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A Preliminary Survey of Pet Dogs Roaming Behaviour in the Periphery of Protected Area in Bhutan: A Case Study in Haa District

Tshering Dorji[1,2*], Tenzin Tenzin[3], Karma Rinzin[4], Hiruka Mahat[5], Waraphon Phimpraphai[1] and Michel de Garine-Wichatitsky[1,6,7]

Abstract

Free-roaming pet dogs pose threats to humans, livestock, wild animals, and the environment through dog bites and the transmission of diseases. We used TK-STAR© GPS-collars designed for tracking pet dogs to study the movement distance and activity range of pet dogs in Haa, western Bhutan. A total of 34 dogs or pet dogs (Uesu gewog, *n* = 17; Katsho gewog, *n* = 17) consisting of 18 (53%) female and 16 (47%) male dogs were collared to trace their movement pattern for 24 hours. In total, 8,109 GPS fixes were recorded and pet dogs travelled a distance of 258.5 ± 8.0 m (mean ± SE), and the maximum distance travelled was 9,472 m in 24 hours. The maximum distance travelled by pet dogs in Katsho and Uesu were 7,916.25 and 9,472 m respectively. The daily activities of pet dogs which include a search for food, exercise, walking, playing, and hunting were less than 1,500 m^2. The 95% activity range of pet dogs in Uesu was 1,440 m^2 and 1,200 m^2 in Katsho gewog without any significant differences between the two gewogs. The majority (81%) of the GPS fixes were located within the gewogs and most of the dogs remained close to human settlements. None of the tracked dogs of Uesu and Katsho gewog entered protected areas. One of the pet dogs that travelled approximately 5,000 m from the home premises of the owner was found to be seropositive against canine distemper virus indicating a risk of disease transmission from dogs to endangered wildlife. So, it is recommended to make pet owners responsible by providing training on proper housing and management to control the country's free-roaming pet dog population.

Keywords: Bhutan, GPS collar, movement, pet dogs, protected area

[1] Kasetsart University, Faculty of Veterinary Medicine, Bangkok, Thailand
[2] Regional Livestock Development Center, Department of Livestock, Zhemgang, Bhutan
[3] National Centre for Animal Health, Department of Livestock, Thimphu, Bhutan (previous affiliation); World Organisation for Animal Health, Gaborone, Botswana (current affiliation)
[4] Animal Health Division, Department of Livestock, Thimphu, Bhutan (previous affiliation); World Organisation for Animal Health, Bangkok, Thailand (current affiliation)
[5] National Center for Animal Health, Department of Livestock, Thimphu, Bhutan
[6] CIRAD, UMR ASTRE, Montpellier, France
[7] ASTRE, Univ Montpellier, CIRAD, INRA, Bangkok, Thailand
*Corresponding Author: tsheringdorjitalop@gmail.com
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Introduction

In most places around the world, particularly in the least developed and middle-income countries, domestic pet dogs are allowed to roam freely without confinement and human supervision (Dalla Villa *et al*., 2010; Belsare and Gompper, 2013). Roaming distances, patterns, and spatial activities of pet dogs potentially result in contact with wildlife, livestock, and human in space and time resulting in transmission of diseases from dogs to humans, livestock, and wildlife (Alexander and Appel, 1994; Gortázar *et al*., 2007; Kesteren *et al*., 2013; Otranto *et al*., 2015; Hudson *et al*., 2017). Domestic dogs pose significant threats to humans (Vanak and Gompper, 2009; Morters *et al*., 2014) through dog bites which may result in injuries and death or transmission of diseases, particularly rabies (Salb *et al*., 2008; Doherty *et al*., 2015; Devleesschauwer *et al*., 2016). Additionally, free-roaming dogs including pet dogs are responsible for significant social and economic loss due to the death of a human by rabies and post-bite treatment (Knobel, 2005; Lim, 2012; Czupryna, 2016).

The number of rabies cases due to dog bites is less in developed countries than in developing nations (Wunner and Briggs 2010). Including rabies, more than 60 zoonoses are associated with dogs (Knobel, 2005; Dalla Villa *et al*., 2010). For instance, a study has shown that 99% of pet dogs act as a reservoir for one or more gastrointestinal zoonotic parasites in the tea-growing community in Assam, India (Traub *et al*., 2002). Similarly, pet dogs harbour some vector-borne diseases such as Leishmania that can be transmitted to humans (Day, 2011). The magnitude of problems associated with free-roaming pet dogs is negatively correlated with the UN's Human Development Index (HDI) standardized for an individual country.

Challenges posed to wildlife by pet dog-transmitted diseases have been described a long time back; however, conservationists paid attention to the problem recently only (Ward, 2015). For instance, rabies and Canine Distemper (CD) virus transmission via pet dogs have reduced the population of endangered Ethiopian wolves *(Canis simensis)* by around 75% over the last 20 years (Lim, 2012; Sepúlveda, 2015). Some recent ecological studies have shown that free-roaming dogs are responsible for the high losses of native mammals (Zapata, 2016). For example, in Cayambe-Coca National Park in the northern Ecuadorian Andes, in areas where feral dogs that originated from abandoned pet dogs are present, four native mammals are absent: mountain coati (*Nasuella olivacea*), mountain paca (*Cuniculus taczanowskii*), long-tailed weasel (*Mustella frenata*), and northern pudu (*Pudu mephistophiles*) (Zapata, 2016). In addition to the loss of native mammals, there are also significant alterations in habitat patterns used by wild animals in areas where there are free-roaming pet dogs (Zapata, 2016). Domestic pet dogs when left free to move may also spread diseases to wild canids and felids, potentially representing a threat to endangered protected species such as Tigers (*Panthera tigris*), Snow leopards (*Panthera uncia*), Dhole (*Cuon alpinus*), and other species.

In Bhutan, it is mandatory to maintain at least 60% of Bhutan's national territory under forest cover by Constitution. Therefore, several parks and protected areas are established in the country (Namgay, 2010). Also, Bhutan is part of one of the biological hotspots with exceptional diversity and originality of flora and fauna that include iconic endangered carnivores such as Tiger, Dhole and Snow leopard, and ungulates such as Takin (*Budorcas taxicolor*), Himalayan musk deer (*Moschus chrysogaster*), and Blue sheep (*Pseudois nayaur*). The conservation policies allow farmers to live within and adjacent to the protected areas, which is one of the challenges for the conservation programme despite the presence of rules and regulations for using natural resources and agriculture practices (Wang, 2006). On the other hand, communities residing within and in the periphery of protected areas face several challenges in terms of crop loss and livestock predation by wildlife.

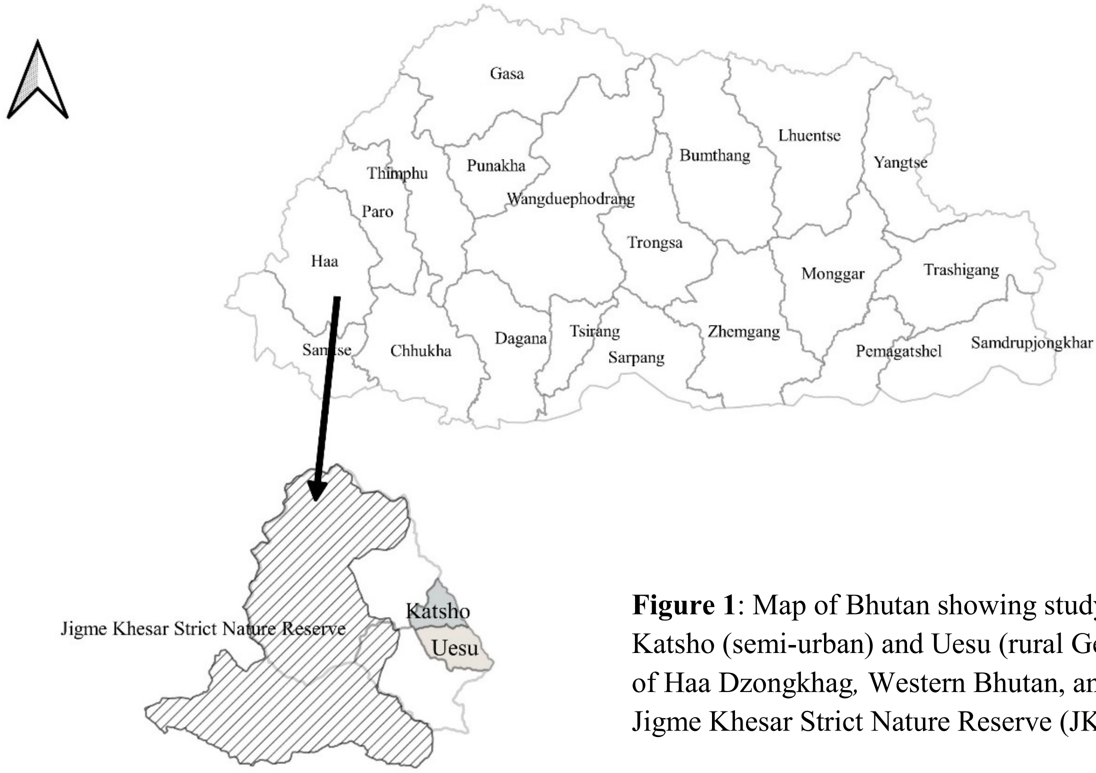

Figure 1: Map of Bhutan showing study area Katsho (semi-urban) and Uesu (rural Gewogs) of Haa Dzongkhag, Western Bhutan, and the Jigme Khesar Strict Nature Reserve (JKSNR)

Approximately 47% of livestock are being affected due to predation. Generally, the prey-predator relationship is dependent on altitude and habitat differences but in Bhutan, Leopards are the main predators affecting livestock, followed by Dhole, Tiger, and Bear (Choden, 2016; Rajaratnam *et al*., 2016).

A large number of free-roaming dogs including pet dogs have conservation impacts on wildlife. For instance, Jigme Khesar Strict Nature Reserve (JKSNR) in Haa district rescued more than 12 different wild animal species in 2017 from dog attacks, mainly Sambar deer (*Cervus unicolor*). Wild animals attacked by dogs are noticed in and around human settlements both in town and rural areas, though the frequencies are higher in remote rural areas. Also, many cases of human-wildlife conflict remain unnoticed and unreported.

Based on the dependency of dogs on humans for food and shelters, they can be classified as; i) "pet dogs", which completely depend on humans for food and are confined at least part of the time, ii) "free-roaming dogs" that depend on humans in part of their food supply only, and iii) "feral dogs" which are completely independent on humans (Slater *et al*., 2008; Blouin, 2013). The community of Haa in west Bhutan distinguished three categories of dogs: pet, stray/free-roaming, and feral dogs based on the dependency on food and shelter, which are the accepted standards of classification (Dorji *et al*., 2020). Abandoned pet dogs could be the source of feral and stray dogs (Headley *et al*., 2013; McNeill *et al*., 2016; Dorji *et al*., 2020). A previous community-based survey carried out in the periphery of JKSNR found that the free-roaming and feral dogs are the main threats to humans, livestock, and wildlife (Dorji *et al*., 2020). Many pet dog owners perceive that on average their pet dogs would travel less than half a kilometre from their homestead, but a few of them perceive that the dogs travel more than 10 kilometres from their homestead (Dorji *et al*., 2020). Moreover, many pet dogs share a habitat with wildlife in the periphery of human settlements (Otranto *et al*., 2015; Hudson *et al*., 2017). However, there is no science-based evidence documenting movements of pet dogs in Bhutan. Study of

Figure 2: The TK-STAR Global Positioning System (GPS) tracker device is applied to the pet dog by the pet dog owner (Photo-TKSTAR TECHNOLOGY CO., LIMITED, http://2.tkstargps.net)

distances travelled by pet dogs using Global Positioning System (GPS) tools will help in planning and imparting responsible pet ownership such as providing proper dog housing, feeding system, and health management.

Over the past decades, GPS is fitted on free-roaming animals to study animal behaviour, home range estimation, habitat use, and activity with precision and accuracy (Zumberge *et al.*, 1997; Bakuła *et al.*, 2015). Furthermore, GPS fitted on smaller animals such as cats and dogs helps in monitoring their movements and tracing pet dogs by their owners in managing pets (Pérez *et al.*, 2018). GPS device captures movement points through a GPS radio collar better compared to ground-based radio telemetry because of real-time messaging and notification systems available through use of a mobile phone. In particular, the availability of cheaper and more robust GPS devices has enabled monitoring of pet dogs' movements and studying impacts of free-roaming dogs in several parts of the world (McNeill *et al.*, 2016; Jin *et al.*, 2017; Pérez *et al.*, 2018).

In Bhutan, Tenzin *et al.* (2013) conducted a study to determine and understand the home range and roaming activity of free-roaming dogs using GPS radio collars over one month in Gelephu, south-central Bhutan. However, there is no study on the dog-wildlife interface and roaming behaviour of pet dogs in determining the distances travelled by them both within and outside the protected areas. Such studies are necessary to understand the movement patterns of domestic dogs in protected areas since close interaction of pet dogs with wildlife would result in predation of wildlife and has a risk of disease transmission to wildlife and vice versa. Also, understanding the frequencies of domestic dog-wildlife interaction would help in making evidence-based policy decisions for free-roaming dog population management and wildlife conservation in Bhutan. In this study, we explored the roaming behaviour and spatial distribution pattern of pet dogs using GPS radio collars in Haa, which is adjacent to the JKSNR.

Materials and Methods

Study area

The study was conducted at the periphery of JKSNR in Haa *Dzongkhag* (district), western part of Bhutan (Figure 1). This protected area was established in 1993 by the Royal Government of Bhutan. This is the only protected area without permanent human settlements in Bhutan, except for a few migratory yak herding communities. A total of 29 species of mammals, 161 species of birds, 64 species of butterflies, and seven species of fish are known to occur in this park (Wangyal *et al.*, 2020). It is home to endangered species such as the Snow Leopard (*Panthera uncia*), Red Panda (*Ailurus fulgens*), Tibetan Snowcock (*Tetraogallus tibetanus*), and Rufous Necked Hornbill (*Aceros nipalensis*). It is also part of the transboundary

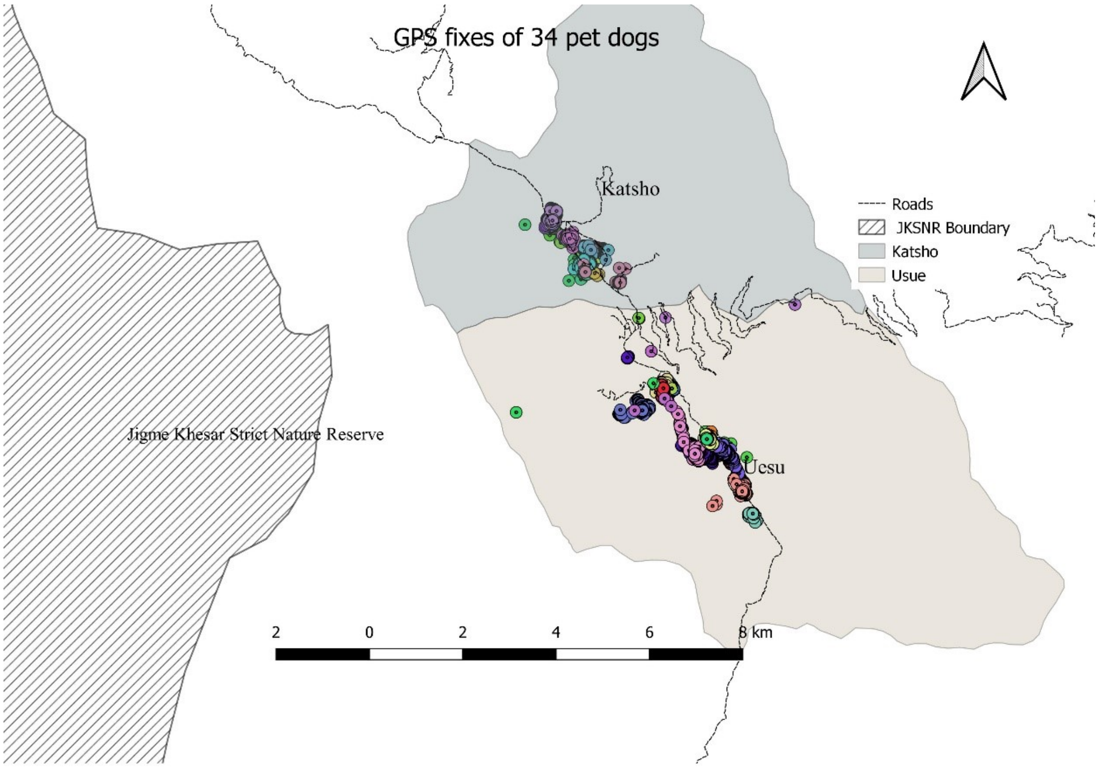

Figure 3: Spatial activity and distribution of 8,109 GPS fixes from all 34 pet dogs in Uesu and Katsho gewog with each point colour representing an individual pet dog

conservation landscape - the Kangchenjunga landscape – that extends up to Sikkim in India and Nepal.

Haa Dzongkhag has six *gewogs* (sub-districts) and we have selected one semi-urban Katsho gewog (town) and one adjacent rural Uesu gewog. These two gewogs are approximately six kilometres away from JKSNR boundary (Figure 1). These communities rear yaks which graze on rangelands located in the protected area.

Selection of pet dogs for the GPS-tracking study

There are 455 registered households and approximately 300 owned dogs in these two gewogs. We selected 34 dogs in this study that constitute little more than 10% of the owned dog population. The pet dogs were selected based on the willingness of the pet owners to participate in the study. We have purposively selected dogs that were 6 months old and above for collaring of GPS tracking devices assuming that they are adult enough and would move out of the homestead. About an equal number of males (n = 18) and females (n = 16) with a total of 34 pet dogs were selected from both the study sites. Serum samples from all the GPS-collared pet dogs, along with stray dogs were collected to determine seroprevalence of canine distemper virus (CDV) in the previous study (Dorji *et al.*, 2020). The approximate distances travelled by the pet dogs were also obtained from the pet owners during the previous study.

GPS radio collar and movement tracking

Initially, three different GPS brands: GPS Pet Tracker Tracer, Pet Locator, and TK-STAR GPS tracker on 10 dogs from March-April 2018 were tagged to give accurate data. TK-STAR GPS tracker was chosen based on its accuracy of recording GPS data (TK-STAR GPS was found to be within 5-10 m similar to Garmin GPS), ease of downloading data remotely, and affordable cost of the device. The GPS collar setting was done to record the geo-coordinates every 10 minutes by considering the battery lifespan of the device (the battery lifespan ranged from 2 d to 7 days).

Ten TK-STAR© GPS collars designed for tracking pet dogs were purchased and fitted around the neck of the dogs. The GPS collar supports the GSI/GSM system, which allows two way-communications through GPRS/ internet to track online movements of pet dogs via the website server 2.tkstargprs.net. The GPS also has a short messaging system to communicate via short message service and a real-time tracking option through a mobile phone application.

Details of the dogs such as age, breed, sex, whether confined within the home premises, neuter status, vaccination status against rabies, and CDV were collected for each dog included in the experiment. The GPS point location of each dog within the pet dog owner's house premises was also recorded at the starting point before fixing GPS collar. Battery life of the GPS device and the movement pattern of the dogs were monitored using a smartphone. The study duration for each dog lasted from 2 to 7 days with an average of 4 days. To avoid data variation bias because of differences in the number of days, data for 24 hours were analyzed. GPS collars were fitted to individual dogs for the first cohort consisting of 10 pet dogs and were observed for their movements until the battery lifespan of the devices got exhausted. The GPS devices were retrieved and then put on another batch of dogs, and so on until all 34 pet dogs' movement distances were observed. The field study was conducted between 11 August and 4 December 2018.

Data management and analysis

The GPS data were downloaded from the server

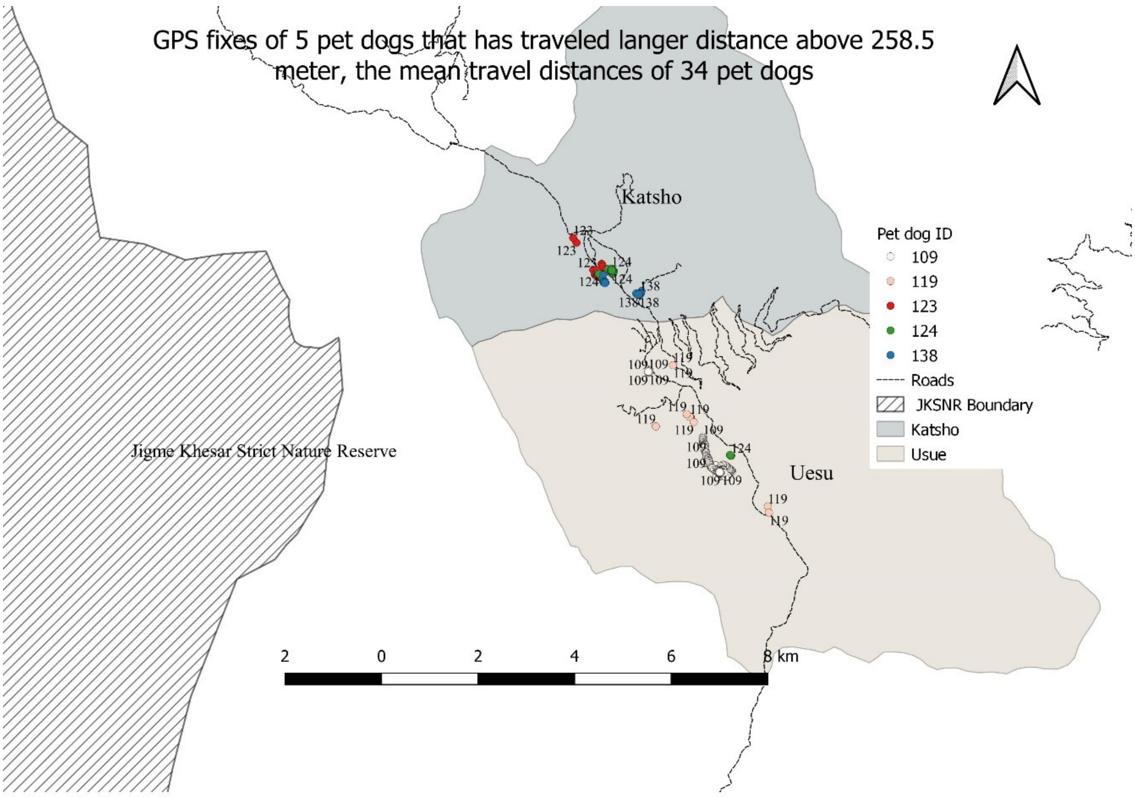

Figure 4: Map of long-distance movement of 5 pet dogs during the GPS tracking session carried out between 12th August and 4th December 2018 in Uesu and Katsho gewogs, Haa. The average mean distances covered by the 34 pet dogs were 258.5 m (SE = 8) and those pet dogs (> 258.5 m) were considered to travel longer distances within 24 hours

(http://2.tkstargps.net) as comma-separated value files by using the EMI/ID of the individual GPS devices. We corrected and standardized the data from all pet dogs to a period of 24 hours tracking sessions for further analysis because the GPS devices captured movement data for all the collared dogs for 24 hours.

The data were analyzed in R version 3.5.2 (R core Team, 2017) by using the "adehabitatHR", "gdal", and "sp" packages. Spatial activities of dogs in square metres and their movement points were analyzed. The mean roaming distance for each pet dog was calculated. Based on the mean roaming distance (258.5 m in 24

Table 1: Characteristics and management of selected pet dogs in Uesu and Katsho (n = 34)

Variables/categories	**Uesu/Rural** ***n (%)***	**Katsho/ Semi-urban** ***n (%)***	**χ^2/Fischer exact/ Student *t test significance***
Gender			
Male			No significant (NS)
Female			
Breed			
Local and Bhutanese Mastiff	12 (71)	12 (71)	NS
Exotic	5 (29)	5 (29)	
Age (month)			
07-Dec	4 (24)	1 (6)	***
13-24	2 (12)	8 (47)	
24-60	9 (52)	6 (35)	
>60	2 (12)	2 (12)	
Physical Body Condition			
Obese	1 (6)	0 (0)	NS
Very Healthy	1 (6)	1 (6)	
Healthy	15 (88)	15 (88)	
Weak	0	1 (6)	
Very weak			
Dog kennel availability			
Yes	9 (53)	8 (47)	NS
No	8 (47)	9 (53)	
Neuter status			
Neutered	11(65)	10 (59)	NS
Not neutered	6 (35)	7(41)	
Distance roaming (>258.5 m)			
Yes	2(12)	5 (29)	**
No	15 (88)	12 (71)	
Vaccination against rabies			
Yes	12(71)	11 (65)	NS
No	5 (29)	6 (35)	
Vaccination against other infectious diseases (DHPPi+L)			
Yes	1 (6)	4 (24)	NS

Significance code: (χ^2 test) NS $p > 0.05$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Distances covered by individual dogs during the GPS tracking session (2-7 days) from the homestead point

Dog ID	GPS tracking session	Movement distance (metre)		
		Minimum	Maximum	Mean
105	6 days	2.2	413.3	93.3
106	6 days	10.2	9472.2	139.3
107	7 days	4.5	1106.2	137.1
108	5 days	2.2	180.1	41.2
109	5 days	2.1	2918.6	2484.1
110	4 days	2.9	503.8	83.5
111	3 days	2.2	202.3	40.4
112	4 days	2.2	108.5	25.5
113	4 days	1.1	210.2	39.2
114	3 days	2.3	199.1	30.1
115	5 days	2.2	1014.1	45.9
116	3 days	0.98	104.2	26.2
117	7 days	3.9	241.5	24.2
118	2 days	24.2	274.6	109.2
119	4 days	689.4	1320.4	885.2
120	2 days	2.9	243.7	86
121	4 days	2.4	692.4	53.1
122	3 days	1.9	4471.3	65.6
123	6 days	5.4	4738.4	535.2
124	6 days	13.6	4739	585.2
125	4 days	2.96	5591.7	46.2
126	3 days	13	352.4	58.5
127	6 days	1	286.2	65.1
128	5 days	1.9	232.5	41.9
129	2 days	3.5	507.3	31.6
130	4 days	2.2	4416.2	31.2
131	4 days	6	320.6	33.7
132	2 days	172	292.1	244.9
133	5 days	2.42	294.6	35.9
134	4 days	17	358.7	66.8
135	5 days	1.1	216.6	47.4
136	3 days	1.9	56.4	26.8
137	3 days	146.9	358.12	188.8
138	5 days	27.1	867.4	717.7

hours), the pet dogs were grouped and coded as below and above, and treated as a dependent variable in logistic regression. A logistic regression analysis was performed to find out factors associated with the roaming distance (above and below the mean value) of the pet dogs. The pet dogs' basic characteristics (e.g., breed, sex, age, physical body condition) and management practices (e.g., sterilization, confinement of dogs through housing, and vaccination against rabies and other major canine infectious diseases) were treated as independent variables in the model. Initially, logistic regression was conducted by considering the roaming distance of dogs that travelled above 258.5 m as a dependent variable with all the above-mentioned variables as independent variables. Only those independent variables with a p-value of ≤ 0.25 were selected for the multivariate logistic regression model. The final models were built using forward stepwise elimination methods and variables with a p-value of ≤ 0.05 were considered significant and retained in the final model. The spatial distribution of GPS fixes data was analyzed using QGIS version 3.16 (Hannover).

Results and Discussion

Characteristics of pet dogs

The majority (71%) of the pet dogs from both the study sites were local and Bhutanese Mastiffs, while the rest (29%) were exotic breeds including Labrador, German and Shepherd. The age of the dogs ranged from 7 months to 12 years with an average of 36 months. There was a higher proportion of young dogs (13-24 months old) in Katsho (47%) than in the Uesu (24%). Most of the pet dogs (88%) were classified as healthy based on the body condition score. There were no differences observed between the two gewogs with regard to the provision of pet dog house, sterilization status, and health-related management (e.g., vaccination against rabies, Canine Distemper, Canine Parvo, Canine Hepatitis, Canine Influenza, Canine Para-influenza, and Canine Leptospirosis) (Table1).

Movements and roaming distances of pet dogs

In total, 8,109 GPS fixes were recorded from 34 dogs' GPS tracking sessions between 11 August and 4 December 2018. The majority (81%) of the GPS fixes of the pet dogs were located within the gewog and remained close to human settlements (Figure 2). Only one of the pet dogs (Dog ID 124) from Katsho travelled beyond the gewog boundary along the main highway. None of the tracked pet dogs entered the protected areas during the experiment. The distances covered by individual dogs during the GPS tracking session (2-7 days) are shown in Table 2.

The average distance travelled by the pet dogs in 24 hours was 258.5 ± 8.0 m (mean ± standard error of the mean). The maximum distance travelled by pet dogs was 9,472 m with a mean distance of 299 m (SE = 7.97) in Uesu gewog while the maximum distance travelled in Katsho gewog was 7,916 m with a mean distance of 206 m (SE = 8.69). The maximum distance (9,427 m) roamed by one of the pet dogs in Uesu was identified as a one-year apparently healthy, local, and not neutered female dog, which was not confined within the home premises and was also not vaccinated against rabies and canine distemper virus. Similarly, one of the pet dogs that travelled the maximum distance of 7,916 m in Katsho was a 7-month-old, apparently healthy, local, and not neutered male dog, and this dog was not confined but was vaccinated against rabies only. The 95% activity range of pet dogs was 1,440 m^2 in Uesu and 1,200 m^2 in Katsho.

Factors associated with long-distance roaming of dogs

Most of the tracked pet dogs (85%) remained within a distance of 260 m from the human settlement and around the homestead. Pet dogs that do not have proper houses are more likely to roam long distances from the human settlements (odds ratio: 1.3; 95% CI: 1.2-1.5) than those dogs that have proper houses (Table 3, Figure 4).

The movement of pet dogs and risk of disease transmission to human-livestock-wildlife and environment interface

In both the communities, more than 70% of the pet dogs were vaccinated against rabies during the nationwide vaccination programme. However, majority (80%) of the pet dogs were not vaccinated against other major infectious canine diseases such as Canine Distemper, Canine Parvo, Canine Hepatitis, Canine Influenza, Canine Para-influenza, and Canine Leptospirosis. The six dogs that travelled longer distances (> 258.5 m) from the human settlements were mostly not neutered, not vaccinated against the

DHPPi+L diseases, and had no proper housing (Table 4). Due to the poor vaccination coverage to protect the population immunity (> 80-90%), there is a possible risk of spreading infectious canine diseases.

This study corroborates with the pet dog owners' perceptions of their dog's roaming behaviour from earlier studies (Dorji *et al.*, 2020). This study records the distances and activity range that pet dogs travel in Katsho and Uesu gewogs of Haa districts in west Bhutan. The results from our GPS tracking study are consistent with the previous study on the community perception that the majority of pet dogs travel less or equal to 1 km from human settlements (Dorji *et al.*, 2020), and no pet dogs entered the protected area. In the previous study, most of the pet dog owners estimated that their pet dogs would remain within less than 1 km of their house, either during the day or night, while only a few pet dog owners opined that their pet dogs would travel more than 10 km away from their homestead (Dorji *et al.*, 2020). We believe that the activity range of pet dogs in Haa is smaller compared to similar studies conducted with pet dogs in Gelephu town area of south Bhutan (Tenzin *et al.*, 2013) and in Australia (Hudson *et al.*, 2017). However, the GPS tracking revealed that few pet dogs (18%) in the current study travelled more than 5 km, which is similar to the results found in Chile (Pérez *et al.*, 2018). The duration for the GPS tracking was short (24 hours) in our study because of the short battery life used in GPS devises and also was not extended to different seasons. It is important to study the activity range for a longer period and over different seasons to account for the seasonal factors associated with the roaming behaviour of pet dogs because seasons affect the roaming distances of pet dogs (Hall *et al.*, 2021).

Understanding the distances travelled and activity ranges of pet dogs is important in Haa because the human settlements are close to the protected area (approximately 6 km away from JKSNR). Consequently, this proximity probably results in human-wildlife conflicts (Wangchuk *et al.*, 2018) (depredation of wildlife) and also a risk of disease transmission from pet dogs to wildlife and vice versa. For instance, in JKSNR in Haa district, more than 12 different wild animal species were rescued in 2017 from free-roaming dogs which included pet dog attacks, mainly the Sambar deer (*Cervus unicolor*). Although wild animal attacks by dogs are reported in and around human settlements, the attack frequencies are higher in rural areas which have similar patterns elsewhere (Sepúlveda *et al.*, 2014). However, many human-wildlife conflicts are unreported to park officials. One possible explanation is that the dogs attack wild animals (e.g., Sambar deer) when the wild herbivores intrude or raid agricultural crops because the dogs are kept as guards to protect agricultural crops and properties like in any other countries (Warembourg *et al.*, 2021).

One of the pet dogs (infected with Canine Distemper Virus) travelled a longer distance of about 5 km (Dorji *et al.*, 2020). This finding is essential information for wildlife conservationists and also to dog population management agencies in Bhutan because these infected dogs could be a source of spillover infections of such diseases to wild animals, which could threaten endangered species (Woodroffe and Donnelly, 2011; Martinez-Gutierrez and Ruiz-Saenz, 2016).

Also, free-roaming pet dogs may pose risks to humans because dogs harbour more than 60 types of zoonotic parasites (Macpherson, 2012). Therefore, the dog population should be

Table 3: Final logistic regression model associated with long-distance movement of dogs in Uesu and Katsho

Variable	Coefficient	SE	*p*-value (Sig.)	Odds Ratio (95% CI)
Housing				
Yes	1.742	0.081	0.11	1.3 (1.2-1.5)
No	0.25	0.113	0.03	

Table 4: The characteristics of 5 pet dogs that travelled longer distances during the GPS tracking session

Dog Id	Breed	Sex	Age in month	Physical body condition	DHPPi+L vaccination	CDV antibody	Neuter status	Housing/ confinement
109	Local	female	12	healthy	Not vaccinated	Positive	Not neutered	Not available
119	Local	male	36	healthy	Not vaccinated	Negative	Not neutered	Not available
123	Local	female	36	healthy	Not vaccinated	Negative	Not neutered	Not available
124	Local	male	24	weak	Not vaccinated	Negative	Neutered	Not available
138	exotic	female	24	healthy	Not vaccinated	Negative	Not neutered	Available

controlled by encouraging responsible pet ownership in order to reduce the risk of human-livestock-wildlife-environment conflicts because one of the main causes for the increasing number of stray and feral dogs is a consequence of abandoned pet dogs (Rohlf *et al*., 2010; Acosta-Jamett *et al*., 2011; Villatoro, 2016). Also, education and awareness of waste management practices are keys to reducing free-roaming pet dog population in Bhutan as they forage on such waste.

Conclusion

Our preliminary study suggests that most of the pet dogs in Haa remained within and around human settlements, and do not travel long distance. No pet dogs, collared with GPS devices, entered the adjoining protected area within 24 hours of the study duration. However, some pet dogs travel longer distances that could intrude into the protected areas which could result in human-wildlife conflicts and increase the risk of disease transmissions. We encourage responsible pet ownership through confinement and good management practices to reduce conflicts at the dog-human-livestock-wildlife-environment interface in the country.

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Availability of data and materials
All data generated or analyzed during this study are included in the result section. The full datasets will be made available from the corresponding author upon request.

Ethics approval and consent to participate
This study was approved by the Research Ethics Board, Department of Livestock, Ministry of Agriculture and Forests, Bhutan (vide letter No. DoL/Gen/RED/2017–18/056/Feb-11/18). Verbal consent was obtained from all participating pet dog owners for serum sample collection and collaring of GPS devices.

Consent for publication
Not applicable.

Competing Interests
Declared there is no competing interest among the authors.

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