Dogs finally have their day? Aspects of Free-ranging Dog Ecology at Hanle, Changthang Wildlife Sanctuary – Ladakh

Dissertation submitted to Saurashtra University, Rajkot in partial fulfillment of Master's Degree in Wildlife Science

Submitted by

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भारतीय वन्यजीव संस्थान
Wildlife Institute of India

To the magic of Trans-Himalaya, the heart-warming people of Hanle, and that lone female wolf!

And to the dogs -

Knowing me in my soul the very same –
One who would die to spare you touch of ill!
Will you not grant to old affection's claim
The hand of friendship down Life's sunless hill?
Thomas Hardy

DECLARATION

I, **Ms.Subhashini.K**, hereby declare that the research work titled "**Dogs finally have their day? Aspects of Free-ranging Dog ecology at Hanle, Changthang Wildlife Sanctuary – Ladakh**" carried out in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot is an original piece of work. These investigations were carried out under the supervision of Dr. Lallianpuii Kawlni, Dr. Y. V. Jhala and Dr. Sutirtha Dutta at the Wildlife Institute of India from December 2018 to June 2019. I also declare that this work has not been submitted for any other degree of any university.

Date: 30th June, 2019

Place: Dehradun Ms. Subhashini. K

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that **Ms.Subhashini.K** has carried out original research from the Wildlife Institute of India, titled **"Dogs finally have their day? Aspects of Free-ranging Dog ecology at Hanle, Changthang Wildlife Sanctuary – Ladakh"**, in partial fulfilment of Master's Degree in Wildlife Science from Saurashtra University, Rajkot, India. The study was carried out under our supervision from December 2018 to June 2019. We hereby certify that this work has not been submitted for any degree to any university.

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Acknowledgement

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Pleasures are like poppies spread, You seize the flower, its bloom is shed;

Or like the snow falls in the river, A moment white – then melts forever.

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Summary

1. In a country with increasing numbers of free-ranging dogs that often times foray into wildlife habitats, even their presence has been established as a threat for biodiversity conservation in any landscape. Stated that they pose a problem, the means and extent of the problem needs an understanding of their ecology. This study aims to understand the effect of anthropogenic subsidies on the population, ranging, and subsidy resource usage patterns of free-ranging dogs. Placing subsidies in the centre of the ecology of these dogs, the study also attempts to understand inter-species interactions and potential for dogs to act as disease reservoirs in the unique trans-Himalayan landscape.

2. After demarcating the definitions of various forms of subsidies that would be used in this study, the six dogs that were radio-collared through the track-and-dart method of capturing were used as representatives of certain type classes of subsidies. Their movement and behaviour were monitored for a total of 576 hours in the months of January and March (early April too). February was spent with estimating their densities by traversing along fixed pathways and taking note of their unique identities and locations to use in a Mark-resight framework. Subsidies sites and characteristics were recorded on other days.

3. With a detection probability of 0.63, the dog densities were about 1 dog/Km^2. The distribution of the dogs in the landscape was bound by the presence of subsidy. Their home

range patterns also indicate a strong ranging pattern around areas with higher subsidies than in areas with lower or no subsidies.

4. Continuous focal behavioural sampling yielded durational data for various activities performed by the dogs. Feeding durations on a particular type of subsidy was based on its availability across January and March. Nonetheless, they were highly dependent for subsidies throughout the study period. Interaction observations gave insights on the rare but negative interactions with wildlife - foxes being the most commonly interacting wild animal.

5. Absence of antigens for Canine Distemper and Canine Parvovirus indicated the absence of live infection in blood during the study period, but the small sample size and brittle nature of the virus makes it difficult to rule out absence of the virus in the population.

6. The study concludes with the message that subsidies determine the densities and home ranges of dogs. Behavioural observations also indicate that free-ranging dogs can have negative impacts on the sparse wildlife of this arid cold desert.

Keywords: Free-ranging dogs, Subsidy, Densities, Home Range, Resource utilisation, Interaction, Disease transmission, Ladakh

1.1 General Introduction

My acquaintance with dogs echoes that of thousands of humans across the world. As a companion, a playmate, a therapist, a shoulder to lean on – dog's uncanny ability to pick up on human moods and actions still makes me wonder if even humans are capable of this

ability. There were times in my life where fights ensued when my dog or any dog underwent abuse of any kind. Over time, with increasing comprehension and widening perspectives, dogs were also put on my mental prosecution stand -they bite, cause injury, and sometimes even death.

As a budding wildlife enthusiast following wildlife news and anecdotes of our country, a noticeable pattern of increasing dog attacks on wildlife, and dogs threatening conservation activities led me towards a path of dissonance. Learning about these effects and interactions within the ecosystem, the need to examine the underlying causal mechanisms led to the initiation of this work in a landscape that presented special uniqueness and a formidable challenge.

1.2 Literature review

1.2.1 When humans first planted the seeds unwittingly

As Carl Sagan (2006) eloquently put it, *'Extinction is the rule; Survival is the exception'*; the primitive dogs knew they were an exception. As they underwent a lot of selection to be compatible with us and our world, dogs found themselves in this juncture between human society and wildlife. In landscapes where these two entities are tightly bound by the same laws and resources, dogs add to the tension. Despite, Serpell (1995) establishing that the ecological niche created by humans serves as the niche for the dog, the complexity of this niche that they occupy is difficult to understand and quantify. Domestication has shaped the cognitive ability of dogs, unseen even in non-human primates. The companionship thus

offered, also aiding in hunting and guarding, is believed to have led to the selection of those dogs showing higher fitness in these above-mentioned qualities (Mancini, 2012).

Diverse morphology, geography, and behaviour make Canids a fascinating family of carnivores. With forty extant species across the world, there are at least one canid species in every continent, with the exception of Antarctica (Sillero-Zubiri et al.,2004). With regards to domestic dogs, genome sequencing studies have given us insights to understand their origin and evolution. Largely agreed to be a two-stage process, the modern dogs have evolved from primitive dog-like ancestors who had grey wolves as their direct wild ancestors. Whole genome sequencing studies have helped to map out the origin and diversification of dogs from South-East Asia to the Middle East and Europe about 33000 years ago (Wang et al. 2016).

1.2.2 Somebody let the dogs out

Domestic dogs are the most abundant terrestrial carnivore with a systematic global estimate of about 700 million dogs (Huges and Macdonald, 2013). Versatile biological traits and adaptability (Axelsson et al., 2013) allow the dogs to occur at higher densities than their similar sized wild carnivores. Subsisting primarily on human-derived or provided resources (Vanak and Gompper, 2009 a), the growing dog populations are becoming a growing menace (Gompper, 2013) as these ‘domesticated predators’ begin to play impactful ecological roles in an ecosystem alongside humans, and interact highly with the native

wildlife (Butler et al., 2004; Lacerda et al., 2009; Vanak et al., 2009) mostly with detrimental effects.

Domestic dogs are called free-ranging dogs when they are not under direct human supervision and whose activities are not restricted by human activities (Caffazo et al. 2010). It is important to understand the effects of dogs on wildlife as they are reported to pose a risk to nearly two hundred threatened vertebrate species, worldwide (Doherty et al., 2017). Along with unpleasant encounters and conflicts with human beings and livestock, they are identified as an important threat to wildlife conservation (Ritchie et al., 2014). Of the many studies that have been conducted in assessing the effect of free-ranging dogs on wildlife, most have found that dogs negatively affect the native wild animals (Young et al., 2011).

A quick literature review highlight that dogs are an important cause of mortality for wide variety of wildlife like the Marine iguanas *Amblyrhynchus cristatus* (Kruuk and Snell, 1981), the Kiwis *Apteryx australis* (Taborsky, 1988), the Huemul Deer *Hippocamleus bisulcus* (Corti et al., 2010), and the Pudu deer *Pudu puda* (Silva-Rodríguez et al., 2010). Lenth et al., 2008 have studied the effects of increased stress and energetically costly behaviour in endemic species. They also concluded that the mere presence of dogs deters the use of habitat by wildlife. Most of the encounters with wildlife had ungulates as the target species with carnivores being the second target (Vanak & Gompper, 2009) and the deleterious effects on the breeding success of ungulates (Gingold et al., 2009) have also been documented. Direct predation (Ritchie et al., 2014), fear-mediated behavioural changes (Zapata-Rios and Branch, 2016), interference competition (Vanak et al., 2014),

disease transmission (Knobel et al., 2014) and hybridization (Leonard et al., 2014) are the ways through which dogs affect wildlife (Gompper, 2014; Home et al., 2017).

1.2.3 Our big nation and her dogs

From ancient times till our present day scenario, the ambivalence towards dogs has still not been addressed and acknowledged. A sacred text called the 'NisīhaCuū' expresses this conundrum as, "..gods come to the world of men in the shape of yaksas - dogs. They are worshipped when they do good, and not when they do not." This duality of relationships between dogs and human is expressed in many other mythological and historical records (Wasik and Murphy, 2013).

India, one of the 35 rich biodiversity hotspots (Mittermeier et al., 2011), also happens to have one of the highest numbers of free-ranging domestic dogs in the world (Gompper, 2014). Canids have instinctive wiring to chase/hunt wildlife leading to wildlife perceiving dogs as an obvious threat (Gabrielson and Smith,1995). Varying from interference competition (Vanak and Gompper, 2010 a,b) to intraguild pathogen transfer (Belsare and Gompper, 2015), there is little evidence of negative impact in the Indian landscape. Few anecdotal accounts of attacks on the Blackbuck *Antilope cervicapra* (Jhala, 1993), Indian Gazelle *Gazella bennettii* (Dutta, pers. Comm., 2017), and Tibetan Antelope *Pantholops hodgsonii* (Pandav and Nair, pers. Comm., 2018) exist

The cold desert landscape of Ladakh exhibits one of the highest overlap of resource utilisation by humans and wildlife (Mishra et al., 2001). The free-ranging dogs of this

landscape pose a major threat as the low density of the rare wildlife in this landscape becomes vulnerable to the growing dog population (Mahar pers. Comm., 2018). The emergent practice of settling by the previously nomadic Changpa tribes of the Changthang plateau along with a high number of defence camps might act as a one of the major cause of the increasing dog densities, as human settlements provide a continuous source of subsidies. This calls drawing up important conservation measures for the native wildlife of Changthang Wildlife Sanctuary as they are now faced with new predator/competitor.

1.2.4 The beginning of a dogged pursuit

The landscape of trans-Himalayan cold desert was chosen not just out of a pure fascination for the landscape, but also for the fact that ecological effects can be determined clearly due to fewer confounding factors operating in the system. Most of the free-ranging dogs' abundance is largely determined by anthropogenic subsidies in the form of direct feeding by humans, and access to garbage or livestock. However, during winters, a period of significant resource deficiency might push the dogs to have increased encounters with wildlife and livestock. Interactions with wildlife are a direct threat to wildlife. Also, the attack on livestock eventually leads to misidentification of attacks by dogs as other carnivore attacks, which is unfavourable for our conservation goals. A study of interactions between dogs and other species would be incomplete without looking at the role played by dogs in disease transmission. Hence a component to look into the viral prevalence is also added to the study.

1.3 Rationale

In a landscape of tiring scarcity, food resources play an important role in determining the survival of a species. As ascertained with the literature above, free-ranging dogs indeed pose problems in area they share with the wildlife. The level or extent to which they can actually be problematic needs an understanding of their ecology in association with their landscape. Finding the free-ranging dogs at the juncture of domestic life and wildlife makes them an interesting group of animals to study the effect of human-derived subsidies on their ecology. Ocular estimation of the availability of food in garbage dumps was used to rank the level of subsidies as low, medium, and high. Presence of village in each grid was used as a surrogate to the presence of any other kind of subsidy (direct food, livestock carcasses, and human waste) which were also consumed by the dogs. This will be used as a premise to premise that can be used to test the effect subsidy on ranging patterns of the dogs.

1.3.1. Population estimation, ranging, and interaction

Understanding the mechanisms the govern distribution and abundance in an ecosystem, have been key challenges throughout the history of ecological studies. Especially so, when anthropogenic activities have an immense influence on these ecological processes (Krebs, 1994). The consistency of the food resource availability made by anthropogenic subsidies lifts off the pressure caused by density-dependent predation (Messier, 1994) on free-

ranging dogs. This tips the scale towards dogs when looked through the prey-predator dynamics model. The focus of the study is hence placed on looking at the effect of subsidies on abundance, ranging, and interaction. The effect of subsidy will aid to understand the issue of dog demography even if the prey abundance decreases. Dogs' adaptable utilization of human resources has important consequences for their distribution in space, thus affecting the distribution and abundance of potential prey in the region (Vanak and Gompper, 2010). Also, the well-defined social structure and hierarchical system of the wild counterparts are absent in domestic dogs (Fox, 1971). Home range sizes of carnivores decrease in urban habitat setting with an increase in population density as few of them evolve the ability to adapt through behavioural flexibility and life history adaptations (Salek et al., 2014). According to Woodroffe and Donnelly (2011), the dog encounter risk is a function of dog density generated by proximity to human houses which is a premise that can be used to test the effect of subsidies on dogs with wildlife. A distinction in interactions, with respect to space use, is expected to be observed between unsubsidized predators and subsidized predators; whose population dynamics, activity levels, and their distribution remain unaffected by the abundance and anti-predator strategies of wild prey found in the region (Silva-Rodriguez and Sieving, 2012).

1.3.2. Food resources utilized

Given their adaptability to sustain on carbohydrates (Bhadra et al., 2016), dogs are known to thrive on human—derived subsidies. It is also known that small-bodied prey is generally taken down by dogs in many cases. In one study, livestock depredation by dogs was found to be higher than that caused by snow leopards (Home et al. 2017). In order to look at the

contents of the major portion of the dog's diet, the feeding instances and time budget allocated for the utilisation of the various resources will be determined. Examining the scat for undigested food can also provide a substantial idea of food being utilized by free-ranging dogs.

1.3.3. Disease prevalence among dogs

Dog related pathogens are known to act as sources of infection causing changes to rates of fecundity, morbidity, and mortality in interacting wildlife. According to Cleaveland et al., out of the 358 pathogens known to infect dogs, about 168 (47%) are shared between dogs and wild mammals. Events of intraspecific transmission can have adverse effects when there is spillover to other interacting species with smaller populations. Cases, where dogs have caused spillover of the virus to Ethiopian wolf and African wild dogs, are recorded. High dog density enables the continued sustenance of the parasites in their hosts which might thereby increase the probability of transmission to native wildlife. Blood and faecal samples would be collected and analysed for canine parvovirus and canine distemper virus as they are the most commonly transmitted pathogens between dogs and other mammals (Knobel et al., 2013).

1.4 Objectives and Questions

a) To understand the effect of human-derived subsidies on the density, ranging behaviour, and food resource utilisation of free-ranging dogs
    i) Does subsidy influence the distribution of dogs in the study area?
    ii) Are the dog ranges different based on the number of subsidies available for them?

iii) What kind of food-resource utilisation patterns are exhibited?

b) To quantify direct interspecific interactions of dogs with the wildlife and livestock of the area

i) What proportion of the time do free-ranging dogs spend in interacting with wildlife and livestock?

c) To identify the prevalence of transmissible viral prevalence among the study group

i) What is the prevalence of viral pathogen among the study dogs?

2.1. Study Area

2.1.1. Area characteristics

Formed as a result of the collision between the Indian plate and Eurasian plate, the region of Ladakh falls under the rain shadow area of the Greater Himalayan range. This combined with altitude ranging from 3000m – 5500m gives it the cold desert character with the river Indus being the main source of water along with other glacial streams. Falling under the Biogeographic Province 1 B of the Indian Trans Himalayan Zone (Rodgers and Panwar, 1988), the eastern Ladakh landscape is a part of the Tibetan high plateau called as the Changthang plateau. The Indian side of Changthang is protected as a Wildlife Sanctuary (WPA of J&K, 1978) and is considered as an important highland grazing ecosystem (Goldstein and Beall, 1990).

The study area of 89Km^2 is a part of this sanctuary and is characterized by low precipitation (200-400mm), low temperature (-30 to 25°C), and high elevation (4100-4500m). Located inside the wildlife sanctuary, the Hanle valley is homogenous landscape

surrounded by hillocks and drained by the glacial river Hanle. The habitat types include marshlands, grasslands, forest department plantations, agricultural fields, and sandy river banks.

The study area has eight villages, two winter camping grounds of pastoralists, three defence establishments, and two substations of central government research institutes. Though all of the indigenous people are of the Changpa nomadic tribe, most of the residents are permanently settled with one village being shared by the Tibetan Refugees.

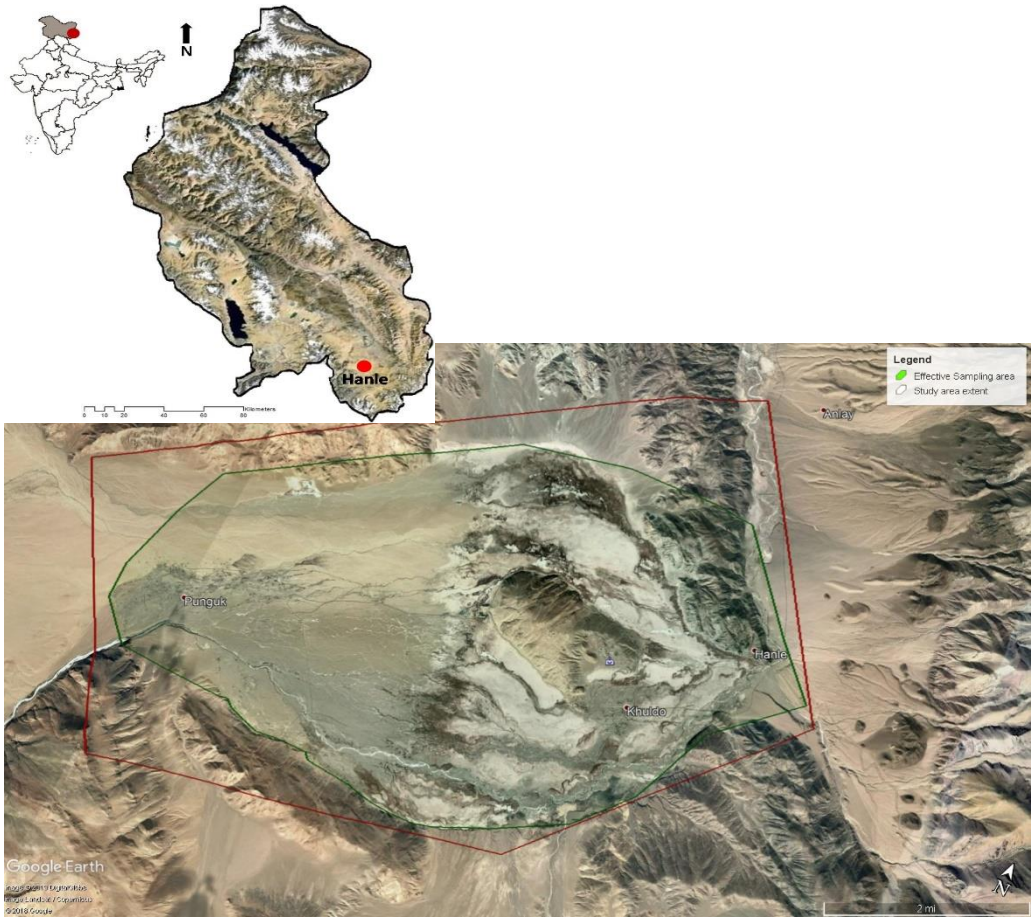

Figure 1: Map showing study area with study area extent and effective sampling area in Hanle, Ladakh. Map inset shows the extent of the Changthang Wildlife Sanctuary.

Table 1: The list of settlements in the Hanle valley with their location, altitude, and number of households as of April 2019

S.No	Village/Settlement Names	Location	Altitude	No. of households
1	Buk	32.74415, 78.93636	4273	12
2	Gompa	32.78998, 78.00042	4268	6+2(temples)
3	GREF	32.78763, 79.09040	4312	3
4	IB	32.77154, 78.97454	4275	3
5	IIAP	32.77950, 78.96376	4505	8
6	ITBP	32.79875, 78.98256	4235	12
7	Khuldo	32.77452, 78.98344	4272	93+1(school)
8	Kunzhi	32.79197, 78.97046	4245	5
9	Naga	32.78380, 78.98172	4266	21
10	Parquque	32.7718, 78.93326	4282	14
11	Punguk	32.76921, 78.91250	4356	90+1(school)
12	Shado	32.75228, 78.91239	4275	16
13	Yengsoma	32.76025, 78.94824	4265	22

2.1.2. Wildlife

Harsh climatic conditions and low primary productivity has resulted in a unique set of fauna and flora in this landscape. The vegetation scene is dominated by Poaceae, Asteraceae, and Cyperaceae species. During the summer months, the intense agriculture presents fields of barley and peas amidst the natural vegetation.

The fauna of this region has much in common with Central Asia and more so, with the Tibetan plateau which is an extension of the Indian Changthang. However, birds from the Indian sub-continent do migrate here during the summer months. Primary mammal species in the field site include Tibetan Wild Ass, Blue Sheep, Tibetan Wolf, Red Fox, Palla's Cat, Eurasian Lynx, Snow Leopard, Wooly Hare, Marmot, Pika, and Vole. The primary resident winter birds include Horned Lark, Tibetan Snowfinch, Hill Pigeon, Northern raven, Upland Buzzard, Golden Eagle, and Bearded Vulture. Summer migrant birds and hibernating mammals like Marmot arrive during the months of April and May.

2.1.3. People and Economy

The Indian Changthang region has a tribal population called as the 'Changpas' who were traditionally nomadic pastoralists. Known for being one of the important

pashmina/cashmere wool production centres (Namgail et al.2007a), the number of goats and sheep seem to have a steady decline in the past twenty years. As the nomads have begun to settle and take up rigorous agricultural practices during the short and conducive growing months from May to September, the numbers of goats and sheep have been on steady the decline with increasing settlements of the pastoralists.

In summers of the recent times, the economy of the landscape has been resting on agriculture, tourism, labour jobs at GREF (General Reserve Engineering Force), IIAP (Indian Institute of Astrophysics) observatory. The winter economy is relatively low with only GREF making labour jobs available. Scarce resources affect the village during winters making the sustenance primarily on barley, wheat, and dry meat. Horse, donkey, kiang, and goats pellets are the main source of fuel for the fire to keep warm during winters. In case of medical emergencies, the nearest health centre with substantial care provision is about two hours away, including for anti-rabies vaccination which has become a frequent need in the past few years.

3.1. Study Methodology

More than the weather and temperature conditions of the landscape, the logistical constraints influenced the leading to impromptu minor methodology changes and data collection. However, with consistent support from the villagers and field assistants at Hanle, major constraints were aptly dealt with enabling a smoother data collection process on most of the fair-weather field days.

3.1.1. Important definitions

i) Subsidy – includes direct human food, livestock carcasses, and human faeces (for ranging pattern, village presence has also been taken as a surrogate for subsidy)

ii) Direct human food -

   a. food scraps (discarded direct human food like kitchen waste, available randomly around human habitation)

   b. meal (direct human food available constantly in space and time)

iii) Low Subsidy – includes all forms of subsidy with zero meal a day

iv) Medium subsidy – includes all forms of subsidy with one meal a day

v) High subsidy – includes all forms of subsidy with three meals a day

vi) Garbage dumps – may or may not have dog edible matter in it along with garbage (plastic, clothes, etc.)

3.1.2. Does the subsidy affect the abundance of dogs in the study area?

Field methods - Normal dog collars were distributed in the study area to be used upon the pet dogs to distinguish them from the free-ranging dogs. To estimate the detection-corrected abundance of dogs, 21 grids were traversed in fixed pathways with the mean effort of three kilometres each (effort/grid). When dogs were sighted, their projected locations were taken using GPS, Laser rangefinder, and magnetic compass. Many

photographs of every dog sighted were taken for mark-resight framework estimation. For every individual, spatial replicates were not collected (i.e) when the same dog was sighted more than once in a single occasion, the location of the first sighting was only considered. Each path in every grid was traversed over five occasions thus giving five temporal replicates per grid. This was done over the month of February only during the daylight hours

Analytical methods - Data explorations were done with MS Excel 2010. The encounter data of marked and unmarked individuals across the survey area were estimated with the corrected count and the detection probability. With the data being put into the '1 0' matrix framework and with the count of unmarked individuals across all the session, the analysis was done using the mixed logit-normal mark-resight model in program MARK (McClintock, 2012). The sighting surveys were in a 'without replacement' sampling framework as each individual's first sighted location was only considered. This was aided by the knowledge of the number of marked individuals available for re-sighting.

The corrected count for each grid was computed in Excel using the mean number of dogs sighted across all occasions in a grid divided by the detection probability (White, 2005). This enabled to arrive at the encounter rate estimate by multiplying the corrected count with the effort in each grid and the detection probability. The maximum distance moved by each marked dog from its recapture locations was computed and averaged across all marked dogs using ArcMap and MS Excel. The half of mean maximum distance moved was used to estimate the effective sampling area over which dogs were captured. The detection-corrected dog encounter rate was log-transformed and modelled on surrogates of subsidy provisioning using linear models, to understand the effect of the subsidy on the

distribution of dogs. Two surrogates of subsidy were used: the presence of village and an ordinal measure of the quantity of garbage in the grid. After comparing alternate models/hypotheses using Information Theoretic approach, the model with low AIC value was used for inference.

3.1.3. Are dog ranges affected by their respective subsidy level?

Field methods - Track-and-dart techniques were used to capture six dogs and fitted with Telonics MOD 400 VHF transmitter radio collars (3 males, 3 females). This is considered a good method to understand foraying behaviour (Sepúlveda et al., 2015) for those individuals from respective subsidy levels. H.A.B.I.T receiver failed to work in January and hence, one of the collared dogs which could not be found was replaced by a paint marked (HAN007) dog for the month of January. The receiver regained its functionality in March and the individual (HAN003) was found in March, however, data for HAN007 could not be collected as the individual died in an inter-group dog fight. In the month of January, five of the VHF collared dogs and one paint marked dog were followed over a period of eight hours. Each individual had three days of continuous eight-hour observations. The extreme temperature drops did not allow for an increased sampling period in January, however, anecdotal observations indicate that dogs did not show movement in the night.

During the month of March, the six VHF collared dogs were continuously followed day and night giving around seventy-two hours of continuous sampling per dog. One individual (HAN002) was incompletely and intermittently followed as the radio collar was removed by presiding defense personnel. During both the sampling sessions, every ten-minute location of the respective dogs was taken. For all the location readings taken, Garmin etrx30 GPS was used along with Laser range finder, and magnetic compass.

The amount of meal in the garbage dump from the area of the collared individual was used to rank the level of subsidy to which these individuals belonged to.

Table 2: The details of the individual dogs that were caught and marked with radio collars/paint at Hanle, Ladakh.

S.no	ID; name	Gender;Age	Location	Subsidy_level	Details
1.	HAN001; Scamper	Male;3	GREF	Medium	Red, in a group of 10 with HAN004
2.	HAN002;Stud	Male;3	Khuldo	Medium	Red, lone village dog
3.	HAN003; Cakey	Male;3	Khuldo	Low	Red, lone village dog
4.	HAN004; Kiaki	Female;3	GREF	Medium	Red, with communal den pups, in a pack of 10 with HAN001
5.	HAN005; Gaia	Female;3	ITBP	High	White, four pups, in a group of 7
6.	HAN006; Phoenix	Female;3	Punguk	Low	Red, with five pups, lone village dog
7.	HAN007; Kada (Paint)	Male;6	IIAP Obs	High	Black, broken canine teeth, in a group of 6

Analytical method - Data explorations were done with MS Excel 2010. The GPS locations were plotted and projected using ArcMap 10.6 software. Convex hull tool enabled to draw the minimum convex polygon and hence calculate the area of each individual in both January and March.

To understand dog range location based on their distance from subsidy points, Euclidean distance tool was used to estimate the distance between the subsidy points and dog location points in the study area. This was then compared to Euclidean distance obtained between subsidy points and random location points generated in the study area. A histogram was plotted to understand the distribution of the dog locations and random points based on their distance to the subsidy points.

3.1.4. What kind of food resource utilization patterns do these dogs show?

Field method - A distance of 20 – 200 m was kept between the observed dogs and the observers. Dogs were also habituated to flashlights and car headlamps before the night observations began. The dogs were tolerant of our presence up to 30 meters without any obvious behavioural changes due to our presence. Six dogs were followed by car/foot in January for eight hours continuously for three consecutive days. In March, six dogs were followed for twenty-four hours continuously for three consecutive days. Thus all of the dogs got about 24 hours in January and about 70 hours in March of continuous focal animal sampling (Altman, 1974). The below ethogram was the guide with which the behavioural observations were collected and then processed to answer specific questions.

Table 3: Ethogram of dogs showing a catalogue of the various behaviours observed during the continuous focal sampling of the radio-collared dogs at Hanle, Ladakh.

ACTIVITY	CODE	DEFINITION
FEEDING	FEEDING	
SCAVENGING	SCAV	Feeding on dead animal carcasses/parts
GARBAGE	GARB	Feeding on garbage
HUMAN FOODSTUFF	CHEW	Feeding on human food remains
WATER/ICE	LICK	Drinking water/ice
LOCOMOTION	LOCOMOTION	
WALKING	WALK	Move at a slow pace
TROTTING	TROT	move at a faster pace than WALK
RUNNING	RUN	Move at the fastest pace
ROAMING	ROAM	Move over a short distance(a circle) slowly
CRAWLING	CRAWL	Move with all feet down; on the belly
SKIDING/SLIPPING	SKID	Move on ice
SOCIALISING	SOCIALISING	
NOSE SNIFFING	NOTIFY	Sniffing noses with others
BOWING	BOW	Going low/under snout of another dog with a tucked tail
SUBMISSIVE	SUB	Lying on back with a tucked tail and all legs on air
DOMINANT	DOM	Holding snout/head above another dog with tail up/short wags
PLAYING/PRANCING	PLAY	Fake bite/grab/chase/tug with another dog
GROOMING	GRO	Grooming another, generally mother and pups
SUCKLING	SUCL	Suckling a pup(s)
TAIL WAGGING	WAG	Approaching with tail wag towards a human
VOCALISING	VOCALISING	
BARKING	BARK	Barking at a foreign object, human, another animal
BARKING AT	BARR	Barking at another dog of same/different group

DOG		
HOWLING	HOWL	Long high pitched vocalisation
WHINING	WHINE	Low moan in physical pain/injury
WHINING IN SUBMISSION	WHINY	Low moan in submission
GROWLING	GROWL	Low deep sound at another dog with barring teeth
RESTING	RESTING	
SITTING	SIT	Body placed on Hind limbs with upper body propped up on forelimbs
LAYING	LAY	Placed on belly/sides with all limbs down
SLEEPING	SLEEP	LAY with eyes closed
STANDING STILL	BASK	Standing with no movement, sometimes with closed eye
EXCRETION	EXCRETION	
URINATING	PEE	Peeing slowly and walking away unhurriedly
URINATNG for MARKING	PEEM	Sniff and peeing with a quicker pace
DEFECATING	POO	Defecating
VOMITING	VOM	Bringing undigested/half-eaten food out through the mouth

During the continuous behaviour sampling in the months of January and March, feeding events of the individuals being monitored were taken to understand the feeding habits of the radio-collared individuals across their respective subsidy levels.

Analytical method - Scat samples were cleaned and the undigested food materials were separated out as samples with bones, hair, plant material, and other miscellaneous substance. Hair samples were mounted on a compound microscope and the species the animal group to which they belong to were identified. Feeding events of the collared individuals were analysed to get the proportion of time spent by the dogs in feeding on human food, garbage dumps, and carcasses.

3.1.5. What proportion of the time do free-ranging dogs spend in interacting with wildlife and livestock?

Field method - It has been established that direct interspecific interactions can be quantified based on direct behavioural observations (dos Santos et al., 2018). Hence, continuous Focal animal sampling (Altman, 1974) of eight hours a day for three consecutive days was conducted in January. Again in March, behaviour sampling of twenty-four hours for three consecutive days was conducted. Binoculars and stopwatch were the needed equipment along with the additional usage of flashlights during the night sampling. Events and states were taken together along with and were differentiated based on duration.

Analytical method - Data explorations were done in MS Excel 2010. The proportions of time spent in other major activities were plotted to understand time spent in each activity. The event data on interactions were separately considered and categorized on the basis of the type of interacting agent. All interactions were considered as events and then categorized into two main types – Agonistic behavioural interactions and Neutral behavioural interactions. Agonistic behavioural interactions included barking, chasing, injuring, and killing as the four types of events. Neutral behavioural interactions were taken down based on social behavioural events within or among dog groups. These observation yielded data to look at the proportion of time spent in interacting with dogs, dogs-livestock, dogs-wildlife, and dogs-humans. A total of 576 hours of observation in the months of

January and March were put together to come up with the proportion of time spent by the dogs of the study area in various interactions.

3.1.6. What is the prevalence of viral pathogen among the study dogs?

Field method - Blood samples were collected from the seven individuals captured by track-and-dart method for the process of radio-collaring, as a part of routine procedure. The blood samples thus were preserved in RNA later. During the field observation, a total of 18 individually identifiable faecal samples were collected.

Analytical method – All laboratory works were done by lab technicians. Nucleic acid extraction – The DNA extraction from the blood and faecal samples was done using the Qiagen DNeasy Blood and tissue kit and Qiagen Stool mini kit as per the manufacturer's protocol. Total RNA was extracted using the Qiagen RNA extraction kit followed by cDNA synthesis using Superscript IV First Strand cDNA synthesis system.

Polymerase chain reaction – Oligonucleotide primers to amplify the CPV 2 gene was used to yield an amplicon of 160 bp (Nandi et al.,2009). The Polymerase Chain Reaction (PCR, henceforth) volume of 12.2 μL was subjected for PCR assay with the following cycling conditions- initial denaturation at 94°C for three minutes, 30 cycles consisting of denaturation at 94°C for thirty seconds, annealing at 52°C for a minute, and extension at 72°C for thirty seconds and a final extension at 72°C for five minutes. The PCR products were electrophoresed along with 100 bp DNA ladder in 1% agarose gel. Vaccine strain of CPV-2 was used as a positive control.

For screening Canine distemper virus, the genes encoding partial nucleocapsid (N) protein were amplified using primers to yield an amplicon of 287 bp at initial denaturation at 94°C for 1 min; 40 cycles consisting of denaturation at 94°C for 1 min, annealing at 59.5°C for 2 min, and extension at 72°C for 1 min, followed by final extension at 72°C for 5 min (Frisk et al., 1999). PCR products were electrophoresed on 1% agarose gel. Vaccine strain of CDV was used as the positive control.

4.1. Results

4.1.1. Subsidy and dog numbers

The σ- value is kept as zero because heterogeneity models do not apply when the individual differences (age,sex, etc.) in the marked individuals are not taken into account for analysis. This gives us the opportunity to interpret the overall real parameter estimate of p=0.64 ± 0.30 as the overall mean re-sighting probability. A mean effort of 3 Km/ grid yielded a total of 52 dogs that were uniquely identified (marked) with photographs.

Table 4: Consolidated list of the marked and unmarked dog sightings across each occasion.

	Occasion 1	Occasion 2	Occasion 3	Occasion 4	Occasion 5	Total
Marked resighted	35	43	32	24	31	165
Unmarked sighted	10	33	21	12	23	99

The location points taken during sighting and resighting of dogs were plotted in ArcMap 10.5 and the Mean Maximum Distance Moved between two points were estimated in Excel. This helped us derive the effective study area size to be 86Km^2. Household surveys helped in arriving at the count of pet dogs to be 80 individuals. This estimate enables us to arrive at a calculation of 187 domestic dogs per 100 Km^2 in the Hanle Valley.

Table 5: Estimates of mark-resight, Mean Maximum Distance Moved, effective study area, and density for free-ranging dogs at Hanle, Ladakh, 2019.

S.no	Estimate	Mean	Standard Error	95% Confidence Interval
1.	Abundance	83.08	2.38	78.75 – 88.11
2.	½ MMDM	190.8	40.34	231.23 – 150.55
3.	Density/Km^2	0.95	0.06	0.89– 1.01

Table 6: Summary statistics of Linear model estimates examining the effect of the subsidy on dog distribution in Hanle, Ladakh.

Variables	R^2- Value	AICs
Null Model	-	49.0940
Subsidy Presence Model	0.2863	41.60027
Garbage Rank + Subsidy Presence Model	0.2791	42.63764
Garbage + Subsidy Presence Model	0.1795	46.56098
Garbage Rank Model	0.2099	49.19423

Detection corrected encounter rates of free-ranging dogs for each grid based - on the number of dogs sighted, distance searched in each grid, and using the estimate of P-hat derived from Mark re-sight analysis – were obtained. This means that the effect of the subsidy on dog encounter was significant but explained only 28% of the variation between the grids across the landscape. The level of subsidy in garbage dump did not significantly explain the dog differences across the study area.

4.1.2. Subsidy and Dog home ranges

Mean home range (95% MCP) across all dogs and across both months came to about 1.43 ±0.51 Km^2. Mean home range between the two months was similar with January 1.29 ±0.65 Km^2 and March 1.56 ±0.82 Km^2.

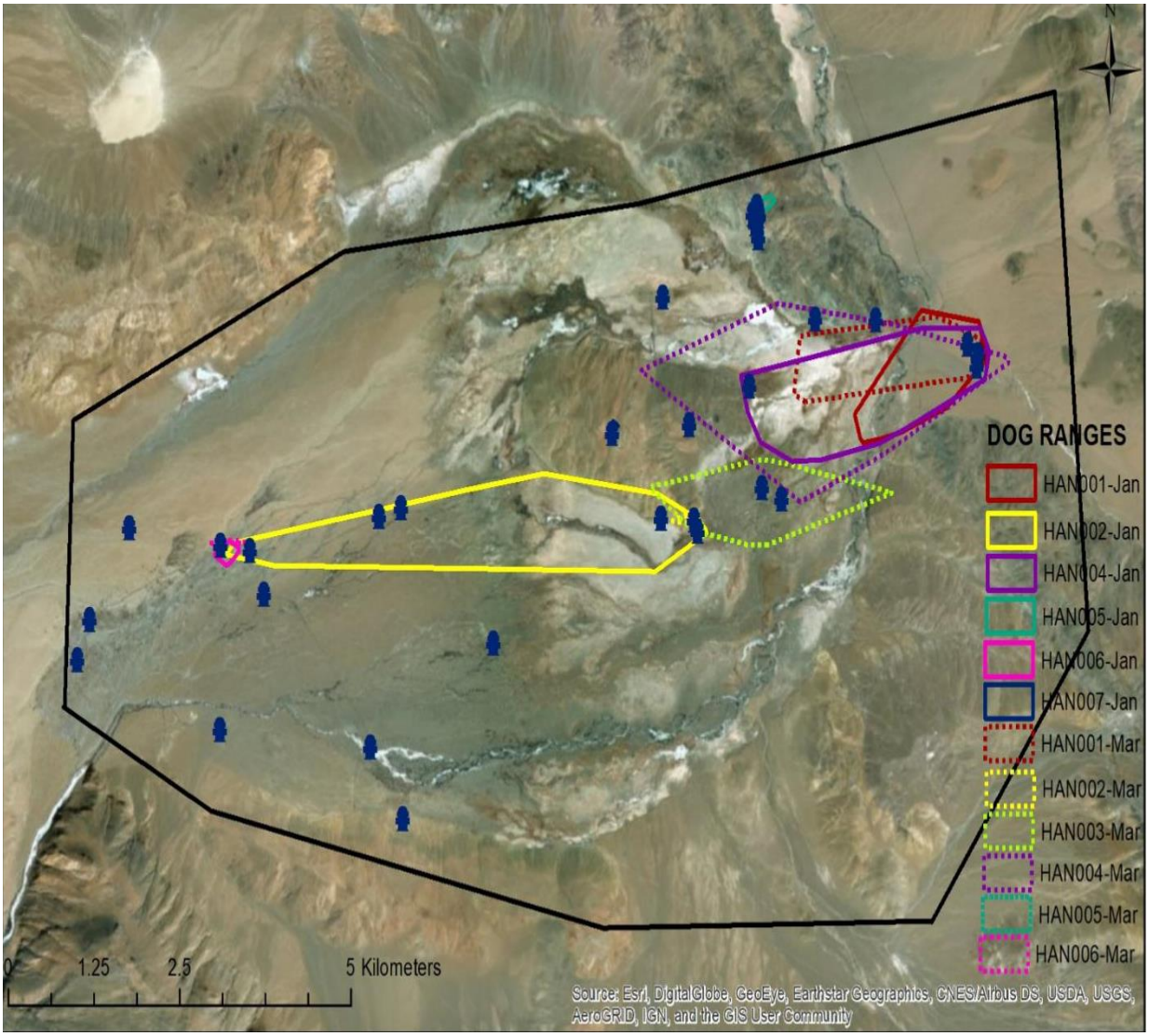

Figure 2: Map showing dog home ranges in January and March. Subsidy points have been indicated as blue totems to give a perspective of dog ranges and subsidies

Table 7: The collared individuals' subsidy level, home range size, and sampling effort across January and March at Hanle, Ladakh.

Dog ID	Parameters	JANUARY	MARCH6
	Subsidy Level	Medium	Medium
	Area(Sq.Km)	**1.2237**	**1.4506**
HAN001	Sampling effort(no. of locations)	147	427
	Subsidy Level	Medium	Medium
	Area(Sq.Km)	**3.7689**	**0.0164**
HAN002	Sampling effort(no. of locations)	141	210
	Subsidy Level	NA	Low
	Area(Sq.Km)	**NA**	**2.8714**
HAN003	Sampling effort(no. of locations)	NA	332
	Subsidy Level	Medium	Medium
	Area(Sq.Km)	**2.6623**	**4.9823**
HAN004	Sampling effort(no. of locations)	147	447
	Subsidy Level	High	High
	Area(Sq.Km)	**0.0291**	**0.0175**
HAN005	Sampling effort(no. of locations)	147	415
	Subsidy Level	Low	High
	Area(Sq.Km)	**0.0434**	**0.008**
HAN006	Sampling effort(no. of locations)	144	331
	Subsidy Level	High	NA
	Area(Sq.Km)	**0.0016**	**NA**
HAN007	Sampling effort(no. of locations)	124	NA

In order to signify the concentration of dog locations around subsidy points, the p-value thus obtained (< 2e-16) after Analysis of Variance analysis between random points and dog points indicates a significant concentration of dog locations towards higher subsidy locations.

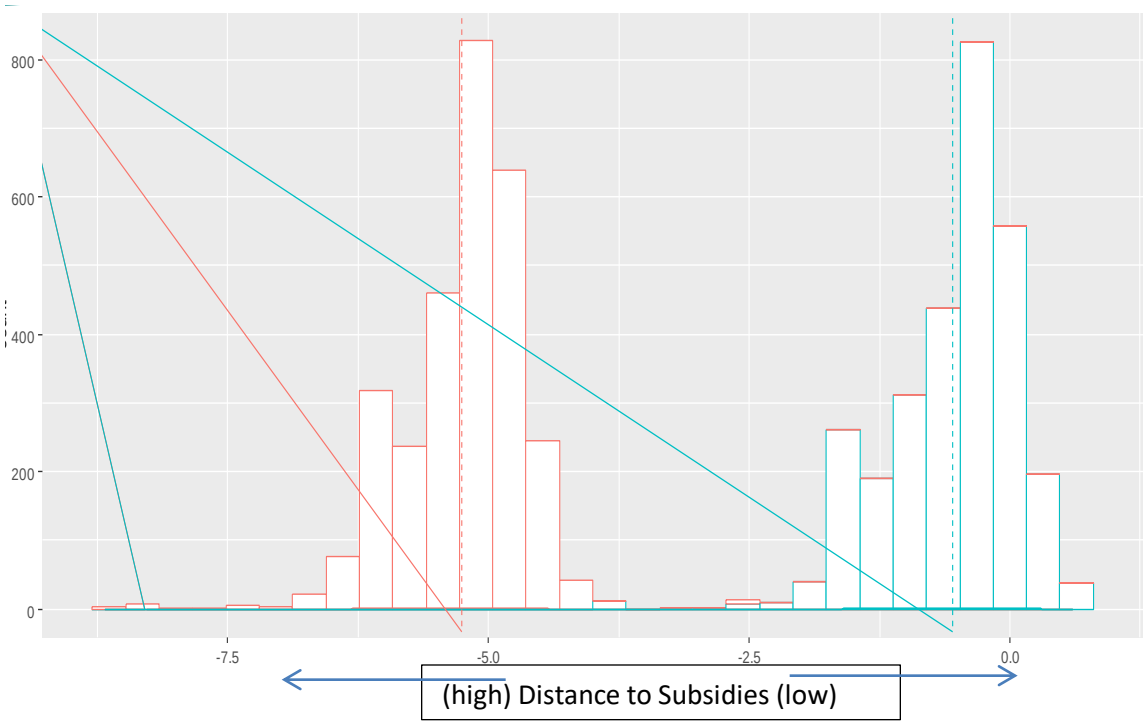

Figure 4: Distribution of dog location points (indicated in red) and random points (indicated in blue) on the axes representing the distance from subsidy availability in the landscape.

4.1.3. Food resource utilization patterns

January

About 9.8% of the feeding time was spent in scavenging followed by 3.1% in the garbage dumps, about 2.1% of the time in feeding on direct human food.

March

In the month of March, dogs spend more time (3.8% of the total feeding time) on direct human food, followed by 1.5% time spent scavenging. Only about 0.7% of the time was spent in garbage dumps.

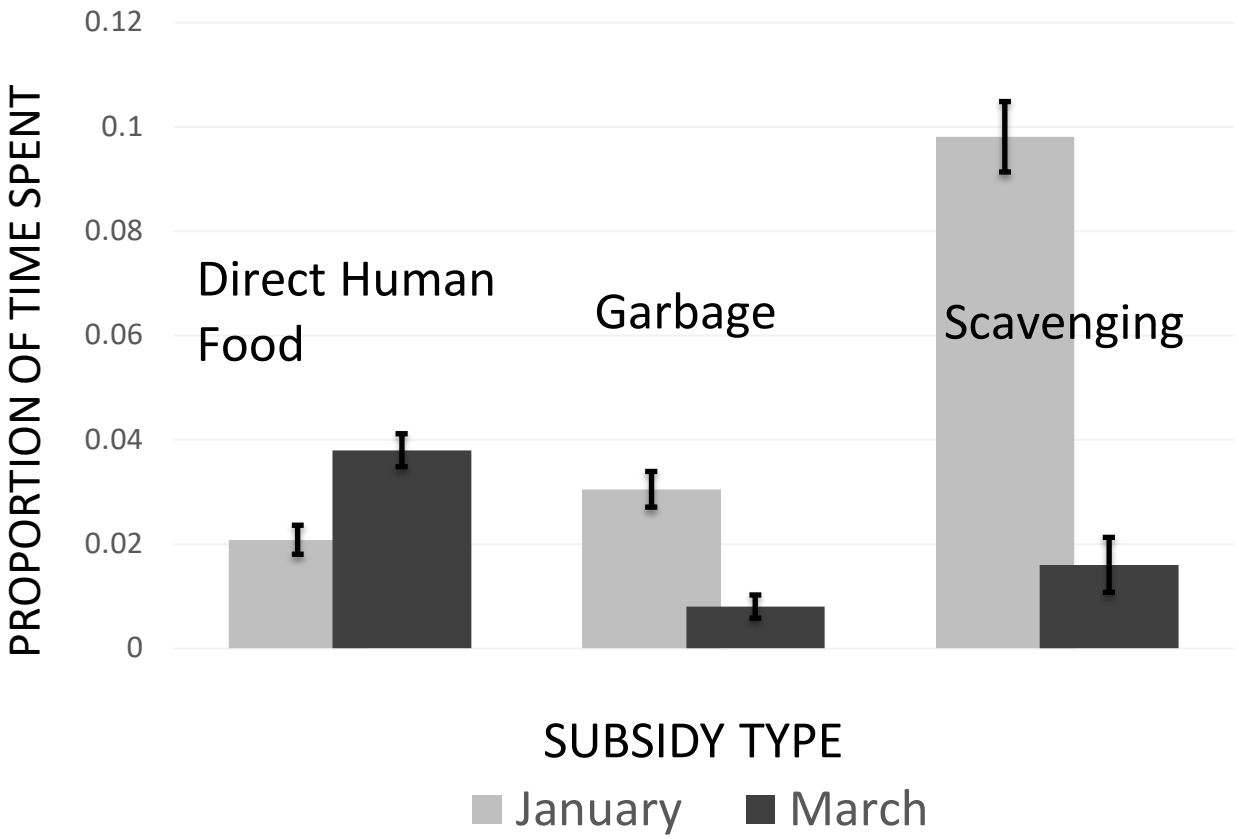

Figure 5: Proportion of time spent in consuming a particular type of food in by the radio-collared dogs in Hanle, Ladakh.

4.1.4. Proportion of time spent in interactions

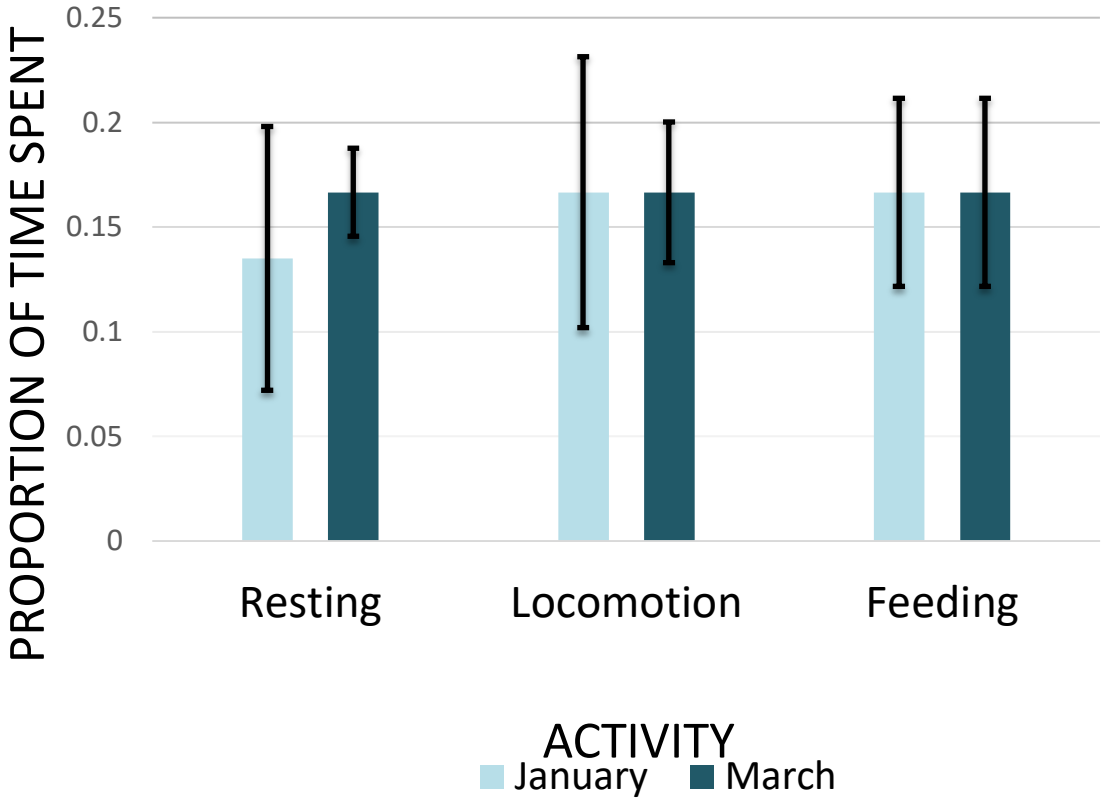

Figure 07: Proportion of time spent in major activities along with standard error by the dogs of Hanle, Ladakh.

There is not high variation in the time spent in various activities by the dogs across the months of January and March.

Figure 8: Proportion of time spent (with standard error) in Interacting with respective agents by the dogs of Hanle, Ladakh.

Most of the time the interactions that dogs had are within their own species (intra-species interactions) followed by interactions with wildlife, humans, and livestock. About 85% of these interactions were grouped under agonistic interactions and the rest of them being neutral interactions.

4.1.5. Viral Pathogen prevalence

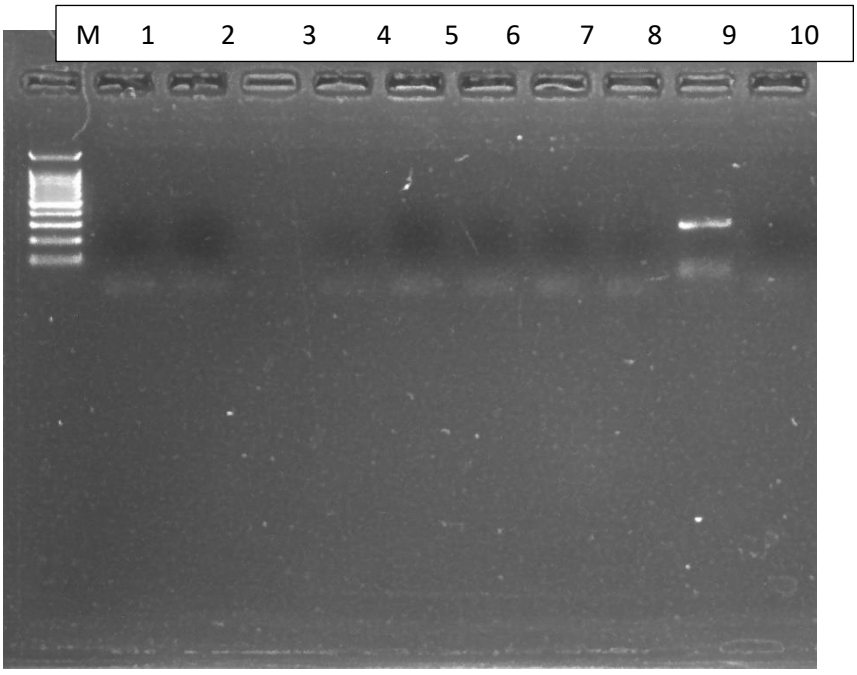

Figure 09: PCR- based demonstration of CDVN gene (287bp). Lane M represents 100bp ladder; lane 1 to 8 represents the samples(negative); lane 9 represents amplified positive control (287bp) and lane 10 represents no template control

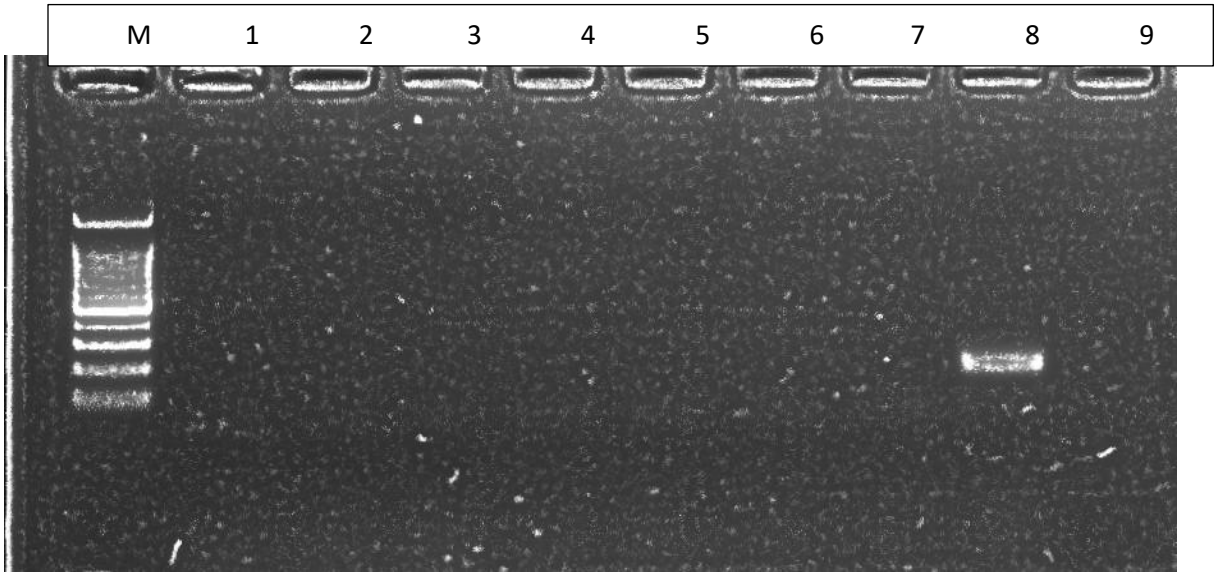

Figure 10: PCR- based demonstration of PCV2 gene (160bp). Lane M represents 100bp ladder; lane 1 to 7 represents the samples(negative); lane 8 represents amplified positive control (160bp) and lane 9 represents no template control

The samples that were tested for Canine Parvo Virus and Canine Distemper virus and tested negative against the vaccine strains that were used as a positive control.

5.1. Discussion

A landscape with high resource utilisation overlap between humans and wildlife (Mishra et al., 2001) presents an ideal setting to understand the importance of food subsidies in the ecology of free-ranging dogs. Placing subsidies in the centre of the ecology of these dogs, a group of villages inside a wildlife sanctuary is taken as surrogates of food subsidy points to look at their effects on the population, movement, and interactions of free-ranging dogs and understand how they can act as the epicenter of free-ranging dog ecology.

5.1.1. Effect of Subsidy on Dog Density –

The logistics and stress of capturing and marking animals to estimate their abundance using mark-recapture method are hugely compensated for in the mark-resight method, where field readable marks on an animal are feasible for re-sighting (McClintock, 2012). The estimation made using the mixed logit normal mark resight model indicated close to one dog in one square kilometre area. The photographs from five temporal replicates over twenty-five days enabled better identification of the marked dogs. The four square kilometre girds helped in maintaining a constant mean effort per grid which enabled corrected dog count estimation for each grid. Then, the encounter rate thus obtained equated with the garbage presence, garbage levels, and any subsidy presence, indicated that the presence of subsidy does, in fact, have a hold over dog abundance in the landscape

which is based on the premise that dog encounter risk is a function of dog density generated by proximity to human habitations (Woodroffe and Donnelly, 2011). The scarcity and sparse distribution of resources, typical of this landscape, could provide a superficial explanation to the concentration of dog numbers around subsidy points.

Future studies should be built around a robust quantification of the subsidies present to better pinpoint on the significance of subsidy quantity and quality. Summer dog densities are higher (Mahar, pers.comm) than in winters. This could possibly be due to the inclusion of new-born pups in the population just at the end of the winter months. Demographic studies with birth and mortality rates of pups would give a wider perspective of dog populations across two regions and seasons. Along with influx of pastoralist camps with their shepherd dogs, the summer also sees an increase in tourists in the region which in turn influences the generation of subsidies (Home et al., 2017) thus increasing dog densities probably due to increased survival of pups being born in the start of summer. Approached at large scales, a long term demography monitoring of dogs based on the resource availability can be helpful while implementing wildlife conservation plans.

5.1.2. Effect of Subsidies on Dog ranges –

Across all the dogs that were monitored for understanding home ranges, the mean home ranges between two seasons (January and March) are 1.43 ±0.51 Km^2 and it did not show considerable difference between the months. However, HAN006 and HAN003, belonging to low subsidy (0 meal /day) locations along with HAN005 and HAN007, belonging to high subsidy (>1 meals/day) locations had relatively smaller home range sizes than those

of HAN001, HAN002, and HAN004 who belong to medium subsidy (1 meal/day) locations.

According to Gittleman and Harvey (1982), metabolic needs of any individual based on the food availability in an area determines the home range of an animal. Consistent and timely food sources kept the high subsidized dogs in tight home ranges. Low subsided dogs could be explained by the fact that they spent more time in searching and utilizing scarp food in familiar locations. Based on anecdotal observations, low subsidies dogs also had weak body conditions indicating they may not have enough energy to explore and range far. In fact, high subsidized dogs could also be considered obese given their carbohydrate-rich food sources. Since water sources were abundant in the form of ice/snow, the presence or absence of water did not seem to affect the movement of dogs. Medium subsidy dogs that show relatively large home ranges also consisted of healthy individuals and an orderly group behaviour which seemed to be of immense value in hunting livestock and wildlife (Boitiani and Ciucci, 1995). Ad libitum observations also indicated that well-structured groups with influential collective behaviour could also aid in long-range movements and explorations as it engages the strength of the group in an event of danger. This can be understood by a conclusion arrived by Ciucci et al. (1997), where it is stated that a flexibility in space use by feral dogs is similar to their wild ancestors which is based on the local conditions, territory utilization, and survival strategies.

5.1.3. Food resource utilisation pattern of dogs –

Tinbergen (1963), rightly penned down that, ‘We would deceive ourselves if we believe that there is no longer a need for descriptive work’. To understand the behaviour of dogs when it comes to their feeding and interaction activities, the collared dogs were continuously monitored based on focal animal sampling (Altman, 1974) to estimate the time spent on various activities.

The feeding observation results indicate that dogs were involved in scavenging more during the month of January when there was a considerable amount of livestock mortality in the villages. March indicates an increase in direct human food consumption, as the two schools in the villages opened and also the Monastery celebrations resulted in lots of leftover food for the dogs. The results support observations by Butler et al., 2018 where they found that human food remains and human faeces as the consistent food available for dogs. They included a component of the importance of these forms of subsidies in maintaining the fertility and health of the dog populations. Similarly, my study demystifies the issue of garbage per se as a major source of subsidy with the understanding that other forms of subsidy available around households (livestock carcasses, direct human food, and human waste) also get represented as subsidies for the free-ranging dogs. The increased presence of carcasses around the villages could have influenced the lesser consumption of wild prey as quite rare unsuccessful hunting events on Kiang, Wooly Hare, and Pika were observed.

To conclude with small sample sizes and single-season observations is not a sound scientific practice. In future, quantification of the carcasses, prey density, and quantitative-qualitative estimation of village subsides would greatly increase the comprehension of the food utilized by the dogs.

5.1.4. Inter and Intraspecific Interactions

The existence of a predator of any kind in a habitat can affect the prey in '…subtle, sublethal, indirect, yet apparently deleterious ways' (Weston and Stankowich, 2013). With the understanding that free-ranging dogs present within the wildlife sanctuary is a threat, the observational interaction data does little to robustly support negative interactions with wildlife.

The ranging or subsidy level of the dogs observed did not seem to influence their interaction with wildlife as foxes and kiang can be seen frequently amidst the domestic/feral animals of the village. Looking at the proportion of time spent with interacting with different agents, dogs spend most of their time interacting within their group or other dog individuals in the vicinity. The second most interacted agents are wildlife with foxes, kiang, wolves, hares, raven, vultures, and shelducks being the common species to be interacted with. Livestock interaction was frequent but many of them were incomplete due to active human intervention. Livestock, having habituated to their own shepherding dogs, seemed to show reduced responses to dog presence and action unless directly pounced upon. It has been shown that unrestrained dogs move "unpredictably" (i.e., their direction and speed are not constant), traits that do not promote habituation but rather 'sensitisation' through enhanced response intensities with increasing exposure to stimuli (Glover et al., 2011).

Anecdotal observations indicate that more than the availability of food, dogs seem to roam farther and interact more with other species when they have a well-established permanent

group that also have structure and discipline. Though intragroup interactions were not quantitatively assessed, interesting insights have been obtained on the free-ranging dog group behaviour in terms of their breeding, feeding, and hunting activities.

5.1.5. Viral disease prevalence –

Negative results that indicate the absence of the viruses does not mean absence from the population or whether the dogs might have been exposed to the disease before. Absence of the antigen that was tested for indicates there was no active or latent infection of either of Canine Parvo and Canine Distemper virus. Given the small number of samples collected, the study could not insist hard on the absence of these diseases as the virus is extremely fragile, vulnerable to transportation temperatures, and are difficult to amplify. This does not remove dogs from being in the equation of potential disease reservoirs for both wildlife and human societies. From observations, it is evident that foxes are the most common wild carnivore that dogs come into frequent contact with thus recommending more robust disease enquires of the dogs and the livestock.

5.1.6. Conservation Implications –

In Trans-Himalayan landscape, resources are sparsely distributed for all life in such a way that there is a necessary and unconditional overlap between human and wildlife systems.

Studies have established that free-ranging dogs are a threat to wildlife especially when they have the same availability of resources (Gompper, 2013). This study is a preliminary attempt to assess the scope of the problem in such landscapes.

With growing subsidies varying in their availability between seasons, the versatile adaptations of dogs make them a formidable competitor and predator. Landscape-level assessment of the scale of the problem will enable to draw up a landscape level action plan to manage the dog population and weaken the threat.

5.1.7. Study limitations

i) The grid size was made too large (4 Km^2) to allocate as many dogs can have zero detection probability if the sampling route misses their ranges. This is a shortcoming which can be rectified by using spatial mark re-sight approach in the future.

ii) Winter dog density estimation in this landscape was constrained by unique factors such as their furry coats making marking difficult, majority of monocoloured individuals, and extreme weather conditions affecting live capturing for radio-collaring/physical marking.

iii) Prey density estimation and carcass density estimation would give a better base for quantification of the food resource availability for the dogs.

iv) The study was limited in the disease aspect as it was constrained by the weather condition of the study period and had a limited sample size to test for the viral presence.

v) The samples across the landscape were not obtained for collaring/marking due to logistical and time constraints which also led to individuals from different levels of subsidy being disproportionately sampled.

vi) The biggest limitation of the study was lack of human resource to aid with the sampling, given the tough weather and landscape constraints.

6.1. Conclusion

The relevance of the study to understand the role of subsidies in some of the ecological aspects of free-ranging dog and the dog's role in impacting wildlife indicates that dogs are sustained at high density primarily due to human-related subsidies. Their encounter rates to a lesser extent and their ranging to a larger extent were dependent on the human subsidies available in the study area.

The interaction with wildlife though of limited occurrence was mostly hostile. In this landscape of sparse wildlife densities, the high dog densities translate this small negative interaction to indicate a certain degree of ill-effects on wildlife when robustly quantified. This is especially true for species like foxes, woolly hares, marmots, and kiang. The presence of virus infection for canine distemper and parvo were not detected in the 7 blood samples and 18 scat samples suggesting that live infection was likely not prevalent in the population during the study period.

My study shows that the high dog density that is sustained due to commensal nature of human subsidies can have negative impacts on the fragile wildlife values of this arid cold desert. Religious sentiments and lopsided rationalities are the major curtains inhibiting

actions against such an established conservation threat. Incidences of dogs threatening human beings are also on the raise and hopefully will bring in fresh perspectives on this problem.

Reference

1. Belsare AV, Vanak AT, Gompper ME. 2014, Epidemiology of viral pathogens of free-ranging dogs and Indian foxes in a human-dominated landscape in central India. Transboundary and emerging diseases 61: 78-86.
2. Bhatt, B., Prabhu, T., & Anupama, G. 2000, *Site characteristics of The Indian Astronomical Observatory, Hanle*.
3. Bhadra, A., Bhattacharjee, D., Paul, M., Singh, A., Gade, P.R., Shrestha, P. and Bhadra, A., 2016, The meat of the matter: a rule of thumb for scavenging dogs?. *Ethology Ecology & Evolution*, *28*(4), pp.427-440.
4. Butler, J., Brown, W., Animals, J. du T.-, & 2018, undefined. (n.d.). Anthropogenic Food Subsidy to a Commensal Carnivore: The Value and Supply of Human Faeces in the Diet of Free-Ranging Dogs. *Mdpi.Com*.
5. Butler JRA, Du Toit JT, Bingham J. 2004, Free-ranging domestic dogs (Canis familiaris) as predators and prey in rural Zimbabwe: threats of competition and disease to large wild carnivores. Biological Conservation 115: 369-378.
6. Cafazzo S, Valsecchi P, Bonanni R, Natoli E. 2010, Dominance in relation to age, sex, and competitive contexts in a group of free-ranging domestic dogs. Behavioural Ecology 21: 443-455.
7. Corti, P., Wittmer, H., Mammalogy, M. F.-B.-J. of, & 2010, undefined. (n.d.). Dynamics of a small population of endangered huemul deer (Hippocamelus bisulcus) in Chilean Patagonia. *Academic.Oup.Com*.

8. dos Santos CL, Le Pendu Y, Giné GA, Dickman CR, Newsome TM, Cassano CR. 2018. Human behaviours determine the direct and indirect impacts of free-ranging dogs on wildlife. Journal of Mammalogy.
9. Fox M. 1971. The behaviour of wolves, dogs and related canids. Dogwise Publishing.
10. Frisk, A. L., Konig, M., Moritz, A. and Baumgartner, W. 1999. Detection of Canine Distemper virus nucleoprotein RNA by reverse transcription-PCR using serum, whole blood, and cerebrospinal fluid from dogs with distemper. J. Clin. Microbiol. 37: 3634–3643
11. Gittleman, J. L., & Harvey, P. H. 1982, Carnivore home-range size, metabolic needs and ecology. *Behavioral Ecology and Sociobiology*, *10*(1), 57–63. doi: 10.1007/BF00296396
12. Home, C., Bhatnagar, Y. V., & Vanak, A. T. 2018, Canine Conundrum: domestic dogs as an invasive species and their impacts on wildlife in India. *Animal Conservation*, *21*(4), 275–282. doi: 10.1111/acv.12389
13. Home, Chandrima, Pal, R., Sharma, R. K., Suryawanshi, K. R., Bhatnagar, Y. V., & Vanak, A. T. 2017, Commensal in conflict: Livestock depredation patterns by free-ranging domestic dogs in the Upper Spiti Landscape, Himachal Pradesh, India. *Ambio*, *46*(6), 655–666. doi: 10.1007/s13280-016-0858-6
14. Hughes J, Macdonald, DW. 2013. A review of the interactions between free-roaming domestic dogs and wildlife. Biological Conservation 157:341-351.
15. Kruuk, H., Ecology, H. S.-J. of applied, & 1981, undefined. (n.d.). Prey selection by feral dogs from a population of marine iguanas (Amblyrhynchus cristatus). *JSTOR*.
16. MARK, B. M.-A. gentle introduction to program, & 2012, undefined. (n.d.). Mark-resight models. *Phidot.Org*.
17. Notornis, M. T.-, & 1988, undefined. (n.d.). Kiwis and dog predation: observations in Waitangi State Forest. *Notornis.Osnz.Org.Nz*.
18. Gingold G, Yom-Tov Y, Kronfeld-Schor N, Geffen E. 2009. Effect of guard dogs on the behaviour and reproduction of gazelles in cattle enclosures on the Golan Heights. Animal Conservation 12: 155-162.

19. Gompper ME (Ed.). 2014. Free-ranging dogs and wildlife conservation. Oxford University Press.
20. Knobel DL, Butler JR, Lembo T, Critchlow R, Gompper ME. 2014. Dogs, disease, and wildlife. Free-ranging dogs and wildlife conservation: 144-164.
21. Kruuk H, Snell H. 1981. Prey selection by feral dogs from a population of marine iguanas (Amblyrhynchus cristatus). Journal of Applied Ecology 197-204.
22. Lacerda AC, Tomas WM, Marinho-Filho J. 2009. Domestic dogs as an edge effect in the Brasília National Park, Brazil: interactions with native mammals. Animal Conservation 12: 477-487.
23. Leonard JA, Echegaray J, Randi E, Vilà C. 2014. Impact of hybridization with domestic dogs on the conservation of wild canids. Free-ranging dogs and wildlife conservation: 170-185.
24. Messier F. 1994. Ungulate population models with predation: a case study with the North American moose. Ecology 75: 478-488.
25. Nandi, S., R. Anbazhagan, M. Kumar and R.S. Chauhan, 2009. Molecular characterization of canine parvovirus strains in vaccines by a polymerase chain reaction and restriction endonuclease analysis. Indian J. Virol., 20: 12-15.
26. Nielsen JM, Clare EL, Hayden B, Brett MT, Kratina P. 2018. Diet tracing in ecology: method comparison and selection. Methods in Ecology and Evolution 9: 278-291.
27. Perri A. 2016. A wolf in dog's clothing: initial dog domestication and Pleistocene wolf variation. Journal of Archaeological Science 68: 1-4.
28. Rajput N, Shrivastav AB, Tonkyn D. Risk of disease spillover from dogs to wild carnivores in Kanha Tiger Reserve, India. bioRxiv. 2018 Jan 1:360271.
29. Research, G. W.-W., & 2005, undefined. (n.d.). Correcting wildlife counts using detection probabilities. *CSIRO*.
30. Ritchie EG, Dickman CR, Letnic M, Vanak AT, Gommper M. 2014, Dogs as predators and trophic regulators. Free-ranging dogs and wildlife conservation: 55-68.

31. Sepúlveda M, Pelican K, Cross P, Eguren A, Singer R. 2015, Fine-scale movements of rural free-ranging dogs in conservation areas in the temperate rainforest of the coastal range of southern Chile. Mammalian Biology 80: 290-297.
32. Sillero-Zubiri C, Hoffmann M, Macdonald DW (Eds.). 2004. Canids: foxes, wolves, jackals, and dogs: status survey and conservation action plan.
33. Silva-Rodríguez EA, Verdugo C, Aleuy OA, Sanderson JG, Ortega-Solís GR, Osorio-Zúñiga F, González-Acuña D. 2010, Evaluating mortality sources for the Vulnerable pudu Pudu puda in Chile: implications for the conservation of a threatened deer. Oryx 44: 97-103.
34. Šálek, M., Drahníková, L., Review, E. T.-M., & 2015, undefined. (n.d.). Changes in home range sizes and population densities of carnivore species along the natural to urban habitat gradient. *Wiley Online Library*.
35. Silva-Rodríguez, E., Conservation, K. S.-B., & 2012, undefined. (n.d.). Domestic dogs shape the landscape-scale distribution of a threatened forest ungulate. *Elsevier*.
36. Spiegel, O., Leu, S. T., Bull, C. M., & Sih, A. 2016, *What's your move? Movement as a link between personality and spatial dynamics in animal populations*. doi: 10.1111/ele.12708
37. Taborsky M. 1988. Kiwis and dog predation: observations in Waitangi State Forest. Notornis 35: 196-202.
38. Vanak AT, Gompper ME. 2010, Interference competition at the landscape level: the effect of free-ranging dogs on a native mesocarnivore. Journal of Applied Ecology 47: 1225-1232.
39. Vanak AT, Gompper ME. 2009, Dogs Canis familiaris as carnivores: their role and function in intraguild competition. Mammal Review 39: 265-283.
40. Wang, G., Zhai, W., Yang, H., Wang, L., Zhong, L., research, Y. L.-C., & 2016, undefined. (n.d.). Out of southern East Asia: the natural history of domestic dogs across the world. *Nature.Com*.
41. Weston, M.A. and Stankowich, T., 2013, Dogs as agents of disturbance. *Free-Ranging Dogs and Wildlife Conservation. ME Gompper (ed.)*, pp.94-113.

42. Young JK, Olson KA, Reading RP, Amgalanbaatar S, Berger J. 2011. Is wildlife going to the dogs? Impacts of feral and free-roaming dogs on wildlife populations. BioScience 61: 125-132.
43. Zapata-Ríos G, Branch LC. 2016, Altered activity patterns and reduced abundance of native mammals in sites with feral dogs in the high Andes. Biological Conservation 193: 9-16.