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Determinants of scent-marking behavior by Asiatic cheetahs *(Acinonyx jubatus venaticus)* at camera traps in Iran

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Preface

This Master's thesis was written at the Department of Ecology and Natural Resource management at the Norwegian University of Life Sciences (NMBU). I would like to thank the Iranian Cheetah Society for providing me with the data I have used for my thesis, which was received from their ongoing cheetah monitoring project in Iran.

I would especially like to thank my supervisors Richard Bischof (NMBU) and Ehsan Moqanaki (NMBU) for their continuous feedback, support and guidance throughout this thesis. Ehsan Moqanaki has provided me with the data that I have been allowed to use for this thesis, and helping me with statistical analyses, visualisation, structure and valuable comments on the manuscript. I would like to thank Richard for all his comments and continuous guidance on this thesis, while aiding me in statistical analyses and for constructive comments on earlier drafts of this thesis.

Abstract

Scent marking is a common behaviour in large carnivores and serves a multiple of ecological purposes. It functions as a method of communication, either to warn off intruders, attract mates or to mark territory. In surveys and monitoring of rare and elusive carnivores, understanding predictors for where and why the target species scent mark in a certain spot can help to optimize the sampling method. By studying scent marking behaviour of large carnivores in situ, it is possible to link the potential ecological determinants with where one might most likely spot an individual to increase the probability of detection.

In this study, I focused on the scent marking behaviour in Asiatic cheetahs (*Acinonyx jubatus venaticus*) in Iran. The Asiatic cheetah is considered critically endangered, with a population that has significantly declined over the years. I analysed images and video footage taken by trail cameras from 321 stations across nine study areas in Iran during 2009-2014. I collated behavioural data for the individuals that were detected, and environmental data from their surroundings to explore factors influencing the scent-marking behaviour at camera trap locations. In addition, I fitted an occupancy model to the data to estimate the probabilities of detection and site occupancy by cheetahs.

The results showed that: **(1)** Asiatic cheetahs' detection probability was very low (p = 0.03; 95% CI =0.02-0.03); **(2)** detection of cheetah scent marking behaviour at camera traps was positively correlated with presence of marking trees and distance to the nearest water source, with tree presence always resulting as a significant variable.

I will discuss the relevance of my findings to the Asiatic cheetah's research and conservation, providing ideas for refining the current monitoring program for the future.

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1. Introduction

The Asiatic cheetah (*Acinonyx jubatus venaticus*) is a critically endangered large carnivore, with an estimated population size of 50 or less individuals left only in Iran (Durant et al, 2017; Farhadinia et al. 2017). The Asiatic cheetah has experienced one of the highest rates of decline in both population size and geographic range among cheetah populations globally (Durant et al. 2017). With a distribution range that used to span from the Indian subcontinent to Syria and Central Asia, the species has faced a lot of pressure from human disturbances and hunting, which has resulted in a significantly smaller habitat range that is now exclusively restricted to a few protected areas in central and north-eastern Iran (Farhadinia et al., 2017; Moqanaki and Cushman, 2017). Despite ongoing conservation efforts to save the Asiatic cheetah, the latest monitoring data suggest that the population is in decline (Eslami et al. 2017). More information is required to understand what the most effective conservation approach for the species would be to ensure it does not go extinct in the near future. Studying a rare and critically endangered carnivore species that ranges over vast areas in remote habitats is challenging. Non-invasive sampling methods, such as camera trapping, can aid conservation scientists in such situations (Burton et al. 2015).

With the aid of passive motion sensors in cameras placed out in the wild, these cameras allow researchers to monitor habitats and the species that are part of it remotely (Burton et al. 2015; Caravaggi et al. 2017). Camera trapping can provide valuable information in conservation efforts of rare or elusive species, though the method is generally considered to be resource-demanding due to the effort that is required to ensure reliable results (Murphy et al. 2019). The data obtained from camera traps can be used to quantify population distributions and abundances, as well as understanding habitat suitability and/or the selection of the target species (Burton et al. 2015). Camera traps are also useful when studying elusive behaviours that otherwise require traditional observation-based methods, which can be exceedingly difficult when aiming for behaviour detection of rare and threatened species in the wild (Caravaggi et al. 2017). One such behaviour is scent marking, which is a type of social behaviour used to communicate to other species of carnivores, both inter- and intraspecific depending on the scent used (Johnson, 1973; Cornhill & Kerley, 2020). Camera traps have been used to study the Asiatic cheetah during the past two decades (see reviews by Farhadinia et al. 2017; Khalatbari et al. 2017). However, some of the current findings have been debated due to data sparsity and the descriptive nature of the majority of earlier analyses

(Eslami et al. 2017; Farhadinia et al. 2017; Khalatbari et al. 2017). Due to the limited number of camera traps and, in turn, relatively poor spatio-temporal coverage of some of the confirmed cheetah habitats, a re-analysing of the monitoring data seems necessary when addressing some of the current limitations (Farhadinia et al. 2017; Khalatbari et al. 2017). By utilising the available data to address some of the concerns that have been raised, such as imperfect detection using camera traps, this information can be crucial for conservation planning of the Asiatic cheetah.

One limitation of any sampling method, including camera trapping is that there is never a guarantee that the targeted species will show up close to the cameras, or even if it does, whether the species is in frame of the camera. This issue is known as imperfect detection and is common in ecological studies (Kellner and Swihart 2014). Over the years, various tools and methods have been developed to increase the probability of detecting the target species by camera traps. One popular method is using lures, in the form of food or olfactory attractants to draw in individuals or repel unwanted visitors (Du Preez et al. 2014; Tourani et al. 2020). Environmental features, such as marking trees and natural or artificial water sources, can also act as natural baits to increase carnivore detection probabilities (Edwards et al. 2016). Scent marking is a desirable behaviour to study regarding detections due to the animals generally spending extra time while marking, compared to for example an individual walking by a camera trap. If properly implemented and accounted for in analysis of the monitoring data, using attractants can increase the camera capture rates and the amount of time an individual will spend in front of the camera (Gil-Sánchez et al. 2011; Tourani et al. 2020). In camera trap-based monitoring of rare or elusive carnivores, such as the Asiatic cheetah, understanding the factors that may increase the probability of cheetah detection at camera traps and the potential sources of bias can therefore guide future efforts and provide a more realistic picture of the status of the species to prioritise conservation actions.

In this study, I explore the determinants of scent-marking behaviour by Asiatic cheetahs at camera traps. The goal of this study is to aid the conservation monitoring of the Asiatic cheetah population in Iran. I attempt to answer two main questions:

Q1: What are the probabilities of site occupancy and detection by Asiatic cheetahs in Iran?

Q2: What are the environmental factors influencing the scent marking behaviour by Asiatic cheetahs at camera traps?

By assessing determinants of cheetah scent marking behaviour, I explore survey methods to increase cheetah detectability during camera trapping. I test if detecting these behaviours can explain the probability of detection of cheetahs by camera traps. I discuss the importance of considering the potential determinants of Asiatic cheetah scent marking behaviour to improve the current monitoring efforts using camera traps.

2. Methods

The data used for this thesis was collected by the Iranian Cheetah Society from eight reserves in Iran (Fig. 1 & Table 1), between 13.11.2009 and 13.11.2014. I also included data from one additional reserve (i.e. Kavir National Park in Fig. 1 & Table 1) that was surveyed by Ghadirian et al. (2010) in 2009-2010. Thus, camera trapping from nine sites were included in this study, but depending on the study question and data quality, I included different subsets of the data for occupancy and scent-marking analyses (see below).

2.1) Study sites and camera trapping

The Asiatic cheetah monitoring uses camera traps to collect detection and non-detection data of the cheetahs inside a network of reserves in Iran (Fig. 1). The study sites varied in levels of protection and include nine state-run protected areas and no-hunting areas: National Park (n = 2), Wildlife Refuge (n= 4), Protected Area (n = 2), and No-Hunting Area (n = 1). A detailed description of the camera trapping is provided by Farhadinia et al. (2016). In summary, the camera stations were set up mainly along trails and undisturbed dirt roads across the reserves. If present, potential marking trees and water sources were specifically targeted for camera trapping as natural lures to increase the probability of cheetah detection. The number of camera traps deployed in each site was determined by the importance of that site for cheetahs based on the experiential knowledge of researchers and rangers and historical records (Farhadinia et al. 2017), availability of camera traps, and each site's accessibility and logistics. In total, seven different camera trap models were used across all sites (Appendix B).

In locations where cheetah visits were considered to be more likely (e.g. water sources during summer), camera traps with the possibility to record videos were used. For each camera trap station, the start and end dates were recorded in specific spreadsheets. The investigators checked each station on average every 3-4 weeks and extracted the photos, noting malfunctions or any errors as detailed as possible. Cheetah photos and videos obtained at each station, if any, were downloaded into separate folders that were labelled by a unique name for that location.

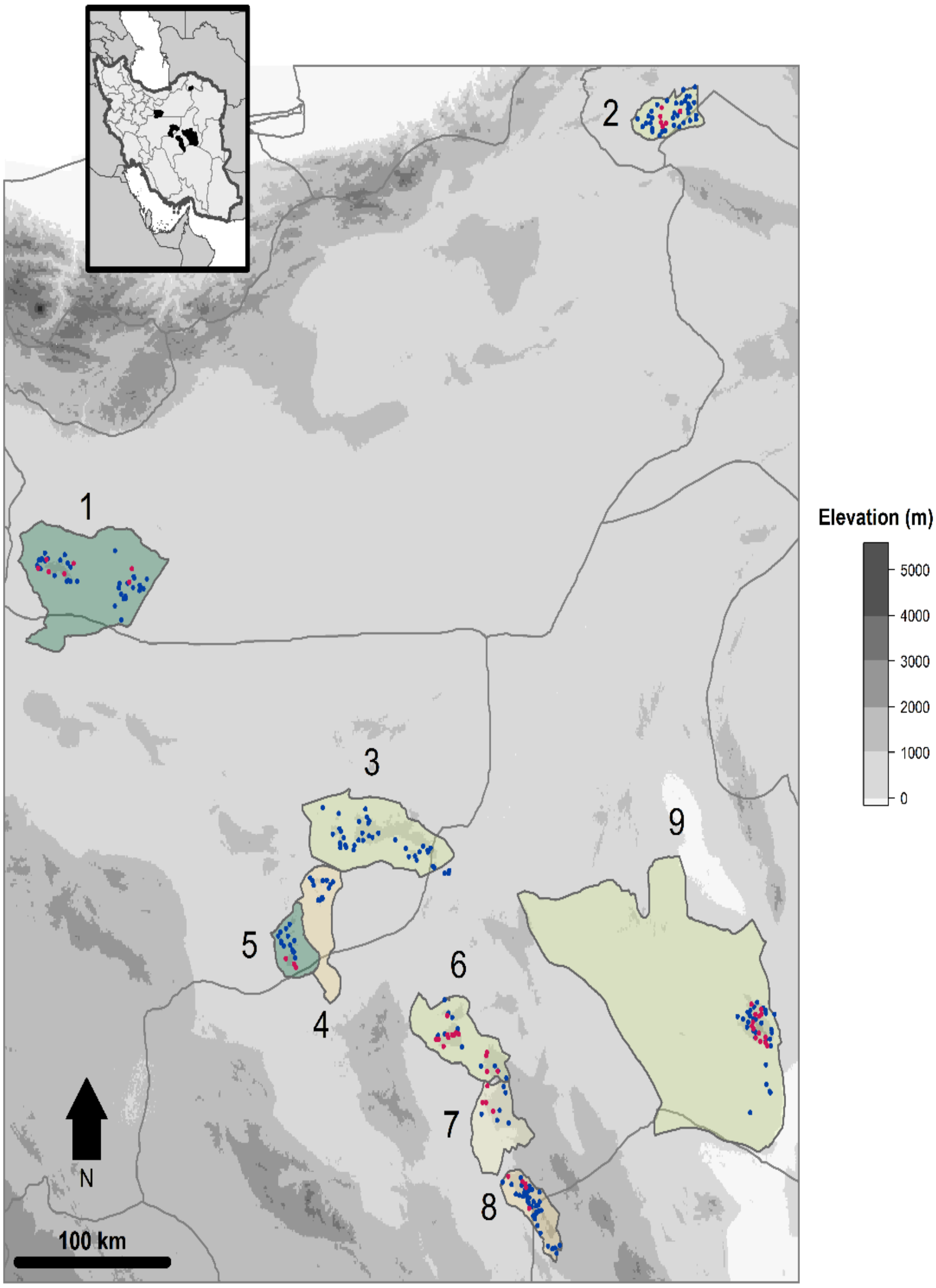

Figure 1: Map showing the study sites in Iran (n = 9): 1. Kavir National Park, 2. Miandasht Wildlife Refuge, 3. Abbas Abad Wildlife Refuge, 4. Siahkouh Protected Area, 5. Siahkouh National Park, 6. Dare Anjir Wildlife Refuge, 7. Ariz No-Hunting Area, 8. Bafq Protected Area, 9. Naybandan Wildlife Refuge. The red circles show positive cheetah detections by camera traps during 2009-2010 (Kavir) and 2011-2014, whereas the blue circles show active camera stations with no cheetah detection. Credit: Ehsan Moqanaki.

Table 1: Description of the camera trapping surveys for the Asiatic cheetah in Iran (2009-2014). Number of cameras and cameras with cheetah detections are based on the filtering criteria described in the main text.

Reserve	Sampling period	No. of cameras	No. of camera with cheetah detections (%)
Kavir National Park	10.2009 – 03.2010	64	8 (13%)
Miandasht Wildlife Refuge	02.2012-11.2014	64	15 (23%)
Abbas Abad Wildlife Refuge	05.2012-07.2012	41	0 (0)
Siahkouh Protected Area	05.2011-09.2012	10	0 (0)
Siahkouh National Park	05.2011-09.2012	14	3 (21%)
Dareh Anjir Wildlife Reserve	12.2011-11.2014	25	13 (52%)
Ariz No-Hunting Area	12.2011-08.2012	10	4 (40%)
Bafq Protected Area	12.2011-03.2012	46	5 (11%)
Naybandan Wildlife Refuge	11.2012-01.2014	47	14 (30)

2.2) Data processing

2.2.1) Extracting time and date

I extracted metadata from cheetah photos and videos using the computer program ExifTool (Toevs 2015). This was done to ensure consistency as some images and videos were missing time and date stamps. I excluded the cheetah detections with no date and time from the occupancy analysis.

2.3) Behavioural data

I reviewed all the cheetah detections and assigned at least one behaviour (scent-marking or/and others) to each photo and video following similar studies (Grünewälder et al. 2012; Soso et al. 2014; Kröschel et al. 2017; Allen et al. 2015). Some images and videos contained more than one individual, and every individual present were assigned their own behaviours respectively in the dataset to account for all individual animals (Fig. 3).

2.3.1) Scent marking

Whenever an individual was caught scent marking, it was given a presence/absence value of 1 or 0. Scent marking behaviour was also classified based on the way the animal was scent marking into (1) Spraying and (2) Rubbing.

2.3.1.1) Spraying

A common way for cheetahs to scent mark is by spraying while either standing up, or slightly crouched over, accompanied with their tail held up (Fig. 2). Spraying means that cheetahs mark with urine or faeces, and is often a territorial form of scent marking, and can serve to mask other scents from different individuals or species, or as a warning to intruders (Ralls, 1971).

2.3.1.2) Rubbing

Cheetahs, like other felines, have glands that contain pheromones (Sunquist & Sunquist, 2017). By rubbing these glands onto a surface, they deposit a scent mark (Fig. 2). This is also a method of scent marking, as they deposit a different scent compared to when they spray. This method is often seen as a form of attracting mates, or to mark an area for cubs or intruders to know where their territory is (Rich & Hurst, 1998).

2.3.2) Other behaviours

In addition to the scent-marking behaviours, I classified each cheetah detection into one of the following behavioural categories:

2.3.2.1) Surveying

An individual was classified as surveying when it was seen smelling, looking at the environment (such as trees, bushes, or the ground) and often before scent marking (Fig. 3). This behaviour is a classic searching behaviour, used when scanning new or old territory, as cheetahs have a strong sense of smell (Hubel et al. 2016).

2.3.2.2) Walking

An individual that was observed moving by the camera was classified as walking (Fig. 3). It was easy to distinguish between walking and running due to its body posture, and the fact that the animal itself was not blurry or at a high speed when captured by the trail camera. It was also seen in videos, as individuals were seen walking by the camera.

2.3.2.3) Running

Some individuals appeared blurrier when captured, and clearly in motion by the posture of its body, and by the movement of the legs (Fig. 3). This was not as common as walking and could be a reaction to the sound and/or light emitted by camera traps when triggered.

2.3.2.4) Vigilant

The vigilance category was given to those individuals who were seen staring at the camera, or something out of frame. This vigilance behaviour was often observed while the individual had its head bent downwards, and a firm posture to follow with it. If not bent downwards, the cheetah would have its head held high, as shown in Fig. 3.

2.3.2.5) Idle

An individual that was considered idle was often sitting down while watching something out of frame, or simply not exhibiting any behaviour (Fig. 3).

2.3.2.6) Drinking

The study reserves contained natural waterholes and artificial water sources (i.e. wildlife drinkers). The pictures taken were mainly of individuals drinking water from the wells and was given their own classification accordingly (Fig. 3).

2.3.3) Camera interaction

A few images contained individuals that were positioned directly in front of the camera trap. Only parts of the individual's body were visible, which made it difficult to identify any behaviour. I classified these images as camera interaction instead, with an example shown in Appendix A.

Figure 2. Examples of cheetah scent-marking behaviours at camera traps: Left shows an individual scent marking by spraying. Image to the right shows an individual scent marking by rubbing on a marking tree. Photo: Iranian Cheetah Society/Iran Department of the Environment/Conservation of the Asiatic Cheetah Project.

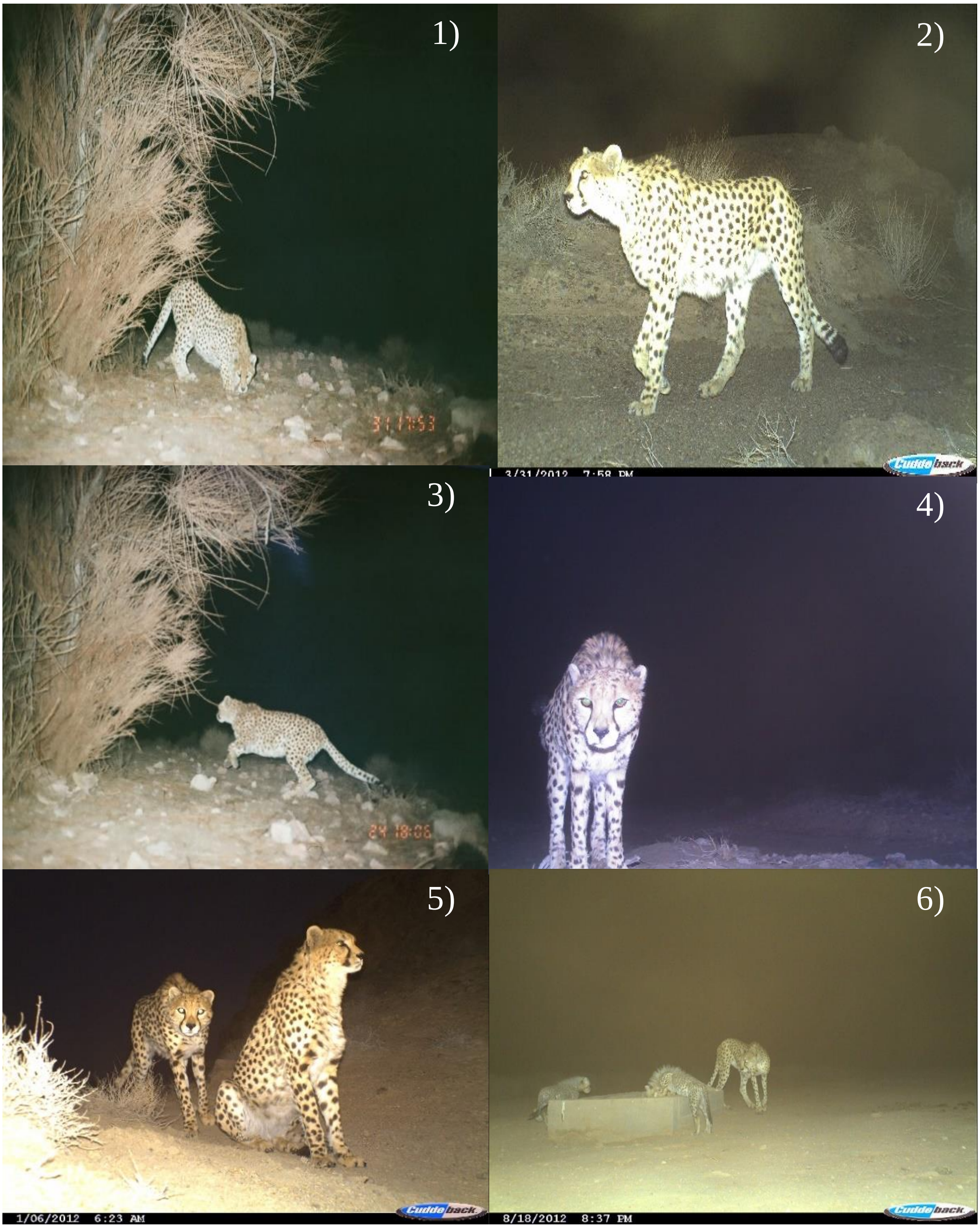

Figure 3: Examples of behaviours other than scent-marking that was observed in camera trap photos: 1) Individual surveying the area near a marking tree; 2) walking; 3) running; 4) vigilant towards camera trap; 5) Individual on the right being idle, while individual to the left expressing vigilance towards camera trap; 6) two cheetah cubs drinking from a wildlife drinker while their mother is standing to their right. Photos: Iranian Cheetah Society/Iran Department of the Environment/Conservation of the Asiatic Cheetah Project.

2.4) Statistical analyses

All statistical analyses were done in R, version 1.3.1093 (R Core Team, 2020). After the picture analyses were finished, it was decided to focus on the scent marking presence and absence data observed as the main response value for statistical analyses. I used presence and absence data of trees as one of my explanatory environmental variables, as well as distance to the nearest water source, which was log transformed to include meters and, and not just kilometres (Table 2).

Table 2: Environmental variables considered to explain cheetah scent-marking behaviour at camera traps.

Variable	Code	Description	Values
Presence of tree	Tree	Presence of marking tree or bushes in the camera viewshed	0/1
Number of cheetahs	n.cheetahs	Number of cheetahs in a detection event. One cheetah = 1, 2 or more = 2.	1/2
Distance to water source	DistWater.log	Distance of camera trap station to the nearest water source (km), which was log transformed to include distance by closet meter.	0-15.0
Camera stations	Station	Each camera trap station by name.	Individual station names

2.4.1) Occupancy analysis

I used cheetah detections from eight sites (i.e. study reserves in Fig. 1 excluding Kavir National Park) to construct cheetah detection histories in a binary system: 1 = at least a cheetah photo/video was taken; 0 = camera station was active but no cheetah was detected; NA = the camera was not active (Fig. 4). Detection histories at each camera station were pooled into consecutive 1-day sampling events. I removed cheetah detections with no reliable date and time information. The detection histories were from six sites over a 380 day matrix (Fig. 4). I ran a basic (null) occupancy model on the cheetah detection history data to show an overview of occupancy and detection probabilities of Asiatic cheetahs in Iran by accounting for imperfect detections of cheetahs at camera traps through repeated surveys (Pease et al. 2016). I used the “unmarked” package (Fiske & Chandler, 2011) to fit the occupancy model and no explanatory variables were included. This was then transformed into a “unmarked” data frame using the *unmarkedFrameOccu* function. Occupancy model outputs were then log transformed to provide an estimate, with occupancy (psi) = 0.2 and detection probabilities (p) = 0.03, with confidence intervals (Ci)

2.4.2) Analysis of scent-marking behaviour

2.4.2.1) Generalised Linear Modeling

I performed generalised linear models to test predictor variables described in Table 2 on scent marking behaviour by cheetahs as a binary response variable. Considering my response variable was of binomial value, I fitted the family with Binomial in the *GLM* function. I tested for six different models in total, using explanatory variables as additive and multiplicative effects.

2.4.2.2) Mixed Generalised Linear Modeling

To test for random effects, which in this case was camera trap stations, a mixed generalised linear model was done using the “lme4” package (Bates et al. 2015). I used the same environmental values as I did for the GLM models.

2.4.2.3) Step AIC

In order to test for the top GLM model, Akaike Information Criterions (AIC) values were used (Burnham & Anderson, 2002). A stepwise AIC was performed to determine the strongest model for scent marking presence and absence. I used the package “MuMIn” (Barton, 2020) to receive not just AIC values, but also ΔAIC, model weights and the cumulative model weights. The model with the lowest AIC value is considered the strongest model.

3. Results

The cameras were operational from October 2009 to November 2014 across nine sites (including Kavir) in Iran. Media from a total of 380 cameras were used, across 321 camera stations. Out of the 321 camera stations, 68 recorded at least one cheetah detection. The median days of activity across all stations was 71. Seven different camera brands were used (Appendix A), capturing both images and videos, with a total of 335 images and videos containing one cheetah or more.

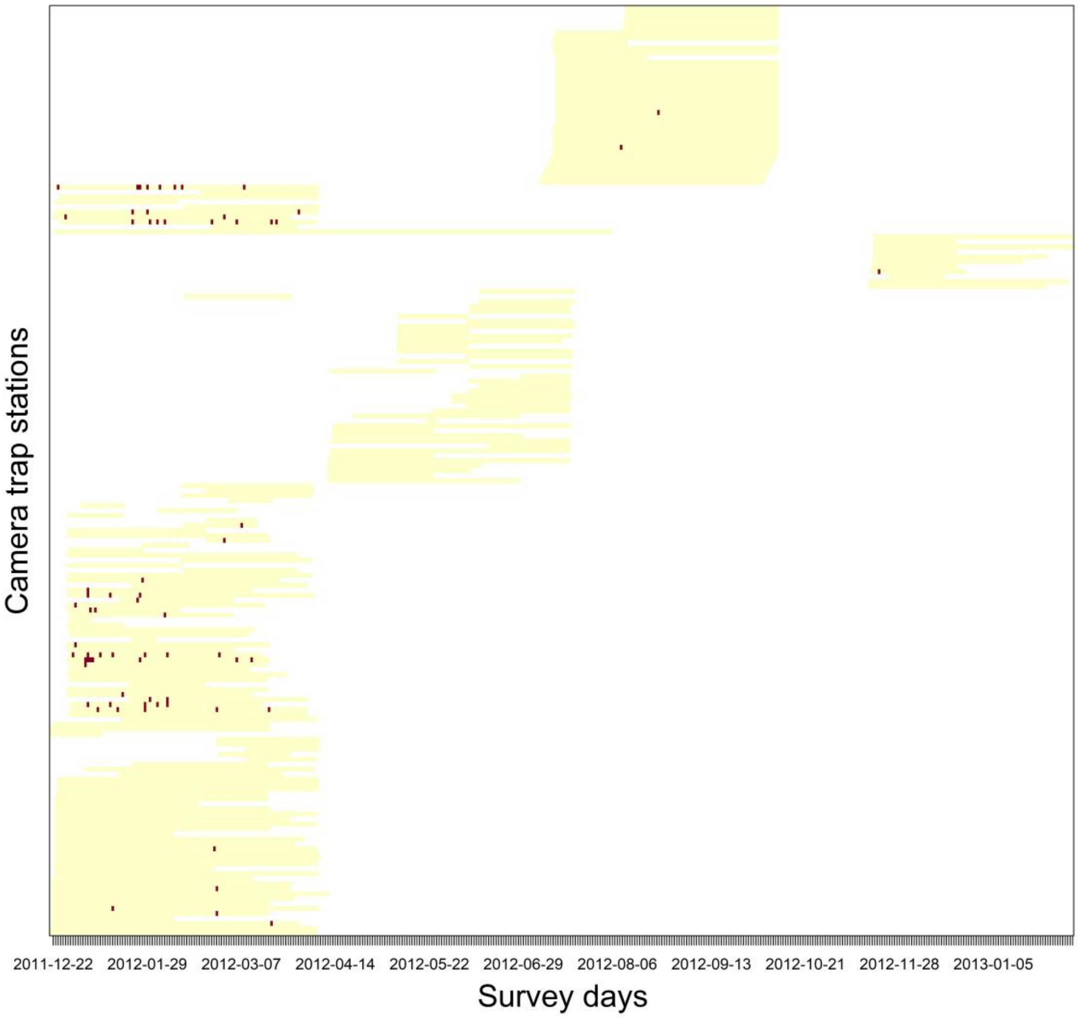

Figure 4: Cheetah detection histories based on data from 321 camera trap stations across eight reserves in Iran. The yellow lines represent each individual camera trap station, with every red mark indicating a cheetah detection, matched with the day of detection on the x-axis.

3.1 Occupancy

A null model was used to determine occupancy and detection estimates. This model produced an occupancy estimate of (Ψ)=0.2, with a confidence interval of 0.14-0.28. The detection estimate was (p)=0.03, with a confidence interval of 0.02-0.03.

3.2 Scent marking

I detected scent marking behaviours (spraying or rubbing) in 38 detection events out of 335 (11%) of the photos and videos analysed. Surveying (32%) and walking (42%) were the most common non-scent marking behaviours observed (Fig. 5).

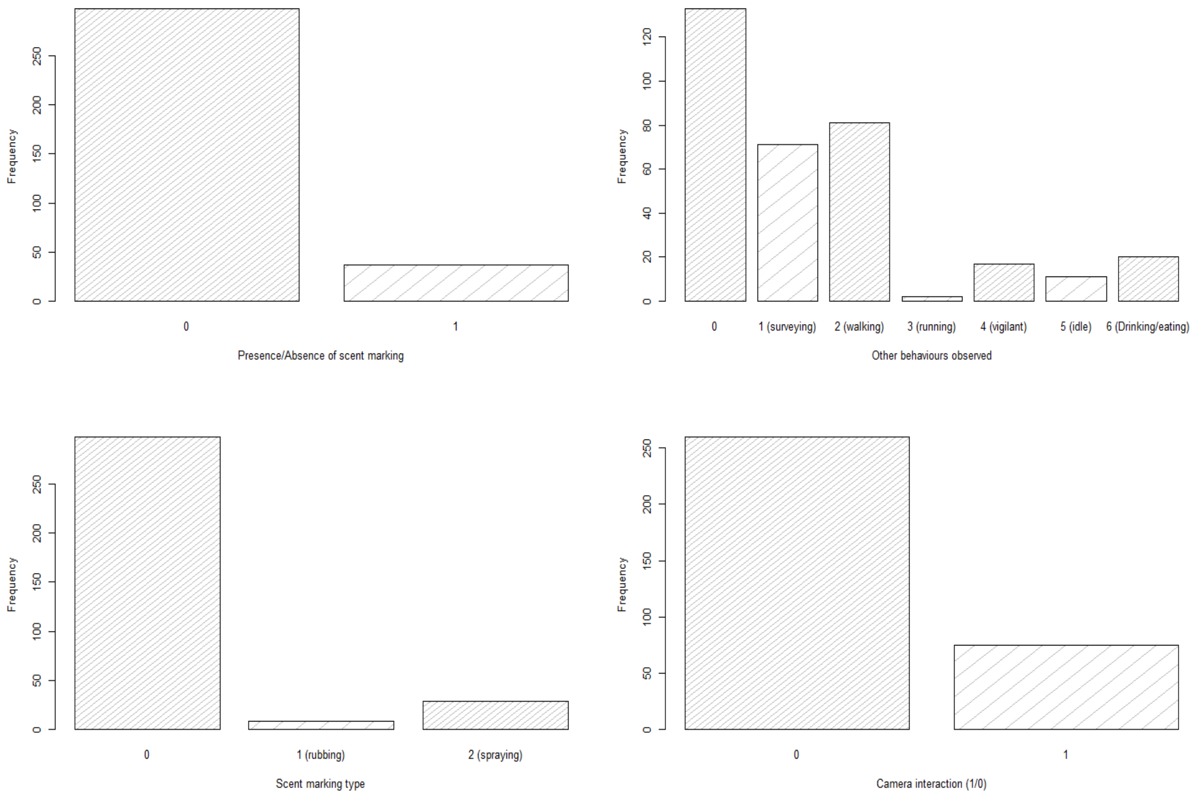

Figure 5: Barplots visualising frequency of different behaviours observed in cheetah detection events using camera traps. Top left) Presence of absence of scent marking. Top right) Frequency of other behaviours observed. Bottom right) Frequency of cheetah camera interactions. Bottom left) Different scent marking types observed. The 0 category indicates no presence or absence of the given behaviour but indicates that a different behaviour occurred, or no cheetah was present.

Represented below is scent marking behaviour observed over 24 hours, based on cheetah detections with reliable date and time. Out of 335 detections, 38 (11%) of these included scent marking detections. The highest activity of spraying occurred at 07:00, and 16:00, while rubbing occurred at 08:00, 13:00 and 17:00 (Fig. 6).

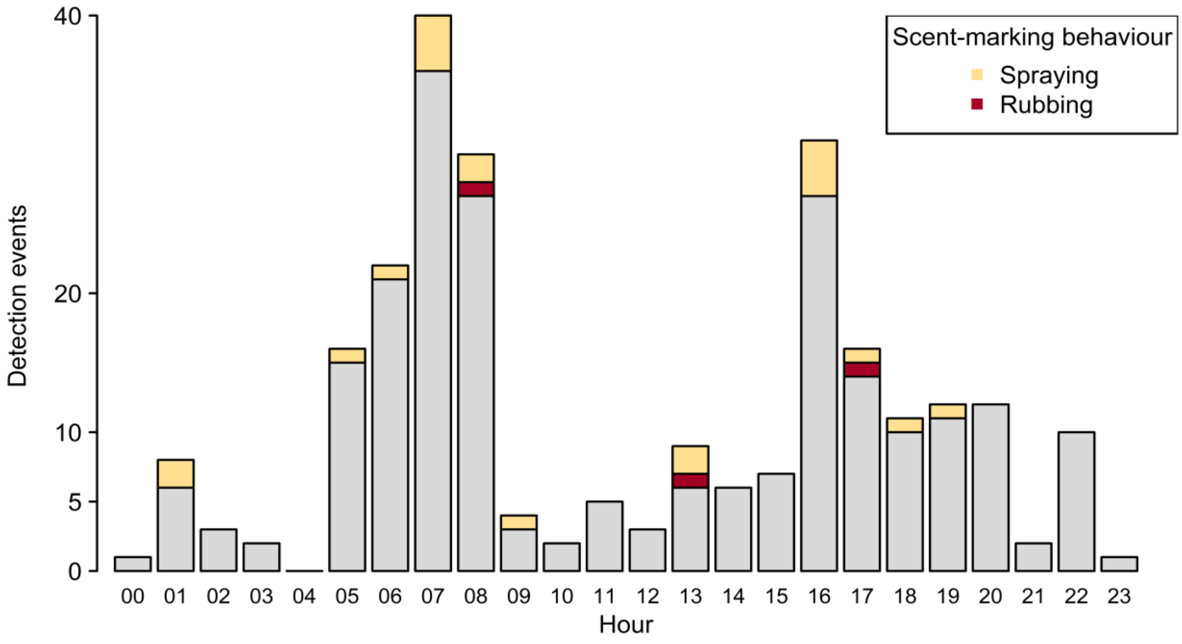

Figure 6: Visualisation of the 24-hour activity pattern for cheetahs during the study period based on detection history data. The grey shading indicates no scent marking observed The grey shading indicates no scent marking observed. Credit: Ehsan Moqanaki.

In order to find the strongest model out of the six proposed GLMs, a stepwise AIC was done. Table 3 which is shown below provides the outputs of these, with the top model based on lowest AIC value highlighted with bold font.

Table 3: Six GLM models ranked by highest AIC value, with ΔAIC, weights and cumulative weights respectively. Tree presence and distance to water is the top model when looking at scent marking.

Model	*df*	*AIC*	*ΔAIC*	*Weight*	*Cumulative weight*
GLM4 – Marking~Tree presence + Distance to water (log scaled)	**3**	**208.7**	**0.00**	**0.348**	**0.3483**
GLM2 – Marking~Tree presence + n.cheetahs + distance to water (log scaled)	4	209.0	0.35	0.292	0.6404
GLM3 – Marking~Tree presence * Distance to water (log scaled)	4	209.9	1.24	0.067	0.8282
GLM1 – Marking~Tree presence + n.cheetahs * Distance to water (log scaled)	5	211.1	2.41	0.104	0.9325
GLM5 – Marking ~Tree presence	2	212.0	3.28	0.067	1.0000
GLM6 – Marking~1	1	238.9	30.27	0.000	1.0000

I detected a significant positive effect when testing with tree presence/absence as an additive effect (estimate=1.8229, SE= 0.4061, Z-value= 4.498, P-value=7.14e-06) for scent marking (Table 4), which is based on the top model (GLM4).

Table 4: The results from the six different GLM models. Numbers represent the estimate, std. error, z-value and p-value, with significant values highlighted in bold.

GLM1 = Marking ~ Tree + n.cheetahs * distwater.log

	Estimate	***Std. Error***	***Z-value***	***P-value***
(Intercept)	-3.01751	0.36827	-8.194	**2.53e-16*** **
Tree1	1.89603	0.41622	4.555	**5.23e-06*** **
n.cheetahs	-0.79227	0.65608	-1.208	0.227
DistWater.log:n.cheetahs	-0.01941	0.48808	-0.040	0.968

GLM2 = Marking ~ Tree + n.cheetahs + distwater.log

(Intercept)	-3.0142	0.3583	-8.412	**< 2e-16*** **
Tree1	1.8933	0.4104	4.614	**3.96e-06*** **
n.cheetahs	-0.7936	0.6554	-1.211	0.226
DistWater.log	0.2979	1.1856	1.606	0.108

GLM3=Marking ~ Tree * distwater.log

(Intercept)	-3.1566	0.4124	-7.655	**1.94e-14*** **
Tree1	1.9767	0.4689	4.216	**2.49e-05*** **
DistWater.log	0.4718	0.2966	1.590	0.112
Tree1:DistWater.log	-0.3562	0.4023	-0.885	0.376

GLM4=Marking ~ Tree + distwater.log

(Intercept)	-3.0610	0.3554	-8.612	**< 2e-16*** **
Tree1	1.8229	0.4061	4.489	**7.14e-06*** **
DistWater.log	0.3247	0.1815	1.789	0.0736.

Glm5=marking ~ tree

(Intercept)	-3.1258	0.3405	-9.180	**< 2e-16*** **
Tree1	1.9713	0.4016	4.908	**9.18e-07*** **

Glm6=marking ~ 1

(Intercept)	-2.0561	0.1723	-11.94	**<2e-16*** **

Summary of GLM4 which was the top model after an AIC model selection (Table 3) is shown in Table 5 below.

Table 5: Model 4 (GLM4) came out the strongest with an AIC of 208.7, and 3 degrees of freedom (Table 3), after testing six different GLM models.

	Estimate	**Std. Error**	**Z-value**	**P-value**
(Intercept)	-3.0610	0.3554	-8.612	**< 2e-16*** **
Tree1	1.8229	0.4061	4.489	**7.14e-06*** **
DistWater.log	0.3247	0.1815	1.789	0.0736.

Table 6 shows the output from a GLMM that contained camera trap stations as a random effect, as there were 321 stations in total used and tested at random against the response variable marking. Tree presence had a significant effect on marking presence (estimate = 1.8981, p=0.0334). Tree presence and distance to water had a positive correlation, though not significant.

Table 6: Output from the GLMM (Marking~Tree+Distwater.log + (1|Station). The effect of fixed and random covariates on the response: Marking.

Fixed effects				
	Estimate	***Std. Error***	***Z-value***	***P-value***
(Intercept)	-3.8861	0.8483	-4.581	**4.63e-06 *** **
Tree1	1.8981	0.8923	2.127	**0.0334 ***
Distwater.log	0.4165	0.3220	1.294	0.1958
Random effects				
Groups	Name	Variance	Std. Dev	
Station	(intercept)	3.269	1.808	
Correlation of fixed effects				
	(intercept)	Tree1		
Tree1	-0.676			
Distwater.log	-0.181	0.108		

When plotting predictions of tree presence and distance to closest water source against the response variable marking, a positive trend was found, represented in Fig 7.

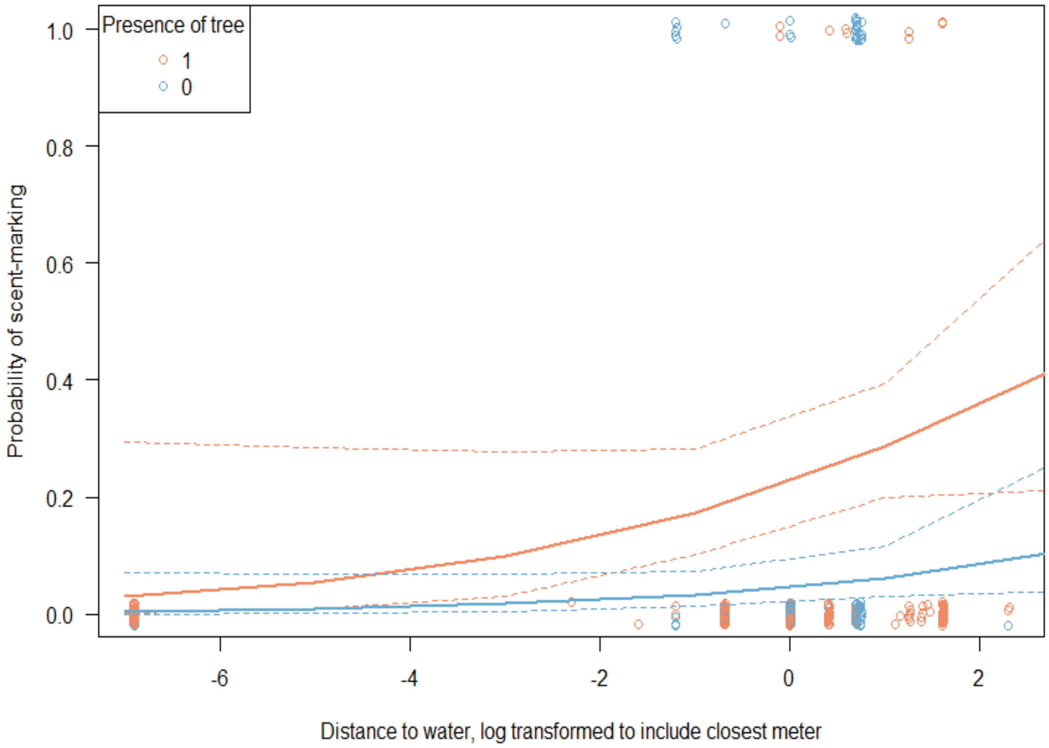

Figure 7: Plot visualising the top model from table 3, with tree presence and distance to water as predictor lines on scent marking probability. The orange line indicates the trend with tree presence/absence, whereas the blue shows how distance to water holes affects presence or absence of scent marking. The striped lines represent the 95% confidence intervals.

4. Discussion

I studied the determinants of scent-marking behaviour by Asiatic cheetahs at camera traps across multiple sites in Iran. In addition to this, I provided estimates of occupancy and detection probabilities from the study areas during the camera trapping period. After testing different determinants against marking presence/absence as a response, the strongest results came from the tree presence and distance to water variables. Figure 6 visualises this result and shows that with a tree present, the probability of scent marking by cheetahs will increase. This in turn can correlate with cheetah detections, as this indicates that there will be a higher chance of a cheetah detection when a camera is in close proximity to a marking tree, compared to if there is no tree present. This can be a useful aid in planning for future cheetah monitoring, as it will more likely guarantee a detection. A major focal point of this study was the behaviour observed in the species, and what determinants triggered them, and so not being able to discern whether something out of frame triggered a certain behaviour was a challenge.

There are different ways of scent marking by carnivores, for example spraying urine, faeces, or other glandular excretions (Thiessen & Rice, 1976). They also rub their scent with glands either in their rectum, face or on their legs (Roberts, 2008). In 11% of the photos and videos I analysed, I found evidence of scent marking by Asiatic cheetahs. 71% of these were done by what I have classified as spraying, and the remaining 29% was done by rubbing. It is unclear what excretions came from this spraying behaviour, as this is difficult to determine when not working with physical sample data (Allen et al. 2015). Capturing scent marking on camera is difficult, and results from this thesis highlights this sentiment, considering the few cases that was recorded. Scent marking was significantly correlated with a scent marking tree, with only 23% of marking detections not including a tree. However, this is not a definite conclusion, as there could have potentially been a tree out of frame which facilitated scent marking, and the animals were simply marking further away from an already present tree that was not shown in frame.

My first research question for this thesis was to look at cheetah detection rates, which was already established to be quite low due to the elusive nature of the species, and the fact that the species is in decline with a decreasing population size. The occupancy analysis that was done highlights this, as it produced very low estimates. This is data collected from 2009-2014 across nine sites, which shines a light on how low these estimates are considering the amount of time given and the geographical range.

My second research question for this thesis was to figure out which determinants that would influence the behaviours of the Asiatic cheetah. Previous studies done on the Asiatic cheetah population have found similar results to what I have shown here. This emphasises the importance of seeing connections between the environment and the species that lives there, and how that it is a powerful aid in studying certain animals. Considering marking trees came out significant in all my statistical analyses, it would be a safe assumption to focus efforts on placing cameras for future monitoring around such trees.

There were two cases of scent marking present in close proximity to an artificial waterhole, with the closest being <300m away of the recording. Artificial water holes are also common targets for camera station placements, as water holes are hotspots for animals in especially arid and semi-arid habitats (Hayward & Hayward, 2012; Edwards et al. 2016). Figure 6 predicts a relationship between scent marking presence and distance to water sources. The predictions show that if distance to water increases, the rate of scent marking will also increase with it. Considering the few cases of scent marking that I had when near water sources it makes sense. When studying scent marking, my results suggest that water sources can be deemed less important when aiming to maximize scent marking detections, but they are nonetheless important due to water sources being hotspots for detecting animals of a variety of species (Epaphras et al. 2008).

Asiatic cheetahs are known to range over vast areas and multiple cheetahs from my study are known to move across the study sites (Farhadinia et al. 2016). As not all individuals were given an ID, this was not pursued further in this thesis, but a study done by Farhadinia et al. (2013) highlights how mobile this species is, as they have records of an individual traveling as far as 40 km across three reserves within three years, over an estimated 4862km^2. The authors also found that males were seen to cross more frequently and over longer distances, which resonates with some of the observations of a few male individuals that I found during the analysis. This is an interesting aspect considering their habitat range has declined significantly (Durant et al. 2017), but it can help provide a better understanding of the habitat scale this species needs for future conservation, especially considering the population is in decline. It would have been interesting to see if some of the individuals I observed scent marked across multiple sites, or at least over a larger distance.

Most of the cheetah detections were male individuals, and were often seen walking alone, or if related in groups, which was present in some of the images analysed for this thesis. This ties in with literature, which have also found a similar result, especially when cameras are placed at biased scent marking trees (Marker et al. 2008; Marnewick et al. 2008). Unfortunately, a large portion of individuals (n=97) were not fully sexed, as these individuals had their back side turned away from the camera, thus making identification difficult. A few of the females seen were accompanied with cubs. Due to there being too many unsexed individuals during the data collection, no statistical analysis was done for this variable, but it is a topic that should be considered as one can argue focusing tracking of male individuals for optimising camera detections is a more efficient way to go for future studies.

After analysing the 17 videos, a few of them provided footage of individuals scent marking, which allowed for some details to be extracted. The videos were on average 1 minute long, with most of the cheetah footage being at the start of the videos. The videos containing scent marking evidence provided an average for how long the cheetahs would spend scent marking. Scent marking would take around 5-10 seconds and was often accompanied with other behaviours such as walking and surveying of about 14 of 17 cases. Marking trees was always present in all cases when scent marking was observed.

Other parts of the footage showed cheetahs ignoring or oblivious to the camera. They walked next to, or near the camera. It shows the individuals not being afraid of getting close to the cameras, and additionally scent marking in front of them. I would argue that the cameras themselves are a trigger for Asiatic cheetahs to scent mark or express different behaviours in front of them (Kelly et al. 2012), or they might notice the scents of the humans that have set up the camera, and feel like their territory is threatened, or they are trying to outcompete the competition.

5. Conclusion

Studies such as this are important for a rare species because it adds to the already sparse knowledge out there, but it also improves on and challenges what approach to take to efficiently study the species. There are many factors to consider when sampling wildlife populations, and most importantly, resources and time. The data for this thesis was provided by camera traps only, which comes with its own strengths and weaknesses. Despite this method being less invasive than others, it also requires a significant amount of time and resources to gather enough data for research, while not being guaranteed sufficient amounts of data. To improve on such a study, the steps taken here needs to be available for future studies that wish to perform similar research. If resources and time allows it, a study like this could benefit from incorporating additional methods, such as faecal DNA and hormone sampling found at scent marking sites. This could potentially improve the data collection and outcome for a future study. Relying on observer data from images is one thing, but physical evidence from areas that the cheetahs have scent marked could greatly improve our understanding of the species. Studies such as these are important for the conservation of rare species, especially for those who are already lacking in data and literature available. Studies focusing on how to study elusive species provides framework more efficiently for future projects and can be used for similar study approaches for other species that require a similar study method. The more we can understand how Asiatic cheetahs communicate in their habitat, the better future research and conservation projects can become. With a greater understanding of how the Asiatic cheetah functions in its environment and its communicative behaviour (i.e. scent marking), future research and conservation for the species can be greatly improved.

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APPENDIX A

Figure A1: Typical camera interaction image, where the individual is right next to the camera trap, and little info can be extracted from the image. This category is a bit challenging because sometimes the individual may just pass by the camera but because the camera was set too close to the trail, the photo will be like this. Photos: Iranian Cheetah Society/Iran Department of the Environment/Conservation of the Asiatic Cheetah Project.

APPENDIX B

Table B1: Overview of camera types and number of each type used. Whether cameras had flash or not was unknown for most of the cameras, as model type was not given.

Camera model	**No. of cameras**
Moultrie (No specified model)	37
Cuddeback (Model 1125)	175
Ecotone	12
Panthera	56
Deercam (DC-200)	70
Bushnell (Bushnell37)	22
StealthCam MC2-GV	8

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