THE SPATIAL AND PARASITE/DISEASE ECOLOGY OF DOMESTIC DOGS IN RURAL LAIKIPIA; IMPLICATIONS FOR WILD CARNIVORE DISEASE DYNAMICS

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Abstract

Understanding the spatial and behavioral ecology of domestic dogs (*Canis familiaris*) is essential for mitigating disease transmission between domestic animals and wildlife, especially for large carnivores of conservation concern (e.g., lions (*Panthera leo*) and wild dogs (*Lycaon pictus*)). Domestic dogs represent an ecologically important host and reservoir for many wildlife diseases known to impact endangered carnivores (e.g., canine distemper virus and rabies), yet so far, the role of domestic dogs in carnivore disease transmission dynamics in Africa remains extremely limited. One particular area of research lacking for domestic dogs in Africa, and vital to understanding disease transmission patterns, is general movement patterns and spatial ecology of these animals in rural communities. Although such data are vital to both modeling and predicting pathogen spread and as such represent a fundamental aspect of any disease management strategy, they are completely lacking for most environments across Africa Using GPS tracking devices combined with laboratory analysis of pathogens (parasites and diseases), I addressed questions of how spatial ecology of domestic dogs varies based on functional role of animals and across time and how these variations influence parasite/disease burden for a population of domestic dogs living along Kenya's human-wildlife-livestock interface. A total of 50 dogs were fit with satellite tracking collars on two communally owned properties, name the properties here!, located in Laikipia County, Kenya. Faecal material, ectoparasites and blood samples were collected and analyzed to help explain pathogen diversity in dogs. Home ranges and movement patterns were estimated using home range tools in the program ArcGIS 10.1. Two factor ANOVA and regression analysis were used to statistically examine patterns of or related interactions between movement and the parasites data. Spatial patterns qualitatively indicated that both herding and home dogs maintained close associations with their home bomas, although individuals utilized multiple bomas throughout the study period. Results from all seasons indicated that domestic dogs infrequently moved into surrounding conservancies, with dogs found along conservancy borders showing more frequent incursions. Large overlap between dogs was recorded with herding dogs supporting higher ectoparasite loads and broader movement patterns with larger home ranges as compared to home dogs. Blood samples collected from this study were bio-banked to allow future screening for blood-borne pathogens which will allow more comparison with the dataset that already exists. This study provides one of the most in-depth assessments of domestic dog ecology and pathogen burdens along Kenya's human-

wildlife-livestock interface. On the other hand, it also provides vital information for effective management of carnivore communities since some interactions were recorded between wild carnivores and domestic dogs where a total of six dogs were preyed on by hyenas and leopards.

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List of Acronyms

MRC	Mpala Research Centre
LRVC	Laikipia Rabies Vaccination Campaign
ANOVA	Analysis of Variance
MSC	Masters of Science
CPV	Canine Parvovirus
CDV	Canine Distemper Virus
GPS	Global Positioning System
USD	United States Dollar
USB	Universal Serial Bus
PIT	Passive Integrated Transponder
CSV	Comma-Separated Values
GIS	Geographic Information System

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CHAPTER ONE

1.1 Background

Domestic dogs (*Canis familiaris*) have been shown to be the most abundant and widely distributed carnivore species worldwide (Green & Gipson, 1994; Daniel & Bekoff, 1989; Gerardo, 2009), arguably as a product of expanding human populations (Butler and Toit, 2001). In Africa, domestic dogs have been used for different roles including; a) security at homes, b) herding livestock, c) hunting, d) assisting police and military and, e) companionship (Kubois du Toit, 2008). Every role played by a dog affects its behaviour and probably its movement patterns and thus may impact the environment differently. For instance, in Zimbabwe, free-ranging domestic dogs scavenged carcasses at any time with a peak at dawn (Butler and du Toit, 2002) where generally, dogs are both diurnal and nocturnal, which gives them a better opportunity to scavenge and hunt.

Dogs are potentially effective predators of native fauna and can therefore have competitive interactions with endemic wild carnivores (Butler *et al*. 2003) with an implication on diseases and their transmission. Furthermore, domestic dogs have been recognized as reservoirs of several wildlife diseases (Lembo *et al.* 2008, Woodroffe & Donnelly, 2011) of conservation concern. Despite documentation of domestic dogs as major reservoirs for diseases that threaten endangered African carnivores, little is known of how diseases are actually transmitted from domestic dogs to these species and vice versa (Woodroffe *et al.* 2012). According to Alexander and Appel (1994), diseases are transmitted readily between susceptible species, but domestic dogs remain primary reservoirs for these diseases (Gorhan, 1996). Knowledge of infection reservoir dynamics including movement patterns, are critical for effective disease control

(Lembo *et al*. 2008) as intrinsic factors within the host function to determine temporal dynamics of viral pathogens (Parker *et al*. 1999). Such factors include the hosts immune system, behavior, and spatial distribution (Anderson & May 1991). All the same, few studies have focused on the long-term effects of diseases on wildlife (Grenfell & Gulland 1995) with even fewer addressing the functional significance of the ecology of host reservoirs in species to species transmission dynamics.

Laikipia ecosystems, located in Kenya's northern part of the Rift Valley, are known to be landscapes where wildlife freely co-exists with human beings, providing a greater opportunity for contact between wild and domestic animals, ultimately creating a greater risk of exposure to pathogens with diverse transmission mechanisms (Woodroffe *et al*. 2011). The human-wildlife-livestock interface has made Laikipia an epicenter for research on human-wildlife conflict, including assessments of human-carnivore interactions. However, the interaction between wild and domestic carnivores is yet to be addressed in this well-studied system. This study sought - to understand the interaction between domestic and wild carnivore species in terms of parasite and disease transmission. In particular the study investigated the movement patterns and behaviors of domestic dogs as well as their pathogen communities to elucidate their role in carnivore disease dynamics in Laikipia County, Kenya.

1.2 Rationale

The abundance of domestic dogs has been well documented (Green and Gipson, 1994; Daniel & Bekoff, 1989) with studies describing them as the most abundant and widely distributed carnivore species worldwide (Gerardo, 2009). Census surveys of domestic dogs in Kenya and Zimbabwe have shown rapid population rises and this is attributed to the rising human population (Waiboci, 2009; Butler & Bingham, 2000). For regions such as Laikipia County, Kenya, human population increase has led to people encroaching on wildlife ranches, parks and reserves, creating a juxtaposition of conserved lands and areas of high human habitation, which aggravates human-wildlife conflicts. One such source of conflict for this region is the increase in domestic dogs. The domestic dogs constitute an important component of rural landscapes where they pose various threats to local wildlife. Disease transmission to wild carnivores in particular poses one of the greatest threats to wildlife, especially for species of conservation concern. Dogs are recognized as important players in many zoonotic diseases and they have also been implicated as the source of infection for several disease outbreaks affecting wild carnivores, including canine distemper virus (CDV) and rabies, which have caused epidemics in wild carnivore populations (CDV in lions: Roelke-Parker *et al*., 1996; Rabies in Ethiopian wolves (*Canis simiensis)*: Laurenson *et al*., 1998). Despite this fact, knowledge of how different behaviors impact the environment, including disease transmission to other closely related, yet wild carnivore species, remains limited.

1.3 Problem statement

The conservation of the world's biological resources is imperiled by habitat loss, over-harvesting and pollution. In addition, although infectious diseases have been ignored as a minor problem to conservation, they are a threat that conservationists have not been able to handle over the past couple of years (Woodroffe, 1999). Studies have shown that diseases pose a very serious problem of concern to endangered species (Dobson, 1993), creating a concern that scientists should gear up towards trying to fight out this huge epidemic.

Domestic dogs are often assumed to act as 'reservoir hosts' for pathogens (Woodroffe and Donnelly, 2011), supporting diseases of conservation concern that require knowledge of infection reservoir dynamics among dogs including movement patterns, to effectively control disease outbreaks (Lembo *et al*. 2008). In Africa, several critical cases lends credence to the need for increased monitoring of spatial interactions between domestic and wild carnivores. Domestic dogs could potentially function as key players in disease transmission in landscapes, such as Laikipia's, where domestic dogs live at higher densities with increased encounters between the dogs themselves, and between the dogs and wild carnivores.

1.4 Goal of the Study

The objective of this study was to investigate the movement ecology of domestic dogs across Kenya's human-wildlife-livestock-interface and document their parasite loads to highlight potential conservation implications for sympatric, wild carnivores Data were collected to achieve the following specific objectives:

1.5 Specific objectives

1. To determine how different functional roles played by dogs shape their movement patterns

2. To examine parasite loads/richness in domestic dogs in rural Laikipia.

3. To examine how different movement patterns of domestic dogs affect their parasite burdens.

1.6 Study hypotheses

1. How do different functional roles of domestic dogs shape their movement patterns?

Hypothesis 1: Movement patterns between herding (i.e. domestic dogs used exclusively for herding livestock) and home (i.e. domestic dogs used exclusively for security at homesteads) dogs will differ based upon their human-assigned roles.

2. What are the parasite loads of domestic dogs in rural Laikipia?

Hypothesis 2: Domestic dogs will be infected with large loads of parasites and variation will appear between dogs used for different roles where herding dogs are expected to have higher ectoparasites loads as compared to home dogs

3. How might different movement patterns of dogs influence parasites/diseases richness?

Hypothesis 3: Domestic dogs moving across larger areas will have greater parasite/disease richness due to greater exposure to environmental conditions and wild hosts

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Dog demographics

Domestic dogs have been shown to be the most abundant and widely distributed carnivore species worldwide (Gerardo, 2009), and this is largely due to their close association with human beings (Butler & Toit, 2001). In Africa, dogs have accompanied humans since their domestication 15,000 years ago (Savolainen *et al*, 2002) and have continually been introduced to new habitats, with resulting increases in abundance becoming a rising concern (Brickner, 2002). For instance, in Zimbabwe, a study conducted by Butler (2002) showed that there was an annual growth rate of 6.5% (Butler & Bingham, 2000) in domestic dog populations where numbers rose from 250,000 in 1954 to 1.36 million in 1994. In a demographic study of dogs conducted in Machakos County, Kenya, ecological and population data showed that the dog population was growing at 9% per annum and was highly dynamic with a rapid population turnover (Waiboci, 2009).

Domestic dogs have been used for different roles including a) security at homes b) herding livestock c) hunting d) assisting police and military and e) companionship (Kubois du Toit, 2008) and especially in places such as Laikipia, dogs are mostly used for herding and protection due to the act that these areas are always surrounded by wildlife. Every role played by a dog affects its behaviour and potentially its movement patterns, resulting in different degrees of interaction between domestic dogs and their environment. Yet knowledge of how different behaviors impact the environment, including disease transmission to other closely related, yet wild carnivore species, remains limited. Although dogs have been globally categorized in three distinct but often overlapping groups; feral dogs, stray dogs and home dogs (Brickner, 2000), Green and Gipson (1994) suggest that all dogs are always active at dawn, dusk and at night much like other canids. In Zimbabwe, free-ranging domestic dogs scavenged carcasses at any time with a peak at dawn (Butler & du Toit, 2002) where generally, dogs are both diurnal and nocturnal, which gives them a better opportunity to scavenge and hunt. Dogs are potentially effective predators of native fauna and can therefore have competitive interactions with endemic wild carnivores (Butler *et al*, 2003) with implications for disease transmission.

2.2 Role of domestic dogs in disease transmission

According to Woodroffe (1999), in comparison to habitat loss, over-harvesting and pollution, infectious diseases may seem to represent a minor problem for conservation but it is a threat that conservationists are ill-equipped to manage. Over the past few decades, however, it has become clear that diseases can pose a very serious threat to endangered species (Smith, 1982; May, 1988; Lyles & Dobson, 1993). Domestic dogs are often assumed to act as 'reservoir hosts' for pathogens (Woodroffe & Donnelly, 2011), which cause diseases of conservation concern such as canine distemper virus (CDV), rabies and canine parvovirus (CPV). Therefore, knowledge of infection reservoir dynamics including movement patterns is critical for effective disease control (Lembo *et al*. 2008). There are factors within the host that determine the temporal dynamics of viral pathogens (Parker *et al*. 1999) including the immune system, the survival and spatial distribution of the host (Anderson & May 1991). However, although transient impacts of novel parasites can be immense, few studies have addressed the long-term effects of diseases in wildlife species (Grenfell & Gulland 1995). According to Lembo *et al.* (2008), key questions in disease dynamics relate to the identification of infection reservoirs, the mechanisms by which infections are sustained within reservoirs, and the sources and routes of transmission from reservoirs to species of concern. The key components of reservoirs of directly transmitted pathogens are the target populations although there is limited data to allow detailed examination of the role of wild carnivores in potential reservoir system. This retains dogs as the core reservoirs of pathogens such as Rabies (Lembo *et al,* 2008). The disappearance of rinderpest from wild ungulates following its eradication in domestic cattle provides further evidence of the role played by domestic hosts in wildlife disease (Plowright, 1982). Although eradicating diseases in domestic dogs might not be the best measure to take, more studies on their behavior and ecology will be important to help in implementing effective control strategies for diseases of both conservation and human-health concern.

Incomplete understanding of reservoirs has hampered control of many diseases in Africa, such as Ebola virus infection, Buruli ulcer, and rabies (Haydon *et al*, 2002). Therefore, research into the role of domestic dogs as reservoirs and other wildlife in diseases transmission dynamics is critical to developing effective management plans allowing close monitoring with efficient feedback strategies to ensure limited or no transmissions of these emerging infectious diseases.

In Africa, several critical cases help to support the need for increased monitoring of spatial interactions between domestic and wild carnivores. For instance, at Serengeti National Park, Tanzania, a molecular analysis of viral isolates from wild dog (*Lycaon pictus*) carcasses suggested that they had died from a strain of rabies contracted from local domestic dogs (Kat *et al.* 1995). Similar analyses indicated that a subsequent CDV epidemic among Serengeti lions (*Panthera leo*) also originated in domestic dogs (Roelke-Parker *et al.* 1996) showing how domestic dogs can be key players in transmission of diseases to other wildlife.

While several factors influence disease dynamics in wild carnivores, behaviour is a key determinant of disease transmission (Woodroffe & Donnelly, 2011) . According to these authors, the risk of contact between domestic and wild dogs , as host species, was limited by their behaviour such that the former were associated with human settlements while the latter avoided them. Additionally, the same study demonstrated that the behavior of the two species, combined with local land use practices, appeared to limit interspecific disease transmission hence increasingly showing the importance of studying the behaviors of domestic dogs under different land-use systems. Beside host behaviour and land-use practices, studies have also shown that the spatial distribution of hosts to pathogens is an important aspect of diseases transmission (Hess, 1996; Hess *et al*. 2002). Therefore, host demographics also influence disease transmission dynamics (Waiboci (2009), host susceptibility being a core player as well. Some animals can be more susceptible than the others as a result of poor health, low immunity or even due to close proximity to an affected community.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1. Study Area

Fieldwork was undertaken at the northern portion of Mpala Ranch (figure 1), home to Mpala Research Centre (MRC) and the adjacent communities of Il Motiok (N 00’28.024 and E 36’56.79) and Koija (N 00’33.49 and E 36’54.47) in Kenya’s centrally located Laikipia County (Fig. 1). Both community lands, Koija and Il Motiok, have the same characteristics in terms of habitat type and the use of dogs, hence no variations were expected between the two landscapes in terms of movement patterns between dogs.

The People in Laikipia County largely depend on livestock pastoralism, although other land uses are also prevalent and these include ranches focused primarily on wildlife (e.g. wildlife sanctuaries) and those that employ an integrated management strategy for both wildlife and livestock. The area has witnessed a few studies along the human-wildlife interface where high densities of people, in permanent constructed homes with associated livestock and domestic animals such as dogs, live adjacent to wildlife-rich conservancies.

Researchers at MRC have a long history of working with the communities of Il Motiok and Koija, which formed the epicenter for this study on domestic dogs. Nearly each household in these communities has at least 1 dog associated with it, although up to 7 have been recorded for a single homeowner (Dedan Ngatia, unpubl. Data). The two communities are surrounded by adjacent sanctuaries and conservancies, which are known to support healthy populations of large and small carnivores, including healthy populations of endangered species like the wild dog, lion, and cheetah (*Acinonyx jubatus*) (Kinnaird & O'Brien 2012). Previous studies have shown that carnivores tend to avoid moving in and out of these communities (Kinnaird & O'Brien 2012, Woodroffe & Donnelly 2011), indicating that movement of dogs out of the communities into adjacent lands may be responsible for linking pathogens between large wild carnivores and domestic dogs. Therefore, in light of the ever-growing human population and the expanding rural-wildlife interface, understanding how interactions between domestic and wild carnivores influence their health and long-term persistence will become increasingly important.

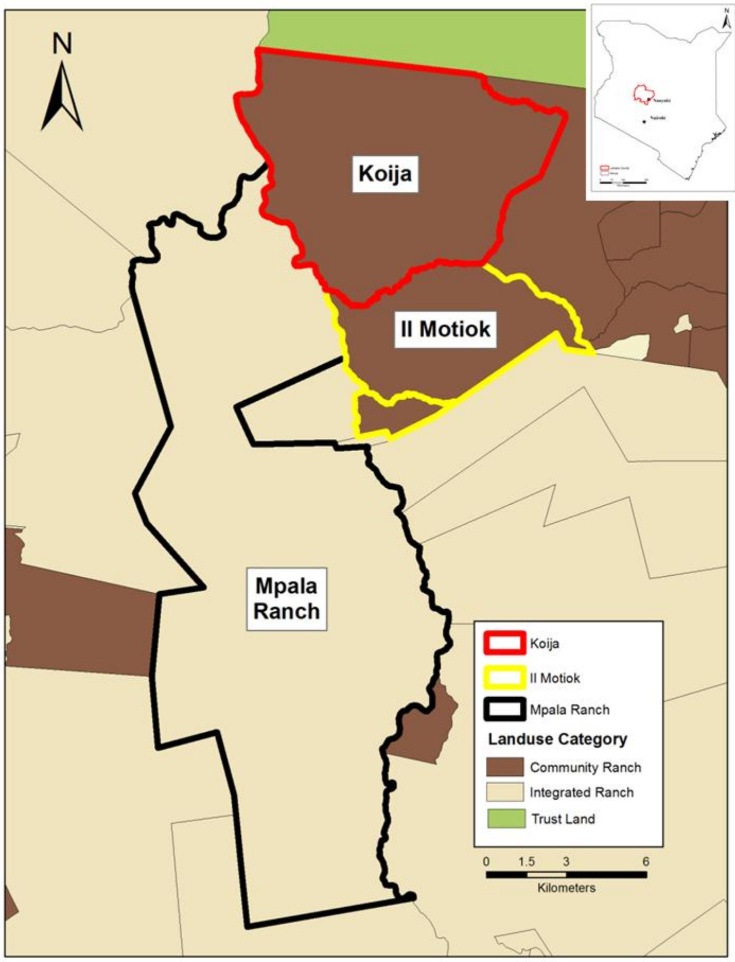

Figure 1: Study area map with the respective communities; Koija and Il Motiok

3.2 Field Methods

3.2.1 Use of iGotU data loggers

GPS Data loggers (GT- 600 model, 46 x 41.5x 14 mm of size, 37g of weight, iGotU, Mobile Action Technologies (http://global.mobileaction.com/) were used to track 50 domestic dogs . The GT- 600 GPS data loggers provided several benefits over earlier models including a longer battery life (10 – 30 days on a single charge) and a motion activation sensor. The GT-600 unit can store up to 262,000 way points which can be subsequently downloaded, cleared, and the unit recharged using a simple USB interface.

Before collaring of dogs, the applicability of these units was tested on security dogs in a confined space in Nairobi and although preliminary results indicated that accuracy can be disrupted by proximity to large buildings, the overall accuracy in open areas provided robust coordinates for accurate tracking (AWF, pers. Obs.). This was the first attempt to apply these technologies on domestic dogs in Africa and thus providing a valid pilot study to investigate the appropriateness of this technology for use in monitoring dog movements in other areas.

Data loggers were set to record a fix every 15 minutes for 24 hours with motion detector deactivated, scheduled control used and the button activated, and were employed for 25-30 consecutive days for each month for 11 months. All collars weighed no more than 5% of the animal's body weight (Wikelski *et al*. 2007) and in fact most weighed well below this cut-off as the GPS loggers are only 37 g and did not require any counterweight to keep them on. The data loggers were put into a custom designed metal casings and then affixed to the animals with commercially available domestic dog collars.

3.2.2 Spatial Ecology

A total of 50 domestic dogs were monitored using GPS data loggers to track their movement patterns. For the success of the project, collaborative agreements were established with the respective communities, with a mutualistic partnership, for them to allow tracking of their dogs and fixing of the data loggers on their dogs as well.

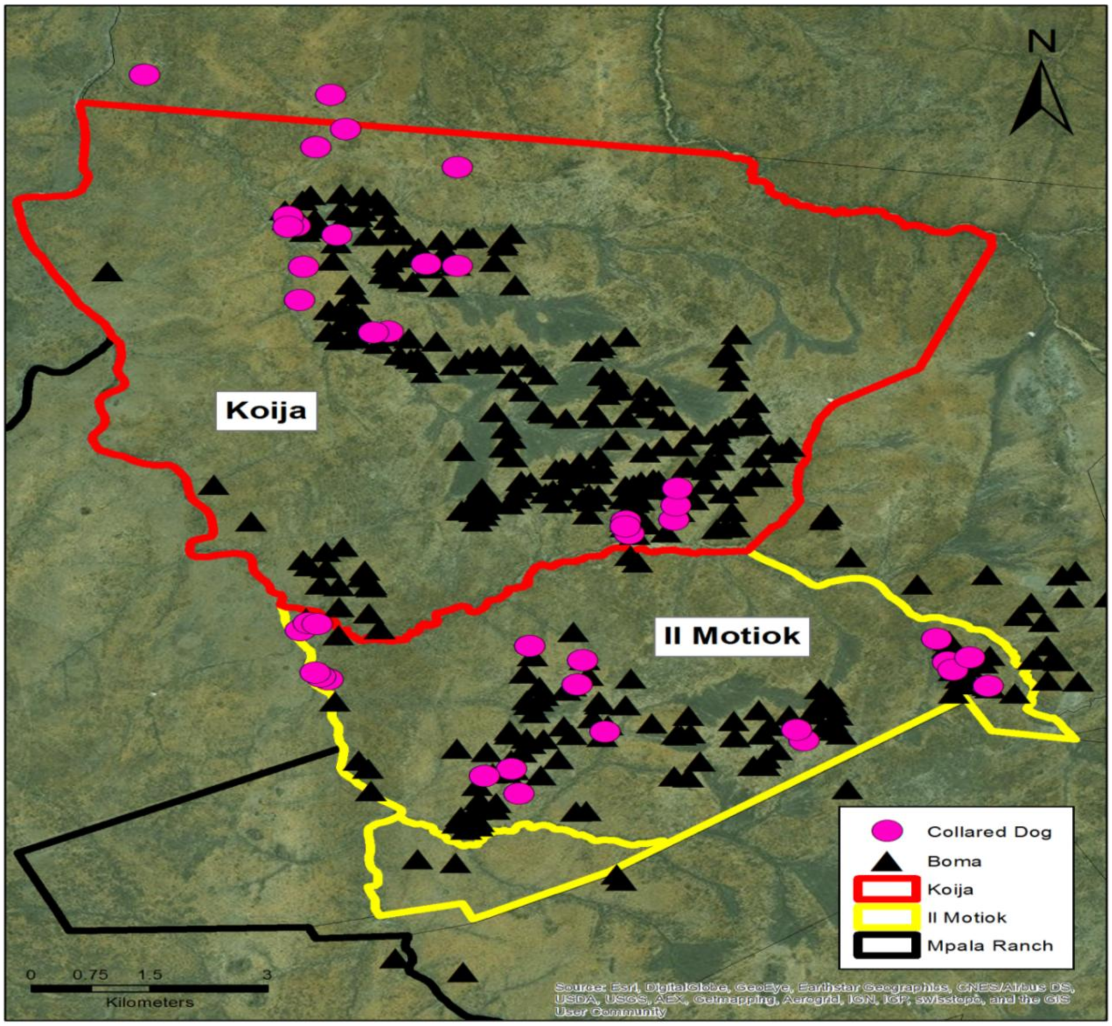

Figure 2: A map of Koija and Il Motiok showing the number/locations of the individual collared domestic dogs in relation to the distribution of 'bomas' or homesteads in the two communities.

In exchange for allowing their dogs to be used as part of the study all collared and non-collared domestic dogs were given a free rabies vaccination whereas the respective bomas (temporary households used by the pastoral communities) with collared dogs were given a kilo of sugar and tea leaves per month for 12 consecutive months. This was meant to form collaboration with the local communities for them to allow collaring of their dogs and it as well positive consequences on curbing the spread of rabies. The collared dogs were selected haphazardly to ensure an even distribution across the landscape and were chosen from a series of four clusters of bomas within each community. Specific domestic dogs were then selected using sex and functional role as two major considerations, attempting to control for these two confounding factors. Five dogs were selected from every cluster where efforts were made to ensure an even distribution of the selected dogs within the cluster. Sex and categorization (herding or home) of the dog were important considerations when selecting the dogs to put collars on since dogs of different sex might move or behave differently whereas a variation in movement and behavior might as well arise between herding and home dogs. An equal number of owner-classified herding versus home dogs were monitored.

Dogs were monitored daily during the collaring period to ensure no chaffing or disturbance to the animal occurred. Most dogs could be recognized individually without additional marking, so no Passive Integrated Transponder (PIT) tags or additional markers besides the collar were applied to these animals although a photographic directory of individual dogs was generated. In line with the battery life of the iGotU data loggers used, collars were retrieved once a month, data downloaded, collars recharged and then replaced. This was done consistently for the entire 12-month sampling period.

3.2.3 Parasite sampling

Blood samples and faecal samples were collected from all collared dogs to enable their analyses, through thorough screening for pathogens and parasites, in the laboratory. Additionally, ticks and fleas were also sampled from collared individuals using complete removal of ticks from the head region and sampled using standardized combing, (a total of 15 combings; 5 at both sides of the body and 5 on top of the body (crest)), for fleas/lice and handpicking for ticks. Blood samples were collected from the cephalic vein using 5 mL syringes and bio-banked to allow for future screening of known pathogens using Sanger and next-generation sequencing technologies. All the blood samples collected throughout the sampling period were subdivided into three different kinds of tubes: flash-frozen whole blood in liquid nitrogen, red-topped tubes for serum collection, and purple topped tubes for whole blood. Samples were stored in either liquid nitrogen or frozen at -20°C in the MRC laboratory for future analysis.

3.3 Data cleaning

Date retrieved from GPS loggers were manually cleaned using a series of steps outlined below. GPS fixes from the dataset for the period when dogs were wearing the collars were used , wrong fixes were excluded from the data set. Wrong fixes are those fixes for which the calculated distances moved, between two consecutive fixes within a specified period of time, was unreasonable meaning that the given animal must have been moving at an extra ordinary speed to cover such a distance within the specified time period. By plotting the locations on a map, fixes which were completely outside of the study area, where the probability of a dog being in such a locality was close to zero, were removed. Also, all fixes taken before the collar was put on a dog and after the collar was retrieved from the dog were excluded. Two reasons were detected that could have caused such errors in GPS fixes: 1) If the collar was not turned off before being replaced on a dog and after retrieving it, 2) Approximated GPS errors as a result of poor satellite signal. Using freely available data filters in the program Movebank, the following additional methods were used to further clean the data;

Simple outlier: we used this method as illustrated in movebank to each location with th previous and subsequent ones. If both neighbouring locations required an implausible speed, the locations were marked as outliers and were subsequently removed from the data. his method tests the filter settings for each record against the previous and subsequent records. For a successive use of this algorithm, we first checked to ensure that the first and last records were not outliers..

Valid anchor: we used this method to compare the first record (fix) with the subsequent ones with the assumption that this record was accurate. To confirm the assumption, all first fixes were plotted and confirmed right. This algorithm was then used to test all other records, testing the filter setting against the subsequent methods. If movement to the next location (from n to n+1) requires an implausible speed, the subsequent record is marked as an outlier and deleted from the database. The first record (n) was then tested against the next record (n+2) and so on,

until a plausible next location is found.

Longest consistent track: we as well used this algorithm which defines data in form of tacks and finds the longest sequence of points in the track that is fully consistent. Using this, we were able to select the longest candidate track as the correct one and flag records not included in this track as outliers. This method was efficient in identifying outliers at the beginning and at the end of a track ensuring that the analysed data was exactly the data retrieved from a moving individual.

Using aforementioned filtering methods, a total of over 10,000 locations were filtered from a dataset of approximately 270,000 locations.

3.4 Data analyses

GPS data were downloaded using the free software @TRIP PC (**http://www.a-trip.com**), exported as a CSV file separately for each unit and imported and stored in movebank (**https://www.movebank.org/**) and in program R (http://www.R-project.org/.) (**http://cran.r-**

project.org, version 3.0.1). R and ArcGIS programs were used for any further data cleaning and analyses.

Pivot tables were created in excel data sheets which allowed estimation of daily distances travelled per dog by grouping data and summing it up in relation to days. Using Home range tools (minimum boundary convex) in ArcGIS, home range (HR) sizes of the dogs were estimated using 100% minimum convex polygon, which allowed the approximation of the total use of space and overlap of the home ranges within the conservancies. Minimum Convex Polygon approach is the most widely used method to estimate HR (Robley et al. 2010) as compared to other methods. In this case, overlap in HR was defined as the total area of a given specific dog's home range occurring inside a conservancy. To further show penetration into the conservancies, the tool transect in ArcGIS was used to subdivide an individual dog's home range in respect to the landscape boundaries as provided by the Laikipia Property Boundary map recently updated in 2015. Using this, it was shown how a specific dog spent time in different landscapes and this was computed by simply calculating the home range size occurring in each specific property type (e.g. conservancy versus community ranch).

To test whether different roles of domestic dogs affected their movement behavior, we compared average distances traveled and home range sizes using multi factor ANOVA to test for significant differences in average distances and home range sizes between the two categories of dogs (i.e. home/security dogs versus herding dogs). Regression analysis were used to test whether the categorization of dogs was an important factor in influencing changes in the number of ectoparasites in an individual dog with respect to distance travelled and the home range size. Differences in ecto-parasite abundance between the two dog categories were tested using repeated measures ANOVA, with with one within-factor (sampling session) and two between-factors (herding and home categorization of dogs).

CHAPTER FOUR

4.0 RESULTS

4.1 Collaring information

A total of 50 dogs were sampled for spatial data (table 1) though some sampling sessions were missed for varied reasons while no data was obtained from a few of the individuals as well as shown in the table below;

Table 1: General information of all individuals (used and not used for the analysis) showing sampling sessions on track data (months).

Category	***Number of individuals sampled throughout***	***No. of individuals missing one sampling session***	***No. of individuals missing two sampling sessions***	***No. of individuals missing three sampling sessions***	***No. of individuals missing ≥ 4 sampling sessions.***	***No. of individuals with no data collected***
Herding	4	5	6	1	4	0
Home	9	6	3	1	8	3

We collected a total of 273,818 fixes from 46 collared dogs where 15 of the dogs had a record of over or close to 10,000 fixes for the whole collaring period. The first two months were used as a pilot study where the preliminary data obtained was used to develop proper GPS configurations/settings which eventually resulted in 11 months of proper data collection. From the preliminary analysis, the GPS motion detector was disabled to help increase battery life of the tags and disable the tag's manual button control. No movement data was obtained from a total of four dogs after the preliminary analysis either because the owner declined or the dog died before the main sampling began.

At the end of the study period, some dogs were not available for sampling for various reasons as shown in table 3 below.

Not all data collected were used for these analyses. Twenty individuals (table 2) with the best data were chosen and this data was used to conduct different comparisons.

Table2: General information of the tracked individuals (only for the individuals whose data were used for the analysis) at Koija and Il Motiok, Laikipia Kenya, for a period of 12 months.

Dog ID	***Sex***	***Category***	***Total fixes obtained (for whole tracking period)***	***Deployment duration in months. (time period tracked)***	***Months missed/Reason***
DG7	Male	Herding	10658	10	2/Collar lost
DG3	Male	Herding	7116	10	2/Dog was sick
DG8	Male	Herding	5472	11	1/could not be found
DG9	Male	Herding	9305	12	0
DG10	Male	Herding	11585	10	2/Collar
DG19	Male	Herding	8923	10	2/Data couldn't download
DG24	Male	Herding	7736	11	1/Collar destroyed
DG34	Male	Herding	11342	12	0
DG41	Male	Herding	9197	12	0
DG42	Male	Herding	9114	12	0
DG17	Female	Home	3693	10	2/Dog became weak
DG20	Male	Home	7389	11	1/Collar lost
DG23	Female	Home	7238	11	1/Data could not download
DG32	Male	Home	10244	12	0
DG33	Male	Home	2945	10	2/Dog died
DG43	Male	Home	2883	8	4/Owner declined
DG45	Male	Home	5875	11	1/Collar lost
DG47	Male	Home	5917	12	0
DG48	Female	Home	4105	12	0
DG49	Male	Home	4305	12	0

.

Table 3: Number of GPS collared domestic dogs (Canis familiaris) lost/killed by wild carnivores from X until X 2015 on Il Motiok and Koija Community Ranches, Laikipia County, Kenya. Total number of domestic dogs by category, are also indicated

Number Monitored	**Owner Declined**	**Died**	**Injured**
24 Herding dogs	8	4 (**killed by leopards**)	1 (**By a hyena**)
26 Guarding dogs	0	2 (**Killed by hyenas**)	0

4.2 Spatial patterns

4.2.1 Average distances traveled

Daily distances traveled by individual dogs varied where some dogs were noted to travel large distances in a day (e.g. 7729.60 km/day) as compared to others which showed limited movements throughout the collaring sessions (e.g. 1833.94 km/day)). Both community lands, Koija and Il Motiok, have the same characteristics in terms of habitat type and the use of dogs, hence no variations were expected between the two landscapes in terms of movement patterns between dogs.

On average, herding dogs moved significantly longer daily distances than home dogs (**P=0.03, $F_{1, 18}$ = 5.395**; Herding dogs **4236.1m ± 1771.9m**, home dogs **2847.8m ± 657.3m**). A few individual home dogs (Dog 20= 3815.22m and Dog 23= 3543.40m) moved longer distances than some herding dogs though on average, herding dogs were shown to move significantly longer distances (Figure 4).

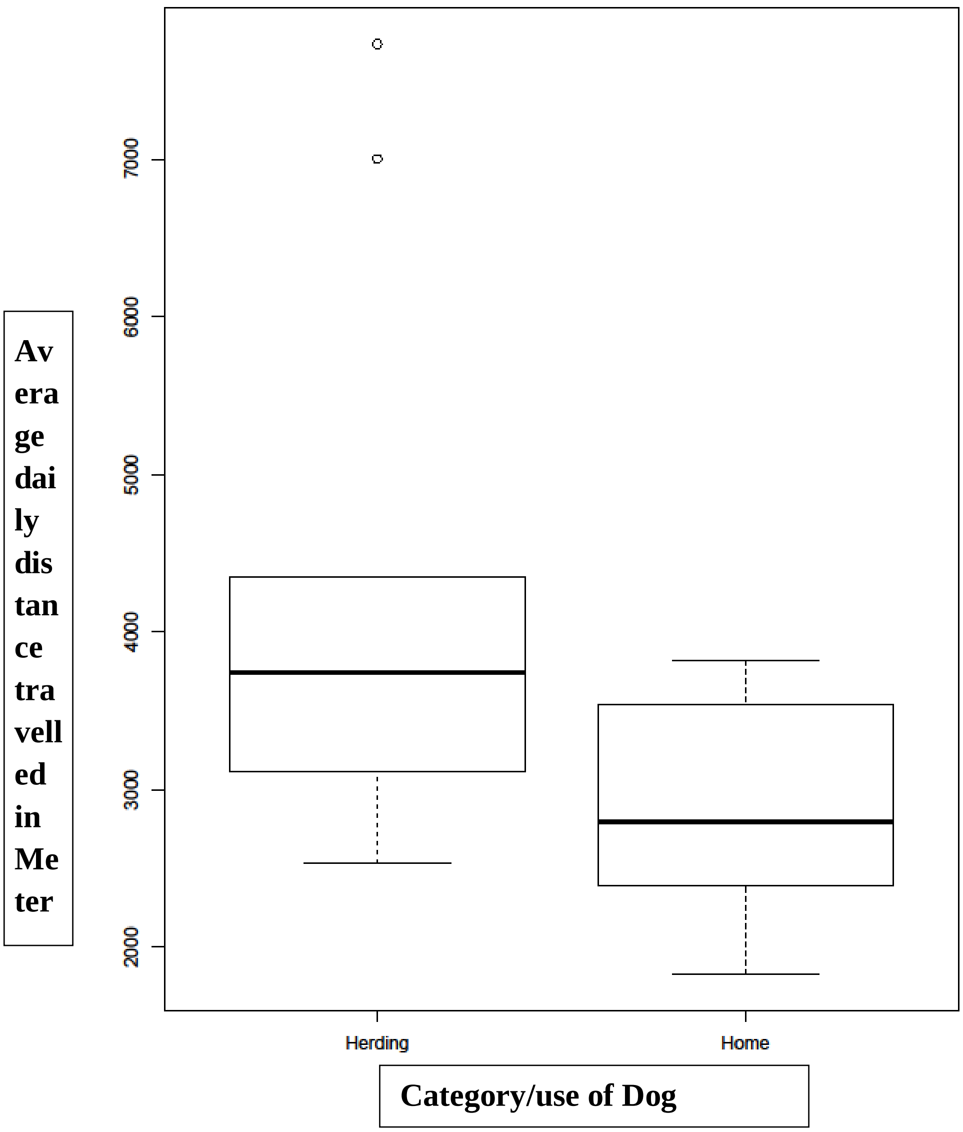

Figure 4: Average differences on daily distances travelled between the two categories of dogs, that is, 10 herding and 10 home dogs at Koija and IlMotiok, Laikipia Kenya ((P=0.03, $F_{1, 18}$ = 5.395; Herding dogs 4236.1m ± 1771.9m, home dogs 2847.8m ± 657.3m)

4.2.2 Home range sizes

All the collared dogs were observed to utilize a large part of their home range around their homesteads where most of the fixes, GPS locations taken, were within or close to their respective bomas. Even though some dogs would show some long and extended forays deep into the ranches or conservancies, most of them tended to display controlled movement within their home ranges characterized by well-defined areas surrounding their respective bomas.

Similar to average distances moved, no variation in terms of home range size was expected between the two community lands where dog collaring happened and this is due to the fact that Koija and IlMotiok represent very similar communities in terms of livelihood, habitats among other factors. Also, although there was limited transgression, overlap between dogs was clear where there occurred to be large percentages of shared home ranges between most of the dogs. Specific movement pattern differences between female and males were not computed part of the reason being that most of the dogs collared (80% of the dogs) were males. Community members in these two landscapes tend to have a negative perception towards female dogs where male dogs are more trusted to perform specific tasks such as herding and protecting the bomas.

On average, herding dogs tended maintain larger home ranges (**38.6 ±16.76 km2, n =10**) than the home dogs (**17.2 ±9.95 km2, n =10**) where they were shown to utilize significantly bigger home ranges compared to the home dogs (**$P < 0.01$, $F_{1, 18} = 12.044$**)

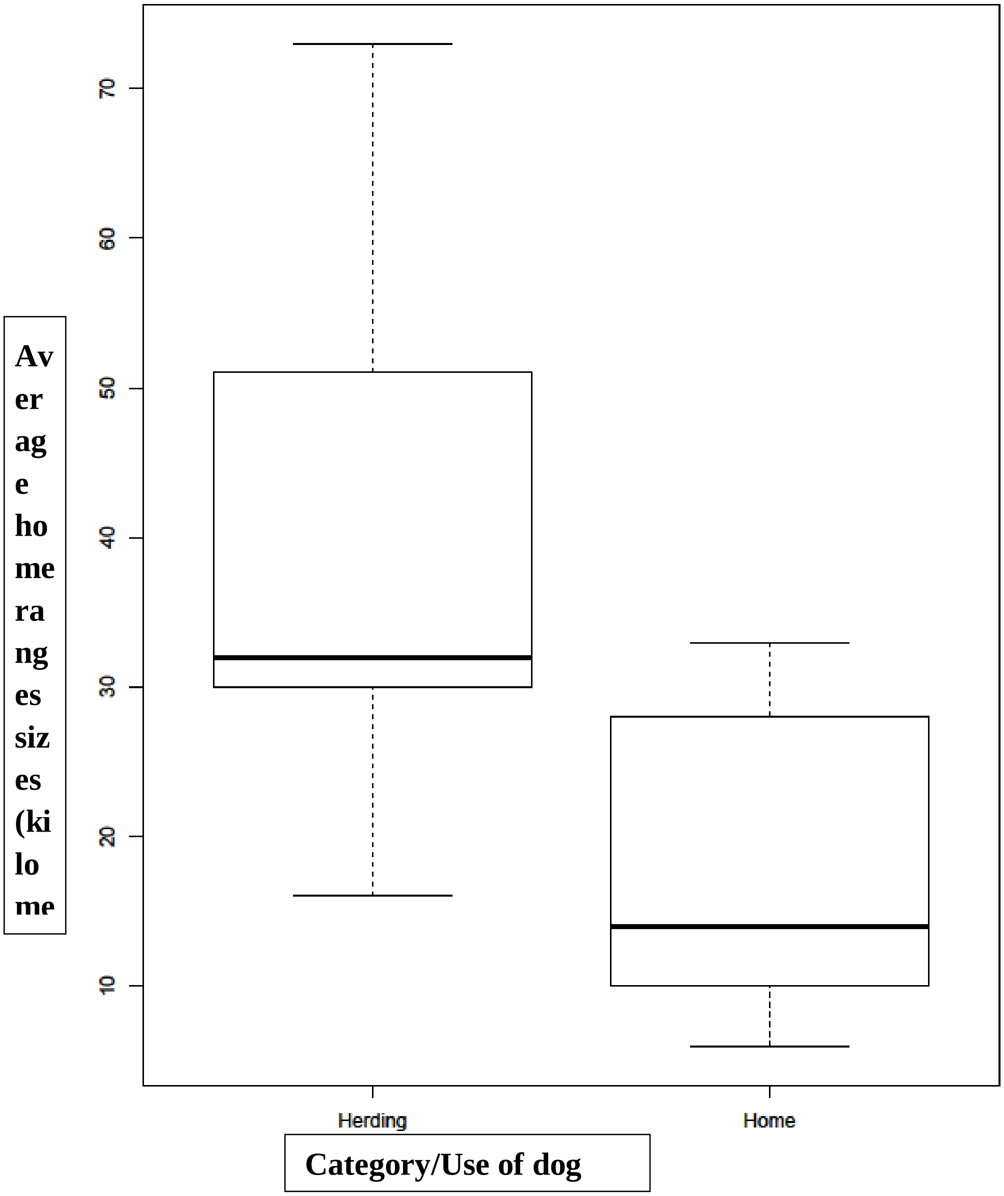

Figure 5: Average differences in home range sizes between the different categories of dogs (n=20, herding dogs and home dogs, at Koija and Il Motiok, Laikipia Kenya ($P < 0.01$, $F_{1, 18}$= 12.044)

4.2.3 Transgression into conservancies

In general, there was limited introgression into conservancies by most of the collared dogs. Most of the dogs were shown to utilize the community lands more than the conservancies with only a few of them entering into conservancies (>90% of the home ranges of all the dogs occurred in the community ranches in close association with the bomas).

Whether a dog entered into the conservancy or not appeared to be in respect with the location of the collared dog, that is, proximity to a conservancy, as opposed to the sex or the categorization of the dog. Most of the dogs entering into the conservancies were associated with bomas adjacent to said conservancies and the extent of their forays into conservancy lands was limited as shown below (Table 2).

Five dogs were shown to exclusively spend 100% of their time in the community land and showed no penetration into the conservancies. Only two dogs, one herding and one home dog, spent more than half of their time in the conservancies, meaning that a considerable amount of their home ranges occurred in theses ranches (**DG19- herding; 53% ± 0.05, DG45-home; 57%± 0.05).** Other dogs showed limited use of the conservancies where some of them made only one visit into these lands.

Herding dogs showed significantly higher associations with the conservancies as compared to home dogs (**$F_{1, 18}$= 8.0405, P=0.01**) and tended to spend more time in them but same time, they as well had relatively larger home ranges in the community lands compared to the other dogs.

Dog ID	Sex	Category	Total HR (km^2)	%Conservancy (km^2)	%Com, Land (km^2)
DG7	Male	Herding	38.07	5.5 (2.1)	94.5 (35.97)
DG3	Male	Herding	30	17 (5)	83 (25)
DG8	Male	Herding	31	26 (8)	74 (23)
DG9	Male	Herding	62	6 (4)	94 (58)
DG10	Male	Herding	25.25	10.5 (2.64)	89.5 (22.61)
DG19	Male	Herding	32	53 (17)	47 (15
DG24	Male	Herding	14	7.1 (1)	92.9 (13)
DG34	Male	Herding	26	0 (0)	100 (26)
DG41	Male	Herding	30.2	0.7 (0.2)	99.3 (30)
DG42	Male	Herding	51	17.6 (9)	82.4 (42)
DG17	Female	Home	10	50 (5)	50 (5)
DG20	Male	Home	18	0 (0)	100 (18)
DG23	Female	Home	19	0 (0)	100 (19)
DG32	Male	Home	31	6.5 (2)	93.5 (29)
DG33	Male	Home	10	0 (0)	100 (10)
DG42	Male	Home	17.5	2.9 (0.5)	97.1 (17)
DG45	Male	Home	11	57.1 (4)	42.9 (7)
DG47	Male	Home	30.5	8.2 (2.5)	91.8 (28)
DG48	Female	Home	6	0 (0)	100 (6)
DG49	Male	Home	9	22.2 (2)	77.8 (7)

Table 4: ***Table showing the total home range sizes of different dogs in relation to their sex and categorization. Also, this table shows time spent in conservancies versus community lands by showing the portion and size of the home ranges occurring in either of these two landscapes.***

In total, 6 dogs (3 home and 3 herding dogs) entered Mpala Ranch at some point although one of them had as little as 0.5 km^2 of its home range in Mpala. Karisia ranch had the largest number of dogs going into it with a total of 6 herding and 2 home dogs showing introgression into the ranch. Some dogs also went into Loisaba conservancy (4 dogs) with just one dog penetrating into Soiti Nyiro conservancy.

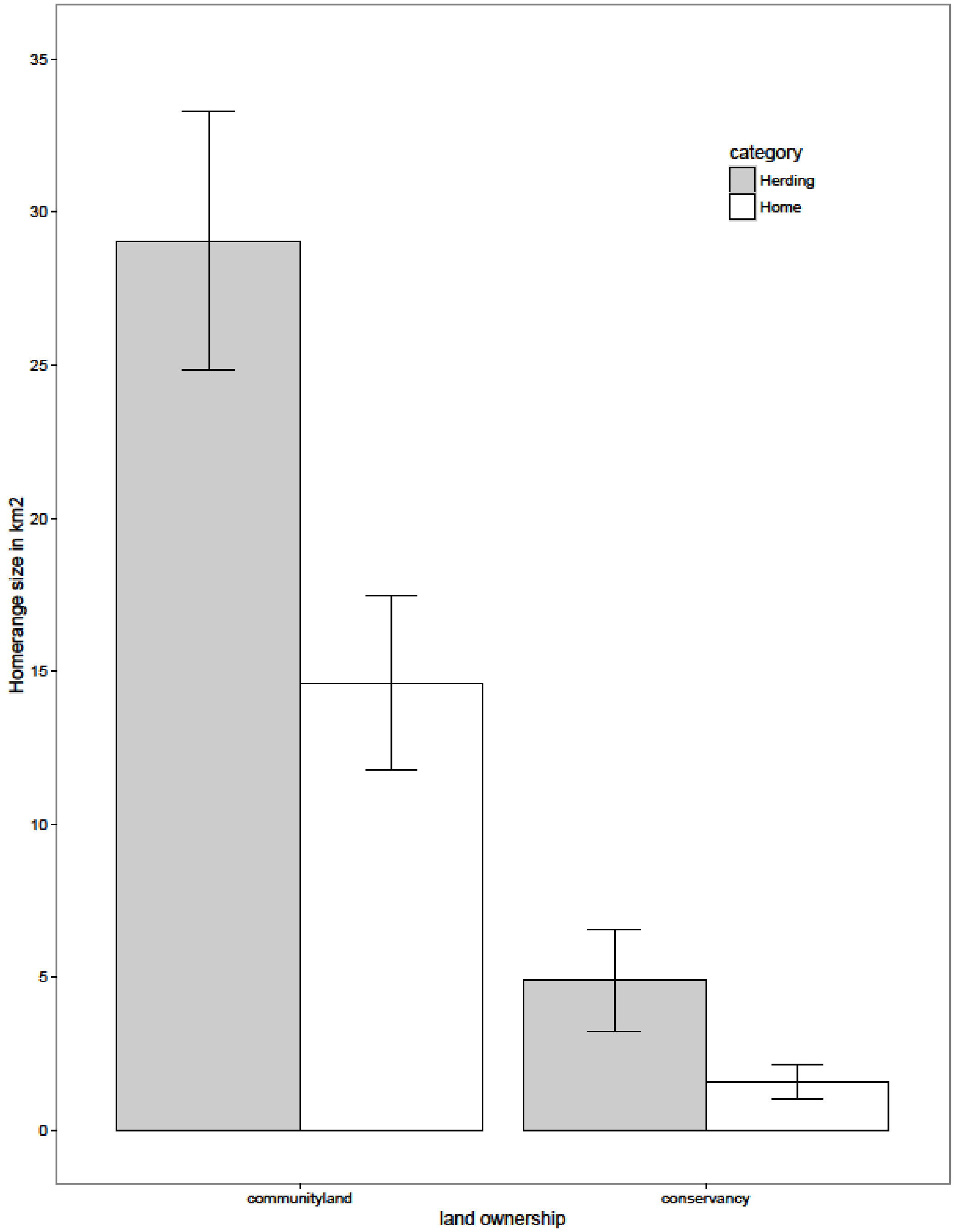

Figure 6: Differences in home ranges sizes of the different categories of dogs (N=20), herding and home dogs, between two landscapes (conservancies and community lands)at Ilmotiok and Koija, Laikipia Kenya ($F_{1,18}$= 8.0405, P=0.01)

4.3 Parasite richness and abundance in dogs

Herding dogs had greater numbers of ectoparasites compared to home dogs where apparently ticks were more abundant on dogs than fleas in general. Differences in abundance of fleas in the two categorizations of dogs appeared to be minimal but the differences were significantly different between the two categories for the abundance of ticks.

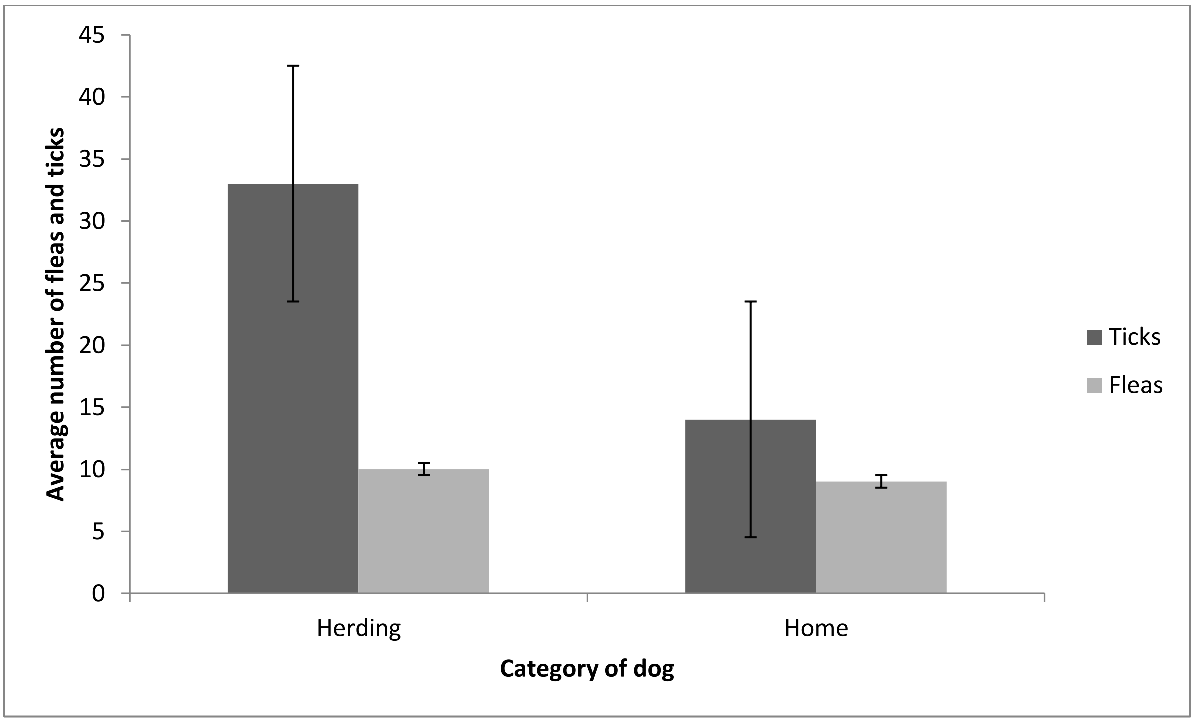

Figure 7: A comparison of parasite loads, ticks and fleas, between the two categories of dogs i.e. herding (n=10) and home dogs(n=10, at Koija and Il Motiok, Laikipia Kenya

4.3.1 Ticks

Several herding dogs appeared to have large numbers of ticks which explains their high average abundance as opposed to home dogs which had low number of ticks as shown in Figure 8. Four herding dogs had more than 40 ticks collected from them where as the home dog with the highest number of ticks had between 20 to 29 ticks.

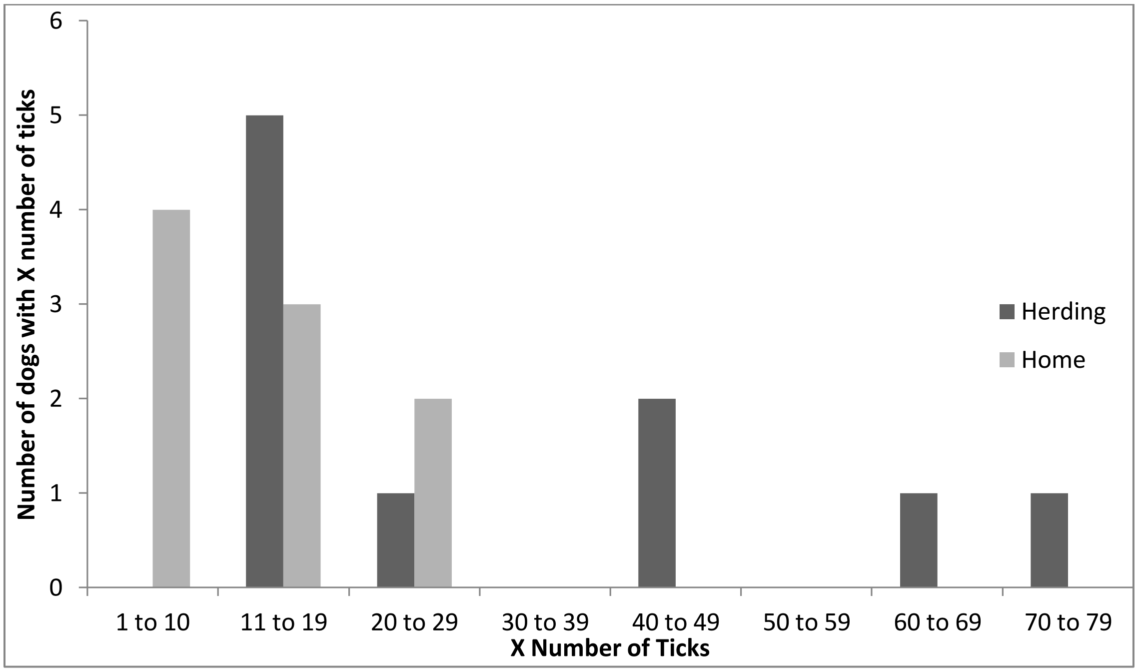

Figure 8: A histogram of the number of dogs with a given number of ticks forming a descriptive analysis of parasite (ticks) loads between herding (n=10) and home (n=10) dogs at Koija and Il Motiok, Laikipia Kenya.

4.3.2 Fleas

A similar pattern as that observed with ticks was not apparent with fleas. There was no significant differences observed between the two categories of dogs and their association with fleas though herding dogs had slightly higher average number of fleas than home dogs

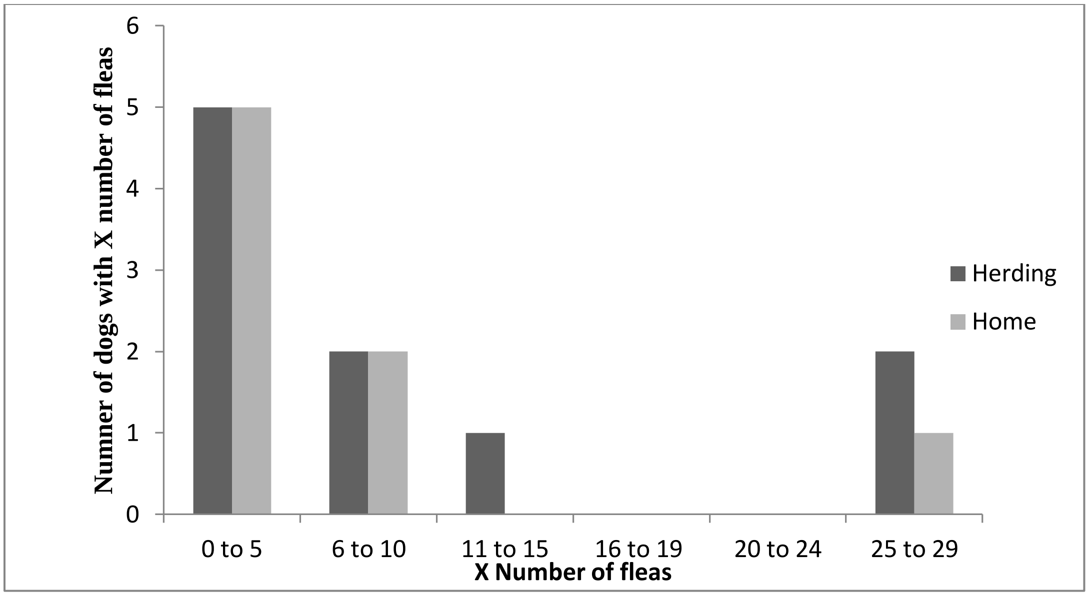

Figure 9: A histogram the number of dogs with a given number of fleas forming a descriptive analysis of parasite (fleas) loads between herding (n=10) and home (n=10) dogs at Koija and Il Motiok, Laikipia Kenya

4.4 Comparing space use and parasites richness

Not all dogs were sampled for ectoparasites as some were too aggressive to be handled while others were excluded from several sampling sessions. To compare this, data on movement patterns and parasites richness from both herding (n=10) and home (n=10) was used where these dogs were sampled for spatial data, ticks and fleas for all the 4 periods. Data used in these comparisons was obtained from the full sampling periods which were conducted after every three months, providing information on seasonal variation between the sampling sessions.

Dog owners are used to washing their dogs to clean ectoparasites from them and this definitely biased the numbers of ticks and fleas collected from the dogs. To cover this bias, data was collected on which dogs were washed, how often and the date they last received a wash. All data used in subsequent analysis are from dogs which never received a wash during the collaring/sampling period (as defined by the owner, n =20). Also, data used for this analysis was obtained from the full sampling sessions and not from the mini sampling sessions (which were conducted monthly).

4.4.1 Home range size vs parasites abundance

There appeared to be no similarity in pattern between herding dog and home dogs while comparing the average sizes of the home ranges with parasites (ticks) associated with them and also, the relationship between the two categories of dogs and the ticks associated with them was insignificant **($P=0.184$, $F_{1,15} = 1.94$).** All the same, there was a significance in the change in the number of parasites with change in home range size when the categorization of dogs was not considered **($P=0.06$, $F_{1, 8} = 0.06$).** In home dogs, there was a rapid increase in the number of ticks with rise in size of the home ranges where as for the herding dogs, the opposite was true. Though not significant, there was a decline in the number of ticks with increase in home range size for the herding dogs.

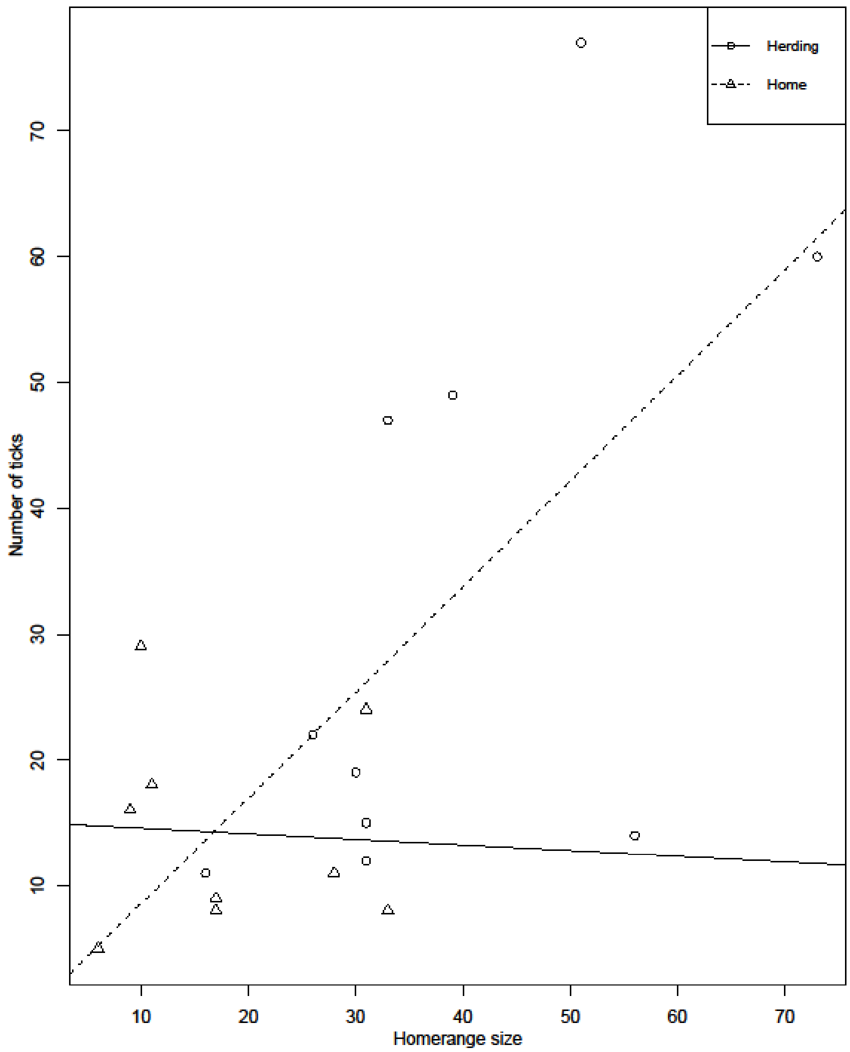

***Figure 10: Regression analysis of the home range sizes and the total number of ticks collected from the two categories of dogs; herding (n=10) and home (n=10) dogs at Koija and Il Motiok, Laikipia Kenya (* **P=0.184, $F_{1,15}$ = 1.94)**

For the fleas, both herding and home dogs showed an increase in the number of fleas with an increase in the home range size and this was contrary of what was observed with the ticks although the relationship between the home range sizes and the number of fleas was found to be non-significant **(P= 0.99, $F_{1. 15}$= 0.00).** There as well appeared to be no significant relationship between the number of fleas and the home range size while ignoring the categories of dogs.

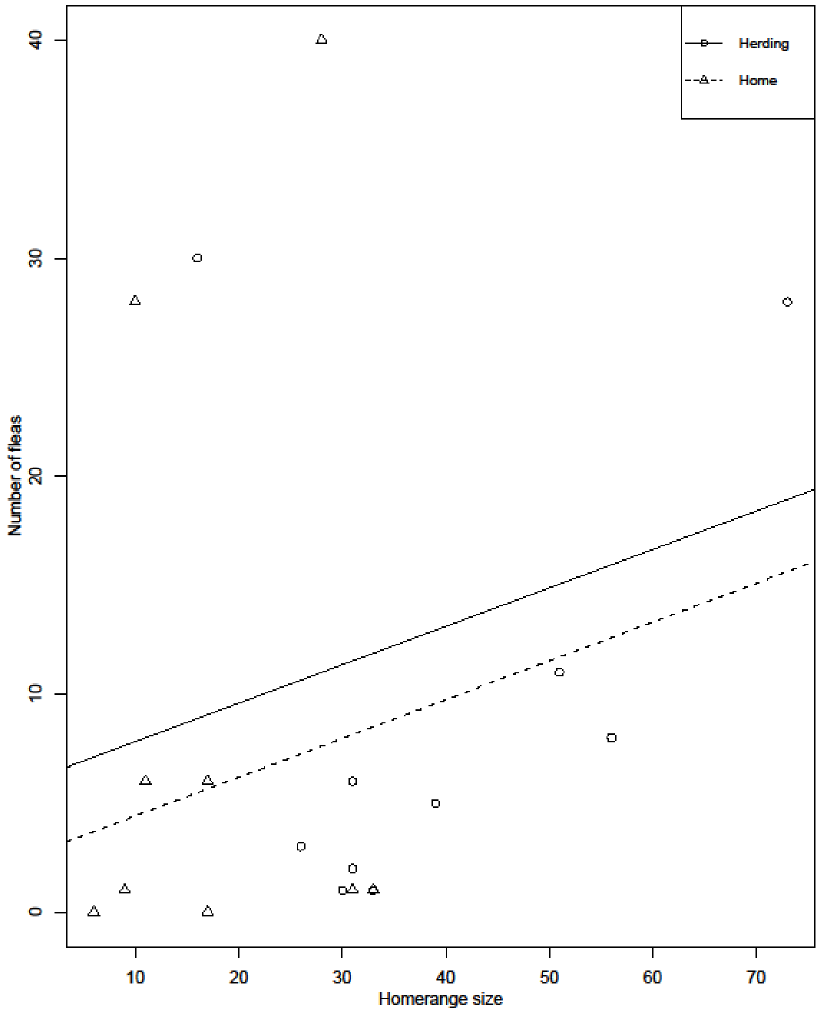

***Figure 11: Regression analysis of the average home sizes and total number of fleas for the two categories of dogs, herding (n=10) and home (n=10) dogs, at Koija and Il Motiok in Laikipia Kenya* (P= 0.99, $F_{1. 15}$= 0.00).**

4.4.2 Average distances moved vs parasites abundance

Ticks were generally more abundant than fleas in all dogs sampled and part of the reason for this is that ticks are bigger and easier to both pick and identify from animals. Some dogs had exemplary large numbers of fleas and ticks (e.g. **DG33; Ticks=284, Fleas=102**) as compared to the others where as some also showed very low numbers of parasites (e.g. **DG 48; Ticks= 5, Fleas=0**) across all the 4 sampling sessions.

On average, herding dogs were shown to be more infested with ticks than home dogs and there appeared to be a positive relationship between the average daily distance travelled by a specified individual and tick abundance (numbers) though not significant. An increase in distances travelled was not significantly associated with a rise in the number of ticks (**$P=0.18$, $F_{1, 15}=1.940$)** for both herding and home dogs. All the same, there was a significant increase in the number ticks with an increase in the average distance travelled

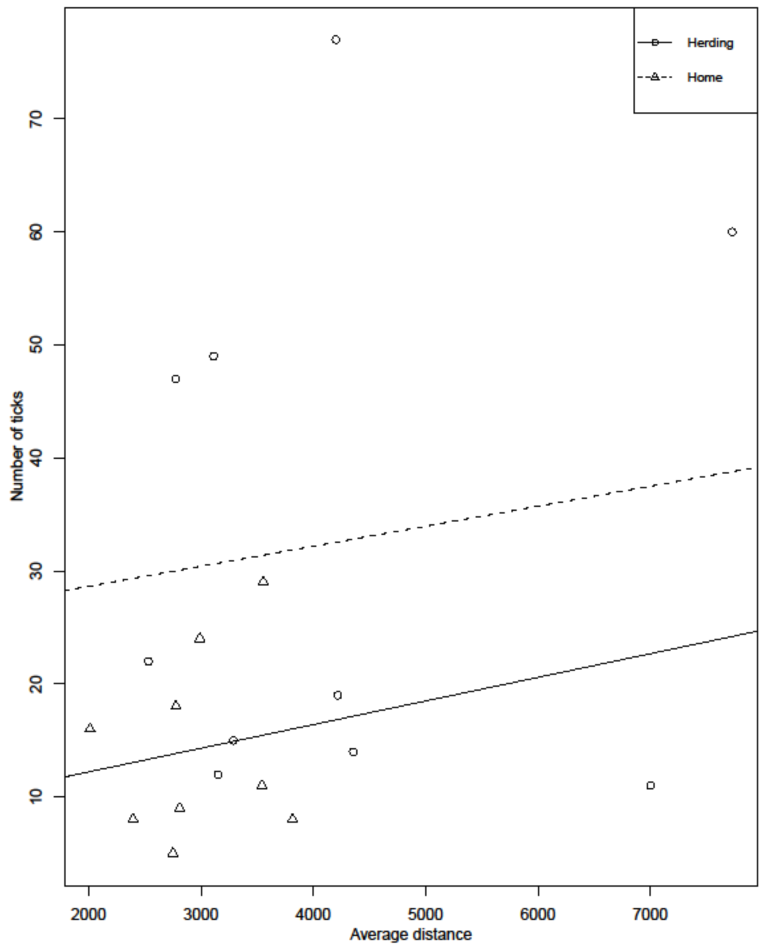

Figure 12: Regression analysis of the average distances travelled by the two categories of dogs, herding (n=10) and home (n=10) and the parasites (ticks) associated with them at Koija and Il Motiok, Laikipia Kenya (($P> 0.01$, $F_{1, 18} = 11.0935$)

There was also a significant association between the number of fleas and the average daily distances **($P> 0.01$, $F_{1, 18} = 11.4556$)** traveled, where the number of fleas per individual dog, in both categorizations, was shown to increase with an increase in the average distance travelled per day. As opposed to ticks, where they were more abundant in home dogs than herding dogs, herding dogs had higher numbers/abundance of fleas than home dogs.

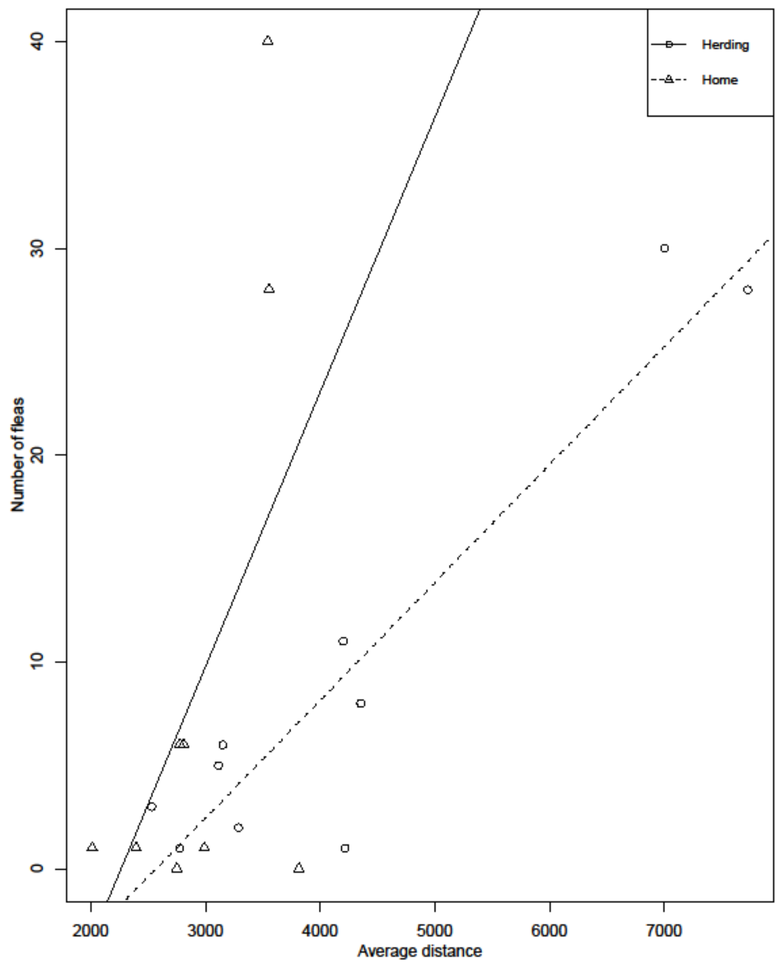

Figure 13: Regression analysis of the average distances travelled by the two categories of dogs, herding (n=10) and home (n=10) and the parasites (fleas) associated with them at Koija and Il Motiok, Laikipia Kenya **(P> 0.01, F= 11.4556)**

CHAPTER FIVE

5.0 DISCUSSION

5.1. Spatial Patterns of domestic dogs

Although domestic dogs, in much of their range, are known to be free ranging irrespective of their ownership status (Wanderer *et al*, 1993), the findings of this study that herding dogs moved longer daily distances and maintained larger home range sizes than home dogs implies that the role of a dog can in a way define its movement patterns and can be useful for predicting differences in movement patterns between different categories of dogs. Studies have shown greater association between domestic dogs and their owners (Butler, 2002) who define the roles for the dogs and this partially means that dogs use or rather dog activities are to a bigger extent controlled by the owner. There exists dynamism in the nature of some dogs' roles where some owners either misclassifies or change the role of their dogs within a given period and such cases were recorded in my study area. Pastoralist communities move long distances every day in search of good pasture for their livestock and this explains why herding dogs showed higher extents of movement ranges as compared to home dogs. Home dogs might be less controlled by the owners and more associated to the bomas as defined by their roles in such rural areas bordering natural conservancies/reserves, but these dogs can interact with wildlife at multiple levels including predation, prey and pathogen reservoirs (Butler, Du Toit & Bingham 2004). These dogs exhibit some percentage of free ranging and always move without control but their less association with cattle might mean fewer impacts to other organisms.

Similar to findings by Woodroffe and Donnelly (2011), movements of domestic dogs were centered on bomas where most of the fixes were concentrated around the homesteads reducing the probability of locating a dog so far away from its associated boma. Herding dogs had significantly larger home ranges compared to home dogs and this can be explained by the greater distances they moved every day and also by their association with cattle which move long distances every day in search of food. Home range size has been used in science to explain lots of factors and interactions (Hampson *et al*. 2009) though other home range contents such as habitat component, overlap, proximity to certain features such as conservancies etc. also define how one's home range can influence its impacts on an individual. In some situations e.g. when a dog is rabid, expanded ranging behaviour has been shown although this has not been recorded in any wildlife and has not been reported anywhere else (Kat *et al*. 1995) showing how important dogs can be in triggering transmission of pathogens. From our results, herding dogs might have high impacts come their role in disease transmission as compared to the home dogs for several reasons. By the fact that they explore larger areas, they tend to have higher chances of coming into contact with either parasites, though this is not true for ticks according to our data., or getting infected through interacting with infected animals whom they might be sharing the same space. According to Woodroffe (2011), it's easy to manage disease threats to wildlife by limiting their interaction with dogs and this can only be achieved by stopping dogs from penetrating into conservancies while also preventing wildlife from coming into community lands. From our results, a good percentage of the dogs had some part of their home ranges occurring inside the conservancies though this was mostly by the dogs living adjacent to conservancies. Introgression into conservancies might mean a lot of things including competition for food but this might have bigger impacts on spread of diseases considering the role of dogs in disease ecology. Two collared individual dogs had more than half of their home ranges occurring in the conservancies meaning that they had a higher probability of interacting with wildlife more than livestock but same time, this means that such dogs would interact with all animals, inside and outside the conservancies, which has a big meaning come transmission of disease between wildlife and livestock.

5.2. Parasite Load and movement

Parasites can act as a good measure of how prone an individual or a group of individuals is to disease, especially ectoparasites which can be easily dropped and picked by different individuals (Penzihorn, 2006). Our data showed that ticks and fleas were the most prevalent ectoparasites on the dogs and although they were not in huge amounts as hypothesized, some specific individuals had high numbers of them. Part of the reason to the lower than expected number of ectoparasites might be that most of the dog owners tend to wash their dogs against ectoparasites which might have interfered with this study although data were controlled for such instances. All the dogs used for this analysis experienced no washing during the sampling period though the livestock associated with the dogs were always washed at least once every two months which automatically reciprocates to a reduced number of ectos available to attack dogs. Whereas Population crashes as a result of tick-borne bacterium are rare (Woodroffe *et al.* 2007), it has been shown that it can be devastating when they occur where less virulent pathogen can undermine population growth in other canids (Mech *et al*. 2008) hence showing how important ecto parasites can be in a system. Pastoral communities tend to be threatened by diseases and are thus always cautious to wash their dogs from the understanding that ticks and fleas tend to be one of the easiest ways of transmitting diseases to their cattle which most often leads to massive loss of cattle.

From our results, the category of dogs was shown to have no significant impact on the number of ecto parasites on a given dog which translates to the role of a dog not being an important factor in defining the parasites associated with the dog. For the herding dogs, there was a slight reduction in the number of ticks with an increase in the home range size whereas for the home dogs, the number of ticks tended to increase with a rise in the home range size. This contradicts the idea of changes in home range size have a similar impact to the number of ticks in both categories and creates a new question on how exactly the categorization of dogs influenced the two very different changes in parasite numbers between herding and home dogs. In general, the size of the home range was shown to have an impact on the number of parasites associated with a dog, without considering the categorization, where the number of fleas increased with increased home range size. Though not enough studies have been done to show the risk of pathogen transmission between domestic dogs and wild animals (Quinnell & Chalmers 2001), Woodroffe and Donnelly (2011) conducted a study that showed that movement patterns of sympatric wild and domestic dogs can be used to explicitly evaluate the risk of pathogen transmission both within and between host species. With a larger home range, an individual would be expected to encounter and come into contact with lots of other animals utilizing the same area which explains the possibilities of it having higher parasites number than an individual with a smaller home range. Furthermore, pathogen can as well be transmitted even without direct contact between hosts where e.g. some tick vector of *Ehrlichia* may remain infectious in the environment for months (Gordon a& Angrick, 1986; Koch & Tuck, 1986) and potentially long enough to allow transmission to other individuals.

The overall pattern of changes on parasites with change in average distance travelled was similar where the more a dog travelled, the more it was associated with parasites in terms of numbers. For both fleas and ticks, though the differences in the two categories was not significant, distance travelled was a key factor in determining the number of parasites on an individual. This can be supported by other findings showing that domestic dogs can submit different pathogens (Woodroffe, 2012) and that with greater scales of movement, there exists greater opportunities of contact between domestic dogs and other wildlife resulting to higher risks of exposure to parasites and most importantly pathogens such as canine parvovirus and possibly rabies virus including more others.

5.3 Impacts of dog movement patterns in conservation

Domestic dogs can result in consequences for conservation practitioners since broader movement patterns translate into increased chances of interaction with other animals including native wildlife, a group negatively impacted by domestic dogs at multiple levels (Gompper, 2010). An increase in interaction potential between domestic and wild carnivores can also impact disease transmission among species of conservation concern, as demonstrated for wild dogs in Kenya (Woodroffe *et al*. 1991) and lions in the Serengeti (Packer *et al*. 1996). With the consideration of Laikipia being a system where all animals roam freely, there are higher chances that herding dogs can interact more with wildlife which creates an opportunity for diseases transmission. It has also been shown by other studies that domestic dogs, in comparison with wild dogs, tend to live at higher population densities and are always attracted to the bomas where they spend considerably a good amount of time together (Woodroffe & Donnelly, 2011) and different dogs from different bomas spend time together. Hence, if only a single individual is sick or manages to interact with another sick individual, chances are that transmission would happen fast and easy between dogs since they tend to spend lots of time together.

Loss of dogs through predation by wild carnivores inside the community ranches is a strong indicator of how far wildlife can move into these lands and freely interact with domestic animals including dogs. Though dogs have been shown to be unsuccessful predators due to their small group size, small body mass and the abundance of alternative food, large carnivores such as lions (*Panthera leo*), Leopards (*Panthera pardus*) and Hyenas (*Crocuta crocuta*), have been recorded preying on dogs providing ideal circumstances for disease transmission (Butler *et al*. 2004). Most wild carnivores will move to community lands in search of food where domestic dogs are always in place to defend and protect livestock from predation, leading to increased potential for lethal interactions between wild and domestic carnivores. Although anecdotal, our data on predation support the idea that although relative abundance of large carnivores has been demonstrated to be lower on group/community ranches compared to conservancies in Laikipia (Kinnaird & O'Brien, 2012) direct interactions between wild and domestic carnivores are still occurring on these ranches. Our hypothesis of wild carnivores being shy of visiting community ranches, although some studies have shown that avoidance of some habitats by carnivores would mainly be caused by presence of competitor more than any other factors (St-Pierre, Ouellet & Crete, 2006). Vanak and Gomper (2010), confirmed that in a given system, presence of dogs may be preventing sympatric carnivores from accessing prey-rich habitats. The results found in this study also indicate that the sex ratio is skewed towards males, which is consistent with finding from other parts of the world (Beran, 1982; Daniels & Bekoff, 1989; Brooks, 1990; Cleaveland, 1996; Butler, 2000; Butler & Bingham, 2000)

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusions

This study revealed some interesting and important patterns that have an implication in conservation of both endangered and non-endangered wildlife species in respect to disease ecology. The conclusions are as below;

i. Dogs are used for different roles in Laikipia and this affects how they tend to move within a system and the amount of space they utilize.

ii. Space use by the dogs determines parasite richness although categorization of dogs is not significantly related to variation between movement patterns and parasite loads.

iii. There is a strong association between dogs and bomas, with movements of most dogs restricted to areas immediately surrounding their home bomas..

iv. Some dogs seem to spend some of their time inside the conservancies but almost all the dogs penetrating into the conserved lands were collared in close proximity to the conservancies.

v. Apart from just domestic dogs being expected to move into the conservancies, the opposite is true where wildlife and mostly carnivores (though we only have anecdotal data on this), were also shown to move and spend some time in the community lands.

6.2. Recommendations

From the findings from this work, extended research needs to be done on the interactions between domestic dogs and wildlife to create a better understanding on how spatial ecology impacts the spread of parasites and pathogens in the savannas. Recommendations are as follows;

i. Though the movement patterns of dogs are still important to evaluate, greater emphasis should be placed on finding out how far wild carnivores penetrate into community lands and the amounts of time that they spend there.

ii. Parallel studies should be conducted on the movement patterns of both domestic dogs and some wild carnivores to have a greater opportunity of showing any chances of contact between these groups of animals.

iii. The association of dogs with different herds of cattle might have an influence in parasite richness on herding dogs as opposed to home dogs and thus it might wise to consider sampling cattle in future studies.

iv. Data on dog demographics in Laikipia would be useful for this and future studies as it is key to understanding disease dynamics and effective coverage during rabies vaccinations.

v. Annual vaccinations, as advocated for by the Laikipia Rabies Vaccination Campaign, should be conducted annually to better protect people, livestock and wildlife form this fatal disease.

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Appendices

Appendix 1

Total home ranges sizes of the dogs with the corresponding size/part of the home range occurring in the neighbouring conserved lands (n=5) to Koija and Il Motiok. This is data for only the dogs (n=20) selected for analysis in this thesis.

Dog ID	Sex	Category	Total HR (KM^2)	Koija (KM^2)	Mpala (KM^2)	IlMotiok (KM^2)	Loisaba (KM^2)	Tiemamut (KM^2)	Karisia (KM^2)	S.Nyiro (KM^2)
DG7	Male	Herding	38.07	1.24	0	29	0	4.73	2.1	0
DG3	Male	Herding	30	1	2	24	0	0	0	3
DG8	Male	Herding	31	0	0	14	0	6	8	0
DG9	Male	Herding	62	6	0	38	0	14	4	0
DG10	Male	Herding	25.25	0	0	16.71	0	5.9	2.64	0
DG19	Male	Herding	32	12	17	3	0	0	0	0
DG24	Male	Herding	14	13	0	0	1	0	0	0
DG34	Male	Herding	26	26	0	0	0	0	0	0
DG41	Male	Herding	30.2	2	0	28	0	0	0.2	0
DG42	Male	Herding	51	6	0	35	0	1	9	0
DG17	Female	Home	10	2	5	3	0	0	0	0
DG20	Male	Home	18	1	0	17	0	0	0	0
DG23	Female	Home	19	19	0	0	0	0	0	0
DG32	Male	Home	31	29	1	0	1	0	0	0
DG33	Male	Home	10	10	0	0	0	0	0	0
DG42	Male	Home	17.5	0	0	17	0	0	0.5	0
DG45	Male	Home	11	0	3	7	0	0	1	0
DG47	Male	Home	30.5	28	0.5	0	2	0	0	0
DG48	Female	Home	6	6	0	0	0	0	0	0
DG49	Male	Home	9	0	0	7	2	0	0	0

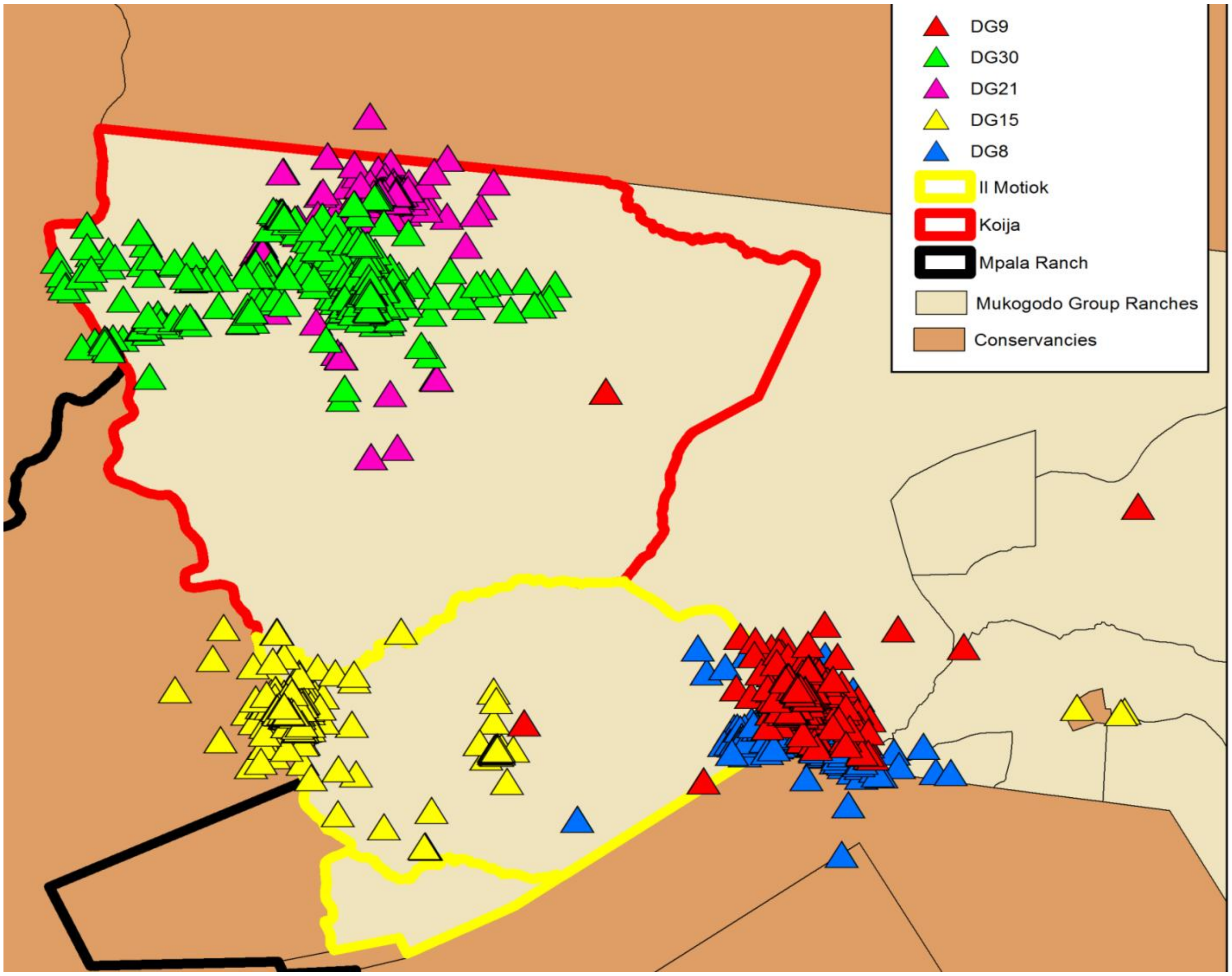
Appendix 2

The different sampling sessions (n=4) conducted on the dogs (n=20) with the respective number of fleas and ticks collected from a specific dog per sampling session., at Koija and Il Motiok, Laikipia Kenya

			Trap. Ses. 1 (June)		Trap. Ses. 2 (Aug)		Trap. Ses. 3 (Nov)		Trap. Ses. 4 (Feb)	
Dog ID	**Sex**	**Category**	Ticks	Fleas	Ticks	Fleas	Ticks	Fleas	Ticks	Fleas
DG7	Male	Herding	0	0	0	0	5	2	10	0
DG3	Male	Herding	2	1	3	0	9	0	5	0
DG8	Male	Herding	5	0	2	6	5	0	0	0
DG9	Male	Herding	4	8	5	0	5	0	0	0
DG10	Male	Herding	10	1	20	4	19	0	0	0
DG19	Male	Herding	9	0	21	0	6	0	11	1
DG24	Male	Herding	2	7	3	3	4	20	2	0
DG34	Male	Herding	20	3	2	0	0	0	0	0
DG41	Male	Herding	0	0	10	1	17	10	50	10
DG42	Male	Herding	20	0	15	8	15	0	10	20
DG17	Female	Home	2	3	20	15	0	0	7	10
DG20	Male	Home	8	0	0	0	0	0	0	0
DG23	Female	Home	4	20	7	20	0	0	0	0
DG32	Male	Home	4	1	0	0	0	0	20	0
DG33	Male	Home	210	2	25	0	9	100	40	0
DG43	Male	Home	9	5	0	0	0	1	0	0
DG45	Male	Home	3	0	6	6	6	0	3	0
DG47	Male	Home	0	0	2	1	2	0	4	0
DG48	Female	Home	0	0	0	0	0	0	5	0
DG49	Male	Home	0	0	0	0	12	0	4	1

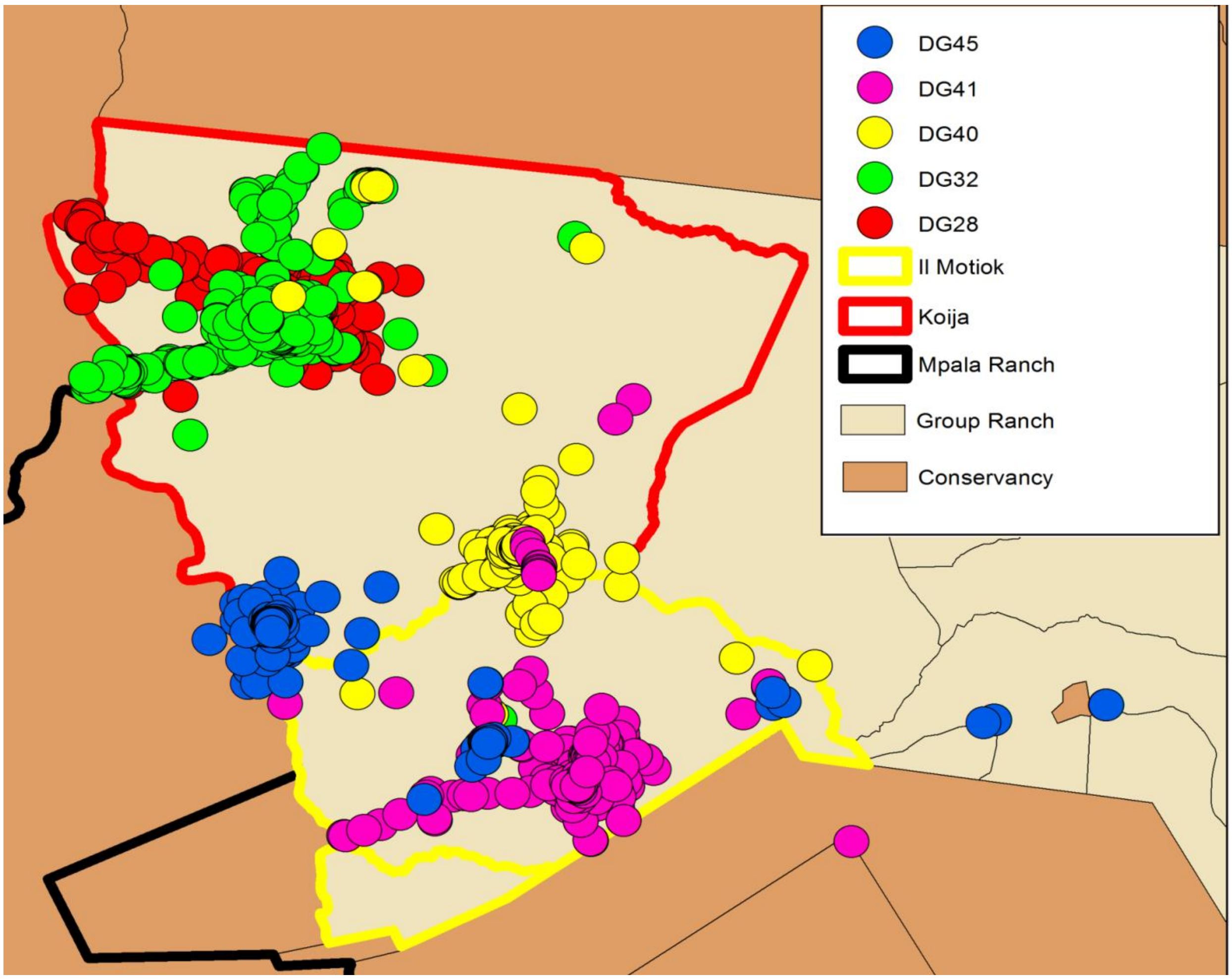
Appendix 3

A sample plot of a few herding dogs dogs (n=5) showing interactions between the (as earlier discussed in the results) at Koija and Il Motiok, Laikipia Kenya, during the tracking period



Appendix 4

A sample plot of a few home dogs dogs (n=5) showing interactions between the (as earlier discussed in the results) at Koija and Il Motiok, Laikipia Kenya, during the tracking period



Appendix 5

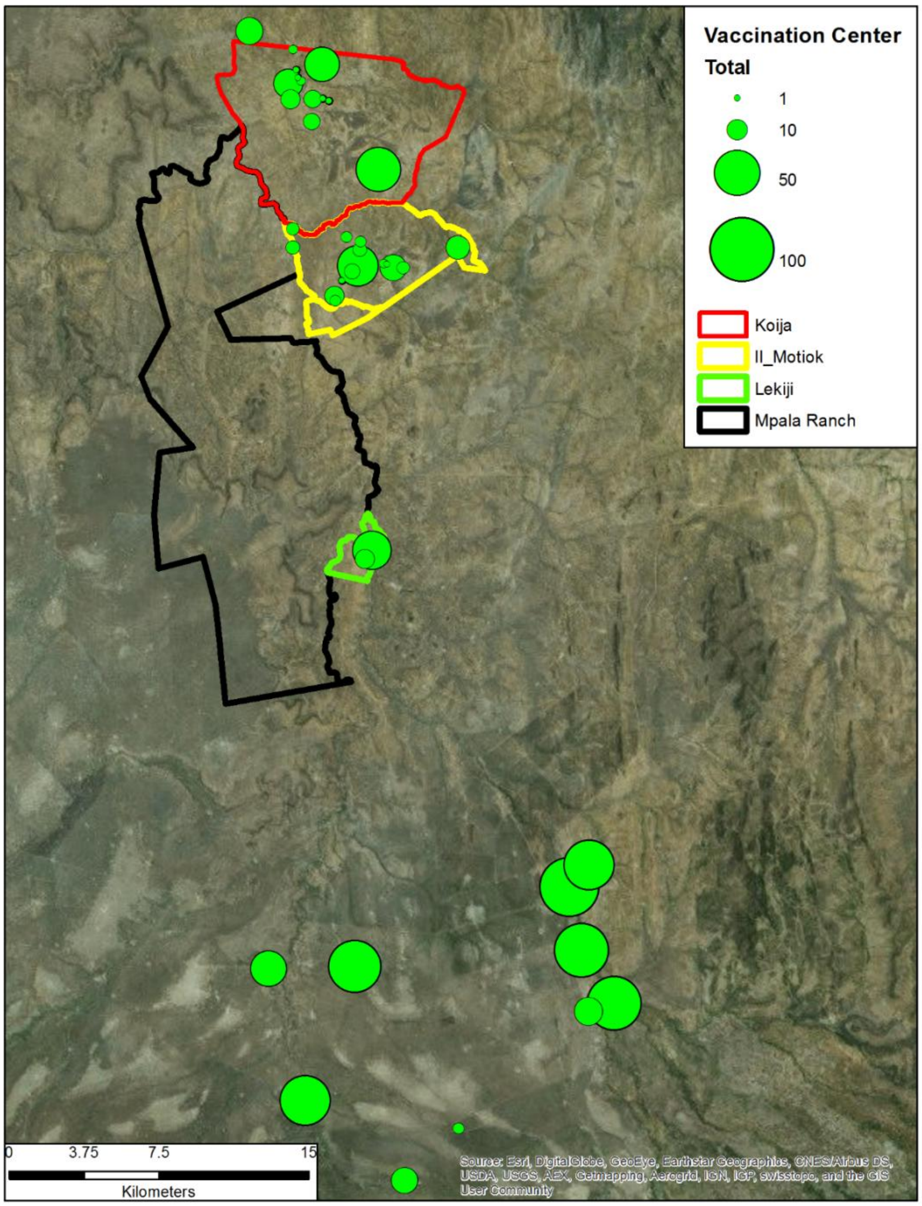
A sample of the iGotU GPS Data loggers (GT- 600 model, 46 x 41.5x 14 mm of size, 37g of weight, iGotU, Mobile Action Technologies (http://global.mobileaction.com/) used for tracking dogs for this study at Koija and Il Motiok

Appendix 6

A collared dog at Il Motiok community ranch showing the custom designed metal casings and the commercially available domestic dog collars.

Appendix 7

Laikipia Rabies Vaccination Campaign; A map showing the different locations which served as our vaccination centers in different community ranches, the point dots are in a scale showing an approximation of the total number of animals vaccinated in a given location



Appendix 8

Education Program; A list of the schools that benefited from the education program and a sample award winning poster drawn by one of the competitors (student)

1. Mpala academy
2. Ol Jogi Primary School
3. Kimanjo Primary School
4. Kimanjo Secondary School
5. Il Motiok Primary School
6. Ewaso Primary School
7. Naiperere Primary School
8. Musul Primary School
9. Olgirgir Primary School
10. Lekiji Primary School
11. Ngabolo Primary School
12. Shiloh Naibor Primary School

Appendix 9

A sample of an award winning poster drawn by one of the students during the poster competition at the education program