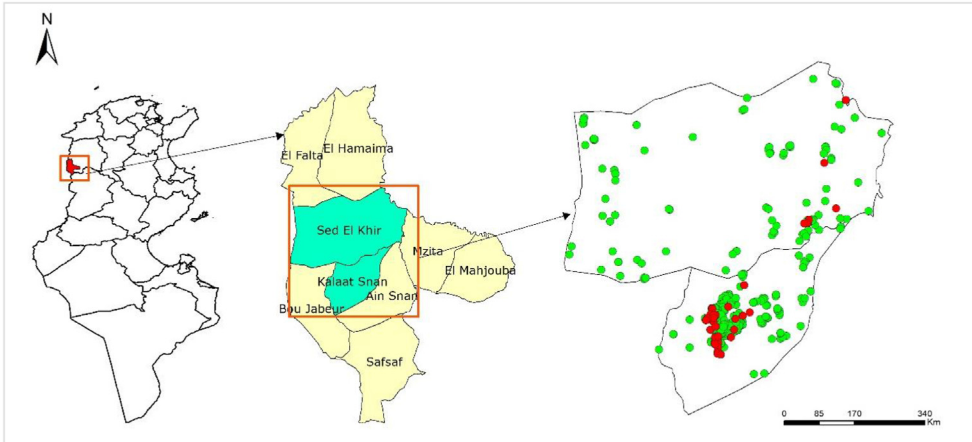

Figure 1. The study areas and the geographical location households with (green point) and without dogs (red point).

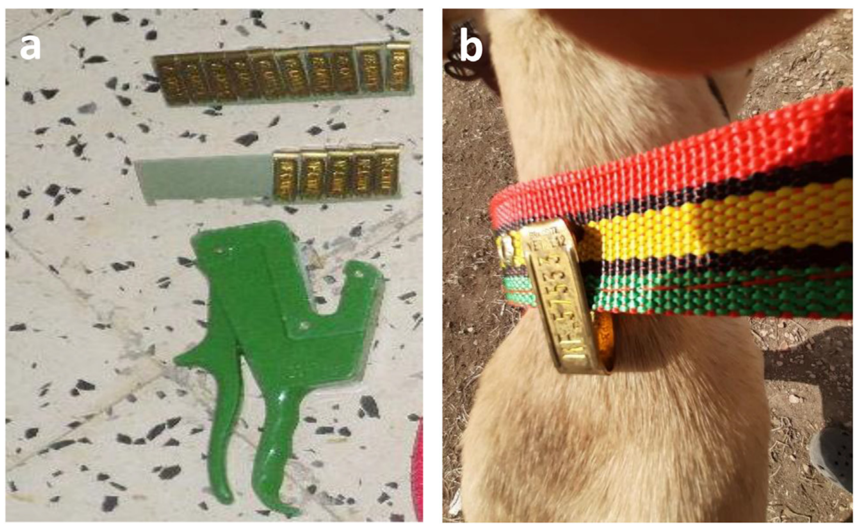

Figure 2. Collars (a) and clips (b) used to mark owned dogs.

Figure 3. Image of vaccinated (and marked with collar) dogs (a and b).

in the urban and rural areas, we used Beck's method (Bögel et al., 1990; Beck, 1973). We counted twice by the same team while walking and driving the survey areas. Each identified dog was photographed and briefly described (sex, age, dog's robe, location) allowing it to be identified as a unique dog and recognized if photographed a second time. A preliminary visit was carried out in the study area to detect the most appropriate time of the day to conduct the free-roaming dog counting. In the urban area (Kalaat Senan), the most convenient time was in the early

Figure 4. Picture taken during the free-roaming dog (a,b,c and d) counting.

morning from 5.00 am to 8:00 am and at the sunset time from 5.30 to 8.00 pm. Wherein the rural area (Sod el khir), the most appropriate time is only early morning between 5:00 am and 8:00 am. At this time, unowned dogs were most active and visible. The counting was carried out in each area on four consecutive days.

3. Data analysis

Data collected during the survey was entered into a Microsoft Access® database (Microsoft Office® 2013). All variables were described as absolute frequency and percentage (%). Dogs were grouped into three classes (Puppies, young and, adults) according to their age. The accessibility of owned dogs for parenteral vaccination was assessed by dividing the number of vaccinated owned dogs by the number of vaccinated and unvaccinated owned dogs.

The owned dog's population size, the number of dogs per household, the density of dogs and, human/dog ratios were assessed for the two sites. The human/dog ratio was calculated by dividing the number of persons in the surveyed households by the number of recorded dogs found in the corresponding households (Butler and Bingham, 2000). The dog population density was obtained by dividing the estimated number of dogs by the area (km^2) of the site calculated with ArcGIS version 10.4 (Environmental Systems Research Institute ESRI, 2018) https://www.esri.com/. The mean litter size was calculated using collected data of female dogs.

The estimated number of unowned dogs at both sites (rural and urban) was calculated using the following equation:

$$N = \sum(Mx\ n) / \sum m$$

With:

M: number of the dog observed for the first time and individually identified by photography;

n: the total number observed the second time;

m: the number of animals observed again (i.e. recognised by photography) and

N: estimate of the total population (Bögel et al., 1990).

The vaccination coverage was calculated by dividing the number of owned vaccinated dogs by the total number of owned and unowned dogs in each site (rural and urban).

Maps were generated with ArcGIS version 10.4. Standard statistical tests were conducted using R software version 3.4 (R Core Team, 2017) to highlight differences between calculated variables in the two sites (chi-square, t-test and, Kruskal Wallis test). P values <0.05 were considered significant at the 95% confidence level.

3.1. Ethical disclosures

The authors declare that the study was conducted according to the national guidelines without causing damage to the animals and respecting their welfare. Information on the breeders was not intentionally published. The study was approved by the Ethics Committee in Animal Experimentation of the Sidi Thabet national school of veterinary medicine in Tunisia (Number: CEEA-ENMV 31/21).

4. Result

4.1. Demography patterns of households and dog population sizes

A total of 1,432 households (5403 inhabitants) were interviewed during the door-to-door survey. A total of 1,298 (90.6%) households with 4860 inhabitants were in the urban site and 134 (9.3%) with 513 inhabitants were in the rural site. The mean size of the household was 2 (range: 1–8) and 3 (range: 1–11) in the urban and rural sites, respectively. A high proportion of households 82.2% (1067/1298) without dogs was observed in the urban site compared to the proportion of dog-owning households which represented 17.8% (231/1298). While the proportion of the households that have at least one dog 76.1% (102/134) was very high in the rural site ($P < 0.0001$), and only 23.9% (32/134) of households were without dogs. A total of 724 dogs were censused in the households during the survey with 411 dogs in the urban site and 313 in the rural site. The average number of dogs per household is estimated to be 1.7 dog/Household (range: 1–8) in the urban site and 3 dogs/household in the rural site (range: 1–10)) (Table 1). In 43.9 % of the surveyed households in the urban site, the owner (head of the family) is responsible for the dog feeding. In fact, 24.8% of wives and 11.3% of children fed the dogs. Dogs were fed by all the household members in 20.0% of the dog-owning households. Whereas, in the rural site, all members of the household take care of the dog (51.0%). Thirteen percent of the owners

Table 1. Demography and determinants of households at urban and rural sites in kalaat Senan district, in 2020.

Indicator	Urban site (Kalaat Senan)	Rural site (Sod el Khir)
Number of surveyed households	1298	134
Number of inhabitants	4890	513
Number of household without dogs	1067	32
Number of household with dogs	231	102
Size of household	2 (1–8)	3 (1–11)
Number of owned dogs	411	313
Number of free-roaming dogs	72	16
Average number of dogs per household	1.7 (1–8)	3 (1–10)
Dog: human ratio	1:11	1:1.6
Dog population density/km2	16 dogs/Km2	4 dogs/Km2

(heads of the family) reported that they fed their dogs and 31.4% of them declared that their wives took care of them. Less than 4.0% of dogs were fed by children (P = 0.0000).

In the urban site, 58.4% of the dog-owning households owned only one dog, 22.0% two dogs, 10.3% three dogs, and 9.0% between 4 and 8 dogs. In the rural site, the distribution is very similar and 24.5%, 20.5%, 22.5% and 32.3% of households with dogs owned one, two, three, and between 4 and 8 dogs, respectively. The dog: human ratio was 1:11 in the urban site and 1:1.6 in the rural site. The dog population density was higher in the urban site (16 dogs/km^2) compared to the rural site (4 dogs/km^2) (Table 1).

Free-roaming dogs were estimated at 72 and 16 dogs in the urban and rural sites, respectively. Most of the free-roaming dogs were observed near the garbage areas, slaughterhouses, and in the street similarly in the rural and urban sites. They represented 14.0% of the dog population in the urban and only 4.0% in the rural site.

4.2. Demography of owned dog

Table 2 shows the demography characteristics of the owned dog population censused in the urban and rural sites during the door-to-door survey. Dog age distribution was significantly different in the two sites (P = 0.03). Most owned dogs were between 1 to 3 years old, representing 45.4% in the urban site and 41.6% in the rural site. The percentage of dogs under the age of one year is higher in the urban site (25.5%) compared to that in the rural site (17.6%) (P = 0.03). The male to female sex ratio ranged between 1.2 (rural site) and 1.4 (urban site). A significant difference in confinement practices was detected among the urban and rural sites (P < 0.0001). The percentage of owned dogs that were allowed to roam all day (i.e unconfined) was higher in the rural site (51.1%) compared to the urban site (31.4%). However, the majority of owned dogs in the urban site were confined (66.6%). The most common source of dogs in the urban site was adoption (56.7%), while, no adoption of dogs was reported in rural site (P = 0.000). More than 49.8% of owners in the rural site, reported that their dogs were acquired as a gift (22.9% in rural site), and for 47.6% of owners, dogs were born in the house. The percentage of dogs that are bought is low in the two sites and does not exceed 11.0%. A high proportion of the adopted dogs (85.8%) in the urban site was acquired from the inside (the same district) and outside (14.1%) (From other districts and governorates) (Figure 5). A significant difference in reasons for keeping dogs in the household was observed when comparing the two sites (P = 0.000). Dogs were kept as a companion only in the urban site (12.7%) and as a guard for house or herd in 80.8% and 98.1% in urban and rural sites, respectively. The use of dogs for hunting is more frequent in the urban (6.6%) than in the rural site (1.9%). The majority of the owned dogs at both sites were local breed (Sloughi and Berger de l'Atlas), with the highest percentage of non-pedigree dogs at the rural site (83.1%).

Table 2. Demographics of owned dogs observed during the survey at urban and rural sites in kalaat Senan district, in 2020.

Demographics	category	rural	urbain
Age group	< 1 year old	55 (17.6%)	105 (25.5%)
	1-3 years old	142 (45.4%)	171 (41.6%)
	> 3 years old	116 (37.1%)	135 (32.8%)
Sex	Female	142 (45.4%)	172 (41.8%)
	Male	171 (54.6%)	239 (58.2%)
Breed	Indigenious	260 (83.1%)	180 (43.8%)
	Cross	43 (13.7%)	141 (34.3%)
	Exotic	10 (3.2%)	90 (21.9%)
Source of dog	Bought	8 (2.6%)	43 (10.5%)
	Adopted	0 (0.0%)	233 (56.7%)
	Received as gift	156 (49.8%)	94 (22.9%)
	From own bitch	149 (47.6%)	41 (10.0%)
Confinement of dogs	unconfined (free all day)	160 (51.1%)	129 (31.4%)
	Confined	125 (39.3%)	273 (66.4%)
	Confined only the day	25 (8.0%)	4 (1.0%)
	Confined only the night	3 (1.0%)	5 (1.2%)
Reasons for keeping dogs	Companion	0 (0.0%)	52 (12.7%)
	Guard (house and herd)	307 (98.1%)	332 (80.8%)
	Hunting	6 (1.9%)	27 (6.6%)

Of the censed female dogs, 27.7% (87/314) had bred in the last previous 12 months. Among them, 91.4 % in the urban and 96.2% in the rural site had one litter with a peak in the winter. The 87 female dogs produced 436 puppies with a mean of 5 puppies at both sites.

4.3. Demography of free-roaming dogs

The demography characteristics of the free-roaming dogs recorded during the survey revealed that the proportion of females in the rural site is higher than in the urban site but no significant differences were found (P = 0.1). However, the age group distribution among the urban and rural sites was significantly different with a predominance of the young dogs (between 1 and 3 years old) in the rural site and the adult dogs (more than 3 years old) in the urban site (P = 0.002) (Table 3).

4.4. Accessibility to parenteral vaccination

First, we analyzed the rabies vaccination coverage in dogs during the previous year based on the responses of households during the interviews. Hence, only 32.0% and 43.1% of the owned dogs have been vaccinated in the urban and rural sites, respectively. During the present door-to-door vaccination campaign, 376 dogs of the 411 owned dogs in the urban site were vaccinated and marked with collars. Hence, the accessibility to rabies parenteral vaccination was estimated at 91.5%. It is slightly lower in the rural site, where 277 of the total owned dogs (313) were vaccinated (88.5%). Non-accessible dogs to the vaccination represented 10.9% of all identified owned dogs in the study area and the main reason was the confinement status of these dogs that were allowed to run lose all day (i.e unconfined). The vaccination coverage calculated based on the total number of dogs (free-roaming and owned) was 84.2% and 77.8% in rural and urban sites, respectively.

5. Discussion

The paper describes a door-to-door survey during a mass vaccination campaign in urban and rural sites in the North West of Tunisia. We aimed to generate key demographic data of the owned and free-roaming dog population to amend the dog rabies control program in Tunisia. Generated data on dog ecology and demography can be used to model the transmission and persistence of the canine diseases.

In this study, the proportion of dog-owning households found in the rural area was higher than that of the urban area. This difference is likely

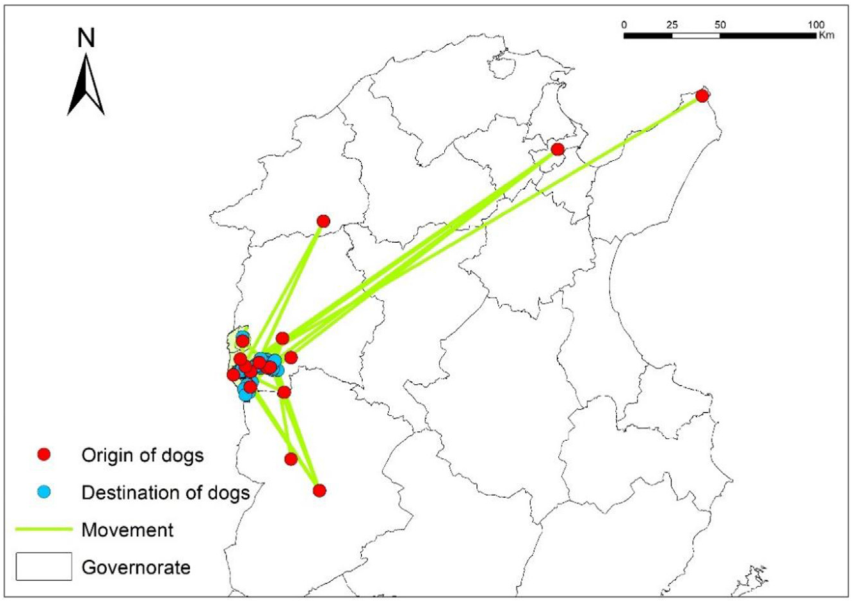

Figure 5. Origin of the adopted dogs in the urban site.

Table 3. Demographics details (age and sex) of unowned dogs observed during the survey at urban and rural sites in kalaat Senan district, in 2020.

Demographics		Urban site (Kalaat Senan)	Rural site (Sod el Khir)
Age group*	Puppy	22.2% (16/72)	20% (3/16)
	Young	13.9% (10/72)	53.3% (8/16)
	Adult	63.9% (46/72)	26.7% (4/16)
Sex	Female	33.3% (24/72)	60.0% (9/16)
	Male	62.5% (45/72)	40% (6/16)
	Sex not seen	4.2% (3/72)	0.0%

* Age group was based on the body size of dogs and the experience of field team.

to arise from socio-cultural practices in the two sites. These results were concordant with previous reports from Tunisia in which corresponding figures were more than 80.0% and less than 20.0% of households in rural and urban areas, respectively (Wandeler et al., 1993). Similar results were reported in South Africa (Hergert et al., 2018), Zambia (de Balogh et a1., 1993), and Tanzania (Gsell A et a. 2009). The observed average number of owned dogs per household was 3 and 1.7 in the rural and urban sites, respectively. Our result is consistent with studies conducted in Morocco (Bouaddi et al., 2018) and Algeria (Kardjadj et al., 2019). In rural areas, there was a strong correlation between the number of owned dogs and the farming activity, especially the number of heads of ruminants (Sikana et al., 2021; Gsell et al., 2009). Most of the households in the urban site owned only one dog similar to what was reported elsewhere (Knobel et al., 2008; Kardjadj et al., 2019; Mustiana et al., 2015). However, in the rural area, we found that the proportion of households that owned 4 dogs or more was the highest (32.3%). Whereas, in the urban area mostly the head of the family took care of the owned dogs, in the rural region all the family members including children are involved. Similar observations were reported by Hergert et al. in South Africa (Hergert et al., 2018).

The dog/human ratios calculated for the urban (1/11) and rural (1/1.6) sites were lower than reported in previous reports in Tunisia (3–5.5 inhabitants per dog in the rural area and 16–46 inhabitants per dog in the urban area) (Wandeler et al., 1993) and elsewhere (1/5.93 in Morocco (Darkaoui et al., 2017), 1/4.45 in Zambia (Kaneko et al., 2021) and 1/3 in Nyimba District (Mulipukwa et al., 2017)). The high dog/human ratio indicates that the risk of rabies transmission is higher in the rural site. The rural populations were more exposed to dog bites due to the frequent contact with dogs (Kalthoum et al., 2021). Dog densities estimated in this study ranged from 4 dogs/km^2 in the rural site to 16 dogs/km^2 in the urban site and this difference can be related to the human density in the two sites. Our finding was similar or slightly higher than those of others studies; 3.4 dogs/km^2 in a rural area in Zimbabwe and 1 dog/km^2 in two rural areas in Chile (Brooks, 1990; Acosta-Jamett et al., 2010). However, previous studies conducted in Tunisia and other regions over the world reported high densities of dogs in both rural and urban areas (Wandeler et al., 1993; Conan et al., 2017; Kitala et al., 2001, Butler and Bingham, 2000). Consequently, in rural areas with high density of the dog population, the risk of developing rabies from a probable rabid animal bite is high because access to the post-exposure prophylaxis was limited in these areas.

Beck method used to estimate the free-roaming dog in the rural and urban sites was very convenient and did not require substantial resources to capture the dogs (Meunier et al., 2019). It was demonstrated that this method provided good estimates of dog population (Tiwari, 2019). The estimated number of free-roaming dogs was higher in the urban site compared to the rural one, 14.0% and 4.0% of the total dog, respectively. Similar to what was reported by Wandeler et al. (1993) in Tunisia (Wandeler et al., 1993). The same figures were reported in Indonesia, Thailand, and Chad (Mustiana et al., 2015; Wongphruksasoong et al., 2016; Kayali et al., 2003). The abundance of free-roaming dogs in the urban area was linked to the availability of waste food and the presence of household dumps which represent a permanent source of food for them (Kato et al., 2003). Since the proportion of free-roaming dogs was lower than 14.0%, their impact on rabies vaccination coverage was rather low on the whole dog population.

The age structure of owned and free-roaming dogs varied significantly between the two sites. Most of the owned dogs were 1–3 years old, with means of 3.4 years and 2.9 years in the rural and the urban sites, respectively. However, in the urban site, free-roaming dogs older than 3 years were the most abundant. This was in accordance with other reports in which the mean age of owned dogs varied between 2.7 and 3.1 years old (Wandeler et al., 1993; Kisiel et al., 2016; Fielding and Plumridge, 2005; Arauco et al., 2015; Ortega-Pacheco et al., 2007). Male dogs were slightly more abundant than the female dogs and the sex ratio was estimated at 1.2 (rural site) and 1.3 (urban site) as for other reports (Tschopp et al., 2016; Kardjadj et al., 2019; Tasiame et al., 2019). Such imbalance can be explained by the fact that female dogs are euthanized by their owners to avoid disturbance during the breeding season (Pal, 2001; Gebremedhin et al., 2020). In addition, others reported that dog owners prefer males to females because they attribute to them better capabilities on their duties of guarding and farming (Kitala et al., 2001). However, in the rural free-roaming population, we found that female dogs were more numerous than male dogs as reported elsewhere (Ratsitorahina et al., 2009). This finding will be very useful for the program of the control of zoonosis such as rabies by implementing sterilization of female dogs in rural areas and male dogs in urban areas in order to better manage the free-roaming dog population.

Most of the owned dogs in the rural site (51.1%) were free-roaming, compared to 33.3% in the urban area, concordant with previous reports in Mexico (Romero-Lopez et al., 2008), Guatemala (Pulczer et al., 2013), and in Bhutan (Rinzin et al., 2016) and slightly different in Morocco (Bouaddi et al., 2018) and Democratic Republic of Congo (Mbilo et al., 2019). Most of the dogs were either guard or herd animals as in Morocco (Bouaddi et al., 2018), Mali (Mauti et al., 2017; Hambolu et al., 2014). The majority of owned dogs were local mongrel breeds at both sites.

Our result showed that a significant proportion of households reported the origin of their dogs being brought from inside or outside (close or far away) the area of study. In the study area, owners imported dogs for adoption from other countries, like Algeria and France, with unknown status. Traveling of dogs from different regions suggest an important role in the increase of local spread of canine rabies and others diseases (Colombi et al., 2020; Talbi et al., 2011). In a study conducted in Chile, long-distance movements of dogs (up to 700 km) were highlighted showing the importance of the human-mediated factors in infectious diseases spillover (Villatoro et al., 2016).

Our finding indicated that the female dogs produced 1 litter per year and the average litter size was 5 pups as reported in South Africa (Conan et al., 2017) and Chile (Acosta-Jamett et al., 2010) and higher than what was recorded in Australia 3.3 pups per litter (Hudson et al., 2018). In light of these results, sterilization of females in rural areas is strongly recommended as it allows stabilization of the free-roaming population by reducing the population turnover rate.

In the current study, the vaccination coverage as checked by marking the dogs with collars was higher than the threshold of 70.0% recommended by the WHO (Coleman and Dye, 1996; WHO, 2005). It is estimated to be 84.2% and 77.8% in the rural and urban sites, respectively. The difference in the vaccination coverage between the two sites can be explained by the difference in the number of free-roaming dogs at both sites. Previous studies conducted in Tunisia reported a low vaccination coverage that varied from 53% and 75% among the urban and rural areas which was lower than the values found in our study (Touihri et al., 2011). As it was shown in our study the vaccination coverage was always better in rural areas than in urban areas (Touihri et al., 2011).

Our study emphasized that the control of canine diseases is highly feasible and highlighted key issues that are required for the success of future control programs of these diseases.

6. Conclusion

In the present survey, we analyzed key demographic parameters of owned and free-roaming dogs in the north of Tunisia (urban and rural sites). Results of this study may be essential for the control of rabies and other canine diseases and will be useful for the management of dog population. This study showed that the eradication of rabies is feasible because the accessibility of owned dogs was high and the size of free-roaming population was rather low compared to the owned dogs. Information provided by this study was in part similar to the previous studies conducted in Tunisia. For this reason, detailed studies that target the renewal and mortality rates in owned and free-roaming dogs are now needed.

Declarations

Author contribution statement

S. Kalthoum: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

C. Ben Salah: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

H. Rzeigui, C: Bahloul: Contributed reagents, materials, analysis tools or data; Wrote the paper.

R. Gharbi, K. Guesmi, A. Ben Salem, S. Ferchichi, F. Zammel, N. Fatnassi: Performed the experiments.

C. Seghaier: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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