RESPONSE OF SMALL CARNIVORE COMMUNITY TO LANDSCAPE AND CLIMATIC VARIABILITY ALONG THE ELEVATION GRADIENT IN THE GREAT HIMALAYAN NATIONAL PARK CONSERVATION AREA, THE WESTERN HIMALAYA, INDIA

THESIS
SUBMITTED TO THE
FOREST RESEARCH INSTITUTE (DEEMED-to-be) UNIVERSITY
DEHRADUN, UTTARAKHAND

For
THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY IN FORESTRY
(Forest Ecology and Environment)

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Wildlife Institute of India

Year

2022

DECLARATION

I hereby declare that the thesis entitled '*Response of small carnivore community to landscape and climatic variability along the elevation gradient in the Great Himalayan National Park, Conservation Area, the western Himalaya*' submitted by myself Ms. Meghna Bandyopadhyay (Enrolment No. 16PHD410), to Forest Research Institute, Deemed to be University, Dehradun for the award of the degree of Doctor of Philosophy in Forestry (Forest Ecology and Environment) is a record of original research work carried out by me under the supervision of Dr. K. Ramesh, Wildlife Institute of India, Dehradun and has not formed the basis for an award of any other degree or diploma. I also declare that the thesis embodies my own work, observations and analysis and in that respect, the investigation appears to advance knowledge in the subject.

Place: Dehradun
Date: 29th August 2022

Meghna Bandyopadhyay

Countersigned:

Dr. K. Ramesh
(Supervisor)

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

DECLARATION

This is to certify that the thesis entitled '*Response of small carnivore community to landscape and climatic variability along the elevation gradient in the Great Himalayan National Park, Conservation Area, the western Himalaya*' submitted by Ms. Meghna Bandyopadhyay (Enrolment No. 16PHD410), to Forest Research Institute (FRI), Deemed to be University, Dehradun for the award of the degree of Doctor of Philosophy in Forestry (Forest Ecology and Environment) is a record of original research work carried out by her under my supervision. The thesis has duly checked through 'URKUND' a plagiarism detection tool approved by FRI, Deemed to be University and the thesis has plagiarism to acceptable limits. No part of this thesis has been submitted for any other degree/diploma of the same institute where the work is carried out or to any other institution. It fulfills all the requirements of the ordinance governing the award of a Ph.D. degree of FRI, Deemed to be University, Dehradun. Ms. Meghna Bandyopadhyay has adequate attendance during her thesis work, and she was not engaged in any paid assignment.

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   (For all further correspondence please quote your enrolment number.)
3. Name of Research Centre: - **Wildlife Institute of India, Dehradun**
4. The Topic of research approved by the FRI University: **"Response of small-carnivore community to landscape and climate variability along the elevation gradient in the Great Himalayan National Park Conservation Area the Western Himalaya."**
5. Name of Discipline: - Forest Ecology & Environment
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6. (i) Name of Supervisor : - **Dr. K. Ramesh**
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EXECUTIVE SUMMARY

The arrangements of carnivores differ along environmental gradients due to disturbances and resources. Structures of carnivore communities are determined by the composition of functional traits, e.g. feeding type, body mass, activity patterns and behaviour. Such structures often vary along environmental gradients due to disturbances and resource availability. However, species of different functional types may differ greatly in responses to environmental gradients and cause variation in the structure of communities along the gradients. Many environments are, at small scales, fairly homogenous in terms of vegetation, whereas there, on landscape scale, often are clear gradients, such as of human-related activities and associated impact. Carnivore community's responses to gradients on landscape scale are complex on account of the variety of species

The Western Himalaya, one of the most biodiversity-rich landscapes, harbours a wide variety of small carnivore species. Several studies have focused on single-species ecology, while fewer have emphasized on multiple species distributions and interactions. Moreover, human habitation is expanding towards the natural forests across the Western Himalaya. In this context, there is evidence that the presence of human habitations adjacent to natural forests altered native small carnivore inter-specific interactions for coexistence and also distribution. In particular to disturbed habitat, influence of anthropogenic disturbances on small carnivore interactions was reported in where coexistence of Geoffroy's cats and culpeo foxes was facilitated by dietary segregation while showing high spatial and temporal overlap. Similarly, small carnivores interactions were influenced in sites with fewer human settlement.

In this context, the Great Himalayan National Park Conservation Area (GHNPCA), situated in Kullu district of Himachal Pradesh, provides the best platform to study for influences of human disturbances on the native wildlife (in this case small carnivores) in a gradient of differential

human disturbances. GHNPCA is a UNESCO World Heritage site due to its rich biodiversity. In 1994, a buffer zone, extending 5 kms from the park's western boundary, was reclassified as an ecozone. According to FREEP (Forestry Research, Education and Extension Project) report in 1999, this zone included approximately 2,300 households in about 160 villages and most of the ecozone's population (around 16,000 residents in 1999) were poor and depend on natural resources for their livelihoods. The report states that the locals had moved away from exploiting the park's resources, they work in areas as diverse as basket making, vermicomposting, organic farming, medicinal plant cultivation, ecotourism and many other income generation activities. Therefore, the ecozone is composed of villages and human activities since 90's. After which no such scientific study was carried out. Various carnivores were documented in GHNPCA earlier, but small carnivores distribution in the study area and their responses to anthropogenic and climatic effects were not studied. Change in carnivore habitat selection from a relatively less human-disturbed to a more human-disturbed area in favour of easily available resources can be seen in a continuum of mosaic habitats. Therefore, studying carnivore distribution along the habitat gradient consisting of both the human-modified and natural forest will aid in (a) understanding the status of the human-wildlife interface and (b) enabling integrated management of nature and people in the susceptible landscapes. In the context of anthropogenic habitat in GHNPCA, the human population was 15000 from 160 villages in 1995, reaching about 9000 in just 6 villages in 2011 (www.census2011.co.in). With the increase of human population, there were conversions of forested habitats into arable lands for agricultural practices. Since settlements and agricultural plots generate human-induced resources, there are chances that the resources are available in more quantity and close to natural habitat than before.

From this perspective, understanding the species site usages and interaction patterns at fine scale might be effective to delineate the processes responsible for species distribution and coexistence in a rural – natural gradient. In this study, small carnivores distribution and changes in niche dynamics across a relatively less disturbed (National Park) and highly disturbed (human-dominated) habitats was quantified and compared. Owing to the rugged landscape of the Western Himalaya, it is often challenging to conduct fieldwork and acquire species detections. Hence a combination of non-invasive tools like; intensive camera trapping and carnivore faecal sample collection in 5 sessions, DNA extraction and diet analyses, were used. In this study intensive field work was conducted in a span of two and half years that involved walk effort of 738 km, deployment of 340 camera traps and collection of 638 carnivore faecal samples, thereby making it perhaps the most exhaustive study in the Western Himalayan landscape. The study design is compact and highly reproducible in other landscapes consisting of habitat gradients especially in remote and rugged areas. The study was the first attempt to understand the effect of fine-scale habitat modification using 3rd and 4th order habitat variables on the distribution of small carnivores using complementary approaches in GHNPCA in the western Himalaya. 3rd order habitat variables included slope, elevation, ruggedness, NDVI, distance to woodland and distance to village whereas the 4th order variables included prey item estimation.

A total of 7 out of 9 small carnivores were recorded from the lower elevations (<2000m), 3 from intermediate (2000m to 2500m) and 4 from higher elevations (>3000m). Red fox and leopard cat were the only small carnivores detected throughout the elevation gradient hence they were chosen as the model species. Variation in the site intensity usage of small carnivores was observed in the ecozone - park gradient, where the ecozone is located at lower reaches and park at higher elevations. For instance, the overall capture rate (RAI) of red fox and leopard cat in the ecozone

was higher than in the park. The result contradicts the established literature from GHNPCA in 1999, where red fox and leopard cat were recorded only inside the park at high elevations. From the previous research, the results were comparable due to the substantial walk effort of 290 km in ecozone and 867 km in the National park. However, carnivore sign surveys on human trails were not as robust compared to camera trapping used in this study. The occurrence of generalist species like red fox and leopard cat in less disturbed forested habitats along with human dominated habitats affirms the presence of increasing human habitations and its associated land usages in the landscape and its effect on native wildlife. The variation in site usages along the disturbed to natural gradient, elucidates the role of small carnivores as indicators of habitat quality. The differences in intensive site usage by native wildlife point towards habitat modifications in terms of increasing households, expanding agricultural plots, availability of human-induced food resources, etc. at the lower reaches of GHNPCA.

Also, small carnivores like red fox and leopard cat coexisted in National park through spatial segregation whereas in ecozone they coexisted through dietary segregation revealed by generalised linear mixed modelling (GLMM), activity overlap and Piankas' overlap index. Changes in dietary niche breadth of the two small carnivores was also observed on comparing the ecozone and National park. Interestingly, human presence did not effect their coexistence pattern but area with human habitations were observed to have changed coexistence patterns. The alteration in species coexistence indicated the effect of presence of human habitations close to protected forested habitats or effect of interactions with other carnivores in the area. After assessing the overall distribution pattern and coexistence, further site sensitivity of small carnivores was investigated using 3rd order habitat variables in National park and ecozone.

Small carnivores like red fox and leopard cat showed non-liner habitat selection, in terms of terrain ruggedness, slope, NDVI, in park that differed from ecozone, reflecting species-specific sensitivities to habitat changes. In this context, the generalised additive modelling (GAM) framework effectively captured the non-linear patterns which would otherwise have been missed if used simple generalised linear modelling (GLM). The change in the occurrence of red fox and leopard cats in selected habitats inside park to a wide range of habitats in ecozone revealed its flexibility in humanized environments and exploitation of niches that form in the wake of human activities. The difference in habitat selection revealed their opportunistic and human adapter behaviour that is an outcome of resource utilisation, especially in resource-scarce and rugged landscapes in the western Himalaya.

Interestingly, the distribution of red fox and leopard cat was not affected by anthropogenic variables like human presence or distance to village but their distribution was influenced by climatic variations. A shift from higher to lower elevation was observed during winters.

This study explains the fine-scale patterns (like distribution, habitat selection, coexistence) of small carnivore behaviour along the habitat gradient but the process (like resource availability, presence of other carnivores, land uses) responsible for such patterns can be further investigated to identify the driving factor. All the results indicate the ecozone as the interface area where human and wildlife are sharing spaces. This makes it sensitive and priority area for conservation managements in entire the elevation gradient of GHNPCA. The high adaptability of small carnivores in ecozone points towards their increasing dependencies on human induced resources that might result in zoonotic disease spread through livestock and vice versa, as red fox and leopard are known to borne zoonoses, and also conflict issues with dogs and livestock (sheep, goat). Since ecozone forms the boundary of the National park, therefore the effects of anthropogenic pressures might ripple through the National park affecting the less exposed wildlife inside the park. Owing to the high biodiversity value of GHNPCA, a World Heritage site, this is high time to initialize the good practices in the Conservation Area to avoid deleterious effects on the wildlife and preserve the sanctity of the habitat. Hence, management strategies in the ecozone aimed at 1) future monitoring of wildlife, 2) proper garbage disposal practices, 3) controlling human habitation expansion in the ecozone so that less anthropogenic food resources are generated and 3) shaping the human-modified areas into highly heterogenous ecosystems can better facilitate fine-scale spatial segregation among wildlife and humans. This study also suggests for monitoring of livestock and wildlife for any infectious diseases that might spread and effect human health.

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CHAPTER-1

Introduction

1.1 General introduction

1.1.1 Habitat gradient and role of small carnivores

Habitat continuum being an integral part of the mountainous landscape serves a gradient of various resources like food, water, shelter, etc. and thus plays crucial role for the existence and survival of a species or group of species, in addition to being corridor (Boydston et al., 2003). Mammal community's responses to gradients on landscape scale are complex on account of the variety of species and functional types. The functional structures of mammal communities vary along environmental gradients e.g. of disturbance and resource availability (Wallgren et al. 2009). Environments at small scale are fairly homogenous in terms of vegetation whereas on landscape scale there are clear gradients. Species of different functional types may differ greatly in responses to environmental gradients and cause variation in the functional structure of communities along the gradients. Large and medium-sized mammals are highly affected by large-scale disturbance gradients, while small mammals are most dependent on small-scale variation in resources, probably shelter and food. Very little is known about their influence on communities and ecosystems. Small carnivores being more diverse in their behaviour and ecology and abundant than large carnivores often reside in closer proximity to humans. This is why some abrupt change in behaviour of the small carnivores can be expected owing to changes in habitat characteristics (Farris et al. 2015; Manlick and Pauli 2020). Such study of small carnivores in response to environmental factors could be of interest in terms of understanding the community dynamics (Gantchoff and Belant 2016, Vitekere et al. 2020).

1.1.2 Threat to habitat gradients in the Himalaya

The Himalaya has faced consistent pressure from increased human settlements due to agricultural practices, more intensive grazing by domestic animals and increased demand for timber (Cronin, 1979; Schaller, 1980, Angelici and Rossi 2020). Consequently, the increasing quantity and proximity of readily available anthropogenic subsidies facilitate increasing dependencies of native carnivores on these resources (Ghoshal 2011; Ghoshal et al. 2016; Khan et al. 2020; Rajaratnam, Vernes, and Sangay 2016). Additionally, the natural resources are localised in the rugged landscapes and often are not readily available to carnivores compared to the anthropogenic food resources. In this scenario human habitations and agricultural practices generate human-induced food resources (Verdade et al. 2011). Moreover, when anthropogenic food resources replace natural prey due to habitat modifications, such changes affect wildlife distribution (Parsons, Newsome, and Young 2022; Ripple et al. 2014). In this context, there is a paucity of information regarding the modified habitats adjacent to less disturbed natural forests and their effect on the native wildlife in the rugged landscape of Himalaya.

1.2 Literature review

1.2.1 The Greater Himalayan landscape

There are four categories of the Himalayan mountains from East to West based on altitudinal differences. The Tethys Himalayan Range lies on the extreme north also known as Tibetan Himalaya merges with the Tibetan plateau and the average height is 5500 m to 6000 m. The Greater Himalayan range is the highest mountain range of the Himalayan system. This always remains snow-covered and is generally referred to as ‘Himadri.’ Its average altitude exceeds 6,000 meters and its average width is 25 kilometers. Almost all the important peaks are located in this range. The Lesser Himalayan range is located in the south of the Greater Himalayas and runs parallel to it in the east-west direction. Its average height is from 3,500 to 4,500 meters and it is nearly 80 kms wide on an average.

1.2.2 Species as model to understand the habitat gradient

The species distribution along the vertical and horizontal gradient reflects typical patterns in which the species organize themselves. The distribution pattern along certain axis can be extended to elevation gradients and the Himalayan system is an ideal landscape for testing such ecological questions. In this context, habitat gradients provide a gradient of valuable habitat for different flora and fauna to thrive at different altitudinal levels and are high in ecological diversity. Alterations to habitat gradients due to anthropogenic activities and changing climatic conditions are likely to cause the most adverse impact on the occupancy and abundance of the mammalian fauna inhabiting the area. Knowledge of such species is important as they can act as indicators of short-term and long-term disturbances in terms of local extinction or colonization (Riggio et al., 2018). Predicting the change in abundance is pivotal for evaluating species' current conservation status and population viability. Empirical works have suggested that species with an increasing abundance have a more aggregated distribution than those with a declining abundance (namely, the Change-Aggregation Hypothesis, CAH).

1.2.3 Importance of small carnivores

In an ecosystem, the large carnivores are ecologically important because relatively few individuals can cause strong predation-driven direct effects or fear-driven indirect effects that can ripple through communities and, ultimately, influence ecosystem structure and function. They are mistakenly thought to have a lower impact at the ecosystem level. Small carnivore population are important ecosystem regulators as they structure small mammal and/or invertebrate communities, which in turn might affect higher trophic levels. They are an important aspect in seed dispersal. It is necessary to assess the extent to which the small carnivore population is pushed towards vulnerability due to increasing anthropogenic stress. For many of the vulnerable species, there is little knowledge of their biology and ecology. Conservation of these species will be difficult without the baseline information. Despite its extensive geographical range, the ecology and behaviour of such species have so far received little attention. It is known to have high ability to adapt with modified habitat (Díaz-Ruiz et al. 2016), like it can thrive in human dominated landscape (Jahren et al., 2020, Ditchkoff et al. 2006). Change in small carnivore interaction in response to the alteration in the anthropogenic or climatic parameter is an interesting mechanism to study for.

1.2.4 Conservation status of small carnivores

Large carnivores have drawn considerable attention, initially through their charisma but also for their potential conflicts and resulting threats to several species and populations (Do Linh San et al. 2013). The Indian Himalayan region is very rich in terms of biological diversity due to its unique location, climate and topographic conditions. In the Great Himalayan National Park Conservation Area, small carnivores found as reported in Vinod & Sathyakumar 1999 are Siberian weasel, Indian grey mongoose, yellow throated marten, masked palm civet, leopard cat, red fox and golden jackal. Very little information is available regarding these elusive and lesser-known species. As after 1999 no scientific study was carried out in this landscape.

1.2.5 Response to environmental parameters

As specialization and resource selectivity is generally stronger in small carnivores than large carnivores, they may serve as useful indicator species in the preservation of keystone habitats. Mapping and subsequent predictive habitat modelling are useful in terms of future projections like conservation planning, detecting distributional changes and species activities for those controlling parameters. Distribution of small carnivores is greatly determined by the resources at the home-range scale. The different environmental parameters include bioclimatic variables, forest and land cover types, topography, vegetation indices and anthropogenic variables. Anthropogenic activities such as urbanisation, commercial plantations, and intensive agriculture practices have led to severe habitat alterations. There are studies indicating small carnivore distribution pattern and its subsequent response to environmental parameters (Kalle et al. 2013).

1.2.6 Distribution and abundance

Camera trap studies have mostly focused on spotted and striped felids owing to their unique natural markings for density and abundance estimations. Species without individual markings have been underrepresented in recent camera trapping research, consideration being restricted largely to presence in mammal inventories or as a supplement to the study of an individually identifiable target species. Models of abundance that can estimate underlying detection probabilities from camera trapping data provide an important advance in this respect. However, currently these methods do not provide estimates of density and the extension of camera trapping methods to do this for species not individually identifiable would greatly extend the value of the technique. Abundance is defined as the proportion of area, patches, or sample units where species is present. It deals with two critical aspects of sampling animal populations; spatial variation and detectability with respect to time and space. Detectability accounts for the missed and undetected animals in a study area. Most of the distribution maps on small carnivores were created by compiling traditional general knowledge and expert opinion on potential habitat. Detection probability is very relevant to the estimation of occupancy. Sampling programs designed to estimate occupancy tend to require less effort than programs designed to estimate abundance (Mackenzie et al. 2002). In the case of rare species, it is sometimes practically impossible to estimate abundance, whereas estimation of occupancy is still possible. Data limitations for small carnivores is a major factor. Hence repeated sampling can yield in increased number of detections.

1.2.7 Behaviour and association of small carnivores

Small carnivores are sympatric depending upon their habitat utilization and niche characteristics (Kalle et al. 2013). As specialization and resource selectivity is generally stronger in small carnivores (Riddhika kalle, Tharmalingam Ramesh 2012), they may serve as useful indicator species in the preservation of keystone habitats. This is the reason why small carnivores are more likely to be affected with change in the environmental parameters. Being small- sized, elusive, secretive, arboreal and sometimes nocturnal, they have low detection probabilities. Despite their high mobility, small carnivores have long been considered particularly sensitive to habitat loss and fragmentation. Probability of patch use decreases with increasing patch isolation and decreasing patch size (Mortelliti and Boitani 2008). Small carnivores are known to have good association within community and with other carnivore species. The association within and across the guild depends upon geographic overlap, habitat overlap, dietary overlap and activity pattern (Caro and Stoner 2003). The intraguild predation can lead to interspecific competition. The study of interspecific competition is of conservation significance for two reasons. First, competition can reduce the population size of an endangered carnivore. And secondly, it can affect population of other species at lower trophic levels (Caro and Stoner 2003).

1.3 Scope of the study

The Western Himalaya is one of biodiversity rich areas worldwide (Pandit, Manish, and Koh 2014) and harbors wide variety of small carnivores (Shao et al. 2021). The increasing human habitation expansions and habitat alterations in the mountainous landscape of Western Himalaya has put the biodiversity at threat. There are studies focusing on single species ecology in the Himalaya (Bashir et al. 2014; Ghoshal et al. 2016; Roy et al. 2018). In this context, studying fine-scale multiple species distributions and interactions on the heterogenous habitat gradients might help in understanding the current status of the remaining forested habitats in the Western Himalaya (Noor et al. 2017; Vernes, Rajaratnam, and Dorji 2021). Small carnivores in this scenario suit the best to be studied for changes in habitat conditions as they are sensitive to small scale changes. Owing to high remoteness and harsh climatic conditions it is often difficult to conduct scientific studies in this landscape and hence the patterns and information remains unrevealed. There is scarce knowledge about the small carnivore distribution in this landscape and hence little information exists regarding the anthropogenic and climatic effects on the native small carnivores. This study will add knowledge about the elusive and lesser-known small carnivores in a gradient of disturbed and less disturbed habitats.

1.4 Objectives

The study focusses on the following objectives:

1) Occurrence and abundance estimation of small carnivores across space and time along the elevation gradient.
2) Assessment of community composition of small carnivores and association with other small carnivore species.
3) Evaluation of landscape sensitivity by representative small carnivore species.
4) Distribution modelling of indicator species to anthropogenic and climatic effects in the current context.

1.5 Organization of thesis

Chapter one introduces general information regarding the habitat gradients in Himalaya and role of small carnivores as indicators. Through literature review, the importance of habitat gradients especially of the Greater Himalayan landscape and how small carnivores respond to environmental parameters was portrayed.

Chapter two introduces the study area and the various methods used to fulfill the objectives. The significance of the study area is also discussed.

Chapter three primarily focusses on the arrangements of small carnivores along the elevation gradient in terms of site intensity usage and abundance of small carnivores. Marked (leopard cat) and unmarked (red fox) species were considered and statistical models were used to find the overall abundance and also across the elevation gradient in space and time. This forms the first objective.

Chapter four demonstrates the coexistence patterns of small carnivores (red fox and leopard cat) in three dimensions; space, time and diet. The niche dynamics was assessed and compared between low human disturbance and high human disturbance areas. This chapter reveals how the coexistence patterns of small carnivores change with differential human disturbances.

Chapter five describes the sensitivity and highly adaptable behaviour of small carnivores (red fox and leopard cat) in the study area. The habitat selection of red fox and leopard cat was assessed and compared between a human dominated area and a less disturbed natural forest. It reveals how the small carnivores change their habitat selection from preferred to less preferred sites in the study area which can be considered as an indicator of habitat alterations adjacent to natural habitats.

Chapter six introduces the overall distribution of small carnivores (red fox and leopard cat) in the study area using species distribution modelling. It also highlights the seasonal shift in species distribution. The species distribution maps provide insights about the species overall presence/habitat use in the study area and supports further studying the resource abundance and distribution to delineate the driving factor of specie distributions.

Chapter seven focusses on general discussion and overall synthesis of chapters-3,4,5 and 6. It also highlights the management strategies that can be undertaken to better manage the human wildlife interface areas along the elevation gradient.

CHAPTER-2

Methodology

2.1 Study area

2.1.1 Description

The Great Himalayan National Park Conservation Area (GHNPCA) in Kullu District of Himachal Pradesh (HP), was established in 1984 and was finally notified in the year 1999 under the Wildlife (Protection) Act 1972 (Fig 2.1). The Park (831.2 km²) is located between 31^0 38' 28" to 31^0 54' 58" N latitudes and 77^0 20'11" to 77^0 45' 00" E longitudes and spread along an elevation range of 1400 to 5500 m above sea level.

2.1.2 History

In 1994, a buffer zone, extending 5kms from the park's western boundary, was identified as an ecozone (265.6km²) and this zone includes approximately 2,300 households in about 160 villages (Tucker, 1997). Sainj Wildlife Sanctuary (96.4 km²) was also created in 1994, to include the three villages of Shakti, Shagwar and Maror. Another protected area, Tirthan Wildlife Sanctuary, was established in GHNPCA which is uninhabited and covers 65.6 km². In 2010, Khirganga National Park (710 km²) alongside the Parvati River catchment, was instated adding further biological diversity, conservation value and physical protection to GHNPCA. The boundaries of GHNPCA are also contiguous with the Pin Valley National Park in the Trans-Himalaya Range (675 km²); the Rupi Bhabha Wildlife Sanctuary in the Sutlej Watershed (503 km²); and the Kanawar Wildlife Sanctuary in Parvati Valley (107.29 km²). The GHNCPA is located on the junction of two great faunal realms; the Palaearctic to the north and Oriental to the South and lies in the biogeographic zone-2A North-West Himalaya. In 2014, GHNPCA was declared a UNESCO World Heritage site. There are four catchment areas of Tirthan, Sainj, Jiwa and Parvati rivers. Tirthan catchment was selected as the intensive study site due to the similarity in habitat characteristics with the entire GHNPCA.

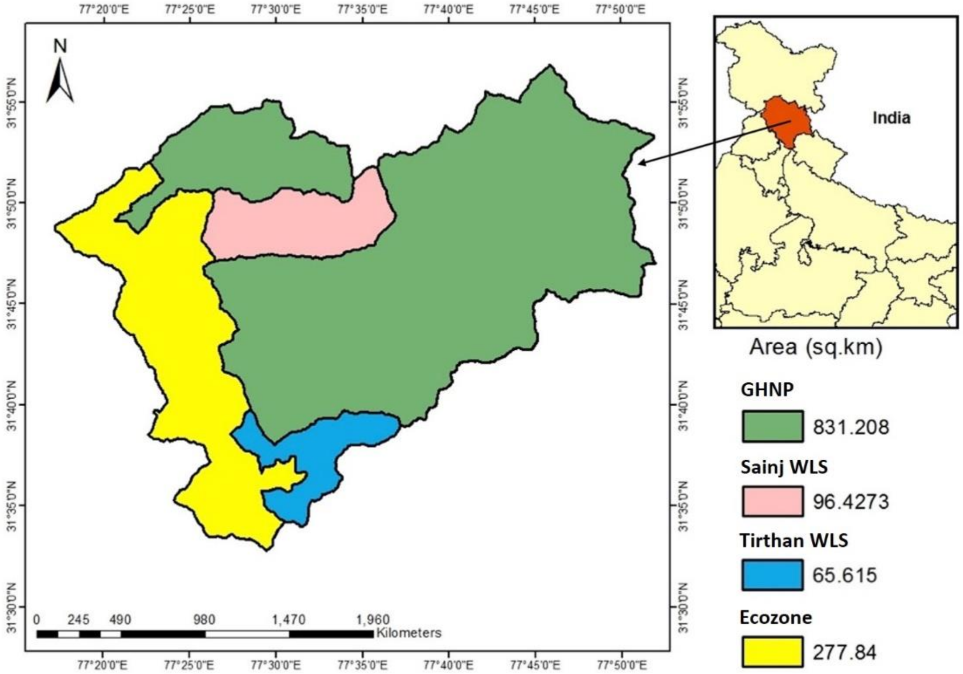


Figure 2.1: Map showing administrative boundary of Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh.

2.1.3 Flora

The geographical area of GHNPCA is mostly covered by meadows, rocky peaks and snow-bound areas because of the preponderance of alpine areas beyond tree line and only 17% is covered by vegetation (habitat images in Appendix-1). However, these barren heights are usually touched on only briefly, if at all, by the average trekker. The following vegetation types can be recognized at various elevations in GHNPCA: Temperate broad-leaved forests (2,000 to 3,000m), Temperate conifer forests (2,000 to 3,000m), Upper temperate broad-leaved and mixed conifer forests (2,500 to 3,500m), Sub-alpine (Birch-Rhododendron) forests (3,000 to 3,500m), Alpine scrubs (3,500m and above), Alpine meadows (3,500m), Riverine forests (along the rivers), Temperate grassy slopes (2,000 to 3,000m), Temperate secondary scrub near village pastures and forest edges (Singh & Rawat, 1999).

2.1.4 Fauna

The GHNPCA harbors a wide variety of mammalian fauna. The carnivores list includes yellow throated marten, Himalayan palm civet, Himalayan weasel, jungle cat, leopard cat, common leopard, snow leopard, red fox, jackal, wolf, Asiatic black bear and Himalayan brown bear (Vinod and Sathyakumar 1999, Ramesh, Sathyakumar, and Rawat 1999). Among the small carnivores found in GHNPCA, red fox, jungle cat and yellow throated marten are categorized as schedule II species whereas leopard cat is a schedule I species according to WPA status. Although covering a relatively small area, the park and ecozone have a complex geography with large variations in altitude. This allows them to sustain a huge range of plant and animal species, characteristic of South-East Asian forests as well as the Siberian and Asian steppes, ranging from the subtropical to the alpine. Few ecological sanctuaries of similar size, encompass such diversity.

Table 2.1: List of the carnivores found in GHNPCA in 1999.

Common Name	Scientific Name
Asiatic black bear	*Ursus thibetanus*
Himalayan brown bear	*Ursus arctos*
Common leopard	*Panthera pardus*
Snow leopard	*Uncia uncia*
Jackal	*Canis aureus*
Red Fox	*Vulpes vulpes*
Leopard cat	*Felis bengalensis*
Jungle cat	*Felis chaus*
Yellow throated marten	*Martes flavigula*
Himalayan weasel	*Mustela sibirica*
Himalayan palm civet	*Paguma larvata*

2.1.5 Climate

The climate is typically the Western Himalayan temperate and alpine type. There are four distinct seasons recognized for GHNP: summer (April-June), rainy (July-September), autumn (October-November) and winter (December-March). Precipitation is moderate for most of the year and abundant during the monsoon. During winter, lower elevations also receive snow fall, whilst higher elevations receive snowfall of over two meters. The ambient temperature in GHNPCA can vary from -10ºC in January to 40ºC in June.

2.1.6 Justification of the study

GHNPCA was extensively studied in 1999 but information on small carnivores and their distribution is lacking. Also no scientific study was conducted in GHNPCA to understand the responses of small carnivores along an elevation gradient starting from human dominated ecozone to less disturbed natural forest inside the park. Hence, the study of community dynamics of small carnivores, its structure and response to anthropogenic and climatic correlates can aid in understanding the current status of the habitat conditions in GHNPCA. The management strategies aimed at restoring the high biodiversity value of GHNPCA can then further strengthened.

2.2 Field methods

2.2.1 Camera trapping

Camera trapping was conducted in five sessions from 2017 to 2019, covering the Tirthan catchment in all the human-established trails. Number of sampling locations (n) and days of effort (t) in the respective five sessions were April-July 2017; n=59, t=2986, October-December 2017; n=78, t=2589, April-July 2018; n=40, t=1791, October-December 2018; n=82, t=2737 and April-June 2019; n=81, t=1763. Total 340 camera traps were deployed from 2017 to 2019 (Fig. 2.2) (Table 2.2). Total camera trap effort was 11866 (no. of camera traps x operational days). The total number of camera traps and effort in the ecozone were 120 and 2582, and in the National park were, 220 and 9284, respectively. Camera traps were deployed systematically with a minimum distance of 0.5 km and a maximum distance of 1 km between each consecutive trap location. Details of camera trapping design is explained below under “analytical methods”.

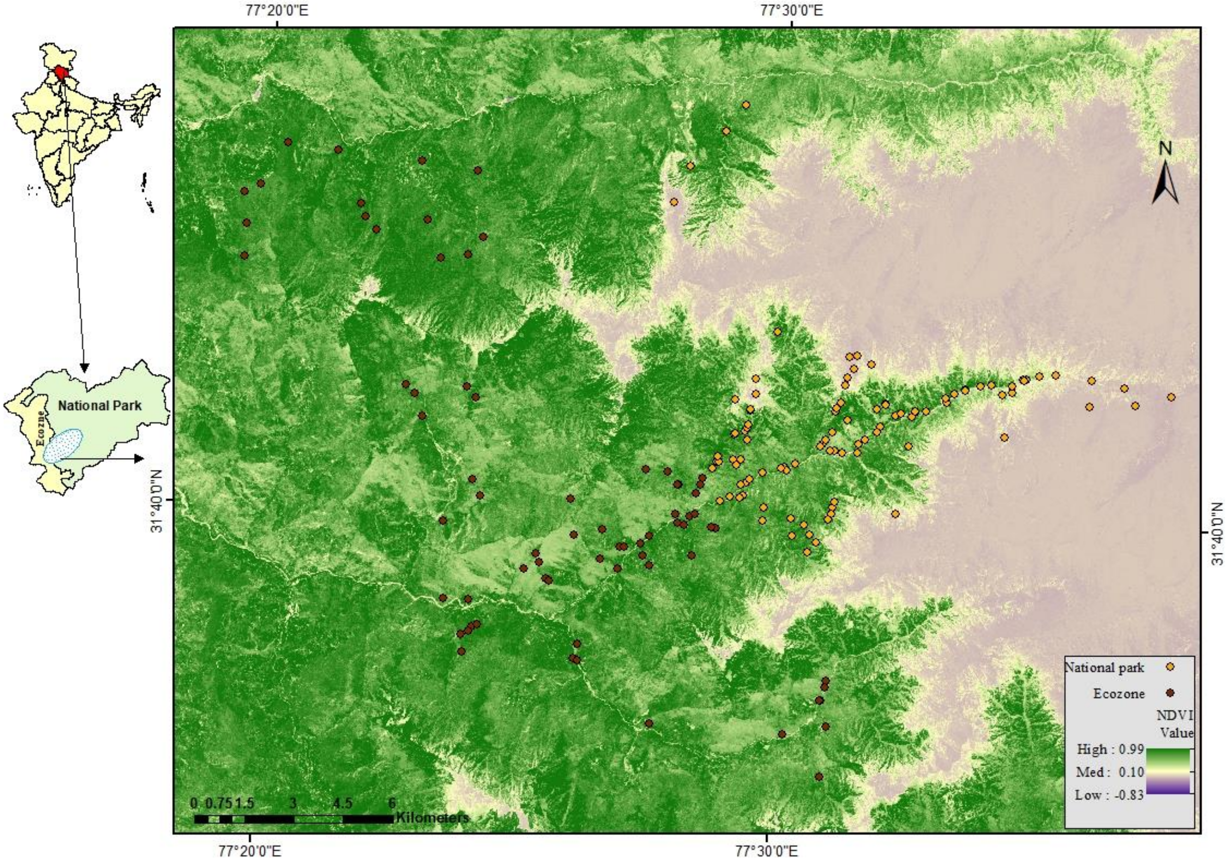


Figure 2.2: Map showing camera trap locations during 2017 to 2019 in National Park and ecozone in the Tirthan catchment in Great Himalayan National Park Conservation Area.

Table 2.2: Session wise camera trapping details in GHNPCA during 2017 to 2019.

Session	Month	Year	Number of camera trap locations		Effort: Sum of no. of operational days of all camera traps	
			National park (low human disturbance)	Ecozone (high human disturbance)	National park (low human disturbance)	Ecozone (high human disturbance)
1	April-July	2017	28	31	1907	1079
2	October-December	2017	47	31	2189	400
3	April-July	2018	35	5	1694	97
4	October-December	2018	52	30	2125	612
5	April-June	2019	58	23	1369	394
		Total	220	120	9284	2582

2.2.2 Carnivore faecal sample collection

Faecal samples were collected opportunistically from the study area along the human-made trails from 2017 to 2019 with a walk effort of 685.38 km (Table 2.2). Total of 683 faecal samples were collected following the dry sampling protocol (Biswas et al., 2019a) and transferred them to the laboratory within a maximum of two weeks of collection and stored at -20°C till further process. Details of faecal sample collection and respective walk efforts in the five sessions are provided in Table 2.3. To avoid misidentification of small carnivore faeces through morphological identification in the field (Morin et al., 2016), the faecal samples were subjected to species confirmation using molecular markers (Cytochrome b, 146 bp) (Farrell et al., 2000).

Table 2.3: Session wise faecal sample collection details in GHNPCA during 2017 to 2019.

Session	Month	Year	Total number of faecal samples collected	Number of faecal samples collected in:		Walk effort (km)	
				National park (low human disturbance)	Ecozone (high human disturbance)	National park (low human disturbance)	Ecozone (high human disturbance)
1	October-December	2017	162	140	30	149.62	15.41
2	April-July	2018	64	61	25	47	10
3	October-December	2018	220	157	48	214.35	63.5
4	April-June	2019	237	196	26	154.5	31
		Total	683	554	129	565.47	119.91

2.3 Laboratory methods

2.3.1 Molecular and morphological tools for carnivore identification from faecal samples

DNA was extracted from faecal samples by swabbing the outer layer and following the protocol described in Ball et al., (2007) and Biswas et al., (2019). Further, carnivore specific molecular marker (Cytochrome b, 146 bp) was used to ascertain the species (Farrell et al., 2000). PCR reactions were performed in 10 µl reaction volumes with 5 µl multiplex master mix, 1 µl of bovine serum albumin (BSA), 0.8 µl of each primer, 0.4 µl RNAse free water and 2 µl of template DNA. All reactions were run along with negative controls. The PCR conditions were 95°C for 10 min followed by 38 cycles at 95°C for 30s, annealing at 55°C for 50s and extension 72°C for 50s, with a final extension of 72°C for 10 min. The effectiveness and consistency of the PCR reactions were monitored using positive and negative controls. The amplified PCR amplicons were visualized in UV light on 2% agarose gel stained with green stain dye. Exonuclease I (EXO-I) and shrimp alkaline phosphatase (SAP) (Thermo Scientific) treatments were given to the amplified PCR products for 15 minutes each at 37°C and 80°C, respectively, to eliminate any residual primer and unused dNTPs. The amplified PCR products were sequenced using the BigDye® Terminator cycle sequencing Kit (v3.1, Thermo Fisher Scientific) and analyzed on an ABI 3500XL Applied Biosystems Genetic Analyzer (ABI 3500xl, Applied Biosystems, USA). Finally, the sequences were identified by comparing them in the NCBI database using the BLAST tool (http://blast.ncbi.nlm.nih.gov/Blast.cgi).

The remaining old samples were identified using the genetically confirmed samples as reference, as combining both methods is helpful for carnivore identification (Descalzo et al., 2021; Lonsinger et al., 2021; Oja et al., 2017). The genetically confirmed small carnivore faecal samples were matched with the old samples (n = 301), using weight and structure to identify the species. Details of total red fox and leopard cat identified from faecal samples using molecular and morphological tools are provided in Table 2.4. Further details of red fox and leopard cat faecal samples are provided in Table A4.4 and Table A4.5 and gene sequences (uncleared) are provided in Annexure.

Table 2.4: Details of total faecal samples identified of red fox and leopard cat using molecular and morphological tools.

Details of identification of total faecal samples of red fox and leopard cat	Number of samples
Number of faecal samples collected	683
Number of samples selected for molecular identification of small carnivore from faecal samples (relatively fresh)	382
Remaining number of samples for morphological identification of small carnivore from faecal samples	301
Number of genetically identified red fox and leopard cat faecal samples (successful PCR amplification)	359
Number of morphologically identified red fox and leopard cat faecal samples	227
Total genetically and morphologically identified red fox and leopard cat faecal samples	586
Number of unidentified faecal samples (from both molecular and morphological approaches)	97
Success rate of PCR amplification	(359/382) x 100=93.98

2.3.2 Prey identification

Both the genetically and morphologically confirmed small carnivore faecal samples were used for prey estimation through medullary hair identification. The faecal samples were washed thoroughly and 20 hair strands were selected randomly. The hair strands were cut into small pieces, dipped in xylene for 15-20 mins and observed under a microscope (40x) for medullary pattern identification (Bahuguna et al., 2010).

2.4 Analytical methods

2.4.1 Camera trapping design: number of camera traps

Power analysis was used to determine the number of camera traps required to sample the study area and detect a significant effect of habitat variables on small carnivores. This kind of assessment does not give an exact number but an idea about the range of number of camera traps one should have depending on the detections of the species. Because in such rugged landscape, it was not possible to follow the traditional grid-based camera trapping, hence trail-based camera trapping approach coupled with power analysis was followed. The number of camera trap locations in session 1 (summer, n = 59) and session 2 (winter, n = 78) were used as the test data. Function *simr* was used from the package "glmer" to evaluate the number of locations. It was found that an increase of sample size from 59 to 100 in summer and 78 to 80 in winter could result in a significant effect (Fig. 2.3). Hence in session 4 (winter), 82 camera traps were deployed and in session 5 (summer), 121 camera traps were deployed. But due to camera malfunctioning and theft issues, the camera numbers in session 5 dropped down to 81.

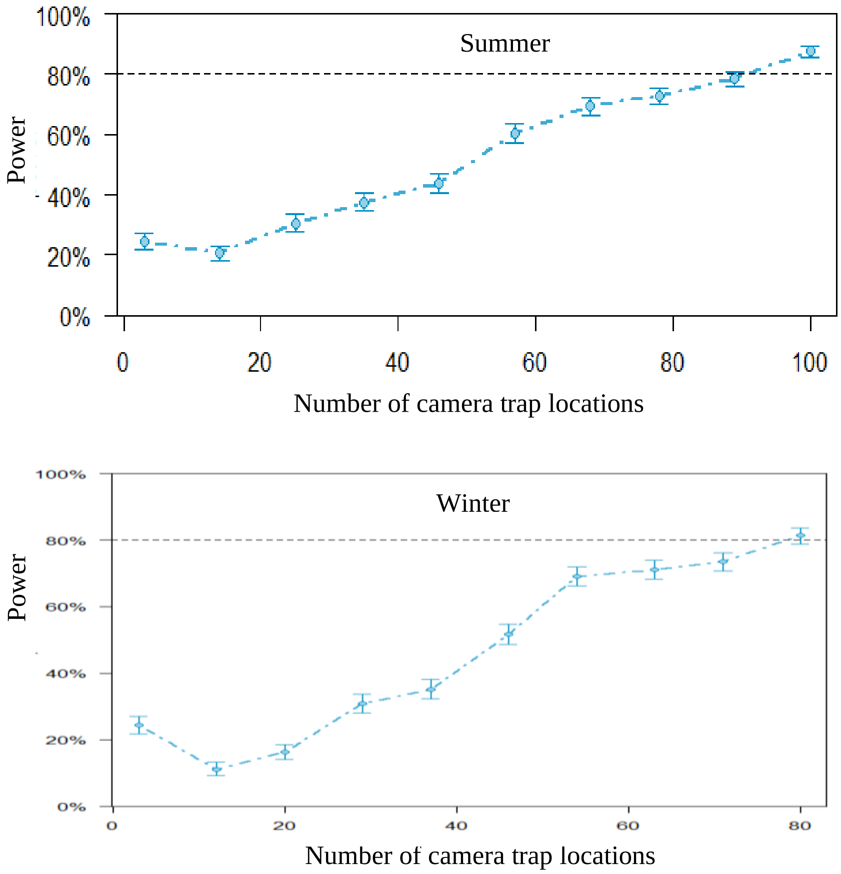


Figure 2.3: Result of power analysis showing sample size in summer and winter.

2.4.2 Camera trapping design: camera trap spacing

Placement of camera traps was conducted according to the most detected small carnivores throughout the study area, which were red fox and leopard cat. Home range of red fox varies from 1 to 4 km^2 (Adkins & Stott, 1998; Cavallini & Lovari, 1991) and that of leopard cat varies from 1.5 to 14 km^2 (Grassman et al., 2005; Rabinowitz, 1990; Rajaratnam et al., 2007). As trap spacing is recommended to be on the same order as the radius of a typical home range (Dillon & Kelly, 2007). Hence in this case, the radius of the home ranges considering both the species varied between 0.5 km to 1 km. Therefore, trap spacing in this study was kept between 0.5 km to 1 km.

Also, 1 km trap spacing approach was considered as compact design and better for capturing elusive and small home range sized species rather than diffused design (more than 1 km trap spacing) (Nawaz et al., 2021).

2.4.3 Data preparation

Habitat covariates like elevation, terrain ruggedness index (TRI), slope, normalized difference vegetation index (NDVI) and distance from woodland (distance between camera trap location and river bed) were used as the explanatory variables. Elevation, TRI and slope data were extracted for each camera trap location from Digital Elevation Model (DEM) (https://earthexplorer.usgs.gov/) layer using ArcMap 10. NDVI was calculated from Sentinel 2 data (https://earthexplorer.usgs.gov/) using ArcMap 10. Vertical distance of each camera trap location from the river was calculated using "nearest feature" function in ArcMap 10. Details of explanatory variables are provided in Table 2.5.

Table 2.5: Details of explanatory variables used in analytical methods in chapters-5 and 6.

Area	Predictor variables	Data acquisition layer	Values range
Ecozone	Elevation	Digital elevation model (DEM)	1512m to 2946m
	Terrain ruggedness index (TRI)	Digital elevation model (DEM)	0.33 to 0.65
	slope	Digital elevation model (DEM)	8.68° to 54.42°
	Normalized difference vegetation index (NDVI)	Sentinel 2: April to July and October to December	0.01 to 0.78
	Distance from woodland	River shapefile: Distance from main river bed to each camera trap location	4m to 3874m
National park	Elevation	Digital elevation model (DEM)	2055m to 4345m
	Terrain ruggedness index (TRI)	Digital elevation model (DEM)	0.21 to 0.73
	slope	Digital elevation model (DEM)	1.04° to 50.64°
	Normalized difference vegetation index (NDVI)	Sentinel 2: April to July and October to December	-0.03 to 0.78
	Distance from woodland	River shapefile: Distance from main river bed to each camera trap location	1m to 3581m

CHAPTER - 3

Occurrence and abundance estimation of small carnivores across space and time along the elevation gradient

3.1 Introduction

Mountainous landscape exhibit complex system; restricting resource availability along vertical and horizontal axes. In view of this, the understanding of the distribution of native wildlife along the elevation gradient is helpful in understanding the status of habitat (Andersen et al. 2017), especially of a Protected Area. Small carnivores are quick to respond to habitat changes and hence are the best model species to study in sensitive habitats. GHNPCA is comprised of a variegated landscape with very distinct habitat types. In the higher elevation, it consists of alpine and sub-alpine zones (Singh and Rawat 1999) whereas in the lower elevation, it consists of lower temperate zones. Additionally, the entire elevation gradient is associated with a continuous river stretch (Tirthan river) and areas associated with rivers are known to be key component of the mountainous landscape. Such contiguous habitat gradient along with river are the most productive part of the landscape and provides gradient of resources influenced by climatic variability. It also acts as a network of corridor where species are exposed to resource limitations and threat risks and plays a crucial role for the survival and maintenance of species or group of species. Also, there is rapid changes in the habitat characteristics in summer and winter seasons, for which there is a shift in abundance of carnivores from higher to lower elevation in mountainous landscape (Barnowe-Meyer et al. 2010; Elbroch et al. 2016).

3.1.1 Research questions

1) What is the small carnivore occurrence along the elevation gradient in terms of site intensity usage across space and time along the elevation gradient?

2) What is the overall abundance of small carnivores and abundance across space and time along the elevation gradient?

3.2 Methods

3.2.1 Data analysis

1) Occurrence pattern: Site intensity usage across space and time along the elevation gradient

To understand the occurrence pattern of small carnivores along the elevation gradient, relative abundance index (RAI) was calculated for each site using the photo captures from the camera traps. Photo captures with minimum interval of 15 mins were considered as independent detections. RAI was calculated as capture rate per 100 trap night and plotted against the respective locations (latitude and longitude) using package *"camtrapR"* in R (v.4.0.5). For site intensity usage across space (elevation gradient), all small carnivores detected during the study period were considered. Whereas for site intensity usage across time (elevation gradient in 5 sessions), small carnivores with good number of detections were considered (5 sessions: April-July 2017, October-December 2017, April-July 2018, October-December 2018 and April-June 2019). Red fox and leopard cat were the only terrestrial small carnivores detected throughout the elevation gradient. RAI of leopard cat and red fox were plotted against the respective locations (latitude and longitude) for all the 5 sessions separately using package *"camtrapR"* in R (v.4.0.5).

2) Overall abundance and abundance across space and time along the elevation gradient:

Since the camera traps were placed on trails and not randomly placed to cover the space like in traditional capture-recapture models, the site-structured model was used to estimate the abundance of red fox and leopard cat (Gilbert et al. 2020). The site-structured model is a hierarchical model (HM) that includes a two-step process; a state process and an observation process (Kéry and Royle 2015, chapter-2).

The simplest formulation of a HM is:

1) State process: $\alpha_i \sim \text{Normal}(0, \sigma^2_\alpha)$
2) Observation process: $y_{ij} \mid \alpha_i \sim \text{Normal}(\mu + \alpha_i, \sigma^2)$

α = random group effect, y = observations, i = spatial units, j = temporal replicates.

A random group effect (α) is introduced in the observation model to warrant the fact that replicate measurements on the same unit are more similar than those among units. The vertical bar ($\mid$) indicates the explicit conditioning of one variable (y in this case) on another (α in this case). The state model here represents the random effect model. HM is therefore a pair of sub models. For ecology, the term HM is used in a more specific context, in which the observation model is specified conditional on a latent variable that represents an actual (i.e., real) biological process or the outcome thereof (Kéry and Royle 2015, chapter-2). For example, the observed data y is conditioned on the true (but unobserved) population size N of a sample unit. The population size N is viewed as the outcome of a real ecological process, or more realistically the aggregate outcome of many ecological processes such as survival and recruitment. In that sense, N is very distinct conceptually from the latent group effect a in the preceding example, in the sense that in some cases N might be observable given sufficient effort, resources, and proper design, whereas a is never observable because it doesn't represent a real state of nature, but rather is a purely hypothetical construct. The model is called an "implicit HM" to distinguish it from the explicit HM in which N results from explicit ecological processes and has an explicit ecological meaning such as "abundance." Thus, while both the classical random effects model and that which is conditional on an explicit ecological process are "HMs," the second case is found to be more interesting and directly relevant to ecology. N-mixture is a form of HM which has been used in this study to estimate small carnivore abundance. N-mixture has the following assumptions:

A) Population closure of the site; which means no individuals enter or leave the population via birth, immigration, death, or emigration.

B) Equal detection probability for all individuals.

C) No false positive detections; which means no misidentification or double counting of individuals.

D) Independent detections of individuals at a camera trap site.

Red fox and leopard cat were considered for abundance estimation because they were the only terrestrial small carnivores found across the elevation gradient. Due to the unmarked nature of red fox, abundance estimation was performed using count data following binomial N-mixture modeling (Kéry and Royle 2015, chapter-6; Gilbert et al. 2020). The N-mixture model is a hierarchical extension of Poisson GLM. In this context, hierarchical model means a two-step process that includes a state process and an observation process. The state process includes the latent variable; the abundance N, as a function of the expected abundance; lambda λ, where Poisson GLM is used as a base model to estimate abundance. The observation process includes the number of counts (C) conditional on the latent variable N as a function of detection probability (p) and is a binomial model. The name, binomial mixture model, stems from the fact that the likelihood is a mixture of binomials each with a different sample size N. The resulting model is also called a binomial/Poisson mixture model. It is an HM consisting of two linked GLMs; a Poisson regression for the spatial variation in abundance and a binomial regression (a.k.a. logistic regression) for the variation of the observed counts at specific sites. Function “pcount” was used from the *unmarked* package for abundance estimation.

The simplest binomial N-mixture model written in algebra is as follows:

1: State process: $N_i \sim \text{Poisson}(\lambda)$
2: Observation process: $C_{ij} \mid N_i \sim \text{Binomial}(N_i, p)$
i = camera trap site, j = occasion, N = abundance as latent variable, λ = expected abundance, p = detection probability

Due to marked nature of leopard cat, individual identification was performed and abundance estimation was conducted using multinomial N-mixture framework where the information of individuals is restored. Leopard cat abundance was also estimated using binomial N-mixture and compared between the two approaches. The multinomial differs from binomial framework in the way that, in binomial there is only two possibilities of an outcome 1) presence or count, 2) absence, while in multinomial there are multiple possibilities of an outcome in the form of capture recapture (Kéry and Royle 2015, chapter-7). This is also known as spatially stratified capture-recapture models. As with the N-mixture model, M sites are sampled by some protocol, and the population size at site i, Ni, is the realization of a random variable such as a Poisson or negative binomial. The data collected at each site are assumed to be outcomes of a multinomial distribution with cell probabilities p determined by the specific protocol being used. In general, the sampling protocol defines the cell probabilities to be a function of some encounter probability parameters pij that depend on site, sample occasion, observer, or some other factor. The function “gmultmix” was used from *unmarked* package for abundance estimation in R (v.4.0.5). Thus, for the Poisson case, the basic multinomial mixture models have the form:

1: State process: $Ni \sim \text{Poisson}(\lambda)$
2: Observation process: $yi \mid Ni \sim \text{Multinomial}(Ni; \pi(p))$

For both the red fox and leopard cat, first overall mean site abundance was estimated for all the 5 sessions using three probability distributions; Poisson, negative binomial and zero inflation Poisson and the best model was selected based on lower AIC value and precise mean site abundance estimate. After that, mean site abundance of both the small carnivores was estimated across space (elevation gradient) and time (5 sessions) using elevation as a covariate in the state process sub model.

3.3 Results

1a) Occurrence of small carnivores across space along the elevation gradient

Total eight small carnivores were recorded during the study period. Three out of eight small carnivores were only detected in the ecozone: grey mongoose (*Herpsetes edwardsii*), jungle cat (*Felis chaus*), and golden jackal (*Canis aureus*). Four were detected in both the ecozone and national park, yellow-throated marten (*Martes flavigula*), masked palm civet (*Paguma larvata*), red fox (*Vulpes vulpes*) and leopard cat (*Prionailurus bengalensis*) and stone marten (*Martes foina*) was detected only inside national park. All the small carnivores were detected in night time exhibiting nocturnal behaviour except for grey mongoose, golden jackal and yellow throated marten which were also detected during day time. Leopard cat showed highest number of photo captures with 524 detections followed by red fox (344), yellow throated marten (152), masked palm civet (79), golden jackal (12), grey mongoose (9), stone marten (5) and jungle cat (1) respectively. Number of photo captures of small carnivores found only in ecozone were grey mongoose: 9, jungle cat: 1, and golden jackal: 12. Small carnivores and their respective photo captures found in both ecozone and national park were yellow-throated marten: 56 and 96, mask palm civet: 67 and 12, red fox: 214 and 130 and leopard cat: 119 and 405, respectively. Stone marten which was only detected in national park and had 5 photo captures. The overall RAI of small carnivores found in the study area were presented in Fig 3.1. Small carnivores were not distributed throughout the elevation gradient and were using different spatial zones. Due to low detections, jungle cat, golden jackal, grey mongoose and limitations of trail camera traps to capture arboreal species, yellow-throated marten (Chutipong et al. 2014), mask palm civet and stone marten (Wereszczuk and Zalewski 2015) were dropped. Red fox and leopard cat showed high detections in ecozone and national park, therefore they were considered for further analyses.

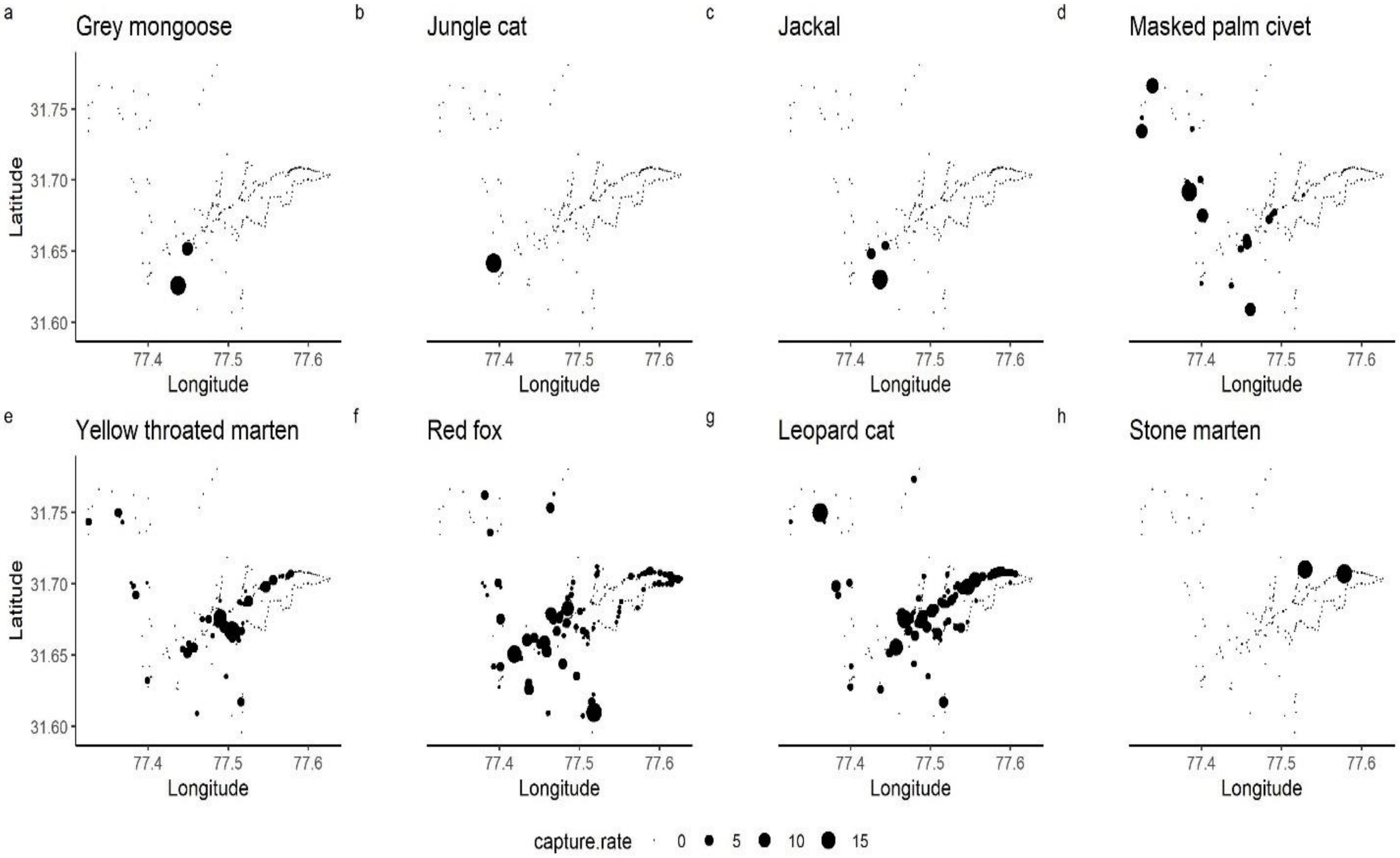
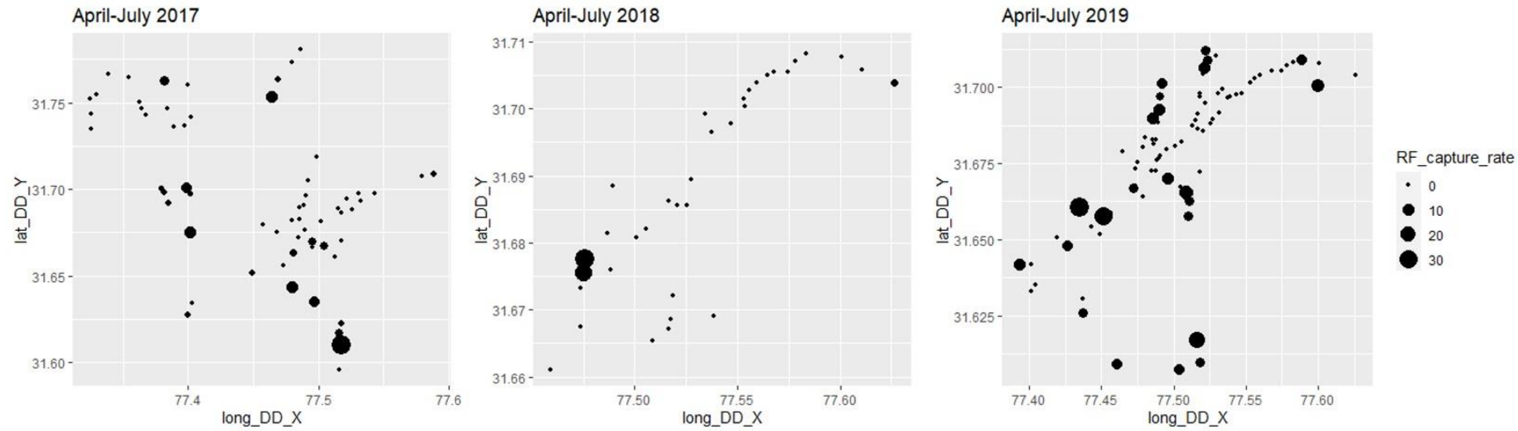


Figure 3.1: RAI of small carnivores across the elevation gradient found in the Great Himalayan National Park Conservation Area (GHNPCA) during 2017 - 2019.

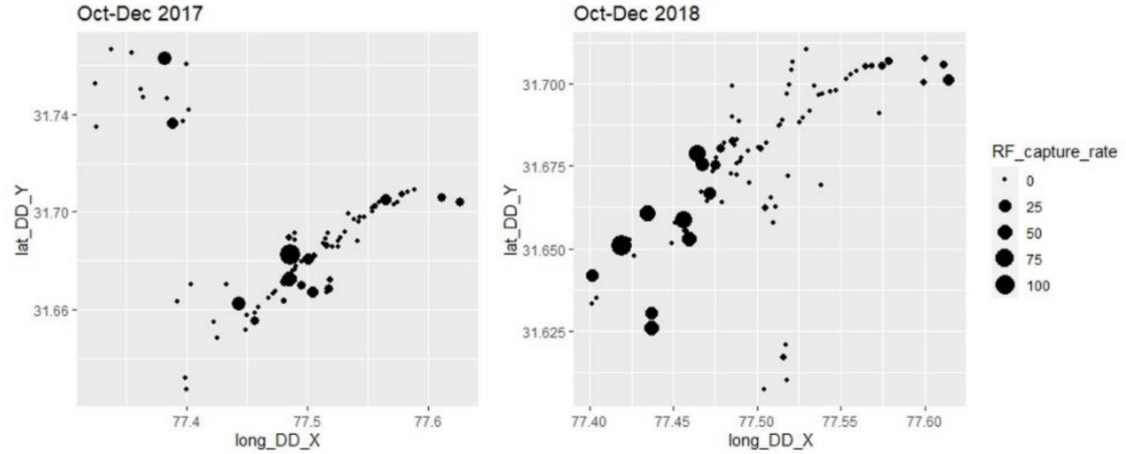
1b) Occurrence of small carnivores across time along the elevation gradient

Site intensity usage (RAI) of red fox and leopard cat across space (elevation gradient) is presented in Fig. 3.1f and 3.1g respectively. For both the species the site intensity usage varied across space. Like for red fox, lower elevations (represented by low latitude, longitude values) showed higher RAI and higher elevation sites. Further, the site intensity usage (RAI) of red fox and leopard cat across time (elevation gradient in 5 sessions) is presented in Fig 3.2, Fig 3.3. Both the small carnivores showed changes in RAI with time along the elevation gradient. For instance, the RAI of leopard cat varied between 0 to 20 in April-July of 2017, 2018 and 2019, and between 0 to 60 in October-December of 2017 and 2018. And that of red fox, the RAI varied between 0 to 30 in April-July and between 0 to 100 in October-December.


April-July 2017

April-July 2018

April-July 2019


Oct-Dec 2017

Oct-Dec 2018

Figure 3.2: RAI of red fox across time (5 sessions) along the elevation gradient in the Great Himalayan National Park Conservation Area (GHNPCA).

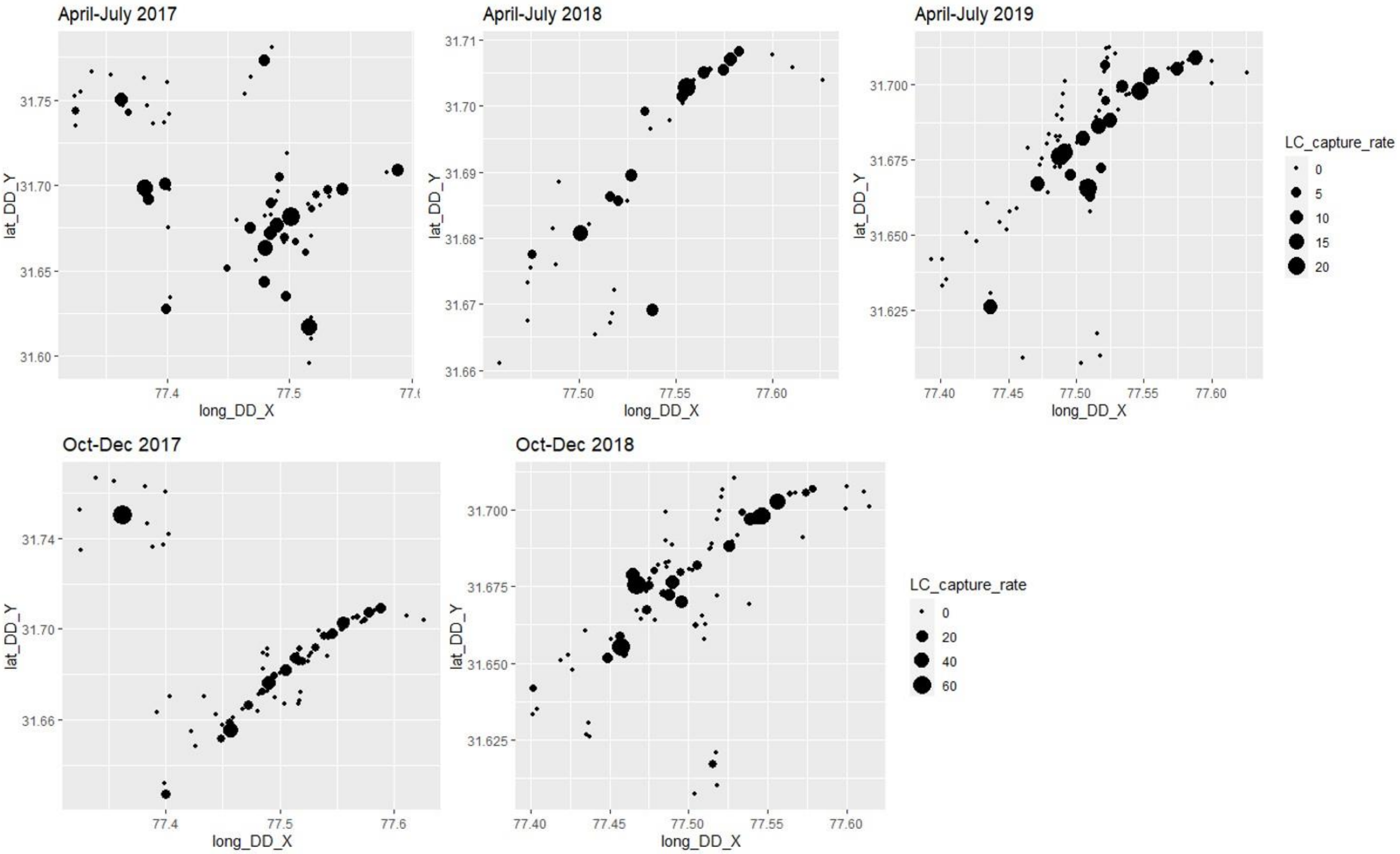


Figure 3.3: RAI of leopard cat across time (5 sessions) along the elevation gradient in the Great Himalayan National Park Conservation Area (GHNPCA).

2) Overall abundance and abundance across space and time of small carnivores along the elevation gradient

Poisson and zero inflation Poisson were selected for estimating red fox overall mean site abundance and detection probability using binomial N-mixture for all the five sessions. Mean site abundance of April-July 2018 was dropped for red fox due to very low detections. The overall mean site abundance of red fox in the respective 4 sessions (April-July 2017, October-December

2017, October-December 2018 and April-June 2019) was found to be 1.06 (0.17), 1.11 (0.38), 1.05 (0.24) and 1.01 (0.15) (values in parenthesis represent standard error) (Table 3.1). The detection probability of red fox of the 4 sessions were; 0.04 (0.01), 0.02 (0.01), 0.02 (0.01), 0.06 (0.01). The overall mean site abundance of leopard cat in the 5 sessions was found to be 1.18 (0.22), 1.18 (0.28), 1.49 (0.12), 1.54 (0.32) and 1.01 (0.11), respectively (Table 3.2). The detection probability of leopard cat of the 5 sessions was; 0.04 (0.01), 0.05 (0.01), 0.06 (0.01), 0.03 (0.004) and 0.08 (0.10). There was not much change in the overall mean site abundance of the 5 sessions for both red fox and leopard cat using binomial N-mixture modeling. While, using multinomial N-mixture modeling (capture-recapture framework), the overall mean site abundance for leopard cat was found to be imprecise and overestimated. For instance, overall mean site abundance in April-July 2017 and October-December 2018 was found to be 5.37 (4.55) and 6.32 (3.72), respectively (Table 3.3). Therefore, binomial N-mixture modeling was considered for mean site abundance and detection probability of leopard cat. Total number of leopard cat individuals identified in the 5 sessions were; 36, 35, 20, 30 and 41 (Table 3.4 and Table 3.5).

The mean site abundance of red fox was found to be varying across space (elevation gradient) and time (5 sessions) (Fig 3.4). For example, it showed more abundance in higher elevations during April-July and in lower elevations during October-December. On the contrary leopard cat abundance varied across space but did not change much with time. Like, leopard cat abundance was more in lower elevations across all the 5 sessions. (Fig 3.5).

Table 3.1: Models for red fox abundance estimation using binomial N-mixture framework (count data). Poisson was the best distribution in all the sessions.

	Model	Distribution family	Mean site abundance (SE)	Detection probability (SE)	AIC
Session 1	lam(.)p(.)	Poisson	1.06 (0.17)	0.044 (0.005)	952.09
	NB,lam(.)p(.)	negative binomial	5.27 (2.09)	0.01 (0.002)	862.55
	ZIP,lam(.)p(.)	zero inflation poisson	4.01 (0.84)	0.031 (0.005)	911.25
Session 2	lam(.)p(.)	Poisson	0.30 (0.2)	0.037 (0.016)	121.39
	NB,lam(.)p(.)	negative binomial	2.93 (3.21)	0.004 (0.004)	103.53
	ZIP,lam(.)p(.)	zero inflation poisson	6.40 (6.45)	0.015 (0.017)	105.67
Session 3	lam(.)p(.)	Poisson	1.11 (0.38)	0.026 (0.009)	448.13
	NB,lam(.)p(.)	negative binomial	7.53 (4.16)	0.004 (0.002)	426.63
	ZIP,lam(.)p(.)	zero inflation poisson	9.40 (1.61)	0.001 (0.001)	427.82
Session 4	lam(.)p(.)	Poisson	1.05 (0.24)	0.024 (0.005)	459.68
	NB,lam(.)p(.)	negative binomial	5.80 (2.74)	0.005 (0.002)	424.05
	ZIP,lam(.)p(.)	zero inflation poisson	2.37 (0.76)	0.021 (0.005)	454.67
Session 5	lam(.)p(.)	Poisson	1.01 (0.15)	0.063 (0.007)	855.88
	NB,lam(.)p(.)	negative binomial	6.71 (2.44)	0.010 (0.002)	744.36
	ZIP,lam(.)p(.)	zero inflation poisson	3.85 (0.72)	0.046 (0.007)	805.07

Table 3.2: Models for leopard cat abundance estimation using binomial N-mixture framework (count data). Poisson was the best distribution in all the sessions.

	Model	Distribution family	Mean site abundance (SE)	Detection probability (SE)	AIC
Session 1	lam(.)p(.)	Poisson	1.18 (0.22)	0.036 (0.005)	1099.45
	NB,lam(.)p(.)	negative binomial	10.20 (9.31)	0.004 (0.003)	1081.69
	ZIP,lam(.)p(.)	zero inflation poisson	2.91 (0.91)	0.024 (0.006)	1092.79
Session 2	lam(.)p(.)	Poisson	1.18 (0.28)	0.051 (0.010)	848.99
	NB,lam(.)p(.)	negative binomial	10.22 (8.95)	0.006 (0.005)	832.34
	ZIP,lam(.)p(.)	zero inflation poisson	5.81 (2.48)	0.02 (0.008)	833.72
Session 3	lam(.)p(.)	Poisson	1.49 (0.12)	0.058 (0.014)	408.07
	ZIP,lam(.)p(.)	negative binomial	4.41 (16.90)	0.006 (0.024)	398.23
	NB,lam(.)p(.)	zero inflation poisson	8.72 (2.31)	0.002 (0.012)	400.88
Session 4	lam(.)p(.)	Poisson	1.54 (0.32)	0.028 (0.004)	987.28
	NB,lam(.)p(.)	negative binomial	9.49 (4.39)	0.004 (0.002)	947.76
	ZIP,lam(.)p(.)	zero inflation poisson	3.91 (1.03)	0.021 (0.004)	971.77
Session 5	lam(.)p(.)	Poisson	1.01 (0.11)	0.083 (0.104)	705.68
	NB,lam(.)p(.)	negative binomial	5.73 (4.54)	0.010 (0.008)	667.18
	ZIP,lam(.)p(.)	zero inflation poisson	2.60 (0.74)	0.056 (0.012)	686.63

Table 3.3: Models for leopard cat abundance estimation using multinomial N-mixture framework (capture -recapture data). Poisson was the best distribution in all the sessions but showed imprecise estimates.

	model	Distribution family	Mean site abundance (SE)	Detection probability (SE)	AIC
Session 1	lam(.)p(.)	Poisson	5.37 (4.55)	0.002 (0.001)	258.69
	NB,lam(.)p(.)	negative binomial	15.12 (9.10)	0.0002 (0.0002)	287.56
Session 2	lam(.)p(.)	Poisson	6.32 (3.72)	0.10 (0.008)	439.49
	NB,lam(.)p(.)	negative binomial	11.03 (8.07)	0.15 (0.005)	460.37
Session 3	lam(.)p(.)	Poisson	4.24 (2.34)	0.02 (0.006)	448.13
	NB,lam(.)p(.)	negative binomial	11.34 (5.02)	0.004(0.003)	426.63
Session 4	lam(.)p(.)	Poisson	6.12 (3.22)	0.03 (0.001)	427.82
	NB,lam(.)p(.)	negative binomial	12.44 (8.01)	0.006(0.024)	459.68
Session 5	lam(.)p(.)	Poisson	5.23 (2.31)	0.02 (0.002)	424.05
	NB,lam(.)p(.)	negative binomial	12.02 (7.23)	0.010(0.008)	454.67

Table 3.4: Number of leopard cat individuals detected in each camera trap location in April-July.

April-July 2017		April-July 2018		April-June 2019	
Station ID	No. of individuals	Station ID	No. of individuals	Station ID	No. of individuals
4	1	1	3	3	2
12	1	4	5	11	2
14	2	10	3	12	1
32	3	12	2	13	2
34	1	17	4	22	3
37	3	18	1	26	1
45	2	19	3	35	1
46	2	20	5	39	1
51	3	21	2	41	2
61	3	26	2	44	1
62	1	36	1	48	1
66	2	37	1	50	1
71	4	43	2	61	1
72	2	67	1	94	1
74	1				
75	2				
77	1				
83	2				

Table 3.5: Number of leopard cat individuals detected in each camera trap location in October-December.

October-December 2017		October-December 2018	
Station ID	No. of individuals	Station ID	No. of individuals
1	1	3	1
5	1	8	2
8	1	10	2
9	1	11	3
13	1	13	4
16	1	17	1
18	2	19	1
20	3	36	1
26	5	37	1
39	3	38	2
44	4	39	3
47	5	42	1
60	1	58	2
63	1	63	6
		64	1
		66	1
		78	5
		79	3
		102	1

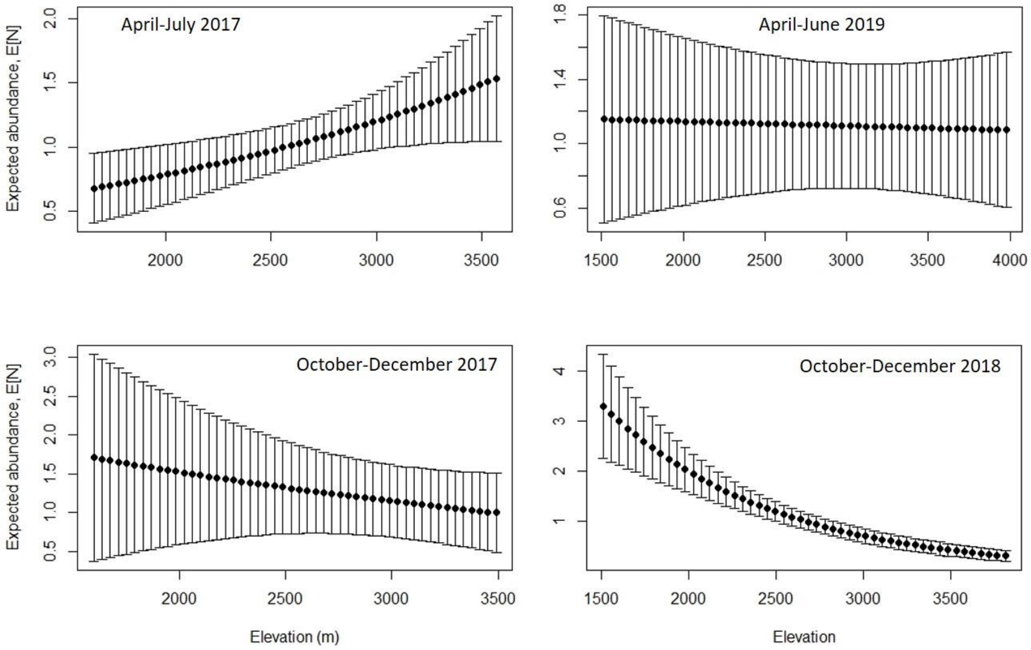


Figure 3.4: Mean site abundance of red fox across space and time in GHNPCA. Due to low detections of red fox, April-July 2018 was dropped. The error bars represent standard error.

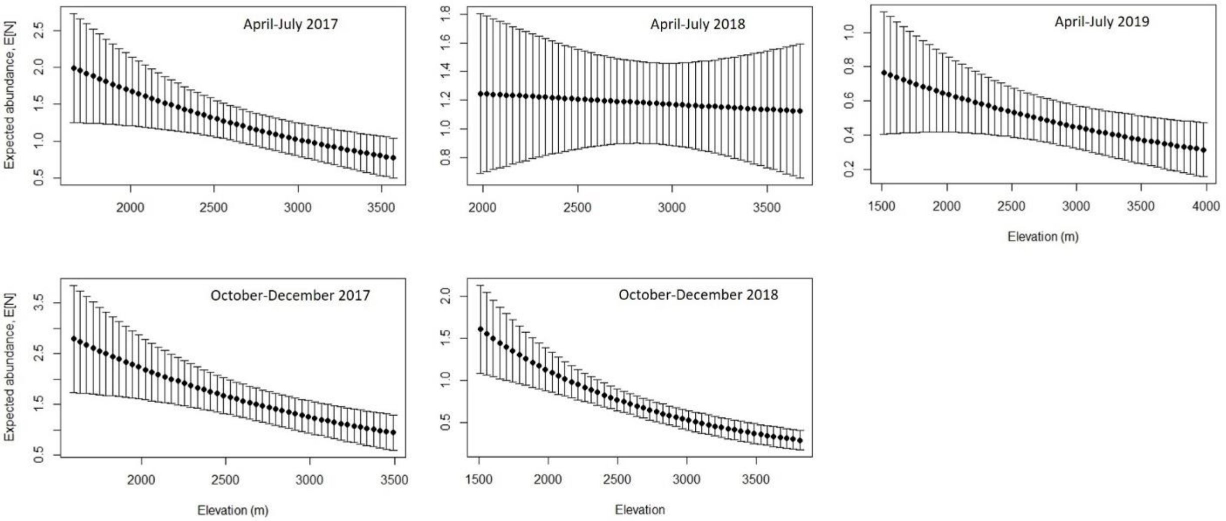


Figure 3.5: Mean site abundance of leopard cat across space and time in GHNPCA. The error bars represent standard error.

3.4 Discussion

A total of nine small carnivores; Siberian weasel, grey mongoose, masked palm civet, yellow throated marten, stone marten, jungle cat, leopard cat, red fox and golden jackal, were found in this study. The results of this study were supported by established literature from GHNPCA twenty years ago (Vinod and Sathyakumar 1999) (in report, trails traversed in ecozone; 290 km and national park; 867 km). However, some of the results were contradictory to expectations based on previous research. For example, jungle cat and golden jackal were recorded from ecozone areas which are in accord with the result, whereas red fox and leopard cat were only recorded inside national park, which were detected in both ecozone and national park in this study. Masked palm civet was reported only once inside national park and our results showed few detections but in ecozone. Although trail survey methods used in earlier studies were not as robust as camera trapping but the information gives an idea about the small carnivores space use along the ecozone and national park when human habitation were lesser in number as compared to current scenario

(Tucker, 1997, www.census2011.co.in). Red fox and leopard cat were the only small carnivores detected throughout the elevation gradient. The distribution pattern and abundance of red fox and leopard cat varied across space and time, representing the species-specific site usage along the elevation gradient. Also, the variation of abundance of red fox and leopard cat across space and time along the elevation gradient synced with the site intensity usage. This depicts that the sites with higher red fox and leopard cat usages also had them in more numbers. Both the results of site intensity usage and abundance of small carnivores indicated towards habitat heterogeneity along the elevation gradient.

3.5 Conclusion

Although GHNPCA has been studied extensively in the year 1999 but information on small carnivores was a significant gap (Vinod & Sathyakumar 1999). In this study, the types of small carnivore inhabiting the study area and their distribution pattern were presented. The variation of site usages and abundance of small carnivore with reference to elevation gradient reflected heterogenous habitat gradient and uneven resource distribution that changed with space and time. Also, the changes in small carnivore presence, although not that prominent, from higher to lower elevation areas in the span of twenty years indicated habitat alterations in the lower reaches. The study encourages investigating the driving factors responsible for the small carnivore site usages and abundance, where such information might aid in habitat managements especially areas adjacent to Protected Areas.

CHAPTER - 4

Assessment of community composition and association of small carnivore species

4.1 Introduction

The community composition is defined by the species assemblages at a particular area. The distinct morphological and behavioural characteristics of species help them grouping together. For example, a space might be shared by both nocturnal and diurnal species. In view of this, the position of a species in a community lies along a set of dimensions of environmental variables (Schoener 1974). Each species exhibits an area of occupancy along the environmental dimensions called an ecological niche (Gray and Lowery 1996). When the ecological niche is similar to other species, they are known as sympatric species. The coexistence of sympatric species is only possible till a threshold of niche similarity as predicted by the limiting similarity theory (Macarthur and Levins 1967). The theory describes that the sympatric species should differ along one or more dimensions in their respective ecological niches to coexist. Else, the species is excluded from the community according to the competitive exclusion principle (Gause 1934; Hardin 1960) through divergent natural resource selection resulting in niche partitioning (Davies et al. 2007). On the contrary, competing or sympatric species might coevolve by achieving spatial, temporal differences in activity (Kronfeld-Schor and Dayan 2003) or by dietary segregation (Walker et al. 2007). In that respect, co-occurrence explains spatial coexistence where the occurrence of similar species in an ecosystem may be the causation of multiple factors. Such as natural evolution resorting to differences or similarities among the animals in character through interspecific interactions influencing niche partitioning by means of competition and avoidance or niche sharing with association (Monterroso, Alves, and Ferreras 2015; Tammeleht and Kuuspu 2018; Torretta et al. 2016). Small carnivores are more sensitive and quick to respond to environmental changes (Randa and Yunger 2006), hence, they are the best model species to study for habitat disturbances and its effect on their niche dynamics. From this perspective, and taking information from the previous chapter regarding human disturbances in the lower reaches of the study area, the elevation gradient was divided into low and high human disturbance areas to understand the fine-scale coexistence patterns of small carnivores.

4.1.1 Research questions

1) What is the community composition of small carnivores in low human disturbance (inside National park) and high human disturbance (ecozone) areas?

2) Whether there is niche segregation in small carnivores existing in low (inside National park) and high human disturbance (ecozone) in any of the three dimensions namely; spatial, time and diet.

4.2 Methods

Camera trapping

Camera trapping was conducted along the elevation gradient covering low (National park) and high human disturbance (ecozone) areas, to understand the spatial and temporal interactions among sympatric small carnivores; red fox and leopard cat. The details of camera trapping are already provided in Chapter-2 of methods section (Table 2.2).

Carnivore faecal sample collection and species identification

Total 683 faecal samples was collected opportunistically from the entire elevation gradient along the human-made trails from 2017 to 2019 with a walk effort of 685.38 km (Fig. 4.1). The faecal samples were subjected to small carnivore species identification using molecular markers. The details of total faecal sample collection and species identification using molecular markers are provided in Chapter-2 under methods section (Table 2.3 and 2.4).

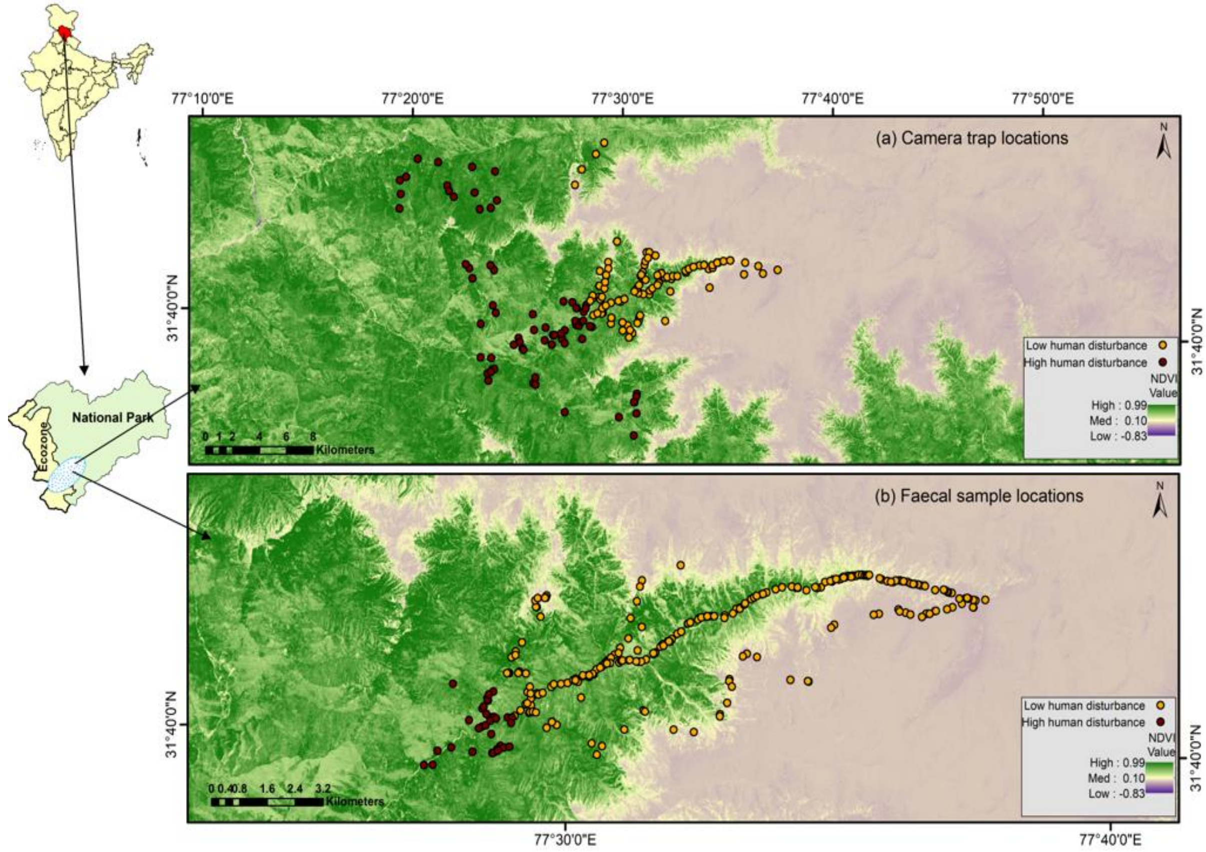


Figure 4.1: Map of Great Himalayan National Park Conservation Area (GHNPCA) showing (a) camera trap locations (n = 340) and (b) genetically identified faecal sample locations (n = 586) in low (National park) and high (ecozone) human disturbance areas.

Prey identification

The hair strands from washed faecal samples were cut into small pieces, dipped in xylene for 15-20 mins and observed under a microscope (40x) for medullary pattern identification (Bahuguna et al. 2010). The medullary patterns of prey items found are provided in Appendix-1 Figure A4.7.

4.2.1 Data analysis

Community composition

The small carnivores were grouped according to their presence in low and high human disturbance areas. Small carnivore weights and behaviour were studied from literatures and categorized accordingly. Small carnivores with good number of detections and similar body size and behaviour were considered for coexistence analysis. From literature review it was found that, the weights of small carnivores were: siberian weasel (0.4kg to 0.8kg), grey mongoose (1.4kg), stone marten (1kg to 2kg), yellow throated marten (1kg to 3kg), leopard cat (3kg to 4kg), mask palm civet (3kg to 5kg), jungle cat (2kg to 16kg), red fox (3kg to 14kg) and golden jackal (10 to 15kg). In the low human disturbance area, the diurnal small carnivores were yellow throated marten and Siberian weasel and nocturnal small carnivores stone marten, leopard cat and red fox. And in high human disturbance diurnal small carnivores were grey mongoose and yellow throated marten and nocturnal small carnivores were leopard cat, jungle cat, masked palm civet, red fox and golden jackal. Therefore, considering similar body size (3kg to 14kg), behaviour (nocturnal) and good number of detections in both the low and high human disturbance areas (from chapter-3), red fox and leopard cat were considered for assessing coexistence in three dimensions; space, time and diet.

Spatial interaction

The detections of red fox and leopard cat at a given camera trap site on a given occasion was modelled as a function of interspecific effects using a generalized linear mixed-effects model (GLMM) (Bolker et al. 2009; Cusack et al. 2017; Tattersall et al. 2020). Photo captures with a minimum interval of 15 minutes were considered as independent detections. The models were tested based on occasion lengths of 7, 14, 21 and 28 days to see if occasion length influenced the co-detection pattern between red fox and leopard cat (Cusack et al. 2017). The detections of red fox and leopard cat of each camera trap location were collapsed into 7 days, 14 days, 21 days and 28 days, respectively and prepared in the framework required for GLMM. Separate models were performed for red fox and leopard cat in low and high disturbance areas. The red fox detections were modelled as a function of inter-specific effects of leopard cat detections and the disturbance effect of human detections. Similarly, leopard cat detections were modelled as a function of red fox detections and the disturbance effect of human detections (Appendix – 2, Table A4.1). A random intercept was included for the camera trap station in all models to account for non-independence of detections at the same site and standardized all the covariates. Occasions were excluded from the analysis when a camera was inactive. A total of 16 models were used; 2 small carnivores x 2 areas x 4 occasion lengths, and implemented in GLMM framework using package "lme4" (Bolker et al. 2009) in R (v.4.0.5). The significance test was performed using p-values for estimated coefficients using an approximation of the Wald statistic (coefficient estimate divided by its standard error).

Temporal interaction

The temporal overlap between red fox and leopard cat was assessed using the time data in camera trap detections for low and high human disturbance areas. In addition to comparing the activity patterns of both small carnivores, they were also analyzed with human activity. To minimize pseudo-replication biases, any subsequent photos of the same species that occurred within 15 minutes were removed. The number of red fox and leopard cat detections was >75 in both areas; hence, Δ_4 was chosen to estimate the overlap coefficient (Meredith and Ridout 2021). The overlap coefficient ranges from 0, meaning the absence of overlap, to 1, meaning complete overlap. 95% CI was generated by bootstrapping 10,000 samples to check for the precision of the estimates (Dias et al. 2019; Mori et al. 2020). The species' overlap coefficient was considered low if $\Delta_4 < 0.50$, intermediate if $0.50 < \Delta_4 < 0.70$, and high if $\Delta_4 > 0.70$ (Monterroso, Alves, and Ferreras 2014). The coefficient of overlap (Δ_4) was evaluated using package "overlap" in R (v.4.0.5).

Food items estimation and dietary interaction

The total number of food items in red fox and leopard cat faeces in low and high human disturbance areas were calculated. An accumulation curve was performed for food items found in red fox and leopard cat faeces to ensure the faecal sample size represented most of the prey items for red fox and leopard cat using the package "vegan" in R (v.4.0.5).

The dietary breadth and overlap for red fox and leopard cat was assessed in low and high human disturbance areas. At first the dietary breadth index was calculated of red fox and leopard cat using the frequency of occurrence (FOO) of food items in the genetically confirmed faecal samples to understand the breadth of prey consumed across the disturbance gradient. The niche breadth was calculated using Hurlbert's standardized niche breadth (B_A), a measure of Levins' formula that is on a [0,1] scale (Hurlbert 1978): $B_A = (B-1)/(n-1)$. Here $B = 1/(P_i)^2$, where 'P_i' is the proportion of each food item (number of records of each food (FOO)/total number of records of all food items) in the faeces of red fox and leopard cat and 'n' is the number of prey items (Smith et al. 2018). After that, the relative frequency of occurrence (RFO) of each food item in the genetically confirmed red fox and leopard cat faecal samples was calculated in low and high human disturbance areas, respectively. The RFO was calculated using the formula i/j*100, where 'i' is the sum of frequency of specific prey in all the faecal samples and 'j' is the total sum of frequency of all prey (Mukherjee, Goyal, and Chellam 1994). The RFO of each prey was used to estimate the Pianka's overlap index of the diet of red fox and leopard cat in low and high human disturbance areas using package "pigrmess" in R (v.4.0.5).

4.3 Results

Community composition

The low human disturbance area along the elevation gradient was composed of 5 small carnivores from 3 families; stone marten, siberian weasel and yellow throated marten (mustelidae), leopard cat (felidae) and red fox (canidae). The high human disturbance area was composed of 7 small carnivores from 5 families; grey mongoose (herpestidae), mask palm civet (viveridae), yellow throated marten (mustelidae), leopard cat and jungle cat (felidae), red fox and golden jackal (Canidae). As red fox and leopard cat shared similar body weight, behaviour and were detected in both low and high human disturbance area hence they were considered for coexistence analysis.

Spatial interaction

The GLMM framework described the co-detection pattern between red fox and leopard cat in low and high human disturbance areas (Fig. 4.2). Red fox and leopard cat showed negative relation to each other in low human disturbance area (Fig. 4.2a, Fig. 4.2b) across all occasion lengths. Red fox was negatively influenced by human detections on 7- and 14-day and later showed positive relationship on 21- and 28-day occasion lengths (Fig. 4.2a). Whereas, leopard cat was positively influenced by human detections throughout (Fig. 4.2b). Interestingly, in high human disturbance area red fox and leopard cat positively influenced each other's detections on all occasion lengths and also showed positive relation to humans (Fig.4.2c, Fig. 4.2d). On the whole, red fox and leopard cat spatially avoided each other in low human disturbance area, whereas they showed spatial association in high human disturbance area. In both the low and high human disturbance areas, the direction of the co-detection pattern (positive or negative) between red fox and leopard cat was identical across all the occasion lengths. However, the magnitude of co-detection pattern (positive or negative) varied across occasion length and area (Fig. 4.2).

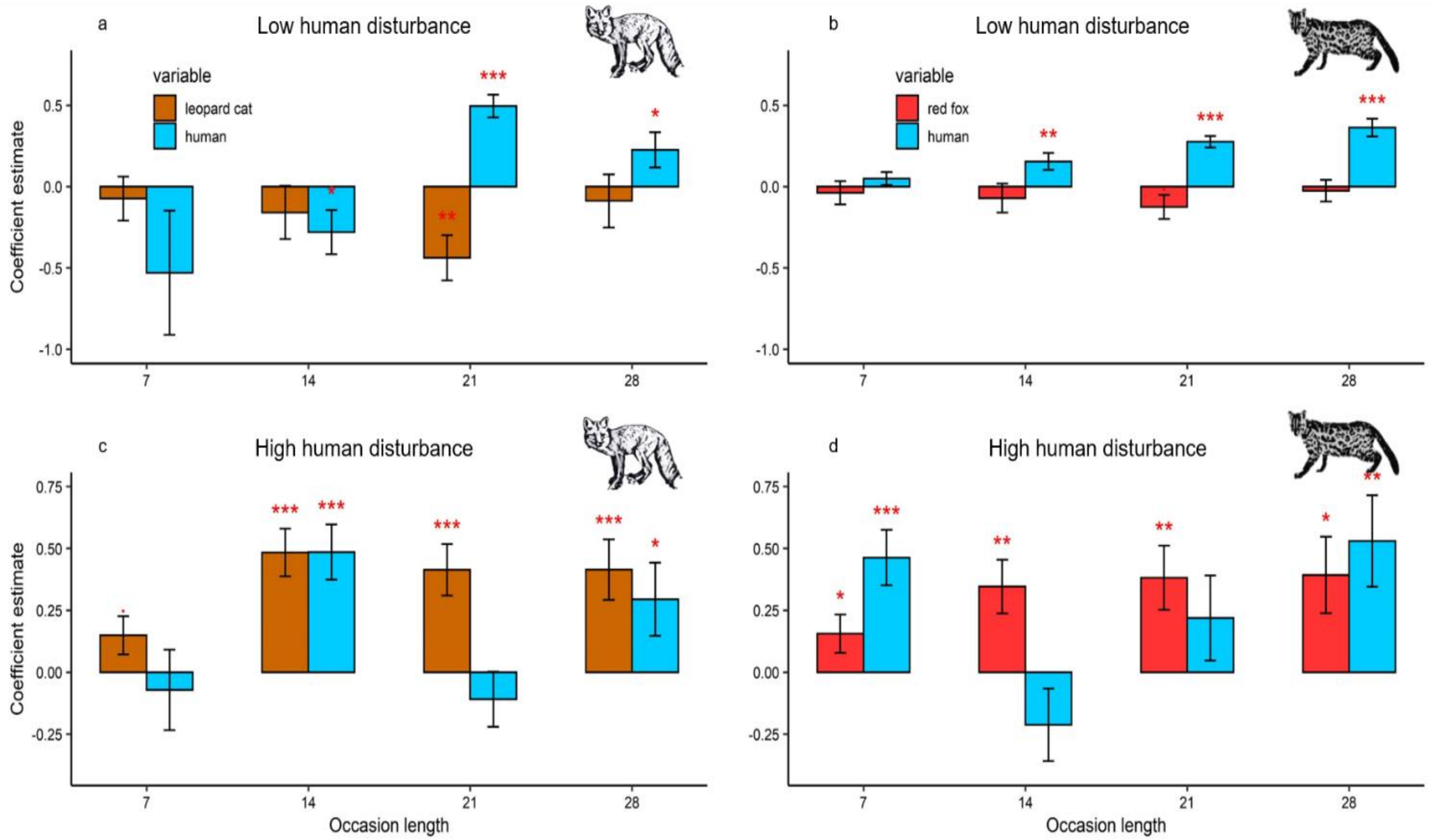


Figure 4.2: Bar plots showing coefficient estimates of co-detection modeling using GLMM framework in low human disturbance area for (a) red fox with leopard cat in presence of human, (b) leopard cat with red fox in presence of human and high human disturbance area for (c) red fox with leopard cat in presence of human and (d) leopard cat with red fox in presence of human (“·” = $p < 0.1$, “*” = $p < 0.01$, “**” = $p < 0.05$, “***” = $p < 0.001$).

Temporal interaction

The activity overlap between red fox and leopard cat was high in both the low and high human disturbance areas (Fig. 4.3). However, the overlap coefficient between the two small carnivores was highest in the high human disturbance area (Δ_4: 0.91, CI: 0.85 – 0.96) as compared to low human disturbance area (Δ_4: 0.83, CI: 0.76 – 0.89). It is due to the flatter kernel density curve of red fox and higher kernel density curve of leopard cat in high human disturbance area (Fig. 4.3b). The compression of the activity density curve of red fox was due to shifting in the peak active time of red fox at 00:00 hours in the low human disturbance area to a range of time; 18:00 hours to 06:00 hours in high human disturbance area. The coefficient of overlap (delta, Δ_4) is the area lying under both the density curves in Fig. 4.3a and Fig. 4.3b. Overlap coefficients between red fox and human and leopard cat and human were low in both the areas (Appendix – 1, Fig A4.1, Fig A4.2, Appendix – 2, Table A4.2).

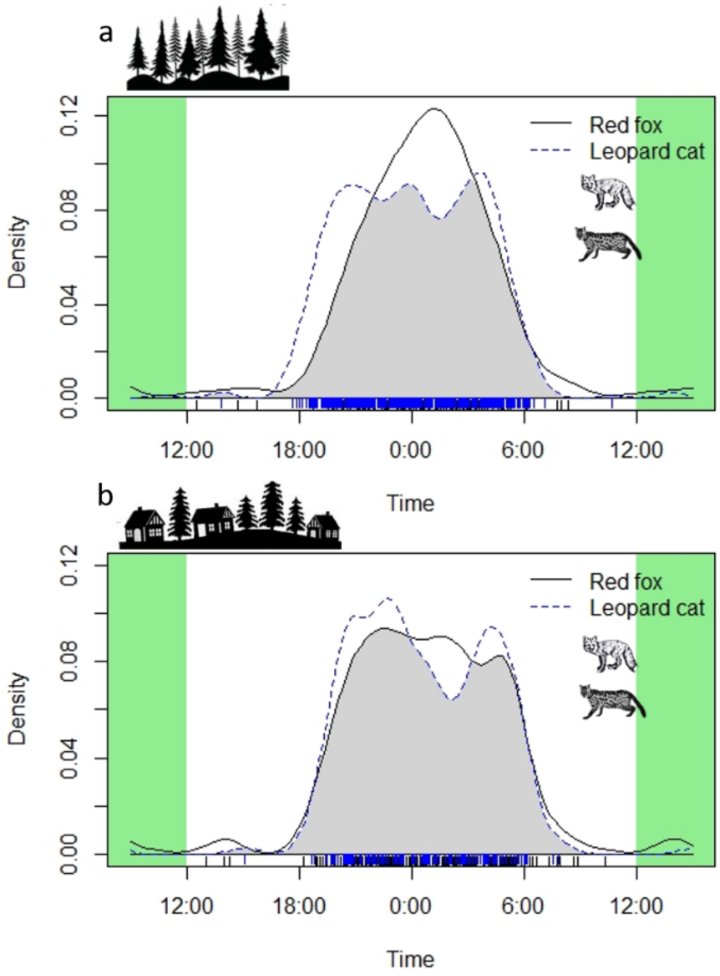


Figure 4.3: Activity density plots showing temporal overlap between red fox and leopard cat in (a) low human disturbance area (National park) and (b) high human disturbance area (ecozone) in Great Himalayan National Park Conservation Area (GHNPCA).

Small carnivore species confirmation from faecal samples

Out of 683 faecal samples, total 586 small carnivore faecal samples were identified using molecular (93.9%) and morphological approaches (Appendix – 2, Table A4.3). The morphological identification was on the basis of the structure and dry weight of genetically identified red fox and leopard cat faecal samples. The average weight of the genetically identified red fox and leopard cat faeces were 4.49 (SE = 0.33) and 10.05 (SE = 0.45). The details of the structure of red fox faeces are in Fig. A4.3 (Appendix – 1), and that of leopard cat in Fig. A4.4 (Appendix – 1). The confirmed 586 small carnivore faecal samples included: 359 samples that amplified for red fox (n = 112) and leopard cat (n = 247), and 227 samples that were identified morphologically for red fox (n = 139) and leopard cat (n = 88) respectively using genetically confirmed samples as reference. Combining both methods, 251 red fox and 335 leopard cat faecal samples were identified (Appendix – 2, Table A4.4, Table A4.5).

Dietary interaction

A total of 19 and 11 food items were found in red fox faeces and 10 and 7 in leopard cat faeces from low and high human disturbance areas, respectively. From the accumulation curves of food items against the number of faecal samples, it was observed that most of the curves reached the asymptote indicating the capture of most of the food items in red fox and leopard cat faeces (Appendix – 1, Fig. A4.5, Fig. A4.6). Plastic and dog hair were observed in red fox faeces in low and high human disturbance area. In case of red fox, a broader niche breadth of consumed food items was found in high human disturbance area compared to low human disturbance area (Table 4.1). In comparison, the niche breadth of leopard cat was narrower in high human disturbance area than low human disturbance area (Table 4.1). Also, rodent was found to be the most frequently consumed prey for the red fox and leopard cat in both areas (Fig. 4.4 and Fig. 4.5) (Appendix – 2, Table A4.6). For instance, the RFO of rodents in red fox diet was 27.67% and 30.77%, and of leopard cat it was 48.67% and 53.68% in low and high human disturbance areas, respectively. A higher overlap in dietary pattern using Pianka's overlap index was observed between red fox and leopard cat in low human disturbance area compared to high human disturbance area (Table 4.1).

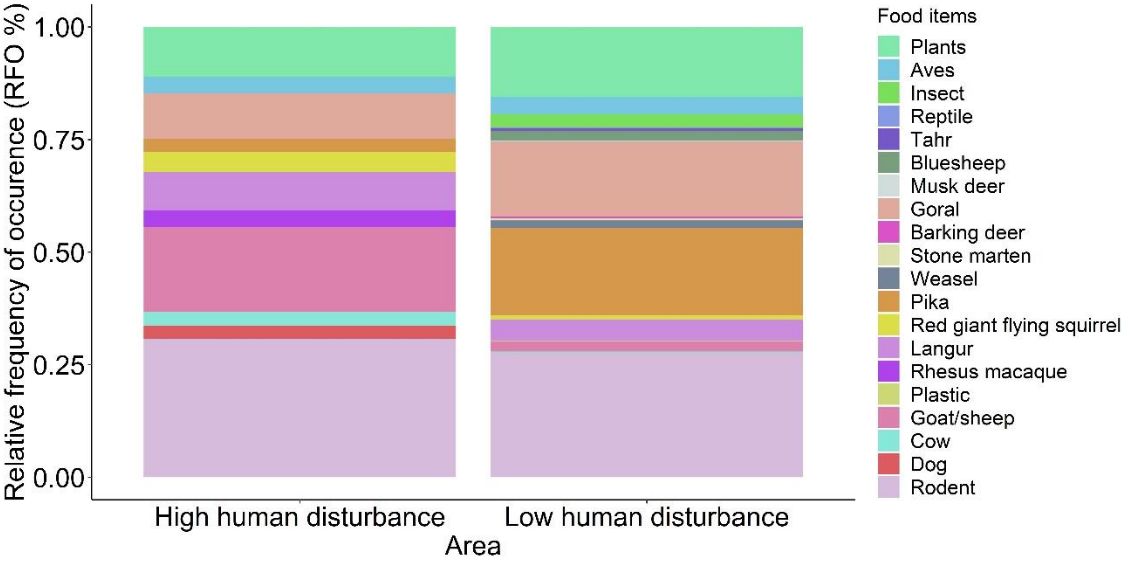


Figure 4.4: Relative frequency of occurrence of prey items in red fox faecal samples in high (ecozone) and low human disturbance (National park) areas in Great Himalayan National Park Conservation Area (GHNPCA). Rodent category consisted of shrew, mole and rat.

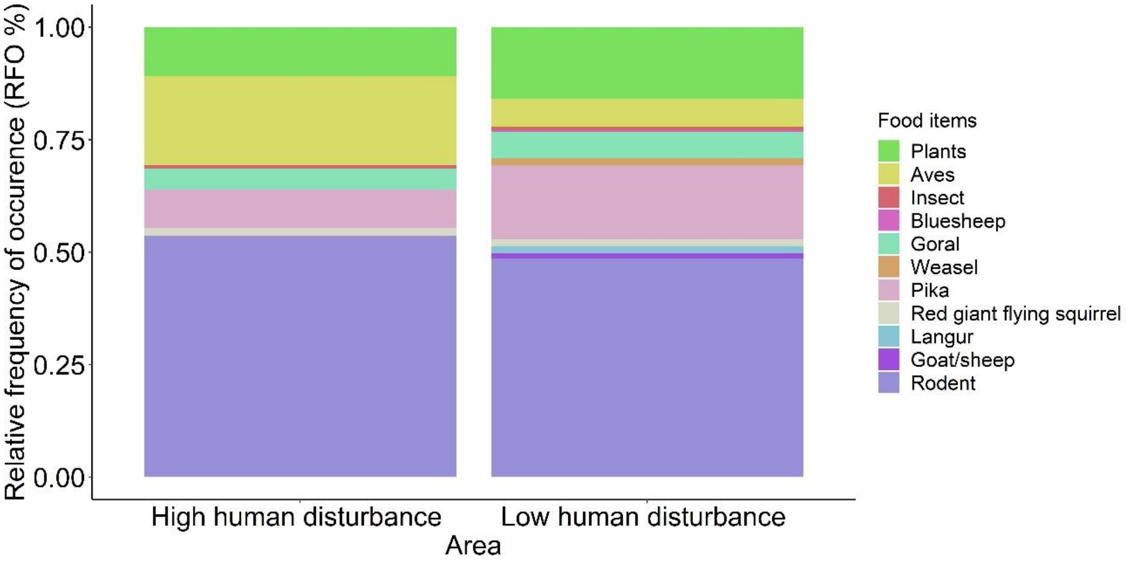


Figure 4.5: Relative frequency of occurrence of prey items in leopard cat faecal samples in high (ecozone) and low human disturbance (National park) areas in Great Himalayan National Park Conservation Area (GHNPCA). Rodent category consisted of shrew, mole and rat.

Table 4.1: Levin’s niche breadth and Piankas’ overlap index of leopard cat and red fox in low and high human disturbance areas in Great Himalayan National Park Conservation Area (GHNPCA).

Area	Levin’s index: Niche breadth		Pianka’s overlap index
	Red fox	Leopard cat	Red fox – Leopard cat
Low human disturbance	0.25	0.13	0.90
High human disturbance	0.26	0.08	0.79

4.4 Discussion

The assemblage of seven small carnivore species in the lower reaches (1400 m to 2500 m) of the gradient and five in the higher end (2500 m to 4000 m) indicated high habitat heterogeneity of the elevation gradient (Goad et al. 2014; Šálek, Drahníková, and Tkadlec 2015; Wang, Allen, and Wilmers 2015). The site usage of different small carnivore species at different elevational zones might be due to resource availability at different spatial zones along the elevation gradient (Zhao et al. 2020).

It is often difficult to determine whether the observed species' coexistence pattern results from interspecific interactions or alternate processes (Steen et al. 2014). In the current scenario, human disturbances alter species’ coexistence patterns (Carricondo-Sanchez et al. 2019; Parsons et al. 2019; Penjor et al. 2022; Sévêque et al. 2020; Smith et al. 2018). In this context, understanding the species interaction patterns at a fine-scale might be central to delineating the processes responsible for species coexistence. Fine-scale coexistence pattern was assessed between red fox and leopard cat in high human disturbance (ecozone) and low human disturbance (National park) areas and compared to test the influence of human disturbances on species coexistence. The small carnivore coexistence was assessed in three dimensions; spatial, temporal and dietary habits in high and low human disturbance areas. In some carnivore guilds, coexistence is facilitated more by spatial or dietary segregation than temporal activity patterns, such as with canids in central Brazil (De Almeida Jácomo, Silveira, and Diniz-Filho 2004), or among medium-sized Mediterranean carnivores (Fedriani, Palomares, and Delibes 1999). Our results indicate fine-scale small carnivore coexistence patterns where spatial and dietary segregation were observed specific to differential human disturbances. The results were comparable to Penjor et al. (2022), which indicates the influence of human disturbances on species' coexistence patterns in GHNPCA. The outcome of the study points toward increasing human habitation, agricultural practices and competition with other carnivores adjacent to natural forests, thereby affecting the coexistence of native wildlife (Rodriguez, Lesmeister, and Levi 2021; Sévêque et al. 2020). In the context of Western Himalaya, which is one of the remaining biodiversity-rich landscapes (Rashid, Romshoo, and Vijayalakshmi 2013), the occurrence of such disturbances poses a threat to other wild animals inhabiting the area like large carnivores, leopards and Himalayan black bears (Naha et al. 2020; Sathyakumar 2000). Knowledge about the coexistence of wild animals in human-dominated areas helps understand the behavioural modifications toward interspecific interactions due to anthropogenic disturbances (Carter et al. 2012). Additionally, the comparison of small carnivore coexistence between National park and ecozone revealed the adaptability of small carnivores for resource utilization in human-modified areas (Ghoshal 2011), implying intensive space usage in ecozone. These shared spaces by red foxes, leopard cats and human-induced entities like livestock, and dog can lead to disease spread and conflict (Chhabra and Muraleedharan 2016; Nadin-Davis et al. 2021; Namusisi et al. 2021; Plumer et al. 2014). Management strategies to shape the human-modified areas into highly heterogenous ecosystems can better facilitate fine-scale spatial segregation among species (Duelli 1997). Also, proper garbage disposal strategies can reduce the readily available anthropogenic food resources. Thereby providing less opportunities to the opportunistic feeders and lessen the future disease spread and conflict outbreaks.

4.5 Conclusion

Patterns and mechanisms of coexistence are of particular research interest when involving carnivores of the same guild with comparable morphologies and overlapping diets (Satgé, Teichman, and Cristescu 2017). Additionally, assessing the species' coexistence in a human-dominated landscape is crucial to comprehending the extent of carnivore adaptation. The results suggest that dietary segregation played a major role in shaping red fox and leopard cat interactions in high human disturbance area. On the contrary, red fox and leopard cat coexisted through spatial segregation in low human disturbance area. Such adaptations to human disturbances point toward intensive anthropogenic activities and increasing competitions with other species adjacent to natural forests and opportunities for shared spaces between small carnivores and humans, leading to future disease spread and conflict issues. Including spatial, temporal and dietary behaviour in conservation and management plans may help promote the coexistence of native wildlife and humans, especially in ecozone, through controlling garbage dumps, increasing households and expanding agricultural practices adjacent to natural forests to dissuade the native wildlife to these sites. While studies reporting the influence of anthropogenic activities on species interactions in the Western Himalayan landscape are largely lacking, there is a need for long-term monitoring of wildlife inhabiting the human-modified areas to ensure human and wildlife coexistence in future.

CHAPTER-5

Evaluation of landscape sensitivity by representative small carnivore species

5.1 Introduction

The Himalaya has faced consistent pressure from increased human settlements due to agricultural practices, more intensive grazing by domestic animals and increased demand for timber (Cronin 1979; Schaller 1980). Consequently, the increasing quantity and proximity of readily available anthropogenic subsidies facilitate increasing dependencies of native carnivores on these resources (Ghoshal, 2011; Rajaratnam, Vernes & Sangay, 2016). Moreover, when anthropogenic food resources replace natural prey due to habitat modifications, such changes affect wildlife distribution (Parsons, Newsome & Young, 2022). In this context, there is a paucity of information regarding the modified habitats adjacent to less disturbed natural forests and their effect on the native wildlife in the rugged landscape of Himalaya. In this study, small carnivores were studied to understand the impact of habitat modification in the western Himalaya. Apart from being an indicator species, small carnivores efficiently utilise anthropogenic food sources, like garbage dumps, agricultural products, kitchen wastes and livestock carrions (Reshamwala et al. 2018), due to their opportunistic behaviour and ability to adapt to modified habitats (Lorica and Heaney 2013; Rajaratnam et al. 2007). Small carnivores are known to be the potential hosts of zoonoses at the wildlife-livestock-human interface (Yang et al. 2021). That is why transmission of diseases like rabies, canine distemper viruses and anthrax can occur bi-directionally, affecting both humans and wildlife (Acharya et al., 2020; Gonzálvez, Martínez-Carrasco & Moleón, 2021). Therefore, knowledge of small carnivore space usage in human-modified habitats can aid in improving management strategies in the light of future outbreaks of zoonotic diseases and conflict probabilities (Alexander et al. 2012; Ferreira et al. 2021; Ng et al. 2019; Theimer et al. 2017; Veals et al. 2021). With this concept, fine-scale responses of small carnivores; red fox and leopard cat, to habitat variables were studied in ecozone (henceforth, anthropogenic site) and National park (henceforth, park) to understand the impact of habitat alterations.

5.1.1 Research question

1) How is the habitat selection of red fox in anthropogenic site and park?

2) How is the habitat selection of leopard cat in anthropogenic site and park?

5.2 Methods

Camera trapping

Camera trapping was conducted along the elevation gradient covering anthropogenic site and park, to understand the responses of red fox and leopard cat to habitat variables. The details of camera trapping are already provided in Chapter-2 of methods section.

5.2.1 Data analysis

Habitat variables

The anthropogenic site was situated at the lower reaches (<2500 m), while the park was at the higher side (>2500 m) of the elevation gradient. The park and anthropogenic site demonstrated overlapping values of the covariates of interest like, terrain ruggedness, slope, NDVI and distance to woodland (because of riparian forest at hill base and grasslands at hill brows). For instance, terrain ruggedness overlapped highly (0.3 to 0.6 in anthropogenic site and 0.3 to 0.7 inside park) and elevation had low overlap (1500 m to 2900 m in anthropogenic site and 2000 m to 4300 m in park) (Fig. 5.1). Thus, the habitat characteristics in park and anthropogenic sites were comparable except for the presence of human settlements in the latter. The villages were majorly located near the river at lower reaches on hill slopes, hill base, less rugged terrain, and woodlands. In this condition, species with specific habitat preferences in their natural state might likely differ when exposed to anthropogenically modified habitats (Schuette et al. 2013).

Habitat variables were selected based on red fox and leopard cat ecology. Five habitat variables were identified as potentially significant predictors where red fox (Martin-Garcia et al. 2022; McDonald et al. 2017; O'Malley et al. 2018; Sacks, Statham, and Wittmer 2017) and leopard cat (Bashir et al. 2014; Can et al. 2020; McCarthy et al. 2015) were likely to occur: elevation, slope, terrain ruggedness, NDVI and distance to woodland (riparian forests at hill base). Red fox preferred alpine meadows (high elevation, moderate slope), rugged terrain, and open and rocky areas (low NDVI) (Kumar, Magar, and Kumar Dhamala 2019; Murdoch et al. 2016; Naseer et al. 2020; Weber and Meia 1996), and grasslands at hill brow (away from woodland at hill base) (Rodríguez et al. 2020; Sacks, Statham, and Wittmer 2017) in natural forests and used variety of habitats in anthropogenic areas (Jackowiak et al. 2021; Jahren et al. 2020; Mueller, Drake, and Allen 2018). Hence, it was expected for red fox to show habitat selection towards high rugged, high elevation, moderate slope, low NDVI and away from woodlands inside the park and no habitat selection pattern in anthropogenic site. On the other hand, leopard cat occurred in temperate to sub-alpine forests (>3000m, moderate slope) (Irawan et al. 2020; Mishra, Madhusudan, and Datta 2006; Thapa et al. 2013). Leopard cats prefer rugged terrain, tree-covered (high NDVI), and woodland habitats (Bashir et al. 2014; Buzzard, Li, and Bleisch 2018; Ghimirey and Ghimire 2010; Pin et al. 2022) in natural forests. It used lower reaches and a wide range of habitats in anthropogenic sites (Lorica and Heaney 2013; Petersen et al. 2019; Wu et al. 2020). Likewise, for leopard cats, it was expected that habitat selection will be towards high rugged, high elevation, moderate slope, high NDVI, closer to woodlands inside the park and no such pattern in the anthropogenic site. The values of all habitat covariates were extracted from each camera trap point location. Collinearity between habitat covariates was checked for park and anthropogenic site using r values (-1 to 1) as it might reduce the precision of the estimated coefficients (Dormann et al. 2013). None of the covariates was co-related in either the anthropogenic site or park. The test was performed on the R platform using package *lattice.*

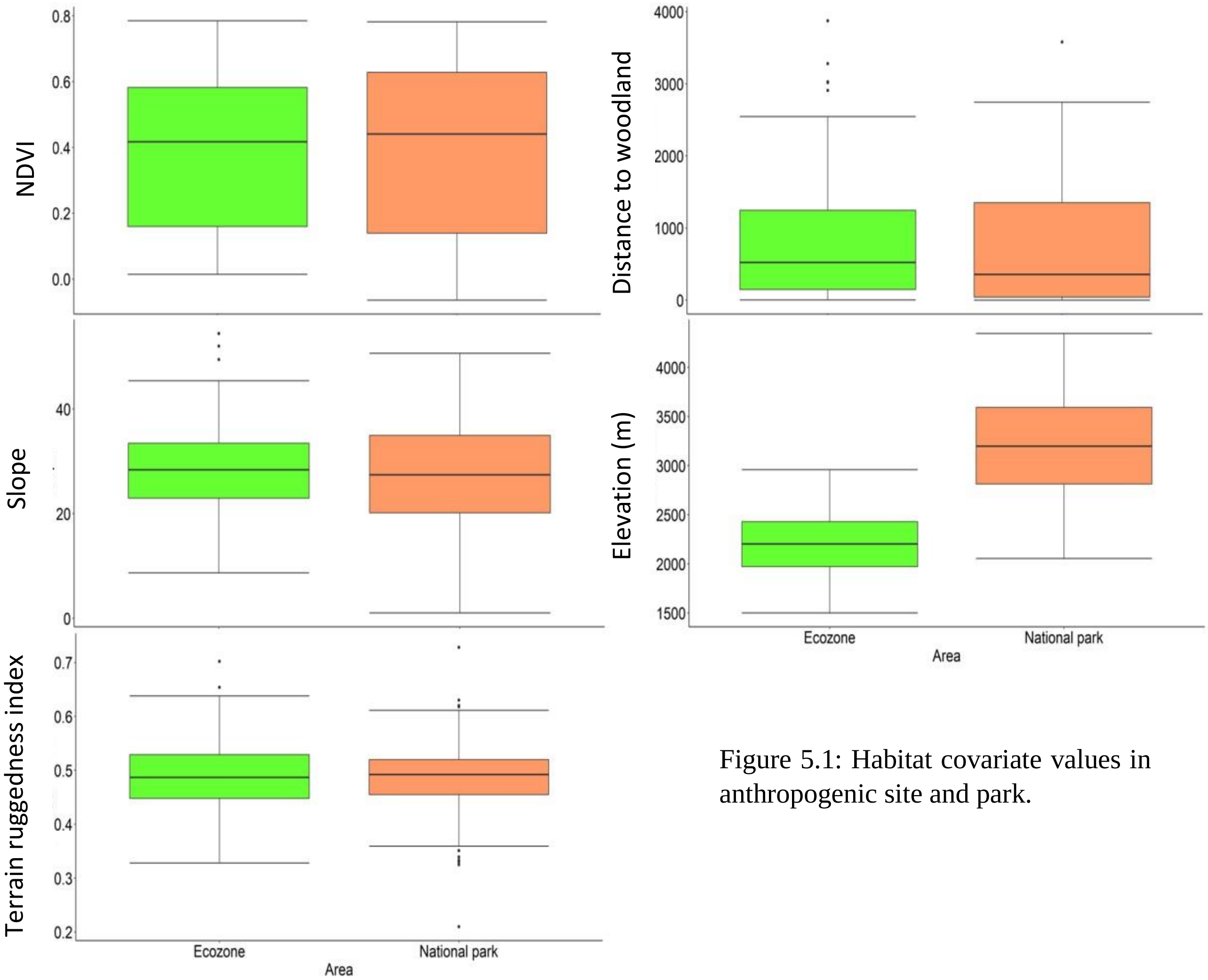


Figure 5.1: Habitat covariate values in anthropogenic site and park.

Data visualisation

The RAI of red fox and leopard cat for each camera trap location was calculated using the capture rate per 100 trap nights in the anthropogenic site and park. The RAI was plotted against the respective habitat covariates for all 5 sampling sessions in the park and anthropogenic site to account for linear, non-linear patterns and outliers. Most of the RAI vs covariate relationships were non-linear; therefore, hierarchical generalized additive modelling (HGAM) (Pedersen et al. 2019) was chosen to model each response of small carnivores to habitat covariates.

Modelling using HGAM

The number of small carnivore detections (C) from each camera traps were used as the response variable and camera operational days as an offset. The park and anthropogenic site were used as two zones and incorporated into the HGAM model as factors. Three probability distributions were used; Gaussian, Poisson and negative binomial. The equation of the additive model using park and anthropogenic sites as factors was:

$$C_i = \alpha + f\,(\text{elevation}_i,\ \text{k=3, by=fzone}) + f\,(\text{TRI}_i,\ \text{k=5, by=fzone}) + f\,(\text{slope}_i,\ \text{k=5, by=fzone}) + f\,(\text{NDVI}_i,\ \text{k=5, by=fzone}) + f\,(\text{distance to woodland}_i,\ \text{k=4, by=fzone}) + \text{offset (logdays)} + \varepsilon_i \qquad (1)$$

Where C_i = number of small carnivore detections from each camera trap location, i = each camera trap location, α = intercept, f = smoother function, logdays = logarithm of camera operational days, fzone = park and anthropogenic site, ε = residuals. The number of candidate models for each small carnivore in park and anthropogenic site was 40: (5 variables x 8 k-values). The underlying idea of spline regression is to separate the covariate into k segments (knots) and apply a bivariate linear regression model to the data of each segment. A smoother was obtained by connecting the regression lines for all segments (Zuur, A. F., & Ieno 2018). To allow for smooth connections at the knots, cubic regression spline was used for each covariate. For example, the equation of smoother function for elevation in equation (1) becomes:

$$f\,(\text{elevation}_j) = \beta_1 \text{ x elevation}_j + \beta_2 \text{ x elevation}_j^2 + \beta_3 \text{ x elevation}_j^3 + \sum^{k}{}_{p=1} \beta_1 \text{ x } (\text{elevation}_{jp} - k_p)^3{}_+ + \varepsilon_j \qquad (2)$$

Where j = each survey trail, β = unknown regression parameters, k = number of knots, p = knot positions in the x-axis. The response curves (detections) of small carnivores were plotted against each significant explanatory variable for park and anthropogenic site using package "*ggplot2*" and *"ggeffects"* in R (v.4.0.5). The significance of the explanatory variables in each model were evaluated using the p-values from the Wald statistics in the *"mgcv"* package. Also, the effective degrees of freedom (edf) was evaluated for each covariate to understand the scale of non-linearity captured by the model. The shaded area in the resulting plots represents 95% point-wise confidence bands of the smoother covariates.

Model selection

The best model was selected based on the lower Akaike Information Criterion (AIC), overdispersion values (OD) and k values with the best ecological meaning. For the combined model of park and anthropogenic site, negative binomial distribution was selected as the best distribution. The best model for red fox (AIC = 744.8, OD = 2.8) and leopard cat (AIC = 988.9, OD = 2.2) was selected out of 40 candidate models.

5.3 Results

HGAM results of red fox and leopard cat inside park revealed preference for certain habitats that red fox preferred areas with rugged terrain (0.6 TRI, p-value: 0.0009, edf = 1.4) (Fig. 5.2a), moderate slope (20°, p-value: 0.0004, edf = 2.8) (Fig. 5.2b) and low NDVI (0.1, p-value: 0.0002, edf = 2.2) (Fig. 5.2c). The preference of rugged terrain and open areas by red fox might be due to better visibility and ease in movement. Also, cameras detected leopard cat most commonly at moderate slope (20°, p-value: 0.0001) (Fig. 5.3a) and high NDVI (0.4 to 0.6, p-value: 0.03) (Fig. 5.3c) inside park. Although leopard cat occurrence decreased with increasing elevation, but a peak in the smoother curve was found at 3000 m elevation (Fig. 5.3b) (p-value: 0.0005). All the p-values mentioned above refer to the significance of the smoother covariate, not the predicted small carnivore counts at a particular value of the smoother covariate. On the other hand, neither red fox nor leopard cat showed any habitat-specific selection in the anthropogenic site. No prominent peak was found in the smoother curves of red fox and leopard cat with either of the habitat covariates (Fig. 5.2 and Fig. 5.3). Except for an additional peak at 0.6 NDVI (edf = 2.9) in case of red fox (Fig. 5.2c). Although the HGAM models revealed species-specific habitat selection but most of the non-linear effect of habitat covariates on red fox and leopard cat detections were small (indicated by small edf values) due to low detections at camera trap locations. Hence precautions should be taken while interpreting results considering ecological meaning.

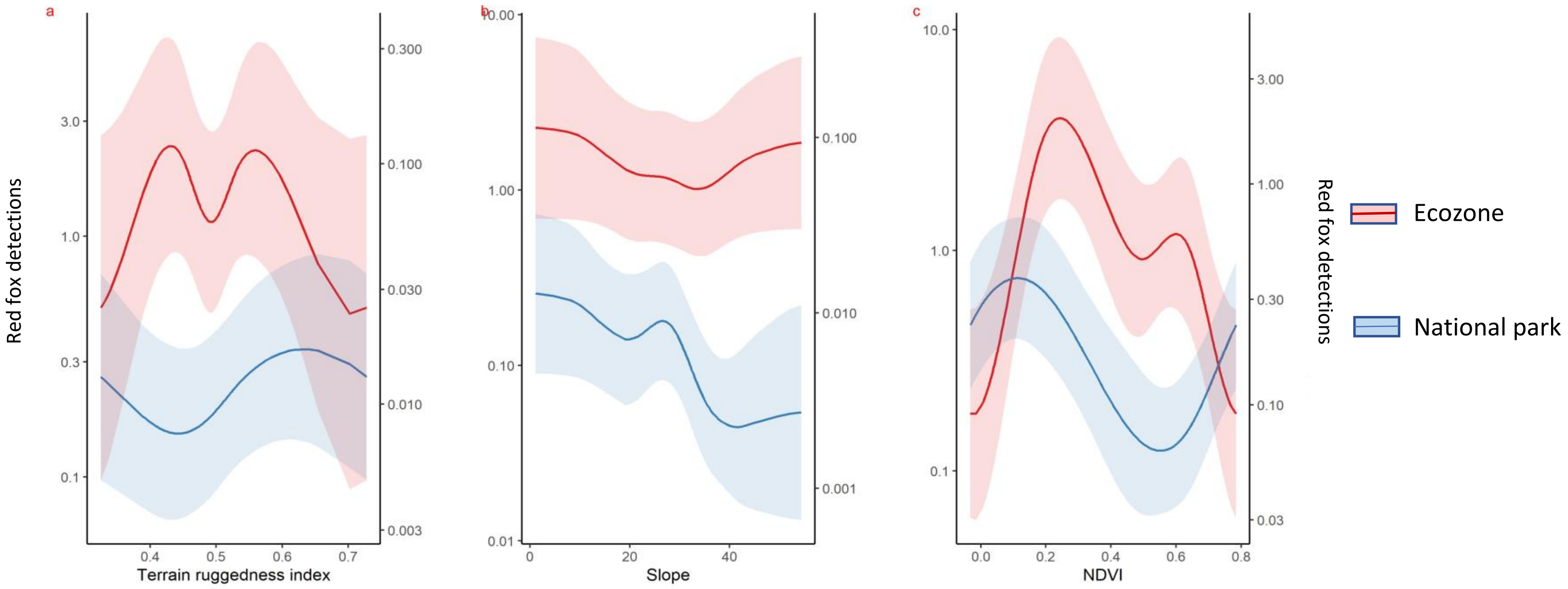


Figure 5.2: Response curves of the best models from HGAM (negative binomial distribution) showing habitat selection of red fox in anthropogenic site (ecozone) and park (National park).

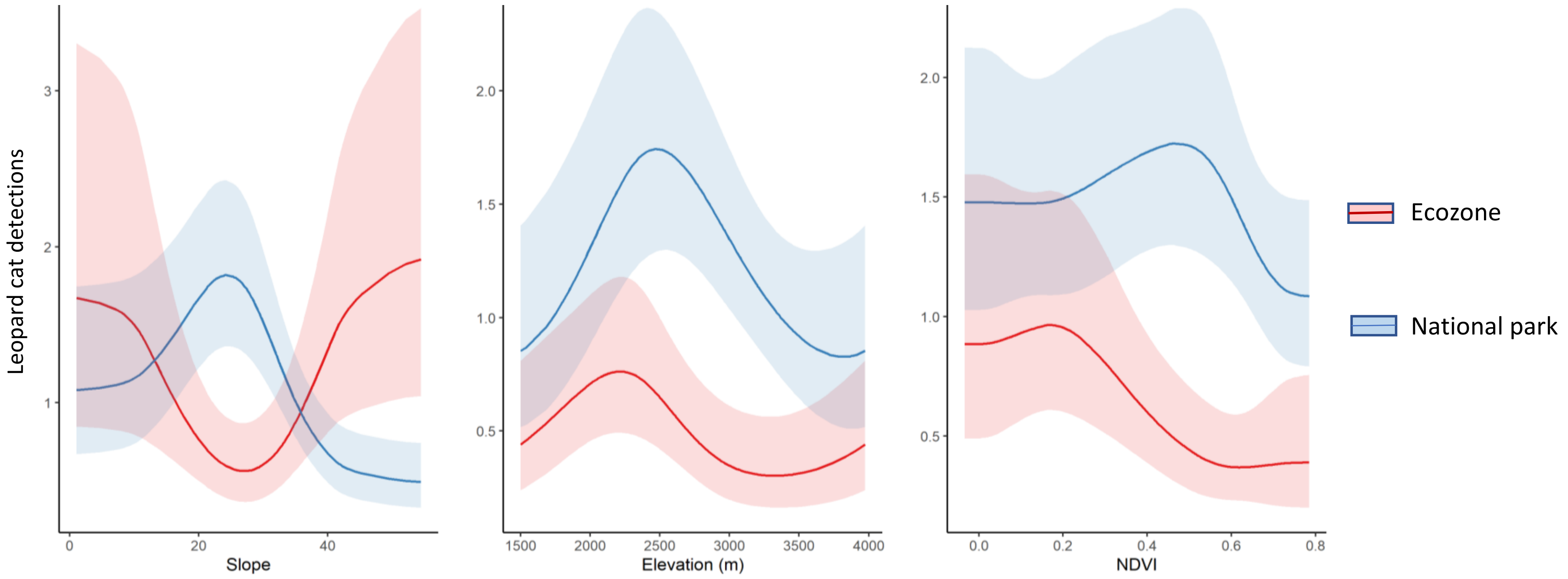


Figure 5.3: Response curves of the best models from HGAM (negative binomial distribution) showing habitat selection of leopard cat in anthropogenic site (ecozone) and park (National park).

5.4 Discussion

The habitat selection of small carnivores along the human-modified and natural gradient indicated the possible effect of increasing and expanding anthropogenic activities around GHNPCA which can be further confirmed by identifying the driving factor responsible for change in habitat selection. The outcome was similar to Schuette et al., (2013) and Ditchkoff, Saalfeld & Gibson, (2006), where small carnivores showed signs of adaptation to expanding human habitations, indicating small carnivore adaptations to human-modified habitats in GHNPCA. The ecozone around the park was delineated as a buffer area to lower anthropogenic activity's direct pressure on the GHNPCA boundary. Although land settlements and agricultural expansions occurred earlier (Tucker 1997), the current status of human habitation around GHNPCA needs re-evaluation to implement effective conservation practices. One of the caveats of human residences adjacent to natural forests adds to the availability of anthropogenic food sources like garbage dumps, agricultural products, kitchen wastes and livestock carrions in village areas (Newsome et al. 2015; Randa and Yunger 2006). Small carnivores, an opportunistic feeder, roam around these areas for food subsidies (Reshamwala et al., 2018). Eventually, these shared spaces can be the most probable zones for zoonotic disease transmissions and human-wildlife conflict (Namusisi et al. 2021). Concurrently, the availability of livestock and crop (like maize) close to GHNPCA also confers the exposure of native large carnivores like leopard and Himalayan black bear to more vulnerable habitat conditions and conflict probabilities (Sathyakumar, 2000; Naha et al., 2020a). Past evidence and our results suggest that wildlife in rural areas do not exhibit the same habitat preferences as their natural counterparts because of adaptation to human-induced modifications (Ditchkoff, Saalfeld, and Gibson 2006). Managers in such situations face challenges in addressing problems associated with rural wildlife and expanding human habitation. There is a need for management strategies for human habitation expansion, proper garbage disposal practices and monitoring of wildlife primarily in the anthropogenic site to safeguard future disease outbreaks and conflict risks that address sustainable development goals.

5.5 Conclusion

As development continues, it is crucial to understand how carnivores might respond to increased human expansions and the factors that might put carnivores and humans at increased risk of conflict and disease spread. Small carnivore distribution and habitat selection along the anthropogenic site-park gradient in GHNPCA showed the influence of anthropogenically modified habitat. The effects can harm other large carnivores like leopard and Himalayan black bear, leading to negative interactions like in other parts of western Himalaya. The anthropogenic site is an interface area where human habitations extend toward the natural habitat. Concurrently small carnivores from adjacent forest areas utilise the human habitations. Therefore, it is crucial to reinforce the conservation practices in anthropogenic site to control the habitat modifications adjacent to natural habitats and reduce the anthropogenic effects on native wildlife. It took more than thirty years (1980 to 2014) from inception (Pandey and Wells 1997) to realization of GHNPCA as a World Heritage Site (UNESCO, 2014 https://whc.unesco.org/en/list/1406/), but the current situation in the buffer zone of GHNPCA threatens its protection status in future. There is a need to implement mitigation strategies and future investigation of the driving factors for changes in habitat selection of native small carnivores especially in the anthropogenic site (human-wildlife interface) to regulate human habitation expansions and its associated caveats to balance the spheres of humans and wildlife in the study area.

CHAPTER-6

Distribution modelling of indicator species to anthropogenic and climatic effects in the current context

6.1 Introduction

A species distribution is characterized by the habitat features of the landscape (Guisan and Thuiller 2005) and the overall distribution in a landscape gives an idea about the presence of the given species. While the previous chapter dealt with changes in habitat selection of small carnivores due to human activities and was more habitat centric. This chapter is more species-centric where an overall distribution of the species is explained. Especially in case of generalist species like red fox and leopard cat, their presence indicates the extent of adaptation to varied habitat types (Dell'Arte et al. 2007) and one can expect to see a spread-out distribution in the study area. In the previous chapter, red fox and leopard cat showed sensitivity towards changes in habitat hence they were considered as indicator species. And pooling information from the previous chapter regarding habitat selection in disturbed and natural sites, here the species detections was modelled in the entire study area to understand the species distribution outside the sampled area. Also, there is no information regarding the seasonal distribution of red fox and leopard cat in the mountainous landscape like Western Himalaya. As spatio-temporal variation in distribution is expected to occur in heterogenous forests subject to changes in season, topography and impact of human activities (Burton et al. 2012). Therefore, rare and elusive species must be investigated by repeated site sampling in multi-season surveys (Gu and Swihart 2004; Hansen, Renken, and Millspaugh 2011). In GHNPCA, human activities have been an integral part of the landscape and is increasing rapidly (Tucker 1997). In this scenario, information regarding the small carnivore distribution in the entire study area might help in better understanding the species and the landscape. That is why modelling species distribution in sensitive landscapes is important, where human-wildlife interface is increasing (Havrda 2022).

6.1.1 Research question

1) Does the distribution of red fox is influenced by anthropogenic or climatic effects in the study area?

2) Does the distribution of leopard cat is influenced by anthropogenic or climatic effects in the study area?

6.2 Methods

Camera trapping

Camera trapping was conducted along the elevation gradient to understand the distribution of red fox and leopard cat in the study area. The details of camera trapping are already provided in Chapter-2 of methods section.

6.2.1 Data analysis

Data visualisation

The RAI of red fox and leopard cat for each camera trap location was calculated using the capture rate per 100 trap nights across the elevation gradient. The explanatory variables used in the modelling consisted of six habitat variables namely; elevation, TRI, NDVI, slope and distance to woodland, and one human disturbance variable which was distance to village. Collinearity of the covariates were checked using Pearson correlation in “ggcorrplot” package. It was found that distance to village was positively correlated (0.5) to elevation, hence distance to village was dropped. The RAI was plotted against the respective habitat covariates for all 5 sampling sessions to account for linear, non-linear patterns and outliers. Most of the RAI vs covariate relationships were non-linear; therefore, generalized additive modelling (GAM) (Pedersen et al. 2019) was chosen to model the detections of red fox and leopard cat using habitat covariates.

Modelling and prediction using GAM

The red fox and leopard cat detections were used as the response variable. The process contained two parts; first modelling the responses against the covariates in the sampled sites and secondly using the coefficients from the models to predict the responses in the entire study area. For the first part, covariates were extracted from the camera trap locations. Negative binomial distribution was used (taking from the previous chapter) to model the responses of red fox and leopard cat across the camera trap sites using "gam" function in "*mgcv"* package in R (v.4.0.5). Occasion was used as an offset in the model. The final models for red fox (RF) and leopard cat (LC) were:

$$RF_i = \alpha + f\,(\text{elevation}_i, k=5) + f\,(\text{TRI}_i, k=6) + f\,(\text{slope}_i, k=3) + f\,(\text{NDVI}_i, k=5) + f\,(\text{distance to woodland}_i, k=4) + \text{offset}\,(\text{logdays}) + \varepsilon_i \qquad (3)$$

$$LC_i = \alpha + f\,(\text{elevation}_i, k=6) + f\,(\text{TRI}_i, k=5) + f\,(\text{slope}_i, k=5) + f\,(\text{NDVI}_i, k=6) + f\,(\text{distance to woodland}_i, k=4) + \text{offset}\,(\text{logdays}) + \varepsilon_i \qquad (4)$$

For the second part, raster layers of all the five covariates were stacked to generate the master layer on which the prediction would take place. After this, the candidate model was fit in the new master layer and the species distribution was predicted across the study area using the "predict" function. Similarly, predicted distributions of red fox and leopard cat in summer and winter were performed for the entire study area.

Model validation

Concurvity test was performed to check for non-linear dependencies in the predictor variables (Amodio, Aria, and Ambrosio 2014) and no concurvity was found in the predictor variables. Homogeneity test was conducted to check for any pattern in the residuals due to model misspecification (Pearson residuals vs fitted values) (Zuur, 2012). Independence test was performed to check for patterns in residuals due to any covariate (Pearson residual vs covariates) (Zuur, A. F., & Ieno, 2018). No clear pattern was found in either of the Pearson residual vs fitted values plots (indicating homogeneity, Appendix – 1, Fig. A6.1) or Pearson residual vs covariate plots (showing independence, Appendix – 1, Fig. A6.2) for red fox and leopard cat. Also, spatial dependency was checked using semi-variogram plots (residual vs space) using package *"gstat"* in R (v.4.0.5). The semi-variogram plots (Pearson residual vs space) indicated no spatial dependency in the photo captures (C) of red fox and leopard cat to the distance between sampling locations. Additionally, influential observations were investigated in the models using cook's distance and found four influential observations for red fox and were not dropped.

6.3 Results

Anthropogenic effect

The non-linear distribution of red fox and leopard cat was captured using GAM. Table 6.1 and Table 6.2 shows the degree of non-linearity (effective degrees of freedom; edf) for red fox and leopard cat.

Table 6.1: Distribution modelling using GAM to determine anthropogenic effects on red fox distributions in GHNPCA. Table showing non-linear relationships with habitat covariates.

Covariates	edf	p-value
Elevation	1.209	< 0.001
Terrain ruggedness	3.713	< 0.01
Slope	1.238	< 0.001
NDVI	3.984	< 0.001
Distance to woodland	2.805	< 0.001

Table 6.2: Distribution modelling using GAM to determine anthropogenic effects on leopard cat distributions in GHNPCA. Table showing non-linear relationships with habitat covariates.

Covariates	edf	p-value
Elevation	4.569	< 0.001
Terrain ruggedness	3.618	< 0.05
Slope	3.431	< 0.001
NDVI	3.619	< 0.05
Distance to woodland	2.635	< 0.001

The UBRE score (Un-Biased Rink Estimator) for red fox model is 2.65 and deviance explained is 32.3%. The UBRE score for leopard cat model is 0.38 and deviance explained is 33%. The UBRE score is used by the cross-validation process to find the optimal amount of smoothing. The deviance explained is used to understand the variation captured by the model. The overall distribution of red fox and leopard cat in the study area was found to be not affected by the anthropogenic covariate because both the species were found to be using sites near villages as well as inside park (Fig. 6.1 and 6.2). The red fox distribution was more spread out as compared to leopard cat depicting red fox as a more generalist species. The differences in species-specific distributions in the study area also implies the tolerance and less tolerance to habitat characteristics.

Climatic effect

The seasonal distribution of red fox revealed changes in predicted detections in the study area. In summer red fox was found to occur in more of higher the elevations inside National park, whereas in winter lower elevation areas more occupied by red foxes (Fig. 6.3, Fig 6.4). In case of leopard cat, the distribution was found to be localized in winter as compared to summer (Fig. 6.5, Fig 6.6). The differences in seasonal distribution were prominent for both the species. Where red fox showed a shift in distribution towards lower elevation in winters and leopard cat showed a shrink in distribution in winters.

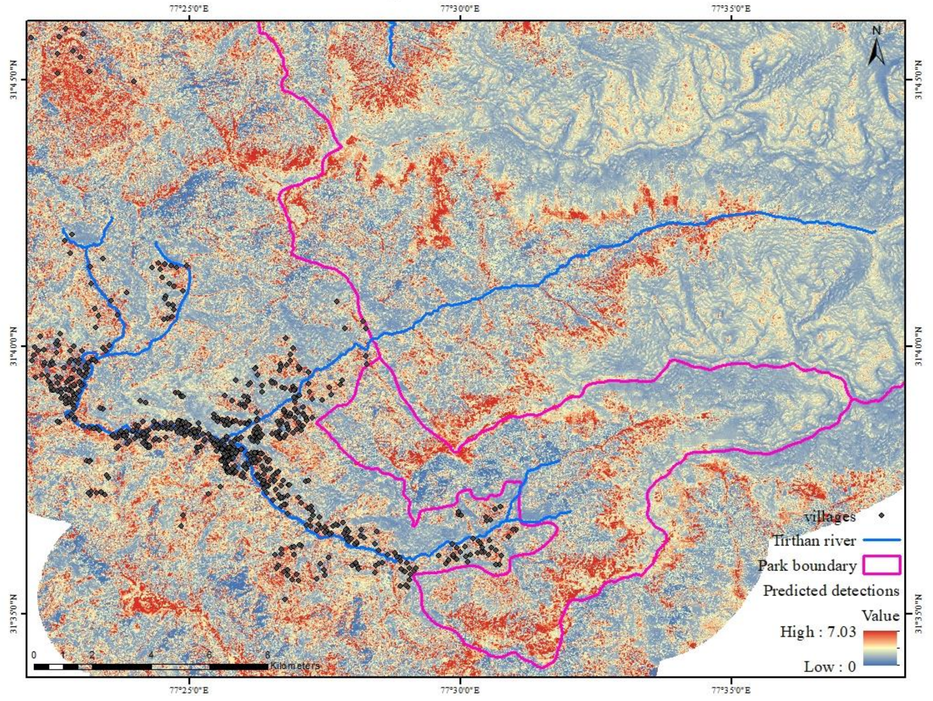


Figure 6.1: Map of red fox predicted distribution using distance to village as anthropogenic effect in GHNPCA under generalized additive modelling framework (GAM).

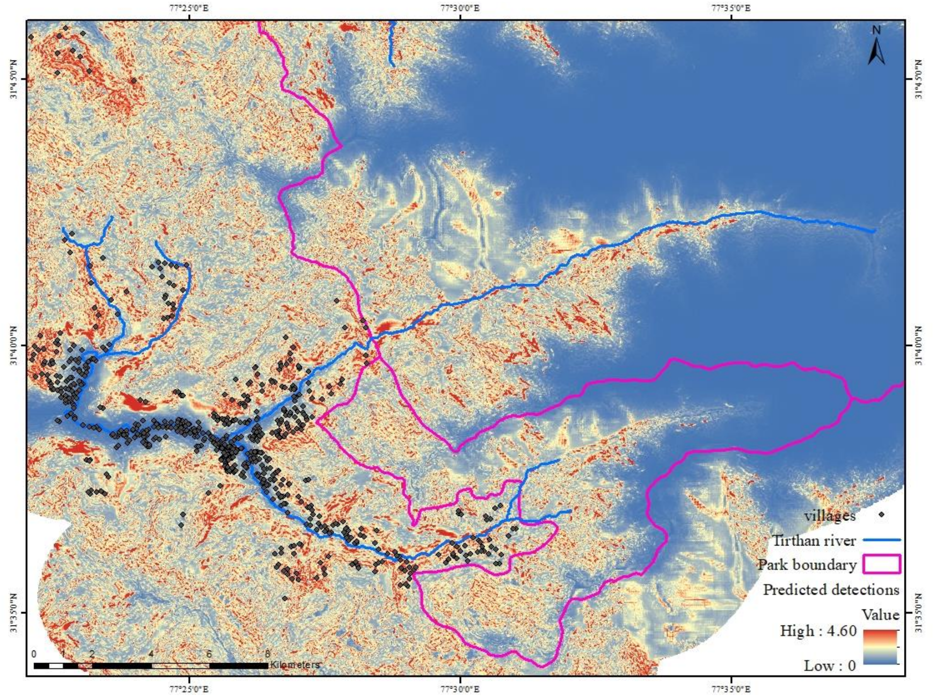


Figure 6.2: Map of leopard cat predicted distribution using distance to village as anthropogenic effect in GHNPCA under generalized additive modelling framework (GAM).

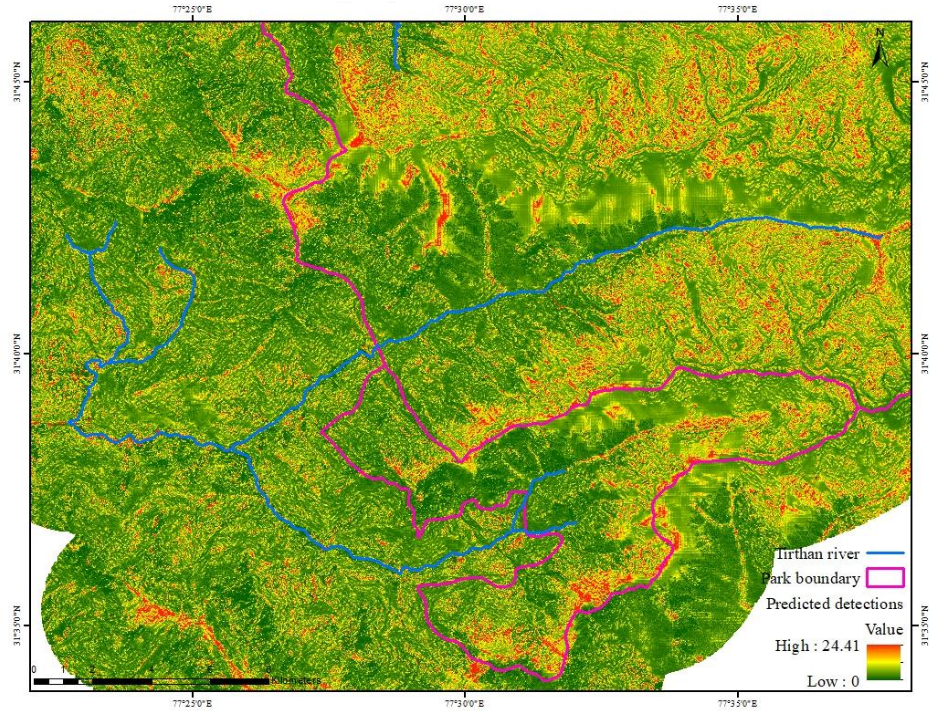


Figure 6.3: Map of red fox predicted distribution using climatic effect; summer, in GHNPCA under generalized additive modelling framework (GAM).

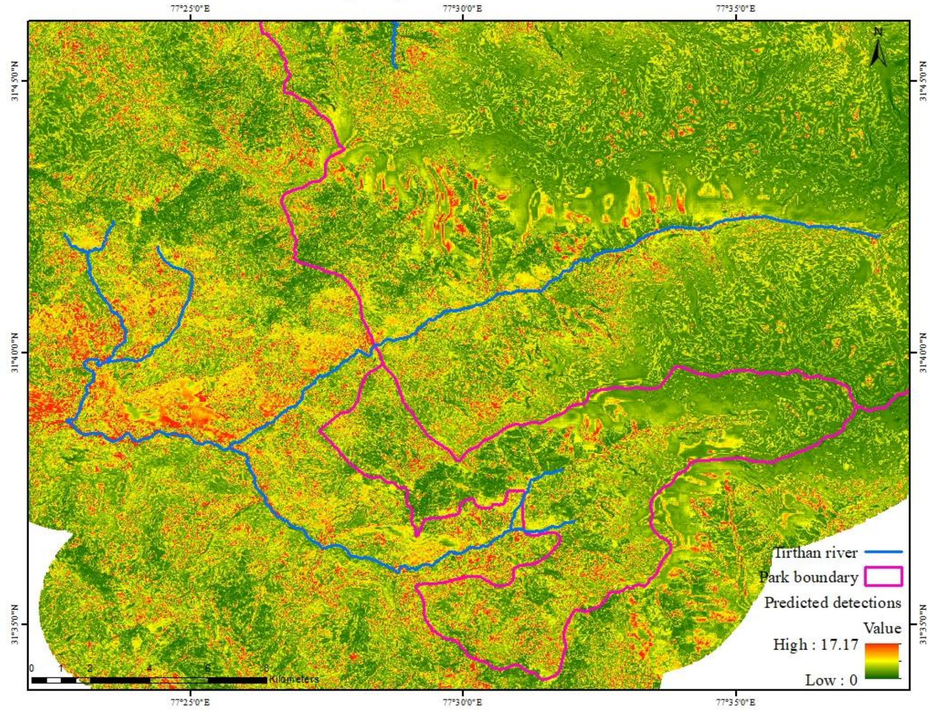


Figure 6.4: Map of red fox predicted distribution using climatic effect; winter, in GHNPCA under generalized additive modelling framework (GAM).

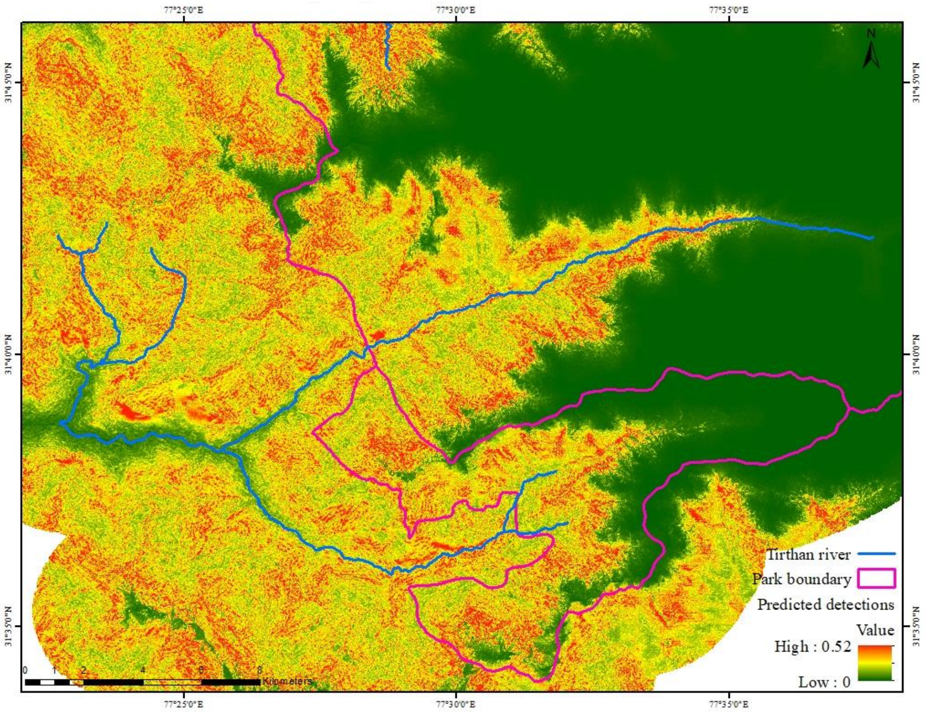


Figure 6.5: Map of leopard cat predicted distribution using climatic effect; summer, in GHNPCA under generalized additive modelling framework (GAM).

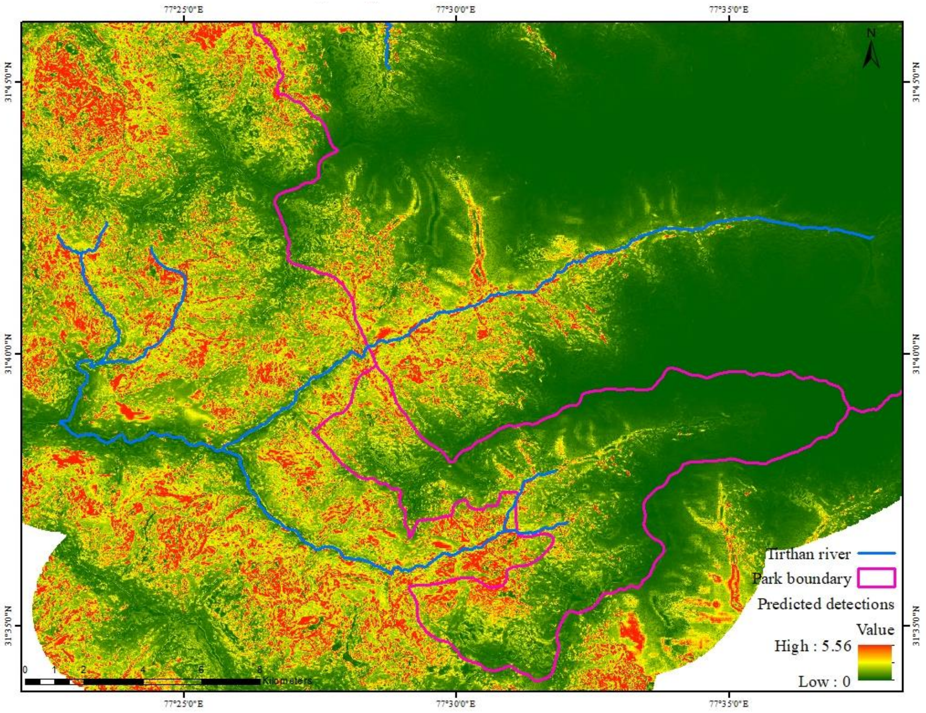


Figure 6.6: Map of leopard cat predicted distribution using climatic effect; winter, in GHNPCA under generalized additive modelling framework (GAM).

6.4 Discussion

The knowledge of species distribution over an area is important as it helps in understanding species ecology better. In this context, species distribution maps especially in sensitive landscapes like the Western Himalaya might aid in understanding the habitats occupied by the elusive species. In the Great Himalayan National Park Conservation Area (GHNPCA), there are evidences of scientific study in 1999 where small carnivores inhabiting the study area were studied and a baseline information was provided regarding their occurrences. But no information exists regarding their distribution in GHNPCA. Hence in this study, small carnivores were studied extensively to understand their distribution in relation to anthropogenic and climatic effects. Being small carnivores, they are indicators of habitat types, hence their distribution in the study area will help in understanding the current habitat status. GHNPCA was declared a World UNESCO Heritage site in 2014 owing to its outstanding Universal value. Hence information regarding carnivores' distribution might add more value to the aesthetics of the Heritage site.

The seasonal effect on red fox and leopard cat distributions were more prominent as compared to the anthropogenic effects. Where red fox predicted distribution was spread-out over the study area revealing more generalist and adaptive behaviour and leopard cat showed restrained predicted distribution. Since there are no distribution maps available for red fox or leopard cat in the Greater Himalayan landscape, therefore such distribution maps will be helpful in understanding the species distribution in rugged and remote landscapes. In general, red fox prefer elevations above 4500 m (McDonald and Reynolds, 2004) and leopard cat around 2500 m (Bashir et al. 2014). From Fig. 6.1 and 6.2, it was prominent how these two species occurred in the lower reaches of the elevation gradient (>2000m) which is not documented yet in the Greater Himalayan landscape. Also, they showed seasonal shift in their distributions to lower reaches of the study area. The villages are located in the ecozone which forms the lower end of the elevation gradient. As it is already known that red fox and leopard cat utilize village areas for resources, hence it can be assumed that due to resource scarce conditions during winter in higher altitudes, these small carnivores tend to shift to lower elevations for exploitation of readily available food resources. This might point towards increasing small carnivore dependencies on human-induced resources in GHNPCA.

6.5 Conclusion

Wildlife distributions in human dominated areas in GHNPCA is an indication towards increasing human-wildlife interface. The knowledge of which is important to understand the status of the protected area and such biodiversity rich landscapes like the Western Himalaya. The anthropogenic variable, distance to village was not found to be affecting the small carnivore distribution directly but the seasonal shift of small carnivores towards lower elevations might indicate towards increasing dependencies of wildlife on human induced resources. Although the seasonal shift of small carnivores can be perceived as a natural tendency and that the small carnivores are inhabiting the lower regions since earlier times when the human population was less. But the presence of increased human disturbances in the immediate neighbour of the protected areas might influence the natural distribution of the small carnivore inside the forested areas and make them more dependent on the anthropogenic resources. This study encourages investigating future monitoring of elusive species in the landscape including other carnivores inhabiting the area. Management strategies aimed at further investigating the resource availabilities in the ecozone and identify the factor responsible that might attract the native carnivores to the area will help in handling the increasing wildlife dependencies on human. It is important to unveil what attracts the small carnivores to the lower elevations especially in winters, whether it the natural prey abundance that also shifts to lower altitudes in winters or human-induced resources.

CHAPTER-7

General discussion

7.1 Background

Studies of elevation gradients of ecological communities date back to the origins of biogeography. A modern resurgence of interests in these elevational gradients is likely to contribute important insights for developing a more general theory of community assemblages especially in sensitive landscapes like Western Himalaya. The river catchments in the Great Himalayan National Park Conservation Area (GHNPCA), although having short stretches of elevation gradients (Approx. 35 km), exhibit very distinct habitat types and possess wide variety of flora and fauna. The tirthan catchment was selected as the representative site due to its similarity to the entire Conservation Area. The area was studied for almost two and half years (February 2017 to June 2019) to understand the patterns of small carnivore distribution and responses to anthropogenic and climatic variations. Small carnivores were considered as model species in this study, because their responses are indicators of habitat types and habitat alterations.

7.2 Distribution and abundance of small carnivores across space and time

The distribution of small carnivores along the elevation gradient of Tirthan catchment revealed species occupancy at different spatial zones. For instance, grey mongoose, jungle cat and golden jackal were found only in some pockets near the village areas in the lower reaches of the elevation gradient. Whereas, yellow throated marten, red fox and leopard cat were found throughout the elevation gradient and stone marten was only found in the higher elevations. Grey mongoose, stone marten were recorded first time in the study area and added to the list of small carnivores in GHNPCA. The variation in site usages by the small carnivores reflected site fidelity. As a matter of fact, all the villages are located at the lower end of the elevation gradient which forms the ecozone. Hence looking at the occupancy pattern, it can be perceived that among the small carnivores found in this study some are urban exploiters (like grey mongoose and golden jackal) while some are urban adapters (like red fox and leopard cat) (Duduś et al. 2014) indicating towards effects of presence of villages in the immediate neighbour of park. The same pattern can be expected to occur in other catchment areas like Parvati, Sainj and Jiwa.

7.3 Coexistence pattern of red fox and leopard cat in ecozone and National park

The distribution of species is latently defined by the coexistence of species. Hence after assessing the distribution, the coexistence of small carnivores detected throughout the catchment area was assessed. There was a stark difference in the habitat conditions in ecozone and National Park. All the villages were located in the ecozone whereas the park was devoid of any human settlements. The park was only visited by locals for herb collections and seasonal tourists; hence the human disturbance was relatively lower inside park then in ecozone. Therefore, the coexistence pattern was investigated into much finer scale between low and high human disturbance area. The niche dynamics was evaluated in three dimensions of space, time and dietary habit. In this case, red fox and leopard cat were chosen as the model species as they were detected throughout the elevation gradient. Interestingly, the small carnivores showed niche segregation in diet in ecozone whereas they showed niche segregation in space inside park. The change in coexistence pattern in differential human disturbances indicated influence of human disturbances or interaction with other carnivores on small carnivores coexistence in GHNPCA. Such kind of flexibility in coexistence pattern was also studied by (Gantchoff and Belant 2016) where small carnivores showed differences in niche segregations. In this context, it becomes difficult to ascertain the hidden reason for such coexistence patterns, whether this is an inherent behaviour or the effect of human disturbances. To arrive a proper statement, it is necessary to continue the monitoring in future and compare the impacts.

7.4 Habitat selection of red fox and leopard cat in ecozone and National park

The habitat selection by small carnivores in ecozone and park differed when compared between the two. It revealed their high adaptive capability and hence were considered as indicator species. The changes in habitat selection from preferred sites inside National park to less preferred sites in ecozone indicated influences of habitat alterations on species site selections. It was clearly seen how small carnivores (red fox and leopard cat) changed their natural site preferences inside park to no preferences in ecozone in order to adapt to changing habitat conditions.

7.5 Distribution modelling of red fox and leopard cat as indicator species to anthropogenic and climatic effects

Finally, the distribution modelling of red fox and leopard cat revealed their presence in the entire study area. Both the small carnivore's distributions were not effected by the anthropogenic covariate like distance to village but was influenced by climatic variations. It was evident from the distribution maps that red fox and leopard cat occupied areas in the study site according to their ecology and showed seasonal shifts in their occupancy (specially in winters) towards lower elevations where villages are located.

7.6 Research achievements

In 1999, scientific study was conducted in GHNPCA where types of carnivores present and their overall occurrence in the area were documented. After which no such scientific study was conducted until 2017. The study site exhibits heterogenous habitats and information regarding fine-scale distribution of small carnivores was lacking. Through this study, not only the information gap regarding the small carnivore distribution was fulfilled but also the effect of presence of human habitations on their distribution and coexistence patterns were revealed. One small carnivore was added to the list of existing carnivores in GHNPCA, which is stone marten (*Martes Fiona*) recorded first time in GHNPCA during the study period 2017- 2019. Additionally, snow leopard (*Panthera uncia*) was photo captured first time in GHNPCA during the study period and holds the lowest elevation presence record in the southern boundary distribution of snow leopard (Bandyopadhyay, Dasgupta, and Krishnamurthy 2019).

Also, in the current study, robust methods like camera trapping and molecular tools were used to understand the current dynamics of small carnivores in the study area in a finer scale. Since sampling in such rugged terrain is difficult due to logistical constrains and failing in detecting the elusive species. Therefore, the entire stretch was sampled five times by walking more than 700 km, deploying 340 camera traps and collecting 638 carnivore faecal samples in a span of two and half years, in order to capture the existent patterns. This perhaps is the most exhaustive and extensive field sampling conducted in the Western Himalaya. Noticeably, the sampling strategy and design used in this study is highly reproducible and effective especially for remote and rugged landscapes.

7.7 Future research directions

Pooling all the information together, it can be assumed that there were influences of human disturbances like habitation, space availability, anthropogenic food resources and human presence on small carnivore distribution in GHNPCA. This can be better understood with further assessment of natural and anthropogenic resource availability like rodent, birds and pika in National park and livestock (goat, sheep) and garbage dumps in ecozone. Additionally, effect of land use types like settlement area, forest area, barren patches on small carnivore distributions can help identifying the driving factor responsible for their distribution in GHNPCA.

7.8 Concluding remarks

The habitat continuum of the Tirthan catchment provided the best rural – natural gradient where indirect (habitat selection) and direct (consumption of livestock and plastic) effects of anthropogenic disturbances could be identified through small carnivore responses. The same can be replicated and studied in other catchment areas of GHNPCA which are more vulnerable and disturbed as compared to Tirthan like Parvati, Sainj and Jiwa to assess the effects of human disturbances on the native wildlife. This sets an example of shared spaces between the wildlife and human in the proximity of natural forested habitat. The consequences of such shared spaces might result in disease spread through livestock and human and vice versa. Also, this paves the way for conflict scenarios in future, although being small carnivores the conflict impact might not be severe but the effects can ripple upto the large carnivores inhabiting the area like leopard and Himalayan black bear. Owing to the high biodiversity value of GHNPCA, this is high time to initialize the good practices in the Conservation Area to avoid deleterious effects on the wildlife and preserve the sanctity of the habitat. All the results from this study points towards ecozone as the sensitive area in GHNPCA where human-wildlife interactions are the most and requires further monitoring of wildlife space usages in the area. Management strategies primarily in ecozone should be aimed at 1) future monitoring of wildlife and identifying the driving factor responsible for changes in distribution and intensive site usages 2) proper garbage disposal practices, 3) controlling human habitation expansion so that less anthropogenic food resources are generated and 4) shaping the human-modified areas into highly heterogenous ecosystems can better facilitate fine-scale spatial segregation among wildlife and humans. This study also suggests for surveillance of livestock and wildlife for any infectious diseases that might spread and effect human health.

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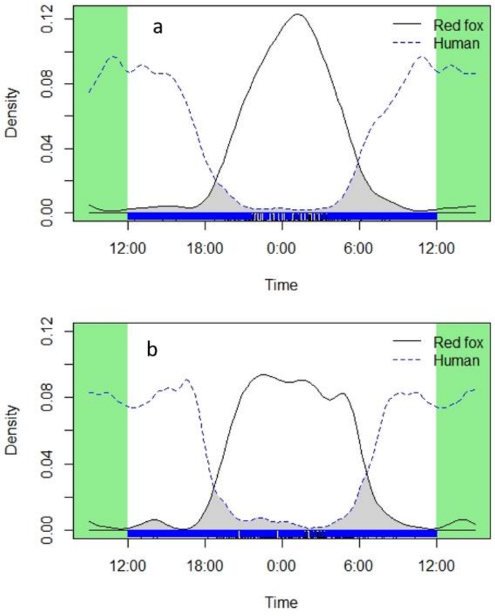


Figure A4.1: Activity density plots showing temporal overlap between red fox and human in (a) low human disturbance area (National Park) and (b) high human disturbance area (ecozone).

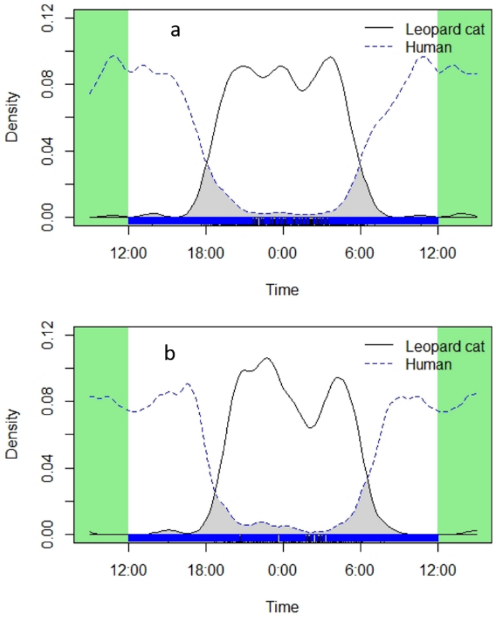


Figure A4.2: Activity density plots showing temporal overlap between leopard cat and human in (a) low human disturbance area (National Park) and (b) high human disturbance area (ecozone).

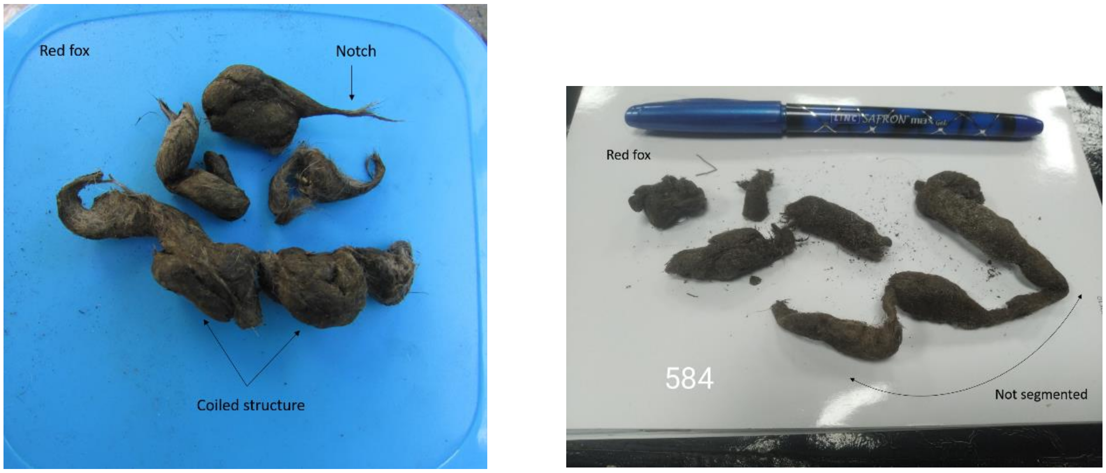


Figure A4.3: Structural description of red fox faeces: Coiled structure, notch ad not segmented.

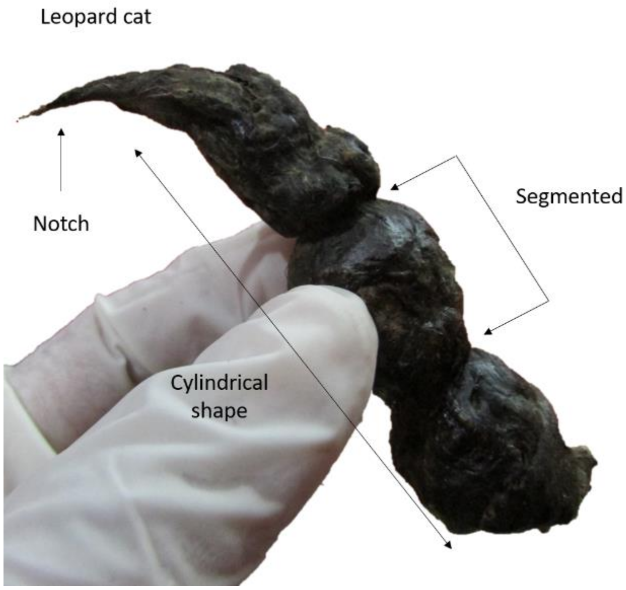


Figure A4.4: Structural description of leopard cat faeces: Cylindrical, segmented and notch.

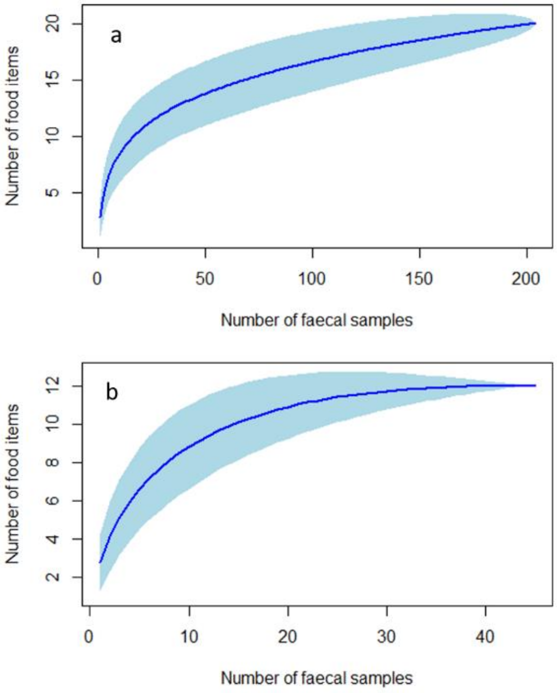


Figure A4.5: Accumulation curves showing number of food items against faeces sample size of red fox in (a) low human disturbance area (National Park) and (b) high human disturbance area (ecozone).

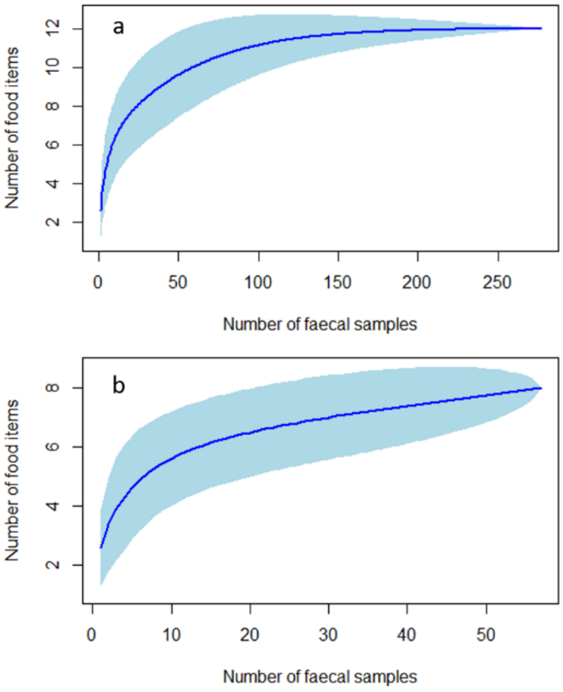


Figure A4.6: Accumulation curves showing number of food items against faeces sample size of leopard cat in (a) low human disturbance area (National Park) and (b) high human disturbance area (ecozone).

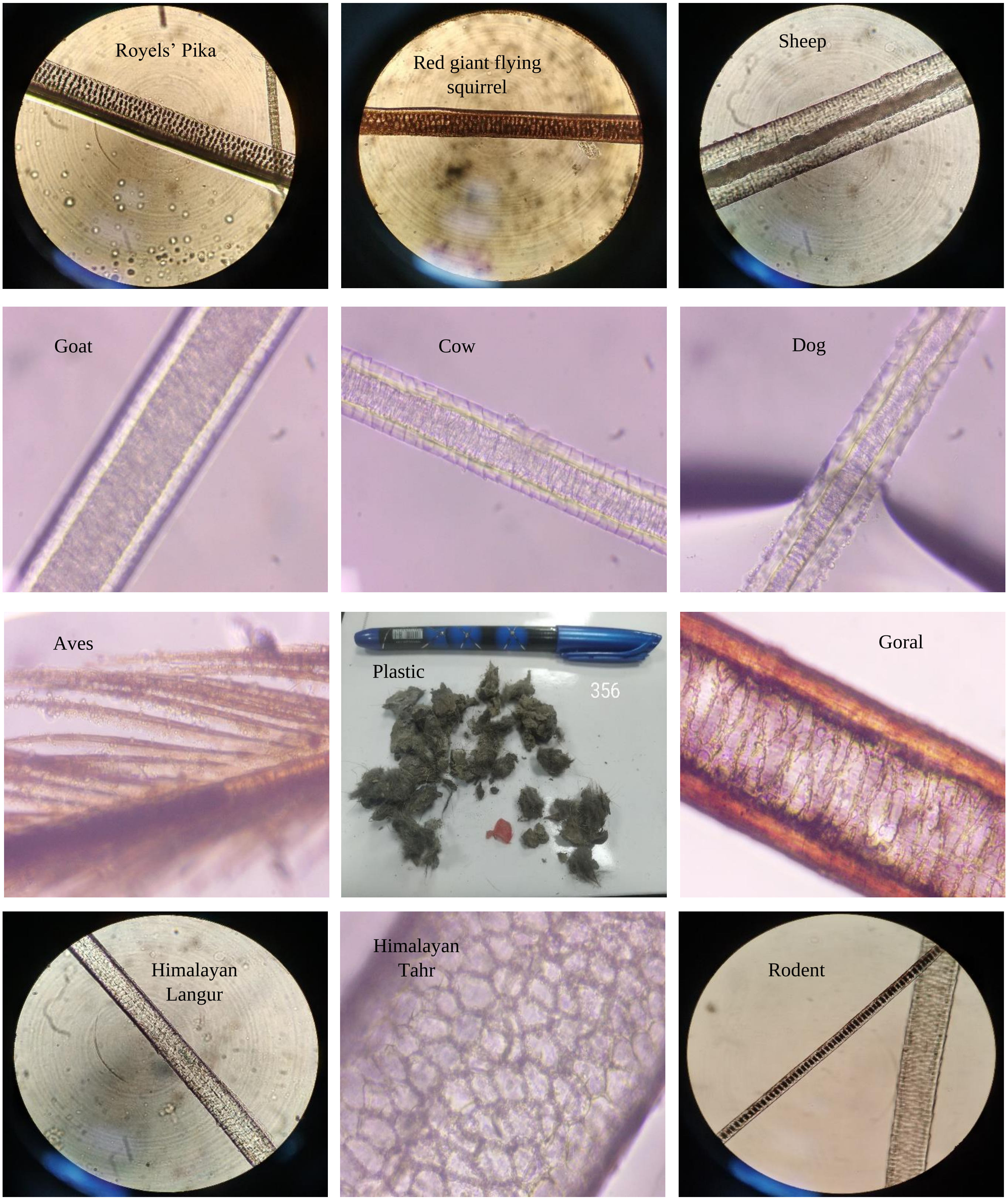


Figure A4.7: Photo documentation of medullary patterns of hair strands of prey species from faecal samples of red fox and leopard cat found from 2017 to 2019 in GHNPCA.

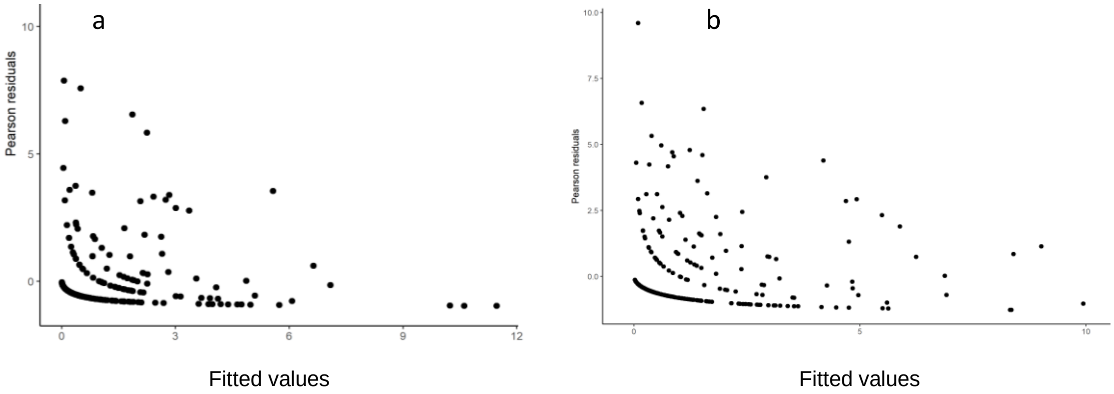


Figure A6.1: Graph showing pearson residuals vs. fitted values of the models from GAM (negative binomial distribution) for a) red fox and b) leopard cat distribution in GHNPCA.

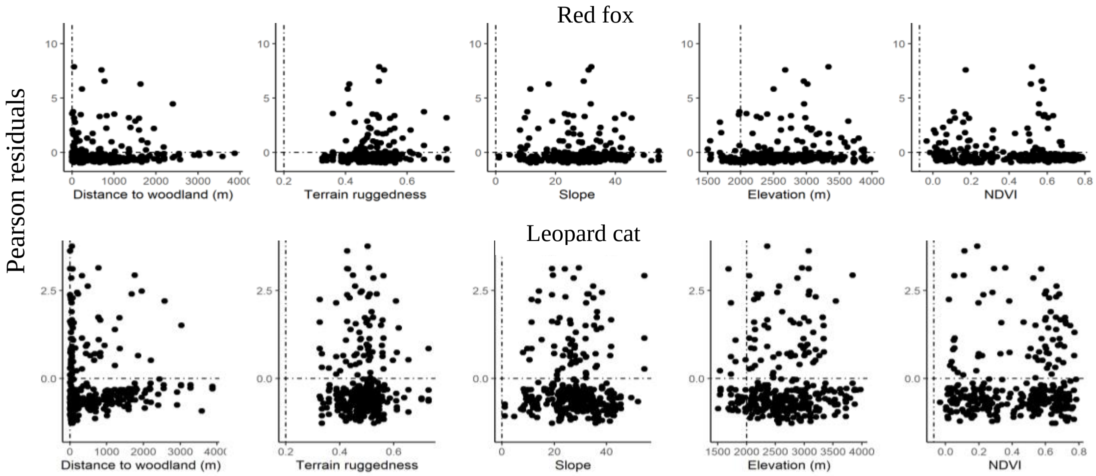


Figure A6.2: Graph showing pearson residuals vs. covariates of the models from GAM (negative binomial distribution) for red fox and leopard cat distribution in GHNPCA.

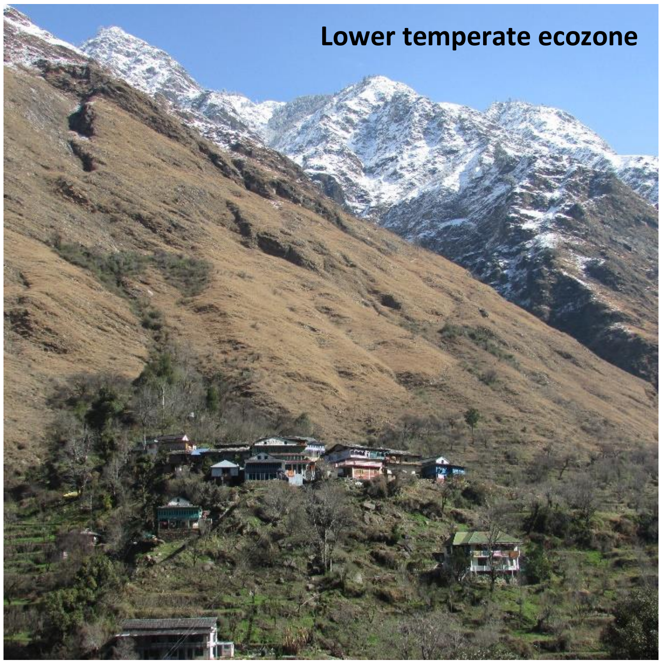
Field images

Habitat types


Alpine meadow

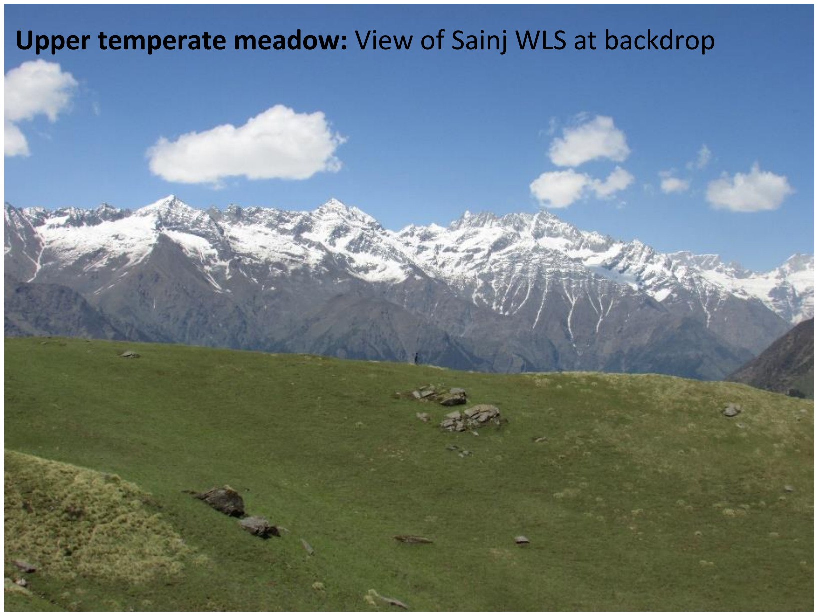

Sub-Alpine grassland

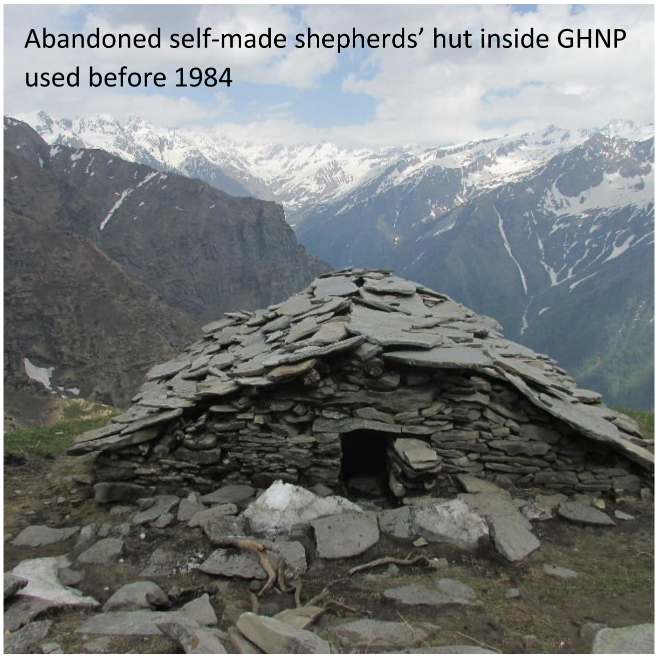

Upper temperate conifer


Lower temperate ecozone


Temperate riverine habitat


Open exposed rocks: Potential snow leopard habitat


Upper temperate meadow: View of Sainj WLS at backdrop


Abandoned self-made shepherds' hut inside GHNP used before 1984

Some prominent locations

Nada hut

Rakhundi top (3700 m)

Dhel meadow

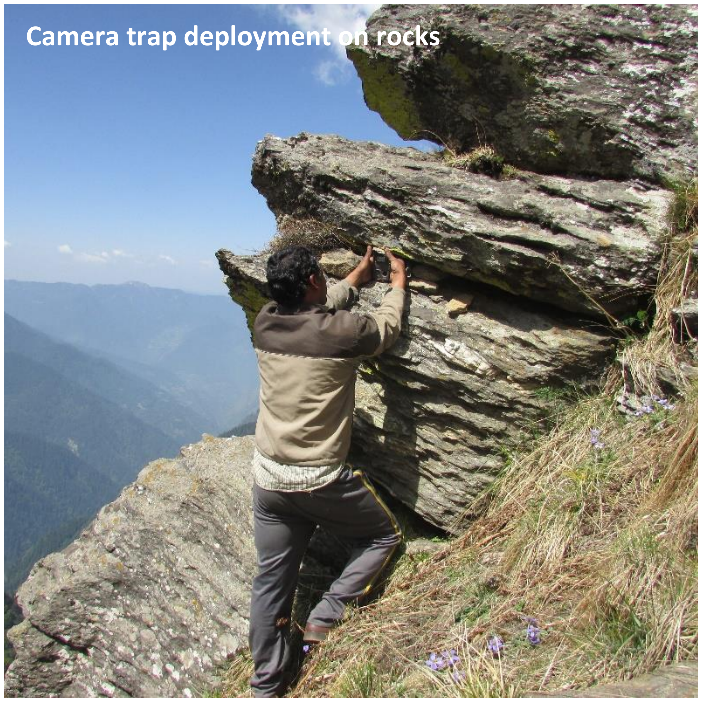
Ghumatrao

Field activities


Camping inside GHNP


Carnivore scat collection (old scat)


Camera trap deployment on tree


Camera trap deployment on rocks

Basecamp in January (mungla)

Outstanding Field team (Kholipoi)

Camera trap images of small carnivores found in GHNPCA

Leopard cat (*Prionailurus bengalensis*)

Red fox (*Vulpes vulpes*)

Yellow throated marten (*Martes flavigula)*

Himalayan Palm Civet *(Paguma larvata)*

Indian grey mongoose (*Herpestes edwarsii)*

Siberian weasel (*Mustela sibirica)*

Golden jackal *(Canis aureus)*

Jungle cat (*Felis chaus*)

Stone marten (*Martes foina*)

Table A4.1: Details of GLMM models used to understand the co-detection pattern between red fox and leopard cat in low and high human disturbance areas in GHNPCA.

Area	Model	Family	Expected relation
Low human disturbance area	Red fox ~ Leopard cat + Human + (1 | camera station)	Poisson	Red fox - Leopard cat: +ve
			Red fox - Human: +ve
Low human disturbance area	Leopard cat ~ Red fox + Human + (1 | camera station)	Poisson	Leopard cat - Red fox: +ve
			Human - Red fox: +ve
High human disturbance area	Red fox ~ Leopard cat + Human + (1 | camera station)	Poisson	Red fox - Leopard cat: +ve
			Red fox - Human: +ve
High human disturbance area	Leopard cat ~ Red fox + Human + (1 | camera station)	Poisson	Leopard cat - Red fox: +ve
			Human - Red fox: +ve

Table A4.2: Temporal overlap coefficient between red fox and human, leopard cat and human in low and high human disturbance area in GHNPCA.

Area	Small carnivore - Human	Temporal overlap coefficient: Δ [CI]
Low human disturbance	Red fox-Human	0.13 [0.09-0.17]
Low human disturbance	Leopard cat-Human	0.14 [0.11-0.15]
High human disturbance	Red fox-Human	0.16 [0.13 – 0.18]
High human disturbance	Leopard cat-Human	0.12 [0.10 – 0.15]

Table A4.3: Details of genetically and morphologically identified small carnivore faecal samples from GHNPCA during 2017 to 2019.

Details of identification of small carnivore from faecal samples	Number of faecal samples
Number of faecal samples collected	683
Number of samples selected for molecular identification of small carnivores from faecal samples (relatively fresh)	382
Remaining number of samples for morphological identification of small carnivores from faecal samples	301
Number of genetically identified small carnivore faecal samples (successful PCR amplification)	359
Number of morphologically identified small carnivore faecal samples	227
Total genetically and morphologically identified small carnivore faecal samples	586
Number of unidentified faecal samples (from both molecular and morphological approaches)	97
Success rate of PCR amplification	(359/382) x 100=93.98

Table A4.4: Details of genetically and morphologically identified red fox faecal samples from high and low human disturbance areas in GHNPCA during 2017 to 2019.

Methods	High human disturbance area (ecozone)	Low human disturbance area (national park)	Total faecal samples identified using different methods
Genetically identified (using molecular marker Cytb)	23	89	112
Morphologically identified	22	117	139
Total faecal samples identified in each area	45	206	251

Table A4.5: Details of genetically and morphologically identified leopard cat faecal samples from high and low human disturbance areas in GHNPCA during 2017 to 2019.

Methods	High human disturbance area (ecozone)	Low human disturbance area (national park)	Total faecal samples identified using different methods
Genetically identified (using molecular marker Cytb)	44	203	247
Morphologically identified	12	76	88
Total faecal samples identified in each area	56	279	335

Table A4.6: Relative frequency of occurrence (RFO) of prey items in red fox and leopard cat faeces from high (ecozone) and low human disturbance (national park) area in GHNPCA.

Area	Dietary items	Prey RFO (%) in red fox faeces	Prey RFO (%) in leopard cat faeces
high human disturbance	Plants	11.09	10.82
high human disturbance	Rodent (mouse, rat, shrew, vole)	30.77	53.69
high human disturbance	Pika	2.96	8.67
high human disturbance	Goral	10.02	4.61
high human disturbance	Goat/sheep	18.88	-
high human disturbance	Cow	2.96	-
high human disturbance	Rhesus macaque	3.70	-
high human disturbance	Langur	8.53	-
high human disturbance	Aves	3.67	19.77
high human disturbance	Dog	2.96	-
high human disturbance	Red giant flying squirrel	4.45	1.63

Low human disturbance	Insect	-	0.81
Low human disturbance	Plants	15.56	15.97
Low human disturbance	Rodent (mouse, rat, shrew, vole)	27.57	48.67
Low human disturbance	Pika	19.37	16.40
Low human disturbance	Stone marten	0.49	-
Low human disturbance	Tahr	0.65	-
Low human disturbance	Bluesheep	2.07	0.30
Low human disturbance	Musk deer	0.32	-
Low human disturbance	Goral	16.59	5.92
Low human disturbance	Barking deer	0.41	-
Low human disturbance	Goat/sheep	2.27	1.08
Low human disturbance	Cow	0.24	-
Low human disturbance	Langur	4.71	1.50
Low human disturbance	Aves	3.82	6.21
Low human disturbance	Dog	0.12	-
Low human disturbance	Plastic	0.16	-
Low human disturbance	Insect	2.92	0.72
Low human disturbance	Reptile	0.12	-
Low human disturbance	Red giant flying squirrel	0.89	1.62
Low human disturbance	Weasel	1.71	1.62

ANNEXURES

List of 359 gene sequences (uncleaned) developed for ed fox and leopard cat during 2017 to 2019 in GHNPCA.

Sample ID	Species	Gene sequence (unclean)
64	Leopard cat	TGWGRYTATGACTGCCAATAAAGMATGATTCCATGTTTAGGTCGCAAGGTGTAGGAGCCATAATATATTCCTCGA
72	Leopard cat	TATGACTGCCATAGCAGCATGATTCCAATGTTTRAGGTCGCAAGGTGTAGGAGCCATAATATATTCCTCGAGAGAGYGTYKWTWGGCAGATAAARAATAAA
88	Leopard cat	GYAAGCTGTGSYTATGACTGCCWATAGCAGCWTGATTCCMTGTTTATGRGCTGAAARGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGGATGTATAGGCAGATAA
90	Leopard cat	TGAAGCTGTGGCTATGACTGCSAWTWGSAGCATGATTCCGRTGTTTCATGTCTCTGAGARGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGSATGTATAGG
92	Leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCAATGTTTAGGTCAGGAAGGTGTAGGAGCCATAATATATTCCTC
104	Leopard cat	TGWGGYTATGACTGCCWWTAKSAGCATGATTCCATGTTTAGGGCGAAAGGTGTAGGAGCCATAATATATTCCTCGAAAGGGCTGTATA
105	Leopard cat	TGTGGCTATGACTGCSAATAGMAGCATGATTCCATGTTTAGGTCAGAGAAGGTGTAGGAGCCATAATATATTCCTC
107	Leopard cat	GCTGKGGCTATGACTGCCWWTAKCAGCATGATTCCRATGTTTAGGTCGAAAGGTGTAGGAGCCATAATATATTCC
108	Leopard cat	CTGTGGCTATGACTGCSAWTAGCAGCATGATTCCRATGTTTAGGGTCGAGAAGGTGTAGGAGCCATAATATATTCCTCGA
112a	Leopard cat	TGWGSCTTGACTGCCAATAGCAGCATGATTCCMTGTTTAGCTCACAAGGTGTASGAGCCATAATATATTCCTCGAAAGGGCTTYTATAGGMAGATAAAGAAWAA
112b	Leopard cat	CATGAAGATGWGGYKATGACTGCCATTAGSAKMATGATTCCRATGTTTAGGTCCCTAGGTGTAGGAGCCATAATATATTCCTCG
113	Leopard cat	TGKGGCTATGACTGCCWWTAGCAGCATGATTCCATGTTTAGGTCGATAAGGTGTAGGAGCCATAATATATTCCTCGAGARKGCTGKRTAGGRGATAAA
117	Leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCAATGTTTAGGTCAGAGAAGGTGTAGGAGCCATAATATATTCCTCGACTAGWGSAKGKATAGGCAGATAAA
119	Leopard cat	GAAGATGWGRYKATGACTGCCAATATAAAAAATGATTCCGRTGTTTAAGGCTACTAGTGTAGGAGCCATAATATATTCCTCGAAAGGGTTTATAGGAGATAAAGAAAA
120	Leopard cat	TGTGGYTATGACTGCCAATAGSAGCATGATTCCATGTTTRGCTCAGCTMGGTGTAGGWGCCATAATATATTCCTCGAGAGAGYAKGKRTAGGMARATAAARAAWAAAMTG
121	Leopard cat	TGTGGCTATGACTGCCAWTWGCASCATGATTCCATGTTTAGGGTCAGCAAGGTGTAGGAGCCATAATATATTCCTC
122	Leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTAGGTCAGGAAGGTGTAGGAGCCATAATATATTCCTC

123	Leopard cat	TGTGGCTATGACTGCRAATAGCAGCATGATTCCATGTTTATGTAACTGARAAGGTGTAGGAGCCATAATATATTCCTCGACTTACGTGCATGTATA
125	Leopard cat	TGAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGTCTMKRRRRAGGTGTAGGAGCCATAATATATTCCTCGACCTWCGTGSATGTATAGGCA
127	Leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTAGGTCAGATAAGGTGTAGGAGCCATAATATATTCCTC
129	Leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCRATGTTTAGGTCAGCAAGGTGTAGGAGCCATAATATATTCCT
130	Leopard cat	TGTGGCTATGACTGCGMATAGCAGCATGATTCCATGTTTCATGATGAGAAGGTGTAGGAGYCATAATATATTCCTCGACCTAGGSAKGWRTAGGCARATAAARAAWA
131	Leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCATGTTTCAGGCTCGAGAAGGTGTAGGAGCCATAATATATTCCTC
133	Leopard cat	TGAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCATGTTTCWTGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCARAT
134	leopard cat	TGTGGCTATGACTGCRAATAGCAGCATGATTCCATGTTTCATGTCTMWRRGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGSATGTATA
135	leopard cat	TATGACTGCRAATAGCAGCATGATTCCRATGTTTCATGYCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATA
138	leopard cat	TATGACTGCCATTAGSAGMATGATTCCATGTTTRGGGTCACAAGGTGTAGGAGCCATAATATATTCCTCGA
139	leopard cat	TGWGGYTATGACTGCCAATAGCAGCATGATTCCATGTTTAGGTCAGGAAGGTGTAGGAGCCATAATATATTCCTCGA
140	leopard cat	TGTGGCTATGACTGCCAATAGMARMATGATTCCATGTTTAGCTCACAGGTGTAGGAGCCATAATATATTCCTCGA
141	leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCRATGTTTATGGTCAGAAAAGGTGTAGGAGCCATAATATATTCCTCGACTAAGTGSAKGWATAGGCAGA
144	leopard cat	TGTGGCTATGACTGCSAATAGMAGCATGATTCCATGTTTATGAAGCKGAARRGGTGTAGGAGCCATAATATATTCCTC
145	leopard cat	TATGACTGCSAATAGCAGCATGATTCCAATGTTTAGGTCAGATAAGGTGTAGGAGCCATAATATATTCCTCGACCAGWGSAKWTWTAGGCARATA
148	leopard cat	TATGACTGCSAATAGCAGCATGATTCCATGTTTATGACGGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGRAKGTATAGGCARAT
149	leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCAATGTTTATGTCTGAAARGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGRAKGTATAGGC
169	leopard cat	TGWGGYTATGACTGCCATTWRAAGMATGATTCCATGTTTAGGTCGGAAGGTGTAGGAGCCATAATATATTCCTCGAGAGGCTGTATAGGAGATAAARAAT
171	leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCATGTTTAGGTCGGAAAAGGTGTAGGAGCCATAATATATTCCTCGAGTARKGCATGKWTAGGCAGATAAA

178	leopard cat	TATGACTGCCAATAGCAGCATGATTCCATGTTTRAGGTCAGGAAGGTGTAGGAGCCATAATATATTCCTCGGGAGTGGATGTWTAGGCARATAAARAATAA
187	Leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCATGTTTAGGGCTGAGARGGTGTAGGAGCCATAATATATTCCTCGACACGTGAAKGTATAGGCARATA
189	Leopard cat	TGTGGCTATGACTGCCAATARMAGCATGATTCCAKGTTTRRRGTCAGTTAAGGTGTAGGAGCCATAATATATTCCTCGAGAGKGGATGKATAGGAGATAA
194	Leopard cat	TGACTGCCAATAGCAKCATGATTCCMTGTTTAAGGTCACCAAGGTGTAGGAGCCATAATATATTCCTCGAGAAGAGCTCTATMGGCAGATAA
195	Leopard cat	TGTGRCTATGACTGCSAATAGCAGCATGATTCCAATGTTTATGTCTGAAAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTRMAKGTATAGGCARATAA
197	Leopard cat	GATGAGGYGATGACTGCCAATAGGAKAWTGATTCTATGTTTAGGCTCACACGTGTAGGAGCCATAATATATTCCTCGAGAGGCTTATAGGAGATAAAGAAAA
199	Leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCAATGTTTGAGGTCAGTAAGGTGTAGGAGCCATAATATATTCCTCGAGGAGGGCTTTTWTWGSCAGATAAAGA
206	Leopard cat	TATGACTGCCAATAAAGMATGATTCCATGTTTAATGAGCTAAAAAGGTGTAGGAGCCATAATATATTCCTCGACACRKGRATGTATAGGCAGATAAAGAATA
222	Leopard cat	GRYTATGACTGCCAATAGCAGCATGATTCCATGTTTRGGTCACTCGTGTAGGAGCCATAATATATTCCTCGAGGAGGTTTTATMGGCAGATAAAGAATAA
223	Leopard cat	TATGACTGCSAATAGCAGCATGATTCCAATGTTTGAGGTCAGGAAGGTGTAGGAGCCATAATATATTCCTCGAAGAGGCTTTTAYAGSCAGATAAAGAATA
225	Leopard cat	TATGWCTGCCATAGSAGMATGATTCCATGTTTAGGTCACTAAGGTGTAGGAGCCATAATATATTCCTCGAAGAGAGCTTTYWYYSGCAGAT
230	Leopard cat	TATGACTGCSAATARMAGCATGATTCCATGTTTCATGCAAMWAAAAAGGTGTAGGAGCCATAATATATTCCTCGACCTMCGTGMAKGTATAGGCARATAAARAAWAA
231	Leopard cat	TGAAGCTGTGGCTATGACTGCSAATAGCAGCATGATTCCATGTTTCATGTCTMKRAGRAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATA
237	Leopard cat	TATGACTGCGMATAGCAGCATGATTCCRATGYTTRAGARAGGCAAGTGTAGGAGYCATAATATATTCCTCGACGAGGYATGTAKAGGCAGATAAARAAWAA
239	Leopard cat	TATGACTGCGAATAGCAGCATGATTCCATGTTTAGGCTAGGAAGGTGTAGGAGCCATAATATATTCCTCGAGAGGCTTTWTWSGCAGATAA
243	leopard cat	TGAGAWTGATTCCTATGTTTCTGCCTCTAAGAAGGGGTAGGAMCCWTAATATATTCCTCGSCCTACGTGYATGTATAGGCGAGGAAACATAAA
245	leopard cat	TGATTCTCTGTTTRTGTCTCTGAAGGGGGGGTSGACCCATAATATRTTCCTCGACCTACGTGCATGTGTAGGAAATAAATCAAAAACTGC
248	leopard cat	CTGCCATAGCAGCATGATTCCAATGTTTCWTGTCACAWRARAAGGTGTAGGASCCWTAATATATTCCTCSACTTACGTGCWTGTATAGGCAGATAAAGAATAATA
249	leopard cat	GMTGRGGCTATGACTGCCAATAGCAGCATGATTCCGATGTTTCRTGTCTMTGAGAAGGKGTAGGAGCCWTAATATATTCCTCGACTTACGTGSATGTATAGACATATAAAGCATAAA

251	leopard cat	TATGACTGCGAATAGCAGCATGATTCCATGTTTAGGTCKRAGRRGGTGTAGGAGCCATAATATATTCCTCGACTACRKGRRRKGTATAGGCARA
238	leopard cat	TGGCTATSACTGCGAATAGCAGCATGATTCCATGTTTAGGTCTGAGARGGTGTAGGAGCCATAATATATTCCTCGACAAAAGRRAKGTATAGGCAGATAAA
252	leopard cat	TGKGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTCTCTGARARGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGG
253	leopard cat	TGATTCCATGTTTAGAGAAAGAGAAGGTGTAGGAGCCATAATATATTCCTCGACTACGWGAATGTATAGGCARATAAA
254	leopard cat	TGWGRYTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCA
260	leopard cat	TGATTCCWRTGTTTAGGAAACAGAGAAGGTGTAGGAGCCWTAATATATTCCTCGATTACRTGAATGTATAGGCAGATAAAGATTA
262	leopard cat	CTGCRAATAGCAGCATGATTCCATGTTTCMTGTCTCTGAGAAGGKGTAGGAGCCWTAATATATTCCTCGACCTACGTGCATGTATAGGCAGA
265	leopard cat	TATGACTGCRAATAGCAGCATGATTCCWMTGTTTCWTGTCTCTGAGAAGGTGTAGGAGCCWTAATATATTCCTCGACCTACGTGCATGTATAGGCAGA
266	leopard cat	TGTGGCTATGACTGCGAATAGCASCATGATTCCATGTTTATGACTCTGAGAAGGKGTAGGAGCCATAATATATTCCTCGATTTACGTGSATGTATAGGCARATA
277	leopard cat	GCGAATAGCAGCATGATTCCATGTTTCWYCYYYTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCSACCTACGTGCATGTATAGG
400	leopard cat	TATGACTGCRAATAGCAGCATGATTCCKRTGTTTCRTGTCTCTGAGAAGGTGTARGAGCCWTAATATATTCCTCSACCTACGTGCWTGTWTAGGCAGATA
402	leopard cat	TGWGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTATGMCKGRRAAGGTGTAGGAGCCATAATATATTCCTCSATTTACGTGWATGTATAGGMA
405	leopard cat	ATGATTCCCTGTTTCATGTCTCTGAGAGGGGGTACGAACCWTAATATATTCCTCGACCTACGTGCATGTATAGGCAAATAAAGCATAAACTGCWTCCCCTCWRAWTGWTTTYTSKCCT
406	leopard cat	TGKGGCTATGACTGCGAATAGSAGCATGATTCCKRTGTTTCATGTCTCTGAGAAGGKGTAGGAGCCWTAATATATTCCTCGACCTACGTGCAT
409	leopard cat	TGAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCATGTTTCWTGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCSACCTACGTGCATGTATAGGCA
410	leopard cat	TATRACTGCRAATAGCAGCATGATTCCTRTGTTTCWTGTCTCTGAGAAGGKGTASGAGCCWTAATATATTCCTCGACCTACGTGCATGT
420	leopard cat	TTTTTCTCTGTTTCTGGRTGGAAAAGGGGGGGGAATTTTAMTATRTTCCTCGACCTACGTGTTTGTWTAGGCAGATAAAAAATAAART
423	leopard cat	TATGACTGCMAATAKSAKMATGATTCCTATGTTTCCTGTCTCTGAGAAGGRGKAGGAGCCATAMTATATTCCTCGACCTACGTGCATGTKTAGGCAAATGAAA
436	leopard cat	TATGACTGCRAATAGCAGCATGATTCCKRTGTTTCWTGTYTCTGAGAAGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGA

437	leopard cat	TATRACTGCGAATATCAKCATGTTTCCTSTGTTTCATGTCTCTGARAAGGKGTASGAGCCWTAATATATTCCTCGACCTACGTGCATGTWTAGGCAAA
439	leopard cat	TATGACTGCRAATAGCAGCATGATTCCKSTGTTTCTGTCTCTGAGAAGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATA
440	leopard cat	CTGCSWATAKCAGCATGATTCCATGTTTRGTGCTGAGRAGGYGTAGGAGCCATAATATATTCCTCGACTACGTGGATGTATAGGCAGATAAAAAATAATATTCTTCC
444	leopard cat	TATGTTTCCTCTGKTKCRTGGCACTGGGGGGGGGTAGGAGCCTTTATATATTCCTCGACCTCTGTGYATGTWTWGGCAGATGAAGAATATTATTCTT
445	leopard cat	CTGCCACTAKGAKCATGATTCCTMTGTTTRTGATATGAGAAGGYGTASGAGCCTTAMTATATTCCTCGACTTACGWGYKTGTRTAGGCAGATAAAGCAAAAACT
447	leopard cat	TATRACTGCGAATAGCAGCATGATTCCKRTGTTTRTGTCTCTGAGAAGGKGTAGGAGCCWTAATATATTCCTCGACCTACGTGCATGTATAGGCA
449	leopard cat	TGCGAMTAGCAGYATGWTTCCKRTGTTTCCTGTYTCTGAGAAGGKGTAGGAGCCWTAATATATTCCTCGACCTACGTGYATGTWTAGGCAGATAAAGAATAATCT
451	leopard cat	GAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCGATGTTTCATGYYTCTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAA
454	leopard cat	TATGACTGCRAATAGSAGCATGATTCCATGTTTCTGTCTCTGAGAAGGKGTAGGAGCCWTAATATATTCCTCGACCTACGTGCATGTATAGGA
456	leopard cat	GWGGCTATGACTGCRAATAGCASCATGATTCCKRTGTTTCTGTYTCTGAGARGGKGTAGGAMCCWTAMTATATTCCTCSACCTACGTGGTGGWAGG
465	leopard cat	GKGGCTATGACTGCRAATAGCAGCATGATTCCATGTTTCATGTCTCTGAGAAGGKGTAGGAGCCWTAATATATTCCTCSACCTACGTGCATGTATAGGCA
466	leopard cat	TATGACTGCCACAGCAGCATGWTTCCTSTGTTTCATGTCTCTGAGAAGGRGTASGAGCCWTAMTATATTCCTCGACCTACGTGCATGTWTAGGCAGAT
468	leopard cat	CTGCGACAAKCATCATGATTCCCCTGTTTCWTGTCTCTGAAAAGGAGTGGGAGCCWTAATATATTCCTCGACCTACGTGYATGTRTAGGCGGATGA
287	leopard cat	TGAAGCTGTGGCTATGACTGCCAATARMARCATGATTCCATGTTTCATGCGTGAAAGGTGTAGGAGYCATAATATATTCCTCGACCTAGGAARGKAWRGGCARATAAARAAWAA
288	leopard cat	TATGACTGCSAATAGCAGCATGATTCCAATGTTTCATGTGAGGGAAGGTGTAGGAGCCATAATATATTCCTCSACCTACKTGCWTGWATAGGCARATAAARA
289	leopard cat	TGACTGCSAATAGMAGCATGATTCCAATGTTTCATGGGGGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGAAAGWAWAGGCARATAAARAA
290	leopard cat	TGTGGCTATGACTGCCAATAKCAGCATGATTCCATGTTTCATGTCCAGARARGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGCWTGWATAGGMARATA
293	leopard cat	TGTGGCTATGACTGCCAATARCAGCATGATTCCATGTTTCATGGGGGGGAGGTGTAGGAGCCATAATATATTCCTCGACCTACGGGAATGAAGAGGSRGATAAAGAA
294	leopard cat	TGTGGYTATGACTGCGCAATARMAGCATGATTCCRAKGTTTCATGTGGGGARAAGGKGTAGGAGCCATAATATATYCCTCGACCTACGTGTATGKAKRGGMARAWAAARAA

301	leopard cat	TGTGGCTATGACTGCCMATAGCAGCATGATTCCRATGTTTCATGTGGTGAAAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGKATAGGCARATAAARAATAA
304	leopard cat	CTGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTTTCTRARARGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGCARATA
305	leopard cat	TGTGGYTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTTTCTRARRRGGTGTAGGAGCCATAATATATTCCTCGACCTACSYKYWTGTATAGGCARATAAARAAW
307	leopard cat	GRYTATGACTGCCAATAGCAGCWTGATTCCRTGTTTCATGTGAGARAAGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGCTTGWATAGGCARA
310	leopard cat	TGTGGCTATGACTGCSAATAGCAGCATGATTCCAATGTTTCATGTTCARRRARGGTGTAGGAGCCATAATATATTCCTCGACCTACGTKYWTGWATAGGCARATAA
311	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGRTTCCRATGTTTCATGYCYYTGARARGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGCARATAAARAAWAA
313	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGTTTCTRARRRGGTGTAGGAGCCATAATATATTCCTCGACCTACSTGYWTGTATAGGCARATAAARAAWAA
314	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTCYCTRARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAAAAATA
315	leopard cat	TATGACTGCCAATARCAGCATGATTCCATGTTTCATGGGGAGGGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGWAWAGGCARAWAAARAA
318	leopard cat	TGAAAGMTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGYCYYTRARRRGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARAA
321	leopard cat	TATGACTGCGAATAGCAGCATGATTCCAAKGTTTCATGYCYYTGARRRGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARA
326	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGYCYYTKARRRGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGCARATAAARA
365	leopard cat	CCATGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGCARATAAARAAWA
369	leopard cat	ATGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGYCYYTKARRRGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGCARATAAARAAW
370	leopard cat	TATGACTGCSAATAKCAGCATGATTCCATGTTTCATGTCTCTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARAATA
372	leopard cat	GCTGTGGYTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCYCTGARARGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGMARATAAAAA
382	leopard cat	GMTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTTTCRRRRARGGTGTAGGAGCCATAATATATTCCTCGACCTACSTKYWTGWATAGGMARATAAARAAWA
386	leopard cat	GCTGTGGCTATGACTGCGAATAGCAGCATGATTCCRAKGTTTCATGYCYYTGARRRGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARAAWA
392	leopard cat	GCTGTGGCTATGACTGCGAATAGCAGCATGATTCCRAKGTTTCATGYCYYTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACSYGYATGTATAGGMARATAAARAATAA

394	leopard cat	GCTGTGGCTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGCARATAAARAAWAA
395	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCTCSACCTACGTGYWTGTATAGGCARATAAARAAWAA
497	leopard cat	CTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGYCYYTRRRRRGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGCARATAAARA
499	leopard cat	TGTGGYTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCTCSACCTACGTGYWTGTATAGGMARATAAARAAWAA
501	leopard cat	CCATGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCRATGTTTCWTGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARAAWAA
502	leopard cat	GMWGTGGYTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCYCSACCTACGTGYWTGTATAGGCARATAAARAAWAA
508	leopard cat	TGWGRYTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGMARATAAARA
509	leopard cat	GAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCRAKGTTTCATGYCYYTGARARGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGCARATAAARAAWAA
510	leopard cat	GMWRWGRYTATGACTGCGAATAGCAGSATGATTCCATGTTTCATGYCTYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARAAWAA
511	leopard cat	AGMWGTGRYTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTRARARGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGMARAWAAARAA
513	leopard cat	GYTGTGGCTATGACTGCSAATAGCAGCATGATTCCATGTTTCATGTCTCARARRGGTGTAGGAGCCATAATATATTCCTCGACCTACSTKYWTGTATAGGCARATAAARAAWAA
516	leopard cat	AWCATTATKATTTCCWRTGSTYCTTGCCTCTTAGAAGGTGTARKAGCCTTAATATATTCCTCKACCTACCTTTWTGTATAGGCARATAAAGAATAT
519	leopard cat	TGTATGATCCGWAGWATAGGCCTCGYCCTACGTGCWTGTATAGGCAGATAAAGAAWAA
520	leopard cat	GCTGTGGYTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGYCYCTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATA
521	leopard cat	TGTGGYTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTTTCTRRRRRGGTGTAGGAGCCATAATATATTCCTCGACCTACSTKYWTGTATAGG
523	leopard cat	TATGACTGCSAATAKCAKWWTGATTCCMTGTTTCATGCCTCTGAGAAGGKGTAGGARCCWTAATATATTCCTCGACCTACGTGTWTGTATAGGCAGATAAAGAATAAAT
524	leopard cat	TGAAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTTTCARARRRGGTGTAGGAGCCATAATATATTCCTCSACCTACGYKYWTGWATAGGCARATAAARAAWAA
526	leopard cat	ACTGCGAATAGCAGCATGATTCCATGTTTCATGYCYYTGARRRGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARAAWAAA
537	leopard cat	GWGGYTATGACTGCAATACAGCWTGATTCCATGTTTCATGTCTCTRARAAGGTGTARGAGCCATAATATATTCCTCGACCTACGTGYATGTATA

541	leopard cat	GWGGCTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGCGAARRRRAGGYGTAGGAGCCATAATATATTCCTCGACCTACGTGMAWGRRKAGGCARAWAAARAAWAA
542	leopard cat	GCCAATARAAGYATGATTCCWMTGTTTCATGGGGGGCGAAGGYGKAGGAGCCATAATATRTTCCTCGACCTACGTGMAKGRRKRGGCARATAAARAAWA
545	leopard cat	TATGACTGCSAATAKSAGMWTGATTCCWMTGTTTCATGTCACAGAAARGGKGTAGGARCCATAATATATTCCTCGACCTACGTGTWTGTATAGGCARATAAAKAATAAACTG
546	leopard cat	GWRRYTATGACTGCSAATAKCAGMATGATTCCMTGTTTCATGTGGCARARARGGTGTAGGAGCCATAATATATTCCTCGACCTACSTGCATGTATAGGCARATAAAGAAWAA
547	leopard cat	TGACTGCGAATAGCAGYATGATTCCAATGTTTCATGTCYCTRARARGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGCWTGTATAGGCARATAAARAAWAA
548	leopard cat	AATAKSAKMWTGATTCCWMTGKTTCATGTCTCTGARAAGGWGTAGGAGCCATAATATATTCCTCGACCTACGTKTWTGTWTAGGCARATAAARAA
550	leopard cat	TGWGGYTATGACTGCSAATAKCAKCWTGATTCCMTGTTTCATGYCTCTGARAAGGKGTAGGARCCATAATATATTCCTCGACCTACGTGCATGTATAGGCARATAAAGAATAAA
154	leopard cat	GGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCWTGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCYCSACCTACGTGYWTGTATAG
155	leopard cat	GTGGCKATGACTGCGAATAGCAGCATGATTCCWKGTTTCRTGYCTYTGAGARGGKGTAGGAGCCWTAATATATTCCTCGACCTACGTGYATGTATAGGMARATAAARAATAA
4	leopard cat	GCTGTGSTTATGACTGYCAATAGCAGTWTGWTTCTYTGTTTCRTGTCTCTGAGAAGGKGTAKGASCCWTAATATATTCCTCGACCTACGKGYATGTATAGGCAGATAAAGAATA
5	leopard cat	TGAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCTYTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATA
10	leopard cat	ATGACTGCCYTATGGTTTGATTCTCTGTTTCRTGTCTCTGAGAAGGKGTAKRARCCWTAATATATTCCTCGACCTACGKGYATGTATAGGCAAATAAA
14	leopard cat	TGTGGYTATGACTGCTCGTAGCAGCATGATTCCATGTTTCATGYCYYTGARAAGGKGTAGGAGCCWTAATATATTCCTCGACCTACGTGYATGTATAGGCAA
16	leopard cat	GACTGCGAATAGCAGCATGATTCCRAKGKTTCATGTCYYTGRRRRGGKGTAGGAGCCATAATATATTCCYCSACCTACSTGYATGTATAGGCARAWAAARAAWAA
19	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGMARA
24	leopard cat	TAGCAGCATGATTCCATGTTTCATGYCTYTGARAAGGTGTAGGAGCCWTAATATATTCCTCGACCTACGTGYWTGTATAGGCARATAA
26	leopard cat	GTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCYYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGMARATA
31	leopard cat	GGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCTYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCA
32	leopard cat	GTGGYTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCTYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCA

33	leopard cat	GAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCAKGTTTCATGYCTYTGARARGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGG
34a	leopard cat	TGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCATGKTTCWTGYYTYTGAGAAGGTGTAGGAGCCATAATATATTCCTCGMCCTACGTGYATGTATAGGMARA
34b	leopard cat	TGTGGYTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCTYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATA
35	leopard cat	TATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTCTCTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATA
41	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCTYTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATA
43	leopard cat	TGTGGYTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCYYTGARARGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCAA
48	leopard cat	TGATGCTGTGGYTATGACTGCSAATAGCAGCATGATTCCMTGTTTCATGTCTCTGARAAGGKGTAGGAGCCATAATATATTCCT
58	leopard cat	TATGACTGCGAATAGCAGCATGATTCCAKGTTTCATGTCTCTGARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGSWTGTATAGGMAGA
59	leopard cat	GATGTGCTTATGACTGCCAATATCAGTATGATTCCKMTGTTYCRTGTGGCAGARARGGKGTAGGAGCCWTAATATATTCCTCGACCTACGTGMTTGTATAGGCARATAAAAAATAA
66	leopard cat	TGTGGYTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCTYTGARAAGGTGTAGGAGCCWTAATATATTCCTCGACCTACGTGYATGTATAGGMARAWA
476	leopard cat	TATGACTGCGAATARAGATGATTCCWKGTTTCATGTAGAAGAAAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGRATGTATAGGSRRATAAA
551	leopard cat	TGAAGCTGTGGCTATGACTGCCAATAGCAGCATGATTCCAATGTTTCATGTAGCAGAAAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATA
553	leopard cat	ATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
554	leopard cat	TATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCACAGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAAA
555	leopard cat	CTGCCAATAGGATAATGATTCTCTGTTTCATGTAACAGAGAAGGAGTAGGAGCCATAATATATTCCTCGACCTACGTGTATGTATAGGCAGATAAAGAATAA
557	leopard cat	TGTGGTTATGACTGCCAATAGCAGCATGATTCCCTGTTTCATGTCTCTGAGAGGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAAAATA
559	leopard cat	TATGCAGATGAGGTTATGACTGCCATATSATATGATTCCCTGTTTCATGTCTCTGAAAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
563	leopard cat	TATGACTGCGAATAGCAGCATGATTCCGATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
566	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCGATKGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCSACCTACGTGCATGTATAGGCAGATAAAGAATAAA

568	leopard cat	CCATGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAA
571	leopard cat	ATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATA
573	leopard cat	ATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAAA
574	leopard cat	TATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
576	leopard cat	TATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
594	leopard cat	TGCCACAGCAGATGATTCCCTGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAAA
595	leopard cat	GCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGA
596	leopard cat	TATGACTGCGAATAGCAGCATGATTCCGATGTTTCATGTTTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
600	leopard cat	TGTGAATATCATACTGACTCCGTGTTCCCATGGTCTCTGAGAAGGTGTATGATCCATAATATATTCCTCGTCCTACGTGCATGTATAGGCAGATAAAGAATA
103	leopard cat	TGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
110	leopard cat	TGAAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGA
147	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATA
188	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
212	leopard cat	TATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
219	leopard cat	TGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAAAA
276	leopard cat	TGCGAATATCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
207	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAAA
13	leopard cat	TATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
218	leopard cat	AGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAAGCTG

240	leopard cat	TGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTTTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATA
259	leopard cat	TATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGYCTCTGARAAGGTGTAGGASCCWTAWTWTATTCCTCGACCTACGTGCATGTATAGGCAGATAAARAATAA
1	leopard cat	TGAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGYCTCTGAGAAGGKGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAAA
2	leopard cat	TGWGGCTATGACTGCCAATAGCAGCWTGATTCCMTGTTTCATGTCTCTGAGARGGKGTAGGAGCCWTAATATATTCCTCGACCTACGTGYATGTATAGGCARATAA
8	leopard cat	CCATGAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCSACCTACGTGSATGTATAGGCARATAAARAATA
14	leopard cat	TGTGGYTATGACTGCGAATAGCAGCATGATTCCRATGTTTCWTGYCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGSATGTATAGGCARATAAARAATAA
15	leopard cat	TGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGYCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARAAWAA
40	leopard cat	TGTGGYTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYWTGTATAGGCARATAAARAAWAA
45(10)	leopard cat	TGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTCTCTGAGARGGTGTAGGAGCCWTAATATATTCCTCGACCTACGTGYATGTATAGGCAGAT
47(12)	leopard cat	TGTGGCTATGACTGCCACAGCAGCATGATTCCSTGTTTCATGTCTCTGARAAGGTGTAGGASCCATAATATATTCCTCGACCTACGTGCATGTATAGGCARAT
50(15)	leopard cat	TGWGGYTATGACTGCCAATAKCAGCWTGATTCCMTGTTTCATGTCTCTGARAAGGTGTAGGASCCATAATATATTCCTCGACCTACGTGYATGTATAGGCAGATAAAAAATAA
51(16)	leopard cat	TGAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGTTTYTRARAAGGTGTAGGAGCCATAATATATTCCTCGACCTACKTGYATGTATAGGMARAWAAARAAWAAAMYG
44(9)	leopard cat	TGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGMARATAAAGAAWAAA
73	leopard cat	ATGAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCRATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARAATAA
76	leopard cat	TATGACTGCGAATAGCAGCATGATTCCARTGTTTCATGYYTYTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAARAATAA
77	leopard cat	TGAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCWTGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGYATGTATAGGCARATAAARAATAA
49	leopard cat	TGAAAGCTGTGGYTATGACTGCGAATAGCAGCATGATTCCRATGTTTCWTGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCARATAAARAAWAAAA
113	leopard cat	TATGACTGCGAATAGCAGCATGATTCCRATGTTTCAYGYYTYTGARAAGGTGTAGGAGCCATAATATATTCCTCSACCTMCKTGCATGTATAGGCARATAAAGAATAA
121	leopard cat	TGMWGCCYSYCMMWATGATTTTTGTTCTCTGKGCTGTCATTGAGAGGGGGKAAGAKCCATAATATRTTCCTCGACCTACGTGTWTGTWTAGGCWGATAAAGAATAA

127	leopard cat	TGAAMTGTGCCCCCCTTATGGTTTTTTTCTCTGCTYCKGGAGGAAAAGGAGTAAAAACCATAATATATTCCTCGACCTTGGGRATGTATAGGCAGATAAAGAATA
130	leopard cat	AGCAGMATGATTCCWRTGTTTCATGTCTCTGARAAGGTGTAGGAGCCWTAATATATTCCTCGACCTACGTGCWTGTWTAGGCAGATAAARAATAA
29	leopard cat	CCATGAAGTGTGGTATGACTGCGATAGCAGCATGATCCATGTTTCTGTCTCTGAGAAGGGAGGAGCCATAATATATTCCTCGACCTACGTGATGTATAGGCAGATA
70	leopard cat	CTGCGACTAGCAGCATGTGTTCCCTGTTTCATGTCTCGAGAAGGAGAAGGAGCCATAATATATTCCTCGACCTACGTGCAT
115	leopard cat	CCAGAGCTGAGGCTATGACTGCGAATAGCACATGTGTTCCATGTTTCATGTCTCTGACAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGG
136	leopard cat	CATGCAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGA
143	leopard cat	CCATGAAGTGTGGTATGACTGCGATAGCAGCTGATGCATGTTTCTGTCTCTGAAAGGGAGGACCTAATATATTCCTCGACCTACTGATGATAGGA
167	leopard cat	CCATGAAGTGTGGTATGATGCGATAGCAGCTGATTGCATGTTTCTGTCTCTGAAAGGGAGGACCATAATATATTCCTCGACCTACGTGATGATAGGAGATA
172	leopard cat	TGTGGCTATGACTGCGATAGCAGCATGAGTGCATGTTTCATGTCTCTGAGAAGGAGAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAA
216	leopard cat	TGTATTCCGTGTTTCATGTCTCTGAGAAGAAAGAAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATATGAAGATAAAGA
220	leopard cat	TGATGGCTATGACTGCGCAATAGCAGCATGTATTCCTCTGTTTCATGTCTCTGAGAAGGAGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGTCAGATAAAGAATAA
224	leopard cat	TATGACTGCGATAGCAGCATGATCCATGTTTCTGTCTCTGAAAGGAAAGGAGCCATAATATATTCCTCGACCTACGTGATGTATAGGCAGATAAAGATAA
234	leopard cat	GATGTGCCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGA
257	leopard cat	CCATGAAGTGTGGTATGATGCGATAGAGCTGTTCCATGTTTCTGTCTCTGAGAAGGGAGGAGCCATAATATATTCCTCGACCTACGTGATGATAGGCAGATAAAGAAA
258	leopard cat	TGGCTATGACTGCGAATAGCAGCATGGTTGCATGTTTCATGTCTCTGAGAAGGAGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGTGCAGATAAAGAA
259	leopard cat	GCAAGCTGAGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGA
264	leopard cat	TGTGGCTATGACTGCGAATAGCAGCATGATTCCATGTTTCWTGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAA
267	leopard cat	TGTGCTATGACTGCGATAGCAGCATGATCCATGTTTCTGTCTCTGAGAAGTGAGGAGCCATAATATATTCCTCGACCTACGTGATGTATAGGCAGATAAAGAATAA
268	leopard cat	TGATCCATGTTTCTGTCTCTGAGAAGGATAGGAGCCATAATATATTCCTCGACCTACGTGATGTATAGGCAGATAAAGA

269	leopard cat	TGAAGTGTGGTATGATGCGATAGAGATGATCCATGTTTCTGTCTCTGAAAGGGAGGAGCCTAATATATTCCTCGACCTACGTGATGTATAGGAGATAAAGAA
272	leopard cat	ATGAGCTTGTGTTCTCTGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAA
278	leopard cat	TATGACTGCGAATAGCAGCATGTGTTCCATGTTTCATGTCTCTGAAAAAAGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAA
417	leopard cat	CCATGAAGCTGAGGTATGATGCGATAGCAGCTGATTCCATGTTTCTGTCTCTGAGAAGGAGAGGAGCCATAATATATTCCTCGACCTACGTGATGTATAGG
418	leopard cat	TTGTTCCCTGGTTCTGTCTCTGAAAAGGCGGAGGAGCCTTACTATATTCCTCGGCCTACGTGCATGTATAGGCGGATGGCCCTAAACTGCC
424	leopard cat	TATGACTGCGAATATGAGTATGTGTTCCTCTGTTTCATGTCTCTGAAAAGGTGGAGGAGCCATAATATATTCCTCGACCTACGTGCATGTCTAGGCAGATAA
426	leopard cat	TGCCACATGATMTTGTGTTCTCTGTTTCATGTCTCTGAAAAGGGGAAGGAGCCATAATATATTCCTCGACCTACGTGCTTGTATAGGCAGATAAAGAATA
429	leopard cat	TATGACTGCGATACKAGATGATCCATGTTTCTGTCTCTGAGAAAGGAGGAGCCATAATATATTCCTCGACCTACGTGATGTATAGGAGATAAAGATA
430	leopard cat	CTGCTCACTATCAGTATGTGTTCCTCTGTTTCATGTCTCTGAGAAGGAGAAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATA
431	leopard cat	TGATGACTGCTAAATGATCTTGGTTCCTCTGTTTCATGTCTCTGAAAAGGGAAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATA
432	leopard cat	ATGATGCATAGAGATGATCCATGTTTCTGTCTCTGAGAAGGGRGGAGCCATAATATATTCCTCGACCTACGTGATGATAGGAGATAAAGATA
441	leopard cat	TGATGGCTATGACTGCGAATAGCAGCATGTATTGCTATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAATAA
452	leopard cat	TGAGAATATGACTGCGATAGCAGCATGATTCCATGTTTCTGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGATA
455	leopard cat	TATGGACTGCCACTAGCAGCATGATTCCTATGTTTCATGTCTCTGAGAAGGTGAAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGAAATAA
589	leopard cat	TGCGCCTATGGTTTTTTTCTGTGTTTCATGTCTCTGAAAGGGGAGGAGCTTAATATATTCCTCGACTACGTGCATGTATAGTCTGATTGGAATAA
282	leopard cat	TGCGATCCGCTAGGCTATGACTGCAAAAGCATCATGGTTCCGTGTTTCTGTCTCTGAGAGGTGTAGGAGCCTTAATATATTCCTCGACCTACGTGCATGTATAGGCGGAT
75	Leopard cat	CATGCAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGA
507	Leopard cat	CATGCAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGA
7	Leopard cat	CATGCAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGA

435	Leopard cat	CATGCAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGA
403	Leopard cat	CATGCAAGCTGTGGCTATGACTGCGAATAGCAGCATGATTCCAATGTTTCATGTCTCTGAGAAGGTGTAGGAGCCATAATATATTCCTCGACCTACGTGCATGTATAGGCAGATAAAGA
77	red fox	GAWGWGAWSATGGTTGCGAATATAAGATAAKTCAATATTTGRGGCTCTCTTACATAAGATCCATAATATAAGCCTCGGGGAGGTTTTATMGGCAGATAAAGAATA
168	red fox	ATATTTRAGGTCATTAATACATAAGATCCATAATATAAGCCTCGAGAGGCTAGGTMGGCAGATAAAGAAWAA
179	red fox	TGCSAACAATAAGATAATTCCAATATTTGRTGCTACAATGAATACATAAGATCCATAATATAAGCCTCGTAGGRAGGATWWATAGGCARAT
185	red fox	GCTGTGGCCATGGTTGCGAACWATAAGATAATTCCAATATTTCAGGGTATGAATACATAAGATCCATAATATAAGCCTCGTCCTAGGGAATGWRTAGGCARATAAA
464	red fox	GCGACAATRAGATTTTCCWRTATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGC
446	red fox	GCTGWGGCCRTGGYTGCRAACAATAARATAATTCCWATATTTCATGTTTCTATGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGG
448	red fox	ATCCATTATATAAGCCTCGTCCTACGTGYATGTATAGGCAGATAAAAAATATAACTGTTKYCCCGCMTATTGWTGT/ATCCATTATATAAGCCTCGTCCTACGTGYATGTATAGGCAGATAAAAAATATAACTGTTKYCCCGCMTATTGWTGTWCGTCGGGAGAGGTTTGATT
450	red fox	TGGYTGCGAWCAATAAGATAATTCCWATATTTAGGAACGATGAATACATAAGATCCATAATATAAGCCTCGKCTACRWGAATGTATAGGCAGATAAAAAATAA
453	red fox	GGTTGCRAACAATAARATAATTCCAATATTTCAYGTTTCTATGAATACATAARATCCATAATATAASCCYCSYCCTACGTGSATGTATAGGMARAWAA
460	red fox	TTGCSAWCAATAAGATAATTCCAATATTTATGTCKATGAATACATAAGATCCATAATATAAGCCTCGYCCTACGKGKAKGTATAGGMARA
461	red fox	ATAARATAATTCCWRTATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGYCCTACGKGCATGTRTRGGCA
462	red fox	TGTGGCCATGGTTGCRAACAATAARATAATTCCWATATTTCATGTTTCTATGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGATA
467	red fox	TKGCGAACAATAAGATAATTCCAATATTTCRTGKTTCTATGAATACATAAGATCCATAATATAASCCYCSYCCTACGTGSATGTATAGGMA
469	red fox	GCTGTGGCCATGGTTGCGAACAATAARATAATTCCATATTTCATGTTTCTATGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGCATGTAT
470	red fox	GGCTCCCAACATATTTTTTTCCTCTATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGCAGATKC
471	red fox	GCTGTGAGCCATGGCCGCGAACATAAGATATTTCCATATTTCCTGTTTCTATGAGACCTAAGATCCATAATATAAGCCTCGYCCTACGKGSRTGGTAGG
291	red fox	GMTGWGRCCATGGTTGCCAACAATAAGATAATTCCAATATTTCATGTCAAAAGAATACATAAGATCCATAATATAASCCTCGTCCTA
328	red fox	TGGATGCTGWGGCCATGGTTGCSACAATAARATAATTCCAATATTTCATGTTTCTATGAATACATAARATCCATAATATAASCCTCGTCCTACGTGCATGTATAGGCARATAAAGA
337	red fox	TGAATGCTGTGGCCATGGTTGCRAACAATAARATAATTCCAATATTTCATGTTTYTWTRAATACATAARATCCATAATATAAGCCTCGTCCTACGTGYWTGWATAGGMARAWAAA
338	red fox	TGAATGCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCAKGTTYYTWTGAATACATAAGATCCATAATATAAGCCTCG

		YCCTACGTGYWTGWATAGGMARATAA
341	red fox	CGGGTACGTAGCCATAAATGCTGTGSCCATGGTTGCRAACAWTAAGATGATTCCAATWTTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCCACGTGYATGTAT
342	red fox	TGCTGTGSCCATGGTTGCRAACAATAARATGATTCCAATATTTCATGTTYYTWTGAATACATAARATCCATAATATAASCCYCGYCCCACGTGYATGWATAGGMARATAAARAAWAA
343	red fox	GCTGTGGCCATGGTTGCGAACAATAAGATGATTCCAATATTTCATGYYYYTWTGAATACATAARATCCATAATATAASCCYCSYCCCACGTGYATGWATAGGMARATAAARAA
345	red fox	ATATATGCTGWGGCCATGGTTGCSAACAATAAGATGATTCCAATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCCACGTKYATGWATAGGCARA
347	red fox	ATGCTGTGGCCATGGTTGCGAACAATAAGATGATTCCAATATTTCATGTYYYTWTRAATACATAARATCCATAATATAAGCCYCSYCCCACGTGYWTGWATAGGMARATAAARAAWAA
348	red fox	CCATAAATGCTGTGGCCATGGTTGCRAACAATAARATGATTCCAATATTTCATGTTTYTWTRAATACATAAGATCCATAATATAAGCCTCGYCCCACGTGYWTGWATAGGMARATAAARAAWAA
349	red fox	CCATAAATGCTGTGGCCATGGTTGCGAACAATAAGATGATTCCAATATTTCATGTTYYTWTGAATACATAAGATCCATAATATAAGCCYCSYCCCACGTGYATGTATAGGMARATAAARAAWAA
351	red fox	GCTGTGGCCATGGYTGCGAACAATAARATAWTTCCAATATTTCATGTTTCRATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGSATGTATAGGCAGATAAAGAATAA
353	red fox	CCATAAATGCTGTGGCCATGGTTGCRAACAATAARATAATTCCAATATTTCATGYYYYTWTGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGMARAWAA
354	red fox	AATGCTGTGSCCATGGTTGCGAACAATAAKATAWTTCCAATATTTCATGTTTCTWTGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYWTGTATAGGCARA
356	red fox	GCTGWGSCCATGGTTGCMAACAATAAKATGATTCCWMTATTTCATGTTTCTATGARTACATAAGATCCATAATATAAGCCTCGTCCCACGTGTWTGWATA
357	red fox	TGCTGWGRYCATGGTTGCRAACAATAARATGATTCCAATATTTCATGTTTYTWTGAATACATAARATCCATAATATAAGCCTCGTCCCACGTGYWTGWATAGGMARATAAARAAWAA
492	red fox	GCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGYYYYTWTGAATACATAAGATCCATAATATAAGCCTCGYCCTACGTGYATGTATAGGMARATAAARAAWAAAA
494	red fox	GCTGTGGCCATGGTTGCGAACAATARGATAATTCCAATATTTCAKGTYYYTWTGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGMARATAAARAAWAAAA
495	red fox	TGCTGTGGCCATGGTTGCRAACAATAARATAATTCCAATATTTCATGTTTYTWTRAATACATAARATCCATAATATAASCCTCGTCCTACGTGYWTGWATAGGMARAWAAARAA
496	red fox	ATGAATGCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGYYYYTWTGAATACATAAGATCCATAATATAASCCTCSYCCTACGTGYATGWATAGGMARATAAARA
498	red fox	ATGCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGTYYYTWTGAATACATAARATCCATAATATAASCCYCGTCCTACGTGYATGTATAGGMARATAAARAA
500	red fox	GCKGTGGCSATGGTTGCGAACAATAARATAATTCCAATATTTCRKGTYYYTWTGRATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGWATAGGMARATAAARAAWAA
503	red fox	GTRAWGMWGWGRYCATGGYYGCSMACAWTRARATRATTCCWATATTTCATGTTARAGAAAWACATAAGAWCCATAATATAAGCCTCGTCCTACGTGTTTGTRTRGGCAGATAAAGAATA

504	red fox	ATGGTTGCGAACAATAARATAATTCCAATATTTCATGYTTYTWTGRATACATAARATCCATAATATAAGCCYCGTCCTACGTGYATGTATAGGCARATAAARAAWAAAA
505	red fox	GCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGYYYYTWTGAATACATAAGATCCATAATATAAGCCYCGYCCTACGTGYATGWATAGGMARATAAARAAWA
506	red fox	AATGCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGTYYYTWTGAATACATAAGATCCATAATATAAGCCTCSYCCTACGTGYATGTATAGGMARATAAARAA
529	red fox	GWGRYCATGGTTGCGAACAATAAGATAWTTCCWATATTTCATGTTTYTATGAATACATAARATCCATAATATAASCCTCGTCCTACGTGYATGTATAGGMARATAAARAA
463	red fox	TGGYYSCCAAYAATAARATAATTCCAATATTTCATGTGGTAAGAAWACATAAGATCCATAATATAASCCTCGTCCTACGTGCATGWRWAGGCARATAAARAAWAAA
534	red fox	GAATGCTGTGGCCATGGTTGCGAACAATAAGATAATTCCAATATTTCATGYYYYTWTGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGCARATAAARAA
535	red fox	AATGCTGTGGCCATGGTTGCGAACAATARRATARTTCCAATATTTCATGTYYYTWTGAATACATAWSATCCATAATATAAGCCTCGTCCTACGTGYWTGTATAGGCARATAAARAA
491	red fox	TGGTTGCRAACAATAARATAATTCCAATATTTCATGTTTCTATGAATACATAARATCCATAATATAASCCTCGTCCTACGTGYATGTATAGGMARATAA
151	red fox	GMTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGYYTYTWTGAATACATAAGATCCATAATATAASCCYCGTCCTACGTGSATGTATAGGMARAWAAARAAWAAAA
36	red fox	TAAKATAATTCCWTATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGSATGKATAGGCAGATAA
40	red fox	TGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGYYYYTWTGAATACATAARATCCATAATATAAGCCYCGYCCTACGTGYATGWATAGGMA
56	red fox	TTGCGAACAATAARATAATTCCAATATTTCATGTTTCTATGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGSATGTATAG
475	red fox	GATGAGCTTATGGTTGCSAACAATAAKATAATTCCTSATTTCATGTGGAAAGGAATACATAAGAWCCATAATATARGCCTCGTCCTACGTGTTTGWGTGGGCAGATAAAGATAAT
477	red fox	TGAATGCTGTGGCCATGGTTGCRAACAATAARATAATTCCAATATTTCATGTTAAAAGAAWACATAAGATCCATAATATAASCCYCGYCCTACGTKYATGWATRGGMARATAAARAAWAAAAAYTG
486	red fox	TACGTAKSCATGAATGCTGTGSCCATGGTTGCMAAYAWTAAGATAATTCCWTATTTCATGTTAAAAGAAWACATAARAWCCATAATATAAGCCTCGTCCTACG
488	red fox	TGCTGTGGCCATGRTTGCMACAATAAGATAATTCCATATTTCATGTGGACAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGAAAGAATAGGSAA
569	red fox	TGTGGCCATGGTTGCGAACAATAAGATAATTCCAATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGATAAAGA
577	red fox	GCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGTTTCTATGAATACATAARATCCATAATATAASCCTCSTCCTACGTGYATGTATAGGMARAWAAARAA
578	red fox	GCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGTTTYTATGAATACATAARATCCATAATATAASCCYCSTCCTACGTGCATGTATAGGMA
579	red fox	CATGGYTGCSAACAATAAGATAWTTCCAATATTTCATGYYTYTATGAATACATAARATCCATAATATAASCCYCGTCCTACSTGYATGWATAGGMARATAAARAA

580	red fox	CCATGGTTGCGAACAATAARATAATTCCAATATTTCATGTTTCTATGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGCARATAAAGAATAA
581	red fox	TGWGGCCATGGTTGCSAACAATAAGATAATTCCWATATTTCATGTTTCTATGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGYWTGTATAGGCARATAAA
583	red fox	TGGTTGCGAACAATAARATAATTCCAATATTTCATGYTTYTATGAATACATAARATCCATAATATAASCCTCGTCCTACGTGYATGTATAGGCARATAAARAAWAAAA
584	red fox	GMTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCAKGTTTYTATGAATACATAARATCCATAATATAASCCYCGTCCTACGTGYATGTATAGGMARAWAAARAA
585	red fox	TGCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATWTTTCWKGTTTYTATGAATACATAAGATCCATAATATAASCCYCSYCCTACGTGYATGTATAGGMARAWAAARAAWAA
591	red fox	ATGAKATTGTCCTCTMTTTCATGTTTCTATGAATACATAAAATCCATAATATAAGCCTCGTCCTACGTGKATGTATAGGCAGATAAAGAATAAAMAT
592	red fox	CAATAAGATAATTCCAATATTTCRKGTYTYTATGAATACATAARATCCATAATATAAGCCYCSTCCTACSTGYATGTATAGGMARAWAARAAWAAAA
593	red fox	TGCTGTGGYCATGGTTGCGAACAATAARATAWTTCCAATATTTCATGTTTYTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGCARATAAAGAATAA
86	red fox	TGAATGCTGTGGCCATGGTTGCGAACAATAAGATAATTCCAATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGCARATAAARAA
202	red fox	TGGTTGCGAACAATAAGATAATTCCAATATTTCAKGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGCARATAAARAATAA
183	red fox	TGTGGCCATGGTTGCGAACAATAARATAATTCCAATWTTTCRKGTTTYTATGAATACATAAGATCCATAATATAASCCYCSYCCTACGTGYATGTATAGGMARAWAAARAAWAA
54	red fox	TGWGGCCATGGTTGCCACAATAAGATAWTTCCAATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGMAGAT
48(13)	red fox	TGAATGCTGTGSCCATGGYTGCRAACAATAARATAWTTCCAATATTTCATGTTTYTATGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGMARATAAARAA
52(17)	red fox	TGAATGCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGTTTYTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGMARAWAAARAAWAA
53	red fox	TGATGCTGWGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCARATAAARAAWAAAA
55	red fox	TGTATGCTGTGSYCATGGYTGCSAACAATAARATAWTTCCWATATTTCATGTTTCTATGAATACATAARATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGATAAAGAATAAA
56	red fox	TGAATGCTGTGSCCATGGTTGCRAACAATAAGATAATTCCAATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGSATGTATAGGCARATAAARAATAAA
57	red fox	TGAATGCTGTGSCCATGGTTGCRAACAATAARATAWTTCCAATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGATAAAGAATAAA
59	red fox	TGTAATGCTGTGGYCATGGTTGCRAACAATAARATAATTCCWATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGMARATAAA
60	red fox	TGATGCTGTGGCCATGGTTGCGAACAATAAGATAATTCCAATATTTCAKGTTTYTATGAATACATAAGATCCATAATATAAGCCTCGTCC

		TACGTGYATGTATAGGCARATAAARAAWAAAA
63	red fox	TGTAATGCTGTGGCCATGGTTGCRAACAATAAGATAATTCCAATATTTCATGYTTYTATGAATACATAAGATCCATAATATAASCCTCGTCCTACGTGYWTGTATAGGMARATAAARAAWAAAA
65	red fox	TGAATGCTGTGGCCATGGTTGCRAACAATAAGATAATTCCAATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGYATGTATAGGMARATAAARAAWAAAA
66	red fox	CATTATGCTGAGCTGTGCCTGTCACATGATATTTTCCTCTATTTCATGTTTCTATGAATACATAAGATCCWTAATATMMGCCTCGTCCTACGTGTTTGTWTAGGCAGATAA
69	red fox	ATGATGCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCWKGTTTYTATGAATACATAAGATCCATAATATAASCCTCSTCCTACGTGYATGTATAGGMARATAAARAAWAA
70	red fox	CATGAATGCTGTGGCCATGGTTGCGAAYAATAARATAATTCCAATATTTCATGTTTCTAWRRATACATAARATCCATAATATAAGCCTCSTCCTMCSTKYATGWATAGGMARATAAARAAWAA
71	red fox	CATGATGCTGTGGCCATGGTTGCGAACAATAARATAATTCCAATATTTCAKGTTTYTATGAATACATAAGATCCATAATATAASCCTCSTCCTACGTGYATGTATAGGMARATAAARAAWAA
72	red fox	CCATGAATGCTGTGGCCATGGTTGCGAACAATAAGATAATTCCAATATTTCWKGTTTYTATGAATACATAAGATCCATAATATAASCCYCSTCCTACGTGYATGTATAGGCARATAAARAAWAA
82	red fox	AGCCATGAATGCTGTGGCCATGGTTGCGAACAATAAGATAATTCCAATATTTCATGYYTYTATGAATACATAARATCCATAATATAASCCTCGTCCTACGTGYATGTATAGGMARATAAARAAWAAAA
63	red fox	CATGTAATGCTGTGGCCATGGTTGCGAACAATAAGATAATTCCAATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGATA
65	red fox	GGTTGCGAACATAAGATAATTCCATATTTCTGTTTCTATGAAACAAAGGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGATAAAGA
67	red fox	GCATGAGAGCCGTGGCTGCGAACAATAAGATGTATTCCTGTATTTCATGTTTCTATGAAAACATAAGATCCATAATATAAGCCTCGTCCCGCGTGYATGTATAGGCAGATA
106	red fox	TCAAGCTGAGCTCAGGCTGCCAAATTATGATTTTGCTGTATTTCATGTTTCTATGAAAAGAAGATCCATAATATAAGCCTCGTCCTACGTGCTATGTCAGTCTATGAAT
438	red fox	GCTGTGAGCCATGGTTGCGAAAATAAGATAATTCCTATATTTCATGTTTCTATGAAACAGAAGATCCATAATATAAGCCTCGTCCTACGTGSATGTATAGGCAGATAAAGAATAA
479	red fox	ATGCTGTGGCCTGGTTGCGAACATAAGTATTCCATATTTCTGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGATGATAGGCAGATAA
480	red fox	TGCGACATAATTATTCCATATTTCTGTTTCTATGAATACAGTAGAACCATAATATAATCCTCGTCCTACGTGATGTATAGGCAGA
481	red fox	TGCTGTGGCTGGTTGCGAACATAAGAATTCCATATTTCTGTTTCTATGAATAAAAAGATCCATAATATAAGCCTCGTCCTACGTGATGTATAGGAAAATAAAGA
482	red fox	TGTGGCTGGTGCGAAATATGRTTTTCCATATTTCTGTTTCTATGATACTAAGAGCCTAAATAAGCCTCGTCCTACGTGATGATA
483	red fox	TAGATGCTGTGGTCATGGCTGCGAACAATATGATGATTCCTATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGATAAAG
484	red fox	GCTAGGTCCGGCTGCCAAAATATGATTTTGCTCTATTTCTGTTACTATGAATAAGAAAATCCATAATATAAGCCTCGTCCT
485	red fox	CATGATGCTGTGGCATGGTTGCGAACATAAGAAATTCCATATTTCTGTTTCTATGAATACATAAGATCCATAATATAAGCCTCSTCCTACGTGCATGTATAGGCAGAT

487	red fox	TGCTGTGGTCATGGCTGCGAACAATAAGATATATTCCTATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGA
490	red fox	TGCGACAATAAGATTTTCCATATTTCATGTTTCTATGAAACAAAAAATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGAT
587	red fox	TGCGAACAATAAGATAATTCCTATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAG
489	red fox	TAGATGCTGTGGTCATGGCTGCGAACAATATGATGATTCCTATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGATAAAG
323	red fox	GCATGAGAGCCGTGGCTGCGAACAATAAGATGTATTCCTGTATTTCATGTTTCTATGAAAACATAAGATCCATAATATAAGCCTCGTCCCGCGTGYATGTATAGGCAGATA
517	red fox	TCAAGCTGAGCTCAGGCTGCCAAATTATGATTTTGCTGTATTTCATGTTTCTATGAAAAGAAGATCCATAATATAAGCCTCGTCCTACGTGCTATGTCAGTCTATGAAT
518	red fox	GCTGTGAGCCATGGTTGCGAAAATAAGATAATTCCTATATTTCATGTTTCTATGAAACAGAAGATCCATAATATAAGCCTCGTCCTACGTGSATGTATAGGCAGATAAAGAATAA
533	red fox	ATGCTGTGGCCTGGTTGCGAACATAAGTATTCCATATTTCTGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGATGATAGGCAGATAA
164	red fox	TGCGACATAATTATTCCATATTTCTGTTTCTATGAATACAGTAGAACCATAATATAATCCTCGTCCTACGTGATGTATAGGCAGA
165	red fox	TGCTGTGGCTGGTTGCGAACATAAGAATTCCATATTTCTGTTTCTATGAATAAAAAGATCCATAATATAAGCCTCGTCCTACGTGATGTATAGGAAAATAAAGA
527	red fox	TGTGGCTGGTGCGAAATATGRTTTTCCATATTTCTGTTTCTATGATACTAAGAGCCTAAATAAGCCTCGTCCTACGTGATGATA
528	red fox	TAGATGCTGTGGTCATGGCTGCGAACAATATGATGATTCCTATATTTCATGTTTCTATGAATACATAAGATCCATAATATAAGCCTCGTCCTACGTGCATGTATAGGCAGATAAAG
531	red fox	GCTAGGTCCGGCTGCCAAAATATGATTTTGCTCTATTTCTGTTACTATGAATAAGAAAATCCATAATATAAGCCTCGTCCT

Understanding the distribution and fine-scale habitat selection of mesocarnivores along a habitat quality gradient in western Himalaya

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ABSTRACT

Background: Human activities have resulted in a rapid increase of modified habitats in proximity to wildlife habitats in the Himalaya. However, it is crucial to understand the extent to which human habitat modification affects wildlife. Mesocarnivores generally possess broader niches than large carnivores and adapt quickly to human activities. Here, we use a case study in the western Himalaya to test the hypothesis that human disturbance influenced mesocarnivore habitat use.

Methods: We used camera trapping and mitochondrial DNA-based species identification from faecal samples to obtain mesocarnivore detections. We then compared the responses of mesocarnivores between an anthropogenic site and a less disturbed park along a contiguous gradient in habitat quality. The non-linear pattern in species-specific habitat selection and factors responsible for space usage around villages was captured using hierarchical generalized additive modelling (HGAM) and non-metric multidimensional scaling (NMDS) ordination.

Results: Wildlife occurrences along the gradient varied by species. Leopard cat and red fox were the only terrestrial mesocarnivores that occurred in both anthropogenic site and park. We found a shift in habitat selection from less disturbed habitat in the park to disturbed habitat in anthropogenic site for the species detected in both the habitat types. For instance, red fox showed habitat selection towards high terrain ruggedness (0.5 to 0.7 TRI) and low NDVI (−0.05 to 0.2) in the park but no such specific selection in anthropogenic site. Further, leopard cat showed habitat selection towards moderate slope (20°) and medium NDVI (0.5) in park but no prominent habitat selections in anthropogenic site. The results revealed their constrained behaviour which was further supported by the intensive site usage close to houses, agricultural fields and human trails in villages.

Conclusions: Our results indicate shifts in habitat selection and intensive site usage by mesocarnivores in the human-modified habitat. In future, this suggests the possibility of conflict and disease spread affecting both the people and wildlife. Therefore, this study highlights the requisite to test the wildlife responses to rapidly growing human expansions in modified habitats to understand the extent of impact. The management strategies need to have an integrated focus for further expansions of modified habitat and garbage disposal strategies, especially in the human-wildlife interface area.

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Additional Information and Declarations can be found on page 19

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INTRODUCTION

Human settlement is one of the most substantial factors modifying habitat conditions for wildlife worldwide (*Vitousek et al., 1997*; *Andersen et al., 2017*). The encroachment of human settlements into surrounding ecosystems creates new ecological niches (*Mckinney, 2002*) and also alters existing niches. As a result, there are opportunities for an increase in anthropogenic food sources for wildlife in and around the human settlements (*Verdade et al., 2011*). These food sources benefit some species by affecting their behaviour, distributions and interspecific interactions (*Parmesan, 2006*). For instance, coyotes and white-tailed deer were considered sensitive to human activities but have colonised urban landscapes in recent decades (*Ditchkoff, Saalfeld & Gibson, 2006*). Further, a wide range of wild carnivores inhabited the cropland landscape (*Athreya et al., 2013*) and agroecosystem matrix (*Ferreira et al., 2018*). Some carnivores adapt quickly to human-modified habitats by utilising anthropogenic food sources (*Ghoshal, 2011*; *Athreya et al., 2016*; *Naha et al., 2020b*), while some are adversely affected by these habitat alterations (*Carricondo-Sanchez et al., 2019*).

The Himalaya has faced consistent pressure from increased human settlements due to agricultural practices, more intensive grazing by domestic animals and increased demand for timber (*Cronin, 1979*; *Schaller, 1980*). Consequently, the increasing quantity and proximity of readily available anthropogenic subsidies facilitate increasing dependencies of native carnivores on these resources (*Ghoshal, 2011*; *Ghoshal et al., 2016*; *Rajaratnam, Vernes & Sangay, 2016*; *Khan et al., 2020*). Additionally, the natural resources are localised in the rugged landscapes and often are not readily available to carnivores compared to the anthropogenic food resources. Moreover, when anthropogenic food resources replace natural prey due to habitat modifications, such changes affect wildlife distribution (*Ripple et al., 2014*; *Parsons, Newsome & Young, 2022*). In this context, there is a paucity of information regarding the modified habitats adjacent to less disturbed natural forests and their effect on the native wildlife in the rugged landscape of Himalaya.

In this study, we studied mesocarnivores to understand the impact of habitat modification in the western Himalaya. Mesocarnivores are known for their diverse behaviour and ecology; hence they are more generalist when living in close proximity to humans than large carnivores (*Roemer, Gompper & Van Valkenburgh, 2009*). Their diverse nature makes them receptive to small-scale habitat alterations, and they responds more quickly than large carnivores (*Randa & Yunger, 2006*). Thus, they serve as helpful indicator species in preserving sensitive habitats (*Kalle et al., 2013*; *Torre et al., 2022*). Apart from being an indicator species, mesocarnivores efficiently utilise anthropogenic food sources, like garbage dumps, agricultural products, kitchen wastes and livestock carrions (*Reshamwala et al., 2018*), due to their opportunistic behaviour and ability to adapt to modified habitats (*Rajaratnam et al., 2007*; *Lorica & Heaney, 2013*). In this situation, the site usage near human habitations by mesocarnivores enables the shared spaces by wildlife and human to be the most probable zone for zoonotic disease spread (*Ghimire, Regmi & Huettmann, 2020*) and conflict risks (*Peterson et al., 2021*). Mesocarnivores are known to be the potential hosts of zoonoses at the wildlife-livestock-human interface (*Yang et al., 2021*). That is why transmission of diseases like rabies, canine distemper viruses and anthrax can occur bi-directionally, affecting both humans and wildlife (*Beineke, Baumgärtner & Wohlsein, 2015*; *Muturi et al., 2018*; *Acharya et al., 2020*; *Gonzálvez, Martínez-Carrasco & Moleón, 2021*). Therefore, knowledge of mesocarnivore space usage in human-modified habitats can aid in improving management strategies in the light of future outbreaks of zoonotic diseases and conflict probabilities (*Alexander et al., 2012*; *Theimer et al., 2017*; *Ng et al., 2019*; *Ferreira et al., 2021*; *Veals et al., 2021*).

The Great Himalayan National Park Conservation Area (GHNPCA) of Western Himalaya comprises of heterogeneous habitat gradient. Hence, we considered it as the study site to understand the responses of mesocarnivores to habitat modification in ecozone (henceforth, anthropogenic site) and national park (henceforth, park). Change in carnivore habitat selection from a relatively less human-disturbed to a more human-disturbed area in favour of easily available resources can be seen in a continuum of mosaic habitats (*Boydston et al., 2003*). Therefore, studying carnivore distribution along the habitat gradient consisting of both the human-modified and natural forest (*Andersen et al., 2017*) will aid in (a) understanding the status of the human-wildlife interface and (b) enabling integrated management of nature and people in the susceptible landscapes. In the context of anthropogenic habitat in GHNPCA, the human population was 15,000 from 160 villages in 1995 (*Tucker, 1997*), reaching about 9,000 in just six villages in 2011 (www.census2011.co.in). With the increase of human population, there were conversions of forested habitats into arable lands for agricultural practices (*Tucker, 1997*). Since settlements and agricultural plots generate human-induced resources (*Verdade et al., 2011*), there are chances that the resources are available in more quantity and close to natural habitat than before. We used 3rd order habitat selection of mesocarnivores related to the usage of habitat components within the home range (*Johnson, 1980*). We expected mesocarnivores to show changes in habitat selection in anthropogenic site relative to park in GHNPCA. Mesocarnivores prefer fine-scale forest fragments (*Červinka et al., 2011*) and use a variety of habitats (*Gese & Thompson, 2014*). Therefore, we selected habitat variables like slope, ruggedness, elevation, normalized difference vegetation index (NDVI) and distance to woodland (riparian forest at hill base) to identify the changes in the habitat selection. The selected potential habitat variables important for mesocarnivores occurrences also aligned with other studies where elevation, terrain ruggedness, *etc*., were used as explanatory variables for red fox and leopard cat occurrences (*Parsons et al., 2019*; *Kalle et al., 2013*). Although some studies have shown the utilization of human-modified habitats by mesocarnivores in the Himalayas and other areas (*Verdade et al., 2011*; *Lorica & Heaney, 2013*; *Bashir et al., 2014*; *Ghoshal et al., 2016*), information regarding the scale of such utilization is still scarce. Hence, the study focuses on the following objectives: (1) To understand the distribution pattern of mesocarnivores along the habitat gradient; (2) to determine species-specific habitat selection of mesocarnivores in the park and anthropogenic site; and (3) to determine factors responsible for space usages by mesocarnivores in the anthropogenic site.

MATERIALS AND METHODS

Study area

The Great Himalayan National Park Conservation Area (GHNPCA), a UNESCO world heritage site (UNESCO, 2011; UNESCO, 2014: https://whc.unesco.org/en/list/1406/), is located in the Kullu district of Himachal Pradesh, western Himalaya, India (Fig. 1). The area of GHNPCA covers four catchments (river), viz., Parvati, Jiwa, Sainj and Tirthan. The administrative boundary divides into anthropogenic sites representing the buffer area and park representing the core forest area. We selected Tirthan for the intensive studies due to the similarity in habitat characteristics with the entire GHNPCA (*Singh & Rawat, 1999*). Tirthan catchment (300 sq. km.) represents a highly variegated landscape with lower temperate Chir pine (*Pinus roxburghii*), Banj oak (*Quercus leucotrichophora*) and open scrubs at lower elevation (<2,000 m) to upper temperate Fir (*Abies pindrow*), Kharsu oak (*Quercus semecarpifolia*) forests and alpine meadows at high elevation (2,500 to 4,000 m) within an aerial distance of 35 km. A detailed list of the composition of the vegetation structure is available in *Singh & Rawat (1999)*.

Camera trapping

We conducted camera trapping in five sessions from 2017 to 2019, covering the anthropogenic site and park in all the human-established trails. Number of sampling locations (n) and days of effort (t) in the respective five sessions were April–July 2017; n = 59, t = 2,986, October–December 2017; n = 78, t = 2,589, April–July 2018; n = 40, t = 1,791, October–December 2018; n = 82, t = 2,737 and April–June 2019; n = 81, t = 1,763. We deployed 340 camera traps from 2017 to 2019 (Fig. 1, Figs. S1 to S5) (Table S1). Total camera trap effort was 11,866 (no. of camera traps × operational days). The total number of camera traps and effort in the anthropogenic site were 120 and 2,582, and in the park, 220 and 9,284, respectively. Table S1 consists of detailed information regarding the number of days of each camera trap. We deployed camera traps systematically with a minimum distance of 0.5 km and a maximum distance of 1 km between each consecutive trap location.

Faecal sampling

We could not conduct camera trapping and regular monitoring in some areas inside the park as the habitats have rugged terrain and harsh climatic conditions (*Ramesh, Sathyakumar & Rawat, 1999*; *Singh & Rawat, 1999*). Therefore, we adopted non-invasive methods like faecal sample collection to cover the relatively inaccessible areas inside the park for mesocarnivores showing high detections through camera trapping. Following the dry sampling protocol, we collected carnivore faecal samples opportunistically during the same period (*Biswas et al., 2019*). We surveyed 125 trails, each length 500 m (Fig. 1) (Table S1), and collected 161 carnivore faecal samples. We stored the samples at −20 °C

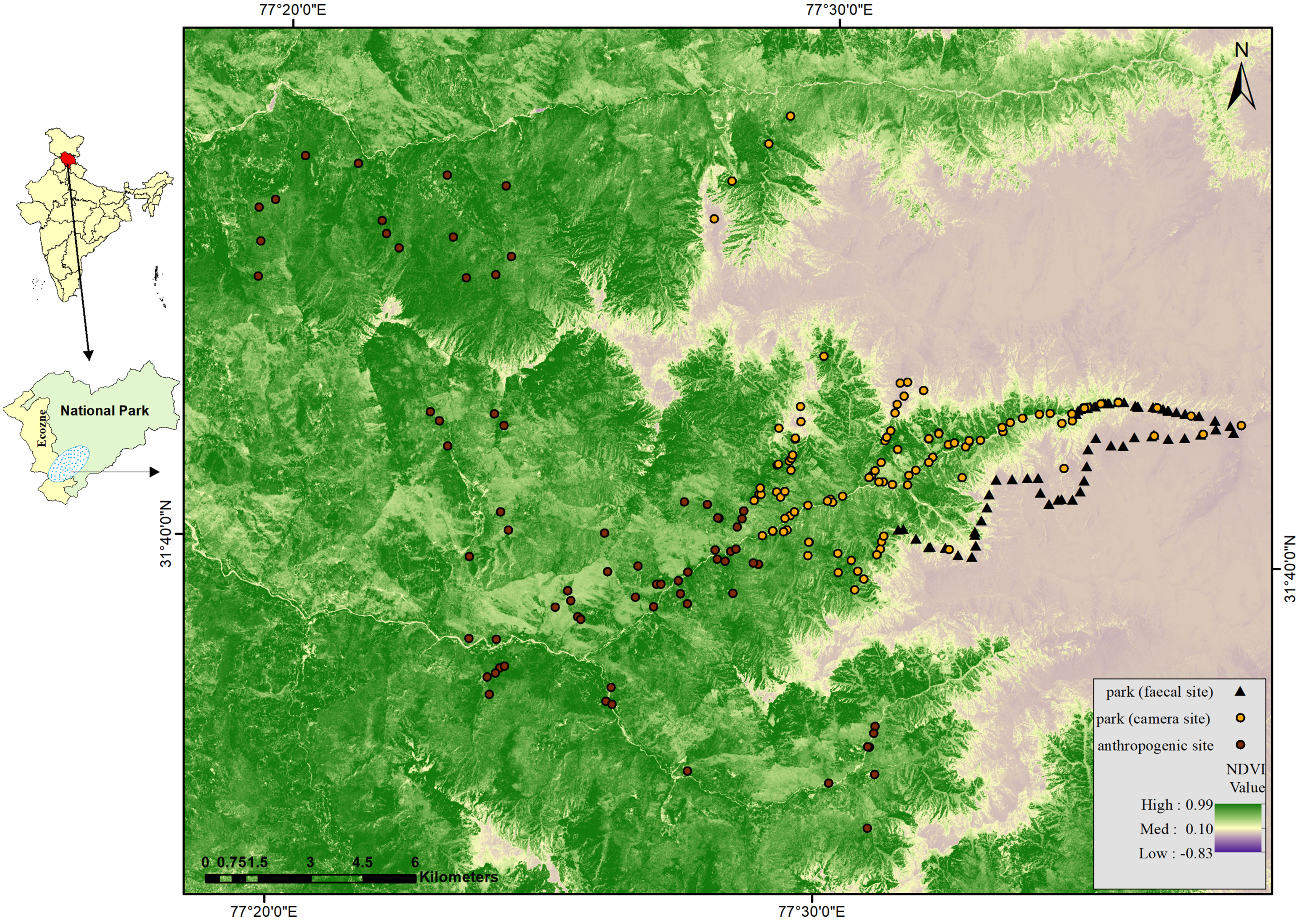

Figure 1 **Map of GHNPCA showing sampling in park (faecal site) (survey trail mid points = 125), park (camera site) (camera trap locations = 220) and anthropogenic site (camera trap locations = 120) during 2017 to 2019.** Full-size DOI: 10.7717/peerj.13993/fig-1

and subjected them for mesocarnivore species confirmation using molecular markers (Cytochrome b, 146 bp) because of the presence of other sympatric carnivores (*Vinod & Sathyakumar, 1999*; *Bandyopadhyay, Dasgupta & Krishnamurthi, 2019*) in the study area.

Species confirmation

We extracted DNA from faecal samples by swabbing the outer layer and following the protocol described in *Ball et al. (2007)* and *Biswas et al. (2019)*. Further, we used a carnivore-specific molecular marker (Cytochrome b, 146 bp) to ascertain the species (*Farrell, Roman & Sunquist, 2000*). We performed PCR reactions in 10 µl reaction volumes with 5 µl multiplex master mix, 1 µl of bovine serum albumin (BSA), 0.8 µl of each primer, 0.4 µl RNAse free water and 2 µl of template DNA. PCR conditions were 95 °C for 10 min followed by 38 cycles at 95 °C for 30 s, annealing at 55 °C for 50 s and extension 72 °C for 50 s, with a final extension of 72 °C for 10 min. We monitored the effectiveness and consistency of the PCR reactions by using positive and negative controls. The amplified

PCR amplicons were visualized in UV light on 2% agarose gel stained with green stain dye. Exonuclease I (EXO-I) and shrimp alkaline phosphatase (SAP) (Thermo Scientific, Waltham, MA, USA) treatments were given to the amplified PCR products for 15 min each at 37 °C and 80 °C, respectively, to eliminate any residual primer and unused dNTPs. The amplified PCR products were sequenced using the BigDye® Terminator cycle sequencing Kit (v3.1; Thermo Fisher Scientific, Waltham, MA, USA) and analyzed on an ABI 3500XL Applied Biosystems Genetic Analyzer (ABI 3500xl, Applied Biosystems, Waltham, MA, USA). Finally, we identified the sequences by comparing them in the NCBI database using the BLAST tool (http://blast.ncbi.nlm.nih.gov/Blast.cgi).

Data analysis

Distribution pattern

We used 15 min as the minimum interval to consider species detection from camera traps (photo capture, C) as independent detections for estimating the relative abundance index (RAI; capture rate per 100 trap night) of mesocarnivores in the park and anthropogenic site. Red fox (*Vulpes vulpes*) and leopard cat (*Prionailurus bengalensis*) were the only terrestrial mesocarnivores detected in the park and anthropogenic site. Thus, we considered red fox and leopard cat for further analyses and calculated the total detections and RAI in the park and anthropogenic site. We calculated the RAI of red fox and leopard cat for all five sessions and plotted it against the respective locations (latitude and longitude). We used the package *"camtrapR"* in R (v.4.0.5; *R Core Team, 2021*) to generate the plots. We used the resulting plots to determine the distribution pattern of each mesocarnivore along the habitat gradient covering park and anthropogenic site.

Habitat selection

The anthropogenic site was situated at the lower reaches (<2,500 m), while the park was at the higher side (>2,500 m) of the elevation gradient. The park and anthropogenic site demonstrated overlapping values of the covariates of interest like, terrain ruggedness, slope, NDVI and distance to woodland (because of riparian forest at hill base and grasslands at hill brows). For instance, terrain ruggedness overlapped highly (0.3 to 0.6 in anthropogenic site and 0.3 to 0.7 inside park) and elevation had low overlap (1,500 to 2,900 m in anthropogenic site and 2,000 to 4,300 m in park) (Figs. S6 to S10, Table S2). Thus, the habitat characteristics in park and anthropogenic sites were comparable except for the presence of human settlements in the latter. The villages were majorly located near the river at lower reaches on hill slopes, hill base, less rugged terrain, and woodlands. In this condition, species with specific habitat preferences in their natural state might likely differ when exposed to anthropogenically modified habitats (*Schuette et al., 2013*).

We selected habitat variables based on red fox and leopard cat ecology. We identified five habitat variables as potentially significant predictors where red fox (*McDonald et al., 2017*; *Sacks, Statham & Wittmer, 2017*; *O'Malley et al., 2018*; *Martin-Garcia et al., 2022*) and leopard cat (*Bashir et al., 2014*; *McCarthy et al., 2015*; *Can et al., 2020*) were likely to occur: elevation, slope, terrain ruggedness, NDVI and distance to woodland (riparian forests at hill base). Red fox preferred alpine meadows (high elevation, moderate slope), rugged terrain, and open and rocky areas (low NDVI) (*Weber & Meia, 1996*; *Murdoch et al., 2016*; *Kumar, Magar & Kumar Dhamala, 2019*; *Naseer et al., 2020*), and grasslands at hill brow (away from woodland at hill base) (*Sacks, Statham & Wittmer, 2017*; *Rodríguez et al., 2020*) in natural forests and used variety of habitats in anthropogenic areas (*Mueller, Drake & Allen, 2018*; *Jahren et al., 2020*; *Jackowiak et al., 2021*). Hence, we expected red fox to show habitat selection towards high rugged, high elevation, moderate slope, low NDVI and away from woodlands inside the park and no habitat selection pattern in anthropogenic site. On the other hand, leopard cat occurred in temperate to sub-alpine forests (>3,000 m, moderate slope) (*Mishra, Madhusudan & Datta, 2006*; *Thapa et al., 2013*; *Irawan et al., 2020*). Leopard cats prefer rugged terrain, tree-covered (high NDVI), and woodland habitats (*Ghimirey & Ghimire, 2010*; *Bashir et al., 2014*; *Buzzard, Li & Bleisch, 2018*; *Pin et al., 2022*) in natural forests. It used lower reaches and a wide range of habitats in anthropogenic sites (*Lorica & Heaney, 2013*; *Petersen et al., 2019*; *Wu et al., 2020*). Likewise, for leopard cats, we expected to see habitat selection towards high rugged, high elevation, moderate slope, high NDVI, closer to woodlands inside the park and no such pattern in the anthropogenic site.

Data preparation

We categorised the area surveyed for carnivore faecal samples inside the national park as park (faecal site). These were the areas where we could not conduct camera trapping due to rugged terrain. We used five explanatory variables as the habitat covariates in the park (faecal site): elevation, terrain ruggedness index (TRI), slope, NDVI and distance to woodland (Table S2). We extracted the habitat covariates from the midpoint of each of the 0.5 km trails.

We categorised the camera trapped area inside the national park as park (camera site). Explanatory variables used as habitat covariates in the park (camera site) and anthropogenic site were the same as park (faecal site). We extracted the values of all habitat covariates from each camera trap point location (Table S2).

We checked for the collinearity between habitat covariates in park (faecal site), park (camera site) and anthropogenic site using r values (−1 to 1) as it might reduce the precision of the estimated coefficients (*Dormann et al., 2013*). None of the covariates was co-related in either the anthropogenic site or park (Figs. S11–S13). The test was performed on the R platform using package *lattice* (*Sarkar, 2008*).

Data visualisation

In park (faecal site), we assessed the total number of genetically confirmed faecal samples of red fox and leopard cat. We considered each mesocarnivores' relative abundance index (RAI) as the number of confirmed faecal samples from each trail (0.5 km). In park (camera site), we calculated the RAI of red fox and leopard cat as the capture rate per 100 trap nights for each camera trap location. Likewise, we calculated the RAI of red fox and leopard cat for each camera trap location using the capture rate per 100 trap nights in the anthropogenic site. We plotted the RAI of the mesocarnivores against the respective habitat covariates for all five sampling sessions in the park (faecal site), park (camera site) and anthropogenic site to account for linear, non-linear patterns and outliers. Most of the RAI vs covariate relationships were non-linear (Figs. S14 to S19); therefore, we chose hierarchical generalized additive modelling (HGAM) (*Zuur, 2012*; *Pedersen et al., 2019*) to model each response of mesocarnivores to habitat covariates.

Statistical analysis

We separately modelled the detections from genetically confirmed mesocarnivore faecal and camera trap data. We performed GAM using "*mgcv*" package (*Wood, 2011*) in R (v.4.0.5) to assess the habitat selection of mesocarnivores in park (faecal site). Here, we considered the number of genetically confirmed red fox faecal samples (F = 83) from each trail as the response variable. Due to the low sample size of genetically confirmed leopard cat faecal samples (F = 40), we dropped leopard cat for habitat selection analysis. We found a linear relationship between red fox faecal count and elevation (Fig. S17) while data visualisation; hence we did not apply a smoother function. The equation of spline regression (*Zuur & Ieno, 2018*) used for the additive model for red fox in park (faecal site) was:

$$\begin{aligned} \mathrm{F_j} = \alpha + f(\mathrm{elevation_j}) + f(\mathrm{TRI_j}) + f(\mathrm{slope_j}) + f(\mathrm{NDVI_j}) \\ + f(\text{distance to woodland}_\mathrm{j}) + \varepsilon_j \end{aligned} \tag{1}$$

where $\mathrm{F_j}$ = number of genetically confirmed red fox faecal samples from each trail, j = each survey trail, α = intercept, *f* = smoother function, Ɛ = residuals. The underlying idea of spline regression is to separate the covariate into k segments (knots) and apply a bivariate linear regression model to the data of each segment. A smoother was obtained by connecting the regression lines for all segments (*Zuur & Ieno, 2018*). To allow for smooth connections at the knots, we used a cubic regression spline for each covariate (*Zuur, 2012*). For example, the equation of smoother function for elevation in Eq. (1) becomes:

$$\begin{aligned} f(\mathrm{elevation_j}) = \beta_1 \times \mathrm{elevation_j} + \beta_2 \times \mathrm{elevation_j^2} + \beta_3 \times \mathrm{elevation_j^3} \\ + \sum\nolimits_{p=1}^{\mathrm{k}} \times (\mathrm{elevation_{jp}} - \mathrm{k_p})_+^3 + \varepsilon_j \end{aligned} \tag{2}$$

where j = each survey trail, β = unknown regression parameters, k = number of knots, p = knot positions in the x-axis. We first modelled Gaussian, Poisson and negative binomial distributions without k-value (to avoid the unnecessarily large number of candidate models) to select the best distribution. We then chose the model with the lowest AIC and tested it with possible 8 k-values (2 to 9). Therefore, the number of candidate models for red fox in park (faecal site) was 40: 5 variables × 8 k-values. In park (camera site) and anthropogenic site, we performed HGAM. We used the number of mesocarnivore detections (C) from each camera traps as the response variable and camera operational days as an offset. The park (camera site) and anthropogenic site were used as two zones and incorporated into the model as factors. The equation of the additive model using park (camera site) and anthropogenic sites as factors was:

$$
\begin{aligned}
C_i = \alpha &+ f(\text{elevation}_i,\ \text{by=fzone}) + f(\text{TRI}_i,\ \text{by=fzone}) + f(\text{slope}_i,\ \text{by=fzone}) \\
&+ f(\text{NDVI}_i,\ \text{by=fzone}) + f(\text{distance to woodland}_i,\ \text{by=fzone}) \\
&+ \text{offset (logdays)} + \varepsilon_i
\end{aligned} \tag{3}
$$

where C_i = number of mesocarnivore detections from each camera trap location, i = each camera trap location, α = intercept, *f* = smoother function, logdays = logarithm of camera operational days, fzone = park (camera site) and disturbed site, Ɛ = residuals. The number of candidate models for each mesocarnivore in park (camera site) and anthropogenic site was 40: (5 variables × 8 k-values). We plotted the response curves (detections) of mesocarnivores against each significant explanatory variable for park (faecal site), park (camera site) and anthropogenic site, respectively. We used the package "*ggplot2*" (*Wickham, 2016*) and "*ggeffects*" (*Lüdecke, 2018*) in R (v.4.0.5) for plotting the response curves. We evaluated the significance of the explanatory variables in each model using the p-values from the Wald statistics in the "*mgcv*" package. We also evaluated the effective degrees of freedom (edf) for each covariate to understand the scale of non-linearity captured by the model. The shaded area in the resulting plots represents 95% point-wise confidence bands of the smoother covariates (*Zuur, 2012*).

Model selection

We selected the best model based on the lower Akaike Information Criterion (AIC), overdispersion values (OD) (*Zuur, 2012*; *Zuur, Hilbe & Ieno, 2013*) and k values with the best ecological meaning (Figs. S14 to S19). For park (faecal site), we selected negative binomial GAM as the best distribution for the habitat selection model for red fox. We chose the best model out of 40 candidate models with AIC = 241.4 and OD = 1.2. For the combined model of park (camera site) and anthropogenic site, we selected negative binomial distribution as the best distribution. We chose the best model each for red fox (AIC = 744.8, OD = 2.8) and leopard cat (AIC = 988.9, OD = 2.2) out of 40 candidate models.

Model validation

We performed concurvity test to check for non-linear dependencies in the predictor variables for each of the best models in park (faecal site) and combined model of park (camera site) and anthropogenic site (*Amodio, Aria & Ambrosio, 2014*). We did not find any concurvity in the predictor variables (Figs. S20–S22). We conducted homogeneity test to check for any pattern in the residuals due to model misspecification (Pearson residuals *vs* fitted values) (*Zuur, Leno & Smith, 2007*; *Zuur, 2012*; *Zuur, Hilbe & Ieno, 2013*). We performed independence test to check for patterns in residuals due to any covariate (Pearson residual *vs* covariates) (*Zuur, 2012*; *Zuur & Ieno, 2018*). We did not find any clear pattern in either of the Pearson residual vs fitted values plots (indicating homogeneity, Figs. S23, S24) or Pearson residual *vs* covariate plots (showing independence, Figs. S25, S26) for red fox and leopard cat in park (faecal site), park (camera site) and anthropogenic site. We checked for spatial dependency using semi-variogram plots (residual *vs* space) using package "*gstat*" (*Pebesma, 2004*) in R (v.4.0.5). The semi-variogram plots (Pearson residual *vs* space) indicated no spatial dependency in the photo captures (C) of red fox and leopard cat to the distance between sampling locations in park (faecal site), park (camera site) and anthropogenic site (Figs. S27, S28). We also investigated the influential observations in the model using cook's distance and found four influential observations for red fox in the anthropogenic site and were not dropped (Figs. S29, S30).

Non-metric multidimensional scaling for factors responsible for space usage by mesocarnivores in anthropogenic site

After assessing the habitat selection by mesocarnivores in the anthropogenic site, we investigated the driving factors that might be possibly responsible for space usage in the anthropogenic site. Since the villages were small and located at a distance, the type of human attributes changed on moving outwards from the village core. For instance, the village centre had the maximum number of houses surrounded by a few agricultural plots. In contrast, the village edges had fewer houses, mainly farming fields and human trails. Therefore, we categorised the camera trap locations into three human attributes: houses, agricultural plots, human trails, and three topography types: hill base, hill slope and hill top. Human disturbances like livestock, humans and dogs also varied with increasing distance to the village. To depict the variation of the three human attributes, three village topography types and three human disturbance variables, we divided the distance to village into three classes; "within village" (0 to 300 m), "near village" (300 to 600 m) and "away from village" (>600 m) based on distances between camera trap locations and village centroids (average village area radius 300 m). We calculated the RAI (capture rate per 100 trap nights) of red fox, leopard cat, human, dog and livestock for all the categories under three distance classes. We used Non-metric Multidimensional Scaling (NMDS) (*Clarke, 1993*) to understand the factors responsible for space usage of mesocarnivores in villages. NMDS was performed in R using "*vegan*" package (*Oksanen et al., 2020*). We modelled the ordination over different dimensions (1, 2 and 3) with Bray-Curtis distance and selected the best model based on the lowest stress value (less than 0.05 is a good fit) (*Zuur, Leno & Smith, 2007*).

RESULTS

Distribution pattern

Total detections of red fox and leopard cat were 344 and 524, respectively. In park, red fox and leopard cat detections were 119 and 405, and in the anthropogenic site, the detections were 214 and 130, respectively. RAI of red fox in the park and anthropogenic site were 1.54 (0.14) and 8.77 (0.39), and of leopard cat were 4.47 (0.29) and 5.01 (0.28), respectively (values in the parenthesis depict standard error). Figure 2 shows the RAI of red fox and leopard cat along the habitat gradient, including all five camera trapping sessions.

Habitat selection

Inside park, GAM results of red fox in remote high elevation areas using genetically confirmed faecal samples revealed preference for certain habitats. Red fox occurred mostly

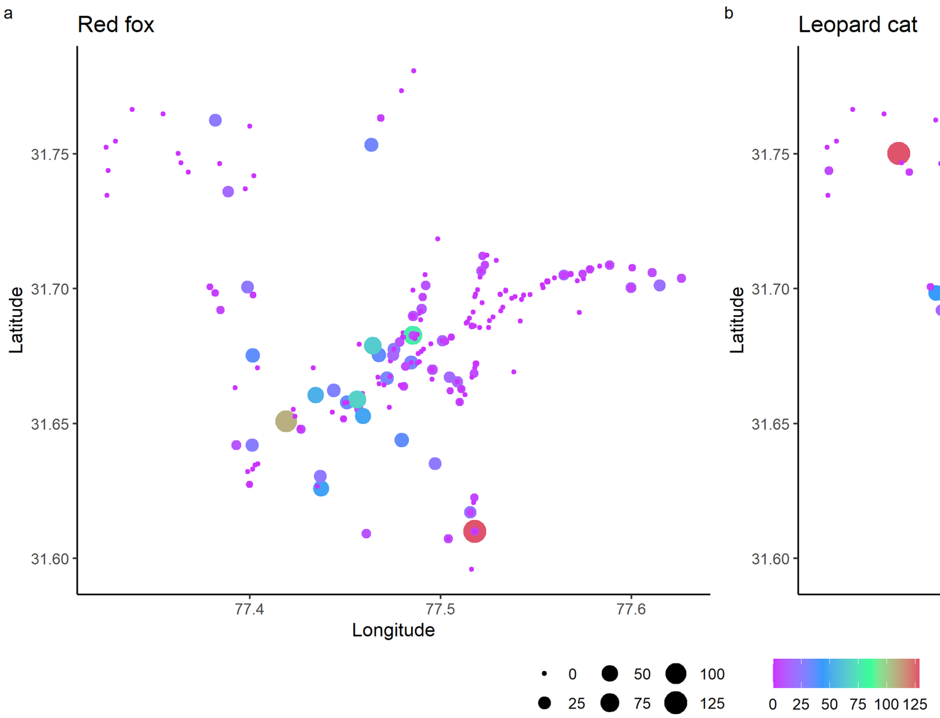

Figure 2 **Relative abundance index (capture rate per 100 trap night) of mesocarnivores in GHNPCA during the sampling period from 2017 to 2019.**
Full-size DOI: 10.7717/peerj.13993/fig-2

at high rugged terrain (0.5 TRI, p-value: 0.0009, edf = 1.8) (Fig. 3D), low slope (edf = 0.7) (Fig. 3E) and low NDVI (0.2, p-value: 0.0002, edf = 1.9) (Fig. 3F) sites.

Using camera traps, we found similar habitat preferences of red fox inside the park. Red fox preferred areas with rugged terrain (0.6 TRI, p-value: 0.0009, edf = 1.4) (Fig. 3A), moderate slope (20°, p-value: 0.0004, edf = 2.8) (Fig. 3B) and low NDVI (0.1, p-value: 0.0002, edf = 2.2) (Fig. 3C). Also, cameras detected leopard cat most commonly at moderate slope (20°, p-value: 0.0001) (Fig. 4A) and high NDVI (0.4 to 0.6, p-value: 0.03) (Fig. 4C) inside park. Although leopard cat occurrence decreased with increasing elevation, we found a peak in the smoother curve at 3,000 m elevation (Fig. 4B) (p-value: 0.0005). All the p-values mentioned above refer to the significance of the smoother covariate, not the predicted mesocarnivore counts at a particular value of the smoother covariate. On the other hand, neither red fox nor leopard cat showed any habitat-specific selection in the anthropogenic site. As we did not find any prominent peak in the smoother curves of red fox and leopard cat with either of the habitat covariates (Figs. 3A–3C and 4A–4C). Except for an additional peak at 0.6 NDVI (edf = 2.9) in case of red fox (Fig. 3C). The other smoother curves of habitat covariates in relation to leopard cat and red fox habitat selection were provided in Figs. S31 and S32, respectively. Although the GAM models revealed species-specific habitat selection but most of the non-linear effect of habitat covariates on red fox and leopard cat detections were small (indicated by small edf values) due to low detections at camera trap locations. Hence precautions should be taken while interpreting results considering ecological meaning.

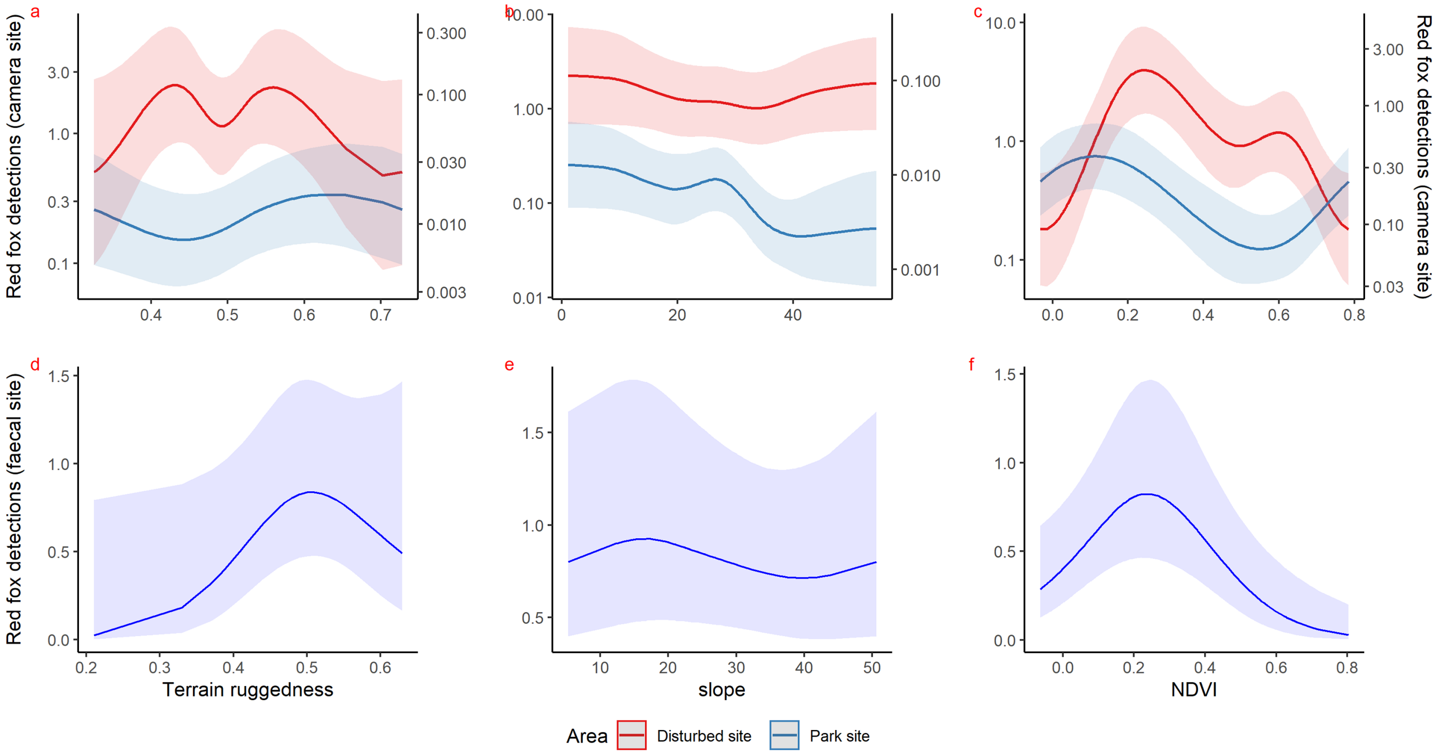

Figure 3 **Response curves of the best models from HGAM (negative binomial distribution) showing habitat selection of red fox in park (camera site, blue line) and anthropogenic site (red line) (A to C) and park (faecal site, blue line) (D to F).**

Full-size DOI: 10.7717/peerj.13993/fig-3

Factors responsible for space usage by mesocarnivore in anthropogenic site

The three-dimensional NMDS ordination identified the factors responsible for intensive site usage in villages by red fox and leopard cat (stress value 0.017; Figs. 5, 6; Tables S3, S4). We have provided the shepherd diagrams (a graphical representation of the stress values) of all the tested models for red fox and leopard cat in Figs. S30 and S31. We found the relationship of red fox and leopard cat to three human attributes (house, agricultural plot, human trail), three village topography types (hill base, hill slope, hill top) and three human disturbance variables (human, dog, livestock). Within villages, red foxes used sites near households and hill slopes, showing positive relation to livestock (Fig. 5). Red foxes near the village used more agricultural plots and hill slopes, showing positive relation to livestock. Away from the village, human-made village trails and hill base were the sites where red foxes mostly occurred. Red fox showed negative relation to the disturbance variables; human and dog. Leopard cats within villages primarily used agricultural plots and hill slopes (Fig. 6). Near the village, they mostly used houses and hill slopes (Fig. 6). Away from the village, leopard cats used human trails and hill base. Overall, leopard cats showed negative relation to humans, dogs and livestock.

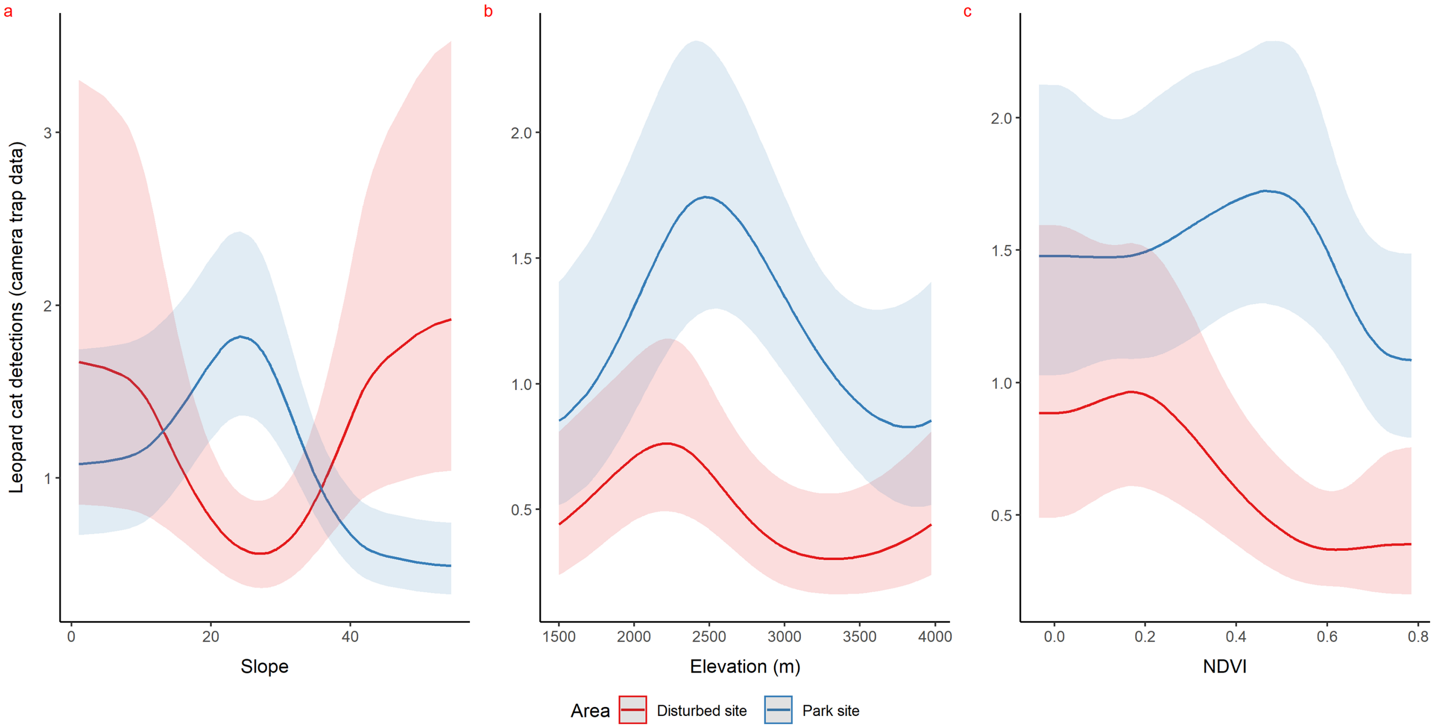

Figure 4 Response curves of the best models from HGAM (negative binomial distribution) showing habitat selection of leopard cat in park (camera site, blue line) and anthropogenic site (red line) (A to C). Due to low faecal sample size leopard cat was dropped for park faecal site.

Full-size DOI: 10.7717/peerj.13993/fig-4

DISCUSSION

Distribution in human-modified – natural gradient

The study was the first attempt to understand the effect of fine-scale habitat modification using habitat covariates like slope, elevation, ruggedness and NDVI on the distribution of mesocarnivores using complementary (camera traps and molecular) approaches in GHNPCA in the western Himalaya. We observed variation in the site intensity usage of mesocarnivore in the anthropogenic site-park gradient, where the anthropogenic site is located at lower reaches and park at higher elevations. For instance, the overall capture rate (RAI) of red fox and leopard cat in the anthropogenic site was higher than in the park. The result contradicts the established literature from GHNPCA in 1999, where red fox and leopard cat were recorded only inside the park at high elevations (*Vinod & Sathyakumar, 1999*). The shift in presence of mesocarnivores from less disturbed forested habitats to human dominated habitats in the last two decades affirms the increasing human population and its associated land usages in the landscape and its effect on native wildlife. In the previous research, some results were comparable due to the substantial walk effort of 290 km in anthropogenic site and 867 km in the park. However, carnivore sign surveys on human trails were not as robust compared to camera trapping used in this study. In the current study, the higher RAI of red fox and leopard cat in the anthropogenic site than in park explains the intensive site usage by the native wildlife in the human-dominated areas in GHNPCA. The result was analogous to studies by *Lorica & Heaney (2013)* and

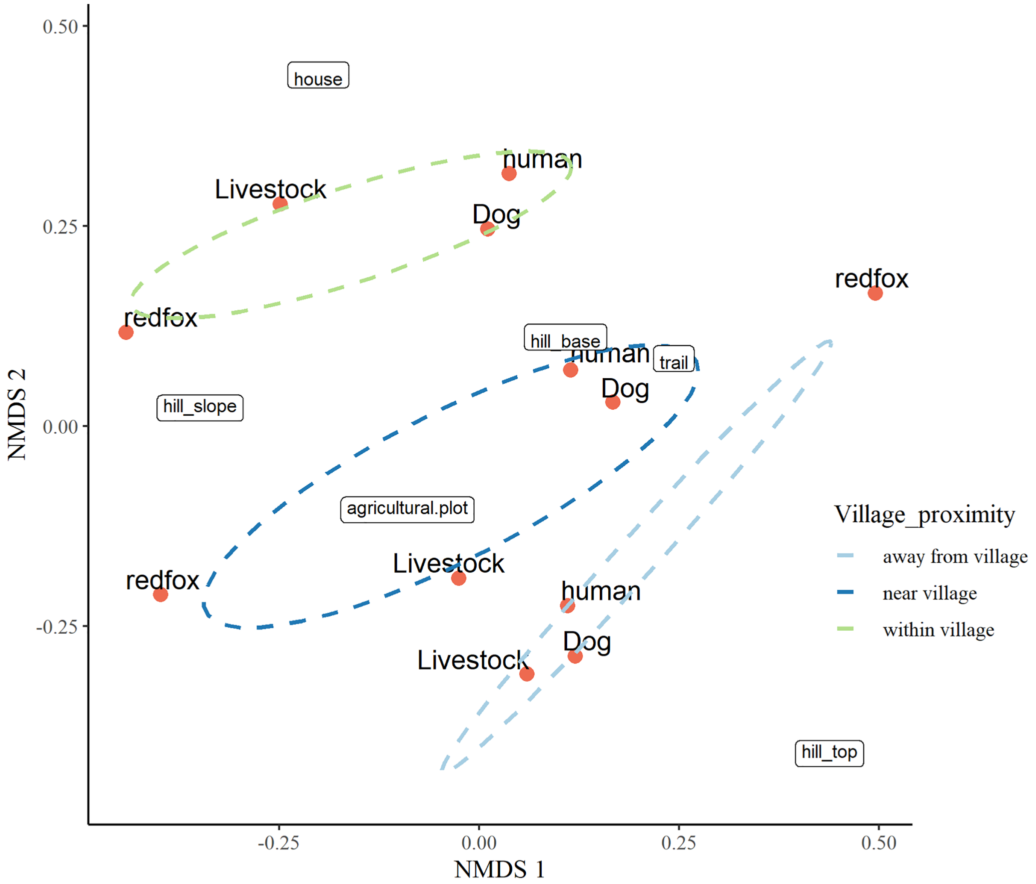

Figure 5 NMDS ordination plot showing factors responsible for space use by red fox in anthropogenic site (ecozone). Full-size DOI: 10.7717/peerj.13993/fig-5

Reshamwala et al. (2018), where red fox and leopard cat occurred more frequently in anthropogenically disturbed areas like human settlements, agricultural plots, *etc*.
The possible reason can be that the disturbed areas favour the native wildlife for readily available food resources like carrions, rodents, kitchen wastes, *etc*. And as a result, they use these areas more frequently than less disturbed habitats. The variation in site usages along the disturbed to natural gradient, elucidates the role of mesocarnivores as indicators of habitat quality (*Goad et al., 2014*; *Šálek, Drahníková & Tkadlec, 2015*; *Wang, Allen & Wilmers, 2015*). The differences in intensive site usage by native wildlife point towards habitat modifications in terms of increasing households, expanding agricultural plots, availability of human-induced food resources, *etc*. at the lower reaches of GHNPCA. After assessing the overall distribution pattern, we further investigated the site-specific occurrences of red fox and leopard cat using 3rd order habitat variables in park and anthropogenic site.

Species-specific habitat selection

Red fox and leopard cat showed habitat selection in park that differed from anthropogenic site. Inside the park, red fox mainly occurred in high rugged (>0.5), moderate slopes and

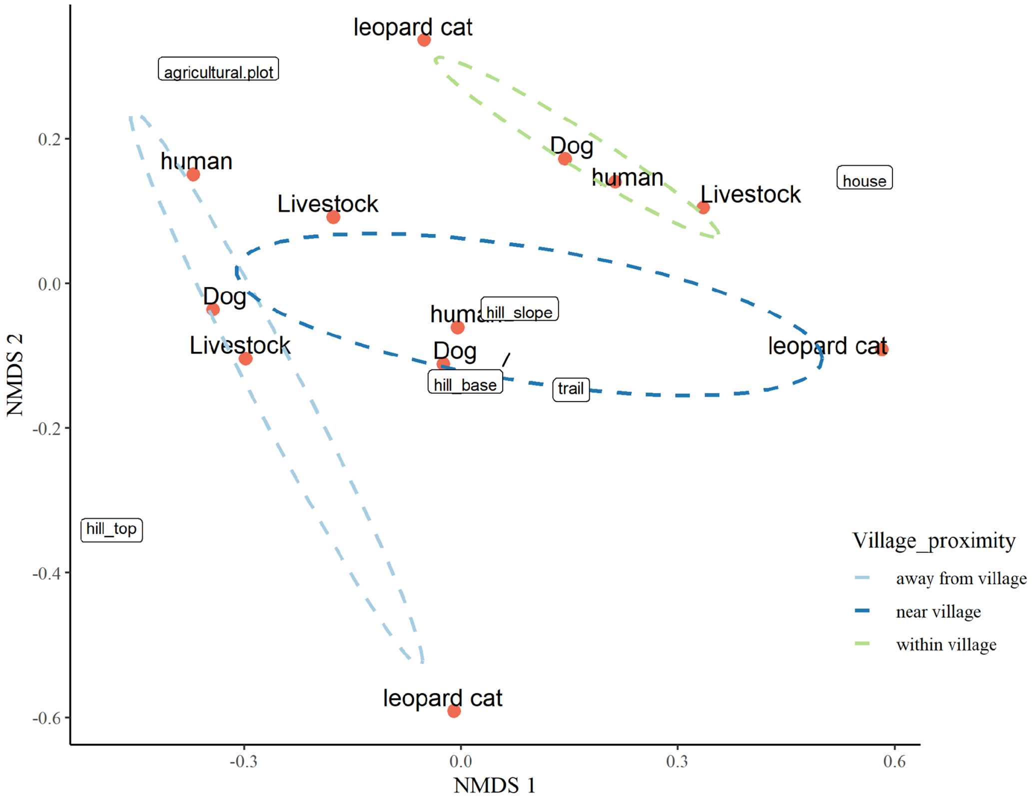

Figure 6 **NMDS ordination plot showing factors responsible for space use by leopard cat in anthropogenic site (ecozone).** Full-size DOI: 10.7717/peerj.13993/fig-6

open and rocky (low NDVI; 0.1 to 0.2) locations depicting temperate grasslands, sub-alpine scrubs and alpine meadows (*Rossi et al., 2019*). The result aligned with the previous study by *Vinod & Sathyakumar (1999)* in GHNPCA and other established literature, *Halpin & Bissonette (1988)* and *Cavallini & Lovari (1991)*. The result explains that given less human disturbance, the red foxes tend to occupy the habitat according to their natural behaviour and ecology. However, in the anthropogenic site, red foxes used a variety of habitats. They did not show any habitat-specific selection, unlike in the park, indicating red foxes using sites which were out of their natural behaviour in disturbed habitats. The change in the occurrence of red fox in selected habitats inside park to a wide range of habitats in anthropogenic site revealed its flexibility in humanized environments (*Díaz-Ruiz et al., 2016*) and exploitation of niches that form in the wake of human activities (*Jahren et al., 2020*). Furthermore, leopard cat mainly occurred in moderate slope, high elevation and high NDVI inside park, which was upper temperate forests with dense tree-cover. The result was supported by the aforementioned study in GHNPCA in 1999 and *Bashir et al. (2014)* in eastern Himalaya, suggesting leopard cats prefer sites as per their ecology in the natural habitats in GHNPCA. Interestingly we did not find such habitat selection in the anthropogenic site, and leopard cats used a variety of locations irrespective of habitat preferences, including open areas (low NDVI). The result was analogous to *Rajaratnam et al. (2007)* and *Izawa et al. (2009)*, where leopard cat utilised a wide range of habitats in a human-modified landscape. We could perceive that leopard cats changed their site selection out of their natural behaviour, based on levels of anthropogenic disturbances in different habitats. In general, leopard cats inhabit diverse habitat types, but they respond differently to the extent of anthropogenic exposures. For instance, in *Bashir et al. (2014)*, leopard cats were reported to have a low tolerance to deviations from their preferred habitat in the eastern Himalaya. Still, it manages to thrive in varied landscapes. Overall, red fox and leopard cat in GHNPCA showed differences in habitat selection in park and anthropogenic sites, reflecting species-specific sensitivities to habitat changes (*Recio et al., 2015*; *Riggio et al., 2018*). The difference in habitat selection revealed their opportunistic and human adapter behaviour (*Ditchkoff, Saalfeld & Gibson, 2006*) that is an outcome of resource utilisation (*Zhao et al., 2020*), especially in resource-scarce and rugged landscapes in the western Himalaya. The change in selection of specific habitats inside the park to a wide range of habitats in anthropogenic site by red fox and leopard cat revealed impact of human disturbances on a finer scale (*Lorica & Heaney, 2013*). This argument can be further supported by the fact that human habitations in GHNPCA were majorly located in the anthropogenic site. Thereby resulting into adaptive behaviour of mesocarnivores through shift in habitat choices for utilising resources in the anthropogenic habitats (*Duduś et al., 2014*). The opportunistic behavior of mesocarnivores was further supported by the site usages close to different human attributes in the anthropogenic sites.

Factors responsible for space usage around human habitation

The NMDS ordination plots revealed that both the mesocarnivores showed close association with human attributes like houses, agricultural plots and human trails in villages. The choices of these attributes varied with increasing distance from villages reflecting resource utilisation at different scales. For instance, space usage by red foxes close to households inside villages, agricultural plots in the village vicinity, and trails outside villages relate to utilising anthropogenic food subsidies in villages. The findings were similar to *Ghoshal (2011)* and *Ghoshal et al. (2016)*, where red foxes used sites close to villages and agricultural plots for anthropogenic food subsidies. It indicates that houses and agricultural plots in anthropogenic site of GHNPCA are the possible sources of food and hence responsible for intensive site usage by red foxes in these areas. Furthermore, red fox was positively related to livestock like goats and sheep, suggesting the possibility of livestock depredation, which aligned with *Aryal, Sathyakumar & Kreigenhofer (2010)* and *Maheshwari & Sathyakumar (2020)*. Also, red foxes showed a negative relationship with humans and dogs in villages possibly due to disturbance and threat from the competitive carnivore (*Gil-Fernández et al., 2020*; *Reshamwala et al., 2021*). Interestingly hill slopes were the most frequently used sites within and near villages. This result was complementary to *Reshamwala et al. (2021)*, where red foxes used the hill slopes for denning sites with minimal human disturbance. Unlike red fox, leopard cat showed close association with agricultural plots within villages and houses near villages which was in accordance with the study by *Rajaratnam et al. (2007)* and *Vitekere et al. (2020)*. Knowing the importance of rodents in leopard cat diet, the abundance of rodents in these areas explains the space usage near agricultural fields and houses (*Lorica & Heaney, 2013*).

The negative relation of leopard cats to human presence and dogs revealed their sensitivity towards disturbance and inter-specific avoidance, which aligned with *Oh et al. (2010)*, *Cheyne & MacDonald (2011)* and *Weng et al. (2022)*. Overall, for red foxes presence of houses played a crucial role in intensive space usage, whereas for leopard cats, agricultural plots were the important factors for frequent space usage in the anthropogenic site of GHNPCA. Hence our results suggest that human-induced disturbances like houses and agricultural plots are the potential factors responsible for thorough space usage by the native wildlife in the study area.

The distribution and habitat selection of mesocarnivores along the human-modified and natural gradient clearly showed the impact of increasing and expanding anthropogenic activities around GHNPCA. The outcome was similar to *Schuette et al. (2013)* and *Ditchkoff, Saalfeld & Gibson (2006)*, where mesocarnivores showed signs of adaptation to expanding human habitations, indicating mesocarnivore adaptations to human-modified habitats in GHNPCA. The ecozone around the park was delineated as a buffer area to lower anthropogenic activity's direct pressure on the GHNPCA boundary. Although land settlements and agricultural expansions occurred earlier (*Tucker, 1997*), the current status of human habitation around GHNPCA needs re-evaluation to implement effective conservation practices. One of the caveats of human residences adjacent to natural forests adds to the availability of anthropogenic food sources like garbage dumps, agricultural products, kitchen wastes and livestock carrions in village areas (*Randa & Yunger, 2006*; *Newsome et al., 2015*). Mesocarnivores, an opportunistic feeder, roam around these areas for food subsidies (*Reshamwala et al., 2018*). Eventually, these shared spaces can be the most probable zones for zoonotic disease transmissions and human-wildlife conflict (*Namusisi et al., 2021*). In particular, the disease spread can be bi-directional, *i.e.*, from red fox, leopard cat to domestic animals or humans (*Plumer et al., 2014*; *Chhabra & Muraleedharan, 2016*; *Nadin-Davis et al., 2021*) or humans, livestock to the mesocarnivores (*Clark et al., 2018*; *Ng et al., 2019*). Concurrently, the availability of livestock and crop (like maize) close to GHNPCA also confers the exposure of native large carnivores like leopard and Himalayan black bear to more vulnerable habitat conditions and conflict probabilities (*Sathyakumar, 2000*; *Chauhan, 2003*; *Charoo, Sharma & Sathyakumar, 2011*; *Naha et al., 2020a*). Past evidence and our results suggest that wildlife in rural areas do not exhibit the same habitat preferences as their natural counterparts because of adaptation to human-induced modifications (*Ditchkoff, Saalfeld & Gibson, 2006*). Managers in such situations face challenges in addressing problems associated with rural wildlife and expanding human habitation. There is a need for management strategies for human habitation expansion and proper garbage disposal practices, primarily in the anthropogenic site. In this context, we posit the need for mitigation efforts aimed at expansion of human habitation and systematic garbage disposal practices at the human-wildlife interface to safeguard future disease outbreaks and conflict risks that address sustainable development goals.

Limitations

Our study had few limitations due to inherent challenges. The study area was devoid of any paved road. Hence, the entire sampling from 2017 to 2019 was carried out on foot. The inaccessible terrain enabled us to conduct either camera trapping or carnivore faecal sampling beyond 4,300 m elevation inside the national park. It restricted us from broadening our understanding of distribution and habitat selection of mesocarnivores at such high altitudes. Also, due to logistical constraints, the number of camera traps in the anthropogenic site was less than in the park, although the capture rates and detections of mesocarnivores in anthropogenic site were comparable to that of the park implying representative area coverage by camera trapping in anthropogenic site. Due to harsh environmental conditions, no fieldwork was conducted in the monsoon (August–September) and snow (January–March) seasons. Therefore, this study was carried out only in the accessible months from April to July and October to December. We excluded data derived from cameras not functioning correctly (due to camera failure, battery failure and heavy snowfall), resulting in the non-detection of the target species. Also, camera placements, orientation, temperature differences, faecal sample detection and degradation due to logistic limitations for storage added to species non-detection. To overcome the non-detection issue, we conducted camera trapping and faecal sample collection in five sessions by walking more than 400 km to sample each trail and maximise species detections. The detections were entirely satisfactory, as revealed by the GAM results. Our results depicted changes in habitat selection in modified habitats and factors responsible for space usage in villages using camera trapping and faecal sampling approach. However, we recommend careful insights while placing camera traps (especially at high altitudes) and collecting faeces in future analogous studies.

CONCLUSION

As development continues, it is crucial to understand how carnivores might respond to increased human expansions and the factors that might put carnivores and humans at increased risk of conflict and disease spread. Mesocarnivore distribution and habitat selection along the anthropogenic site-park gradient in GHNPCA clearly showed the influence of anthropogenically modified habitat. The effects can harm other large carnivores like leopard and Himalayan black bear, leading to negative interactions like in other parts of western Himalaya. The anthropogenic site is an interface area where human habitations extend toward the natural habitat. Concurrently mesocarnivores from adjacent forest areas utilise the human habitations. Therefore, it is crucial to reinforce the conservation practices in anthropogenic site to control the habitat modifications adjacent to natural habitats and reduce the anthropogenic effects on native wildlife. It took more than 30 years (1980 to 2014) from inception (*Pandey & Wells, 1997*) to realization of GHNPCA as a World Heritage Site (UNESCO, 2014: https://whc.unesco.org/en/list/1406/), but the current situation in the buffer zone of GHNPCA threatens its protection status in future. There is a need to implement mitigation strategies in the human-wildlife interface areas to regulate human habitation expansions and its associated caveats to balance the spheres of humans and wildlife in the study area.

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ADDITIONAL INFORMATION AND DECLARATIONS

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Competing Interests

The authors declare that they have no competing interests.

Author Contributions

- Meghna Bandyopadhyay conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
- A. Cole Burton conceived and designed the experiments, authored or reviewed drafts of the article, and approved the final draft.
- Sandeep Kumar Gupta conceived and designed the experiments, authored or reviewed drafts of the article, and approved the final draft.
- Ramesh Krishnamurthy conceived and designed the experiments, authored or reviewed drafts of the article, and approved the final draft.

Data Availability

The following information was supplied regarding data availability:

The raw data is available in the Supplemental Files.

Supplemental Information

Supplemental information for this article can be found online at http://dx.doi.org/10.7717/peerj.13993#supplemental-information.

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Patterns of Small Carnivore Space use along Riverine areas in the Great Himalayan National Park Conservation Area, Western Himalaya

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ABSTRACT: Small carnivores have lesser home range sizes and are generally limited to restricted area for resource selection. Patterns of space use by these carnivores therefore reflect the overall habitat quality and indicate presence of other prey species. Riverine areas are special habitats and require attention due to continuing anthropogenic and climatic impacts. Given that the riverine habitat serves as a gradient of resources, this study focused on the response of small carnivore communities to change in habitat composition along an elevation gradient. In this paper, we present the results of carnivore sign survey (February-March 2017) and intensive camera trap sampling in two seasons; summer (April-June 2017) and winter (October-December 2017) carried out in the Great Himalayan National Park, Himachal Pradesh. Encounter rate of small carnivore signs were 8.8±1 per 10 km. The 87 camera traps placed between 500m and 1km apart and with 1200 trap nights resulted in 61% of carnivore capture within 500m from river and 47% beyond 500m in summer whereas in winter it was 70%and 61% respectively. Red fox, leopard cat and yellow throated marten were photo captured in both seasons showing specific site preference whereas masked palm civet was only recorded in summer. The research is revealing interesting facets of small carnivore occupancy and habitat correlates, and would form strong scientific basis for further research on small carnivore and their conservation in the riverine system in the temperate region of the Himalaya.

Key Words: Small carnivores; Elevation gradient; Habitat variables; Site usage

INTRODUCTION

Riverine area, being an integral part of the mountainous landscape, serves a gradient of various resources like food, water, shelter, etc. and thus plays crucial role for the existence and survival of a species or group of species, in addition to being corridor. Mammal community's responses to gradients on landscape scale are complex on account of the variety of species and functional types. The functional structures of mammal communities vary along environmental gradients e.g. of disturbance and resource availability (Wallgren et al. 2009). Environments at small scale are fairly homogenous interms of vegetation whereas on landscape scale there are clear gradients. Species of different functional types may differ greatly in responses to environmental gradients and cause variation in the functional structure of communities along the gradients. Large and medium-sized mammals are highly affected by large-scale disturbance gradients, while small mammals are most dependent on small scale variation in resources, probably shelter and food. Very little is known about their influence oncommunities and ecosystems. Small carnivores being more diverse in their behaviour and ecology and abundant than large carnivores often reside in closer proximity to humans. This is why some abrupt change in behaviour of the small carnivores can be expected owing to changes in habitat characteristics. Such study of small carnivores in response to environmental factors could be of interest in terms of understanding the community dynamics.

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LITERATURE REVIEW

In an ecosystem, the large carnivores are ecologically important because relatively few individuals can cause strong predation-driven direct effects or fear-driven indirect effects that can ripple through communities and, ultimately, influence ecosystem structure and function. Small carnivore population are important ecosystem regulators as they structure small mammal and/or invertebrate communities, which in turn might affect higher trophic levels. They are mistaken lythought to have a lower impact at the ecosystem level. They are an important aspect in seed dispersal. It is necessary to assess the extent to which the small carnivore population is pushed towards vulnerability due to increasing anthropogenic stress (SAN et al. 2013; Wilting et al. 2010). For many of the vulnerable species, there is little knowledge of theirbiology and ecology (Nowell and Jackson 1996; Mukherjee et al. 2010). Conservation of these species will be difficult without the baseline information (Grassman et al.2005).Despite its extensive geographical range, the ecology and behaviour of such species have so far received little attention (Brodie and Goirdano 2011). It is known to have high ability to adapt with modified habitat, like it canthrive in human dominated landscape (Mortelliti and Boitani 2008). Change in small carnivore interaction in response to the alteration in the anthropogenic or climatic parameter is an interesting mechanism to study.

Large carnivores have drawn considerable attention, initially through their charisma but also for their potential conflicts and resulting threats to several species and populations (SAN et al. 2013). The Indian Himalayan region is very rich in terms of biological diversity due to its unique location, climate and topographic conditions. The Great Himalayan National Park harbors a wide variety of mammalian fauna (Ramesh et al.1999). The carnivores list includes yellow throated marten, Himalayan palm civet, Himalayan weasel, jungle cat, leopard cat, common leopard, snow leopard, red fox, jackal, wolf, Asiatic black bear and Himalayan brown bear (Vinod and Sathyakumar 1999). The study of community dynamics of small carnivores, its structure and response to anthropogenic and climatic correlates needs to be strengthened before it is too late. Among the small carnivores found in Great Himalayan National Park Conservation Area, Red fox, Jungle cat, Yellow throated marten are categorized as schedule II species whereas leopard cat is a schedule I species according to WPA status.

The species distribution along the vertical and horizontal gradient reflects typical patterns in which the species organize themselves. The distribution pattern along certain axis can be extended to elevation gradients and the Himalayan system is an ideal landscape for testing such ecological questions. In this context, riparian corridors (i.e., rivers, streams and adjacent lands) provide a gradient of valuable habitat for different flora and fauna to thrive at different altitudinal levels and are high in ecological diversity. Alterations to riparian areas due to anthropogenic activities and changing climatic conditions are likely to cause the most adverse impact on the occupancy and abundance of the mammalian fauna existing along riverine area. Knowledge of such species is important as they can act as indicators of short-term and long-term disturbances in terms of local extinction or colonization. Predicting the change in abundance is pivotal for evaluating species' current conservation status and population viability. Empirical works have suggested that species with an increasing abundance have a more aggregated distribution than those with a declining abundance (namely, the change-aggregation hypothesis, CAH). It will be interesting to study the change in abundance from changes in occupancy or aggregation.

As specialization and resource selectivity is generally stronger in small carnivores than large carnivores, they may serve as useful indicator species in the preservation of keystone habitats. Mapping and subsequent predictive habitat modelling are useful in terms of future projections like conservation planning, detecting distributional changes and species activities for those controlling parameters (Hirzelet al.2001). Distribution of small carnivores is greatly determined by the resources at the home-range scale (Litvaitis et al.1994). The different environmental parameters include bioclimatic variables, forest and land cover types, topography, vegetation indices and anthropogenic variables (Wallgrenet al.2009;Marino et al.2011). Anthropogenic activities such asurbanisation, commercial plantations, and intensive agriculture practices have led to severe habitatloss and fragmentation. Poaching and hunting is another major threat. There are studies indicating distribution pattern and its subsequent response to environmental parameters (Johnson et al.200;Kalleet al.2013; Parry et al.2013;Pillay 2009;Kalle et al.2012). A large scale study done on pattern of carnivore richness in Texas by James G. Owen (1990) revealed that species richness of carnivores increases as richness for other taxa decreases. According to this study a stable climate allows a finer degree of exploitation of food resources by the existing species and development of more specialized niches. On the contrary, exploitation of unstable climate requires greater tolerances which then otherwise lead to decrease in species richness owing to climatic fluctuations. Also carnivores exhibit an increasing trend in species diversity with increasing productivity (Owen 1998).Owing to individual species tolerance levels there are examples of competing carnivores adjusting their niche according to the changing climatic parameters (Zielinski et al. 2017). Basically different sized animals response differently to different climatic and environmental factors. For example large mammals correlate strongly with annual precipitation accounting for 60-70 % of species richness as compared to <20% for small mammals (Andrews and O'Brien 2000). A study carried out in subtropical forest in Taiwan revealed that elevation is the strongest factor explaining the composition of carnivore community in the habitat dimension (Chiang et al.2012).

In mobile animals, movement behavior is used to maximize fitness by increased access to critical resources and minimizing risk of predation and competition (Caro and Stoner 2003). It is predicated that as organisms move through spatially complex landscapes, they respond to the conditions of multiple ecological attributes, expressing movement paths that optimize fitness benefits while minimizing fitness costs. Measurement of movement paths through complex landscapes provides data to associate movement behavior with ecological attributes, and allows direct assessment of the influences of landscape features on movement path selection (Le Donneet al.2011). In a species specific landscape resistance model, the resistance is a function of the landscape features.. As such, individual-based analysis of movement path selection is a particularly powerful means to quantify habitat fragmentation effects on population structure (Bruggeman et al. 2007; Coulonet al.2008;Cushman and Lewis 2010). For example, such analyses may directly evaluate the relative support for multiple alternative models relating landscape composition, configuration and interspecific interactions to movement cost (Cushman et al. 2010). The path-level randomization approach depicts comparision of animal encounters with landscape features in the available paths with those in a large sample of identical length and topology (Cushman and Lewis 2010; Cushman et al.2010). By holding length and topology constant and randomizing location in the landscape, the approach avoid spseudo-replication and autocorrelation of observations, as may be an issue with some analyses evaluating point data (Harris et al. 1990; Litvaitiset al.1994; Cushman and Lewis 2010).

STUDY AREA AND METHODS

Study Area

The Great Himalayan National Park (GHNPCA) Conservation Area, located in Kullu District of Himachal Pradesh (HP) (Fig. 1), was established in 1984 and was finally notified in the year 1999 under the Wildlife (Protection) Act 1972 after completing the settlement of rights of the local people in the designated park area. The Park (754.4km²) is located between 310 38' 28" to 310 54' 58" N latitudes and 770 20'11" to 770 45' 00" E longitudes and spread along an elevation range of 1400 to 5500 m above sea level. In 1994, two major changes were made to land use around GHNPCA. A buffer zone, extending 5kms from the park's western boundary, was reclassified as an ecozone. The GHNPCA is located on the junction of two great faunal realms; the Palaearctic to the north and Oriental to the South. The CA lies in the biogeographic

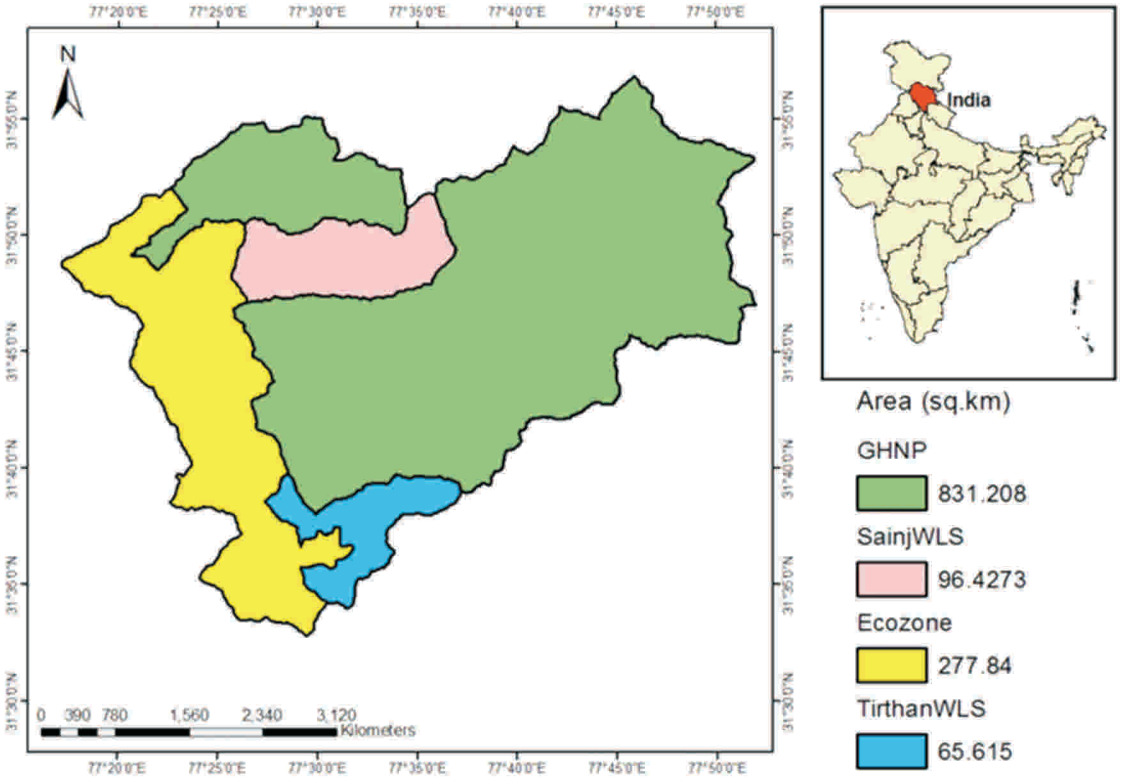

Fig. 1: Map showing the study area

zone-2A North-West Himalaya (Rodgers and Panwar, 1988).The CA makes the catchment of Tirthan, Sainj, Jiwa and Parvati rivers which together form the uppercatchment of one of the major perennial rivers in the region i.e. river Beas. The intensive study areasare the Tirthan and Sainj valley which run along with river Tirthan and Sainj.

Sampling Methods

A total of 184km was walked in both the valleys from February to March 2017 and 162 total carnivore signs were found based on which the camera trap session (Rowcliffe et al. 2008) was followed. The entire area of Tirthan valley was divided into 5 blocks for vertical gradient based on accessibility namely; Gusaini-Kharongcha, Kharongcha-Chalocha, Chalocha-Shankha, Shankha-Majhoni, Majhoni-Tirath (Fig 2.1). Each block was further divided into proximity to river that is within 500m distance to river and away for horizontal gradient (Fig. 2.2). Camera traps were deplored in 59 locations in Tirthan and 28 in Sainj. Camera trap operable days were kept for minimum of 15 to maximum of 20 days which resulted into 1200 trap nights. Initially cameras were deployed at a minimum distance of 1km and but later on reduced to 500 m to account for enhanced probability of carnivore captures. Thus intensive camera trapping was carried out in summer from April to June 2017 (3 months) and winter sampling from October to December 2017 (3 months).

RESULTS AND DISCUSSIONS

A list of carnivores presence at different altitudinal levels reported in previous studies and recorded incurrent study has been given in Table 1. Since every species has their own site preferences, Table 2 shows the areas where the small carnivores got maximum photo captured including both the seasons. The role of

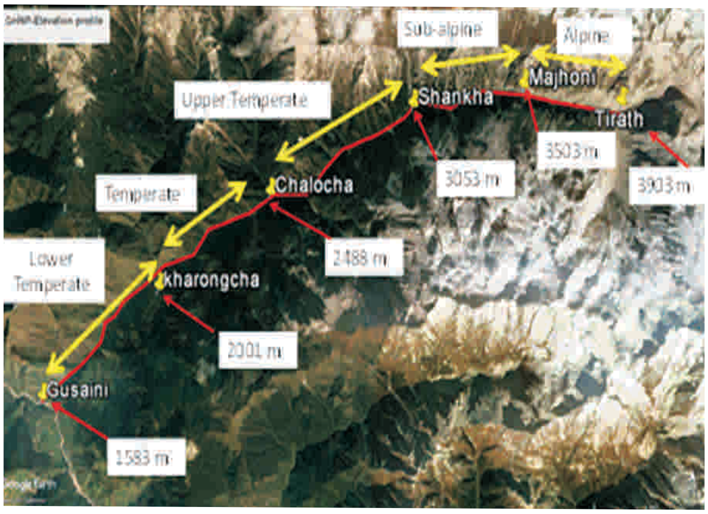

Fig. 2.1: Vertical gradient along river Tirthan

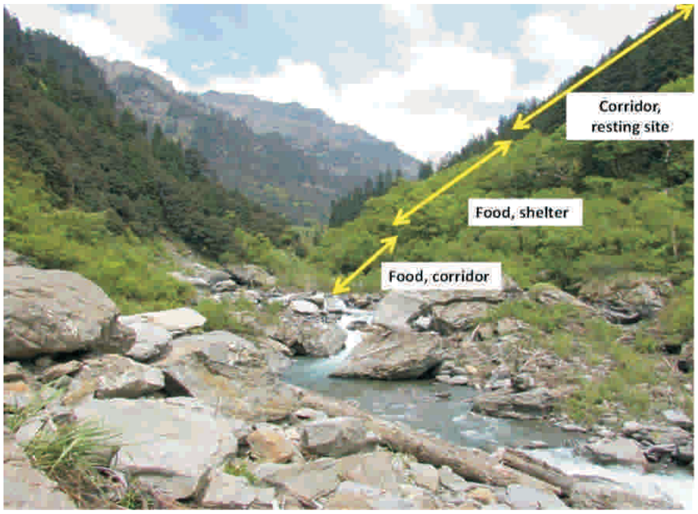

Fig. 2.2 Horizontal gradient along river Tirthan

season in the movement of small carnivores was very much evident from the reduced number of sites visit in winter than in summer in Fig. 3.1(a) which depicts site usage intensity in terms of photo capture rate per 100 trap night for red fox, leopard cat, yellow throated marten and Himalayan palm civet respectively in summer 2017 and Fig. 3.1(b) for winter 2017except Himalayan palm civet which was not recorded in winter. This reduced movement in winter was further supported by site preferences at specific elevations by red fox, leopard cat and yellow throated marten in Figs. 3.2, 3.3 and 3.4, respectively. Himalayan masked palm civet was not recorded in winter and so Fig 3.5 shows capture rate in summer. In summer, all the small carnivores are more widely distributed across different elevation range but in winter it appeared to be shrinked to pockets. It can be attributed to the fact that winter in GHNPCA is harsh and prolonged and so resources are less available than in summer, hence animals tend to attach themselves to sites where they make sure that

Table 1: Altitude record of previous (1998) and current study (2017, ongoing) of all carnivores.

Carnivores previously reported (1998)	Altitude range (m) previously reported (1998)	Altitude range (m) during current session (March-December 2017)
Common leopard	1440-3660	2084-3579
Snow leopard	>3700	2495
Asiatic black bear	1630-3300	2132-3010
Himalayan brown bear	>3300	2432-3579
Golden jackal	1440-2000	2092-2338
Red fox	3500-3670	1711-3645
Wolf	-	No captures yet
Leopard cat	>3000	1711-3579
Jungle cat	1440-2200	No captures yet
Yellow throated marten	1440-3340	1711-3579
Himalayan weasel	3320-3580	No captures yet
Himalayan palm civet	2990	2077-2942

Table 2: Maximum photo capture rates of small carnivores and its area

Species	Photo capture and area	Other areas
Leopard cat	33 (SE=0.13); River	Ridge
Red fox	55 (SE=0.70); Ridge	Meadow, river, village
Yellow throated marten	25 (SE=0.05); River	Ridge
Himalayan palm civet	46 (SE=0.43); River	River, hill slope

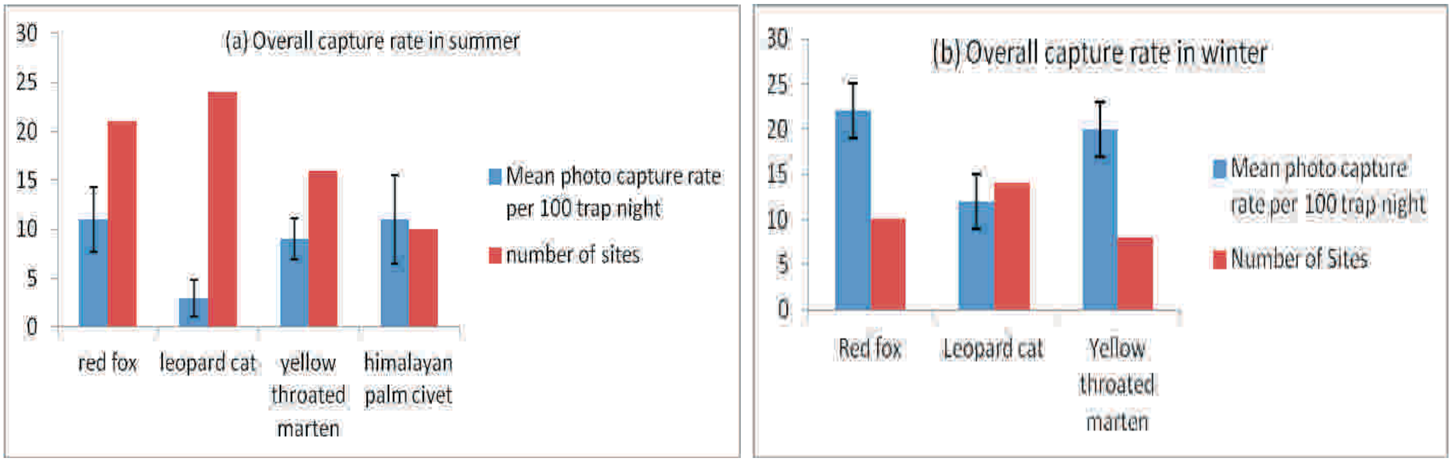

Fig. 3.1: Overall mean photo capture rates per 100 trap nights of small carnivores and its corresponding number of camera trap sites in (a) summer and (b) winter 2017.

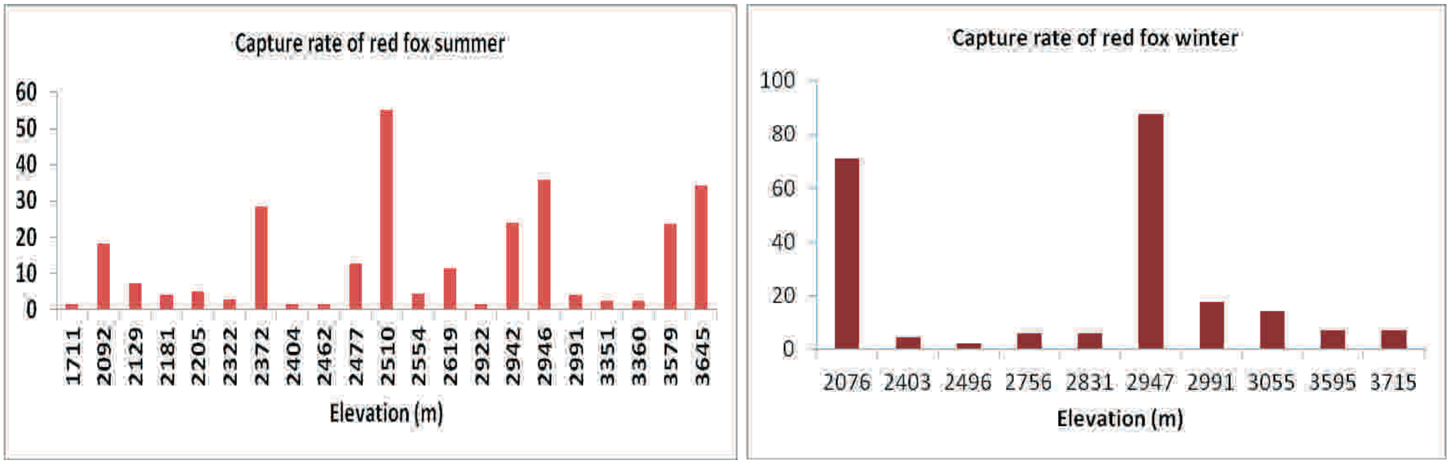

Fig. 3.2: Photo capture rate per 100 trap night at different elevations for red fox in summer and winter 2017 respectively.

resources are available even in harsh conditions. Another interesting result is that small carnivores within 500m from river were recorded in 59% (16 out of 27) of sites in summer and 70% (15 out of 23) in winter (Fig. 6.6(a) and (b)) whereas beyond 500m it is 47% (15 out of 32) in summer and 61% (16 out of 26) in winter respectively (Fig. 3.7(a) and (b)). In all, combining Table 2 and Figs 3.2 and 3.3, it seems that

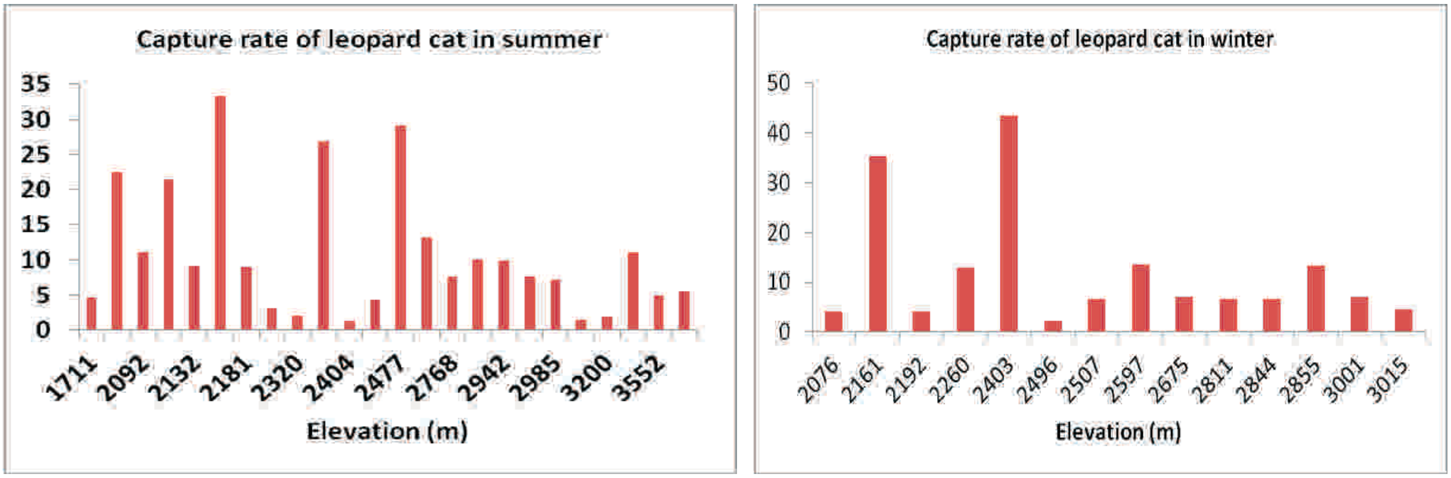

Fig. 3.3: Photo capture rate per 100 trap night at different elevations for leopard cat in summer and winter 2017, respectively.

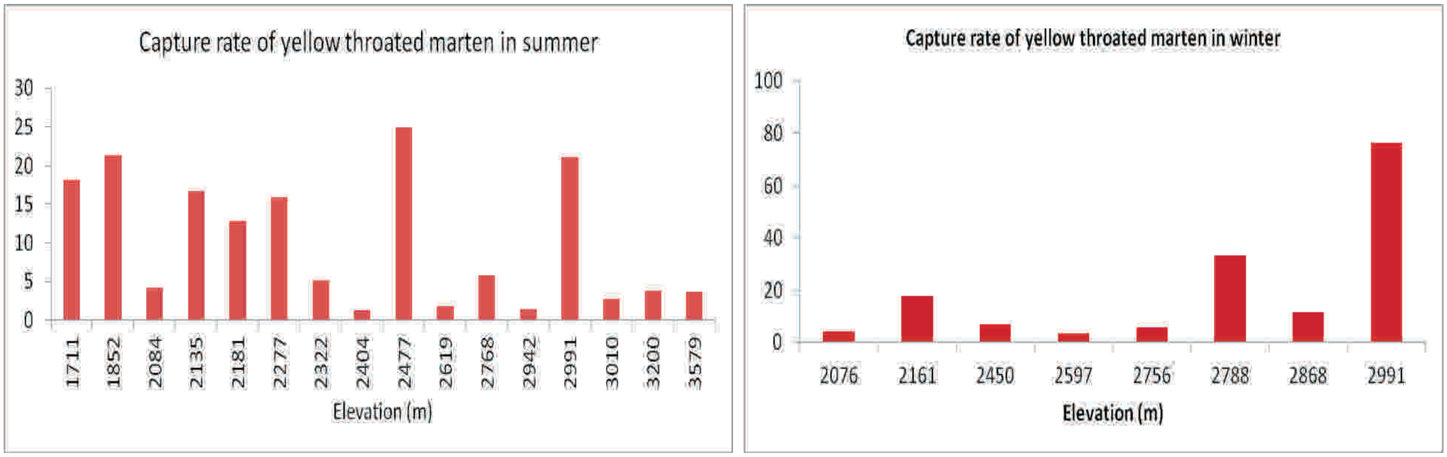

Fig 3.4: Photo capture rate per 100 trap night at different elevations for yellow throated marten in summer and winter 2017 respectively.

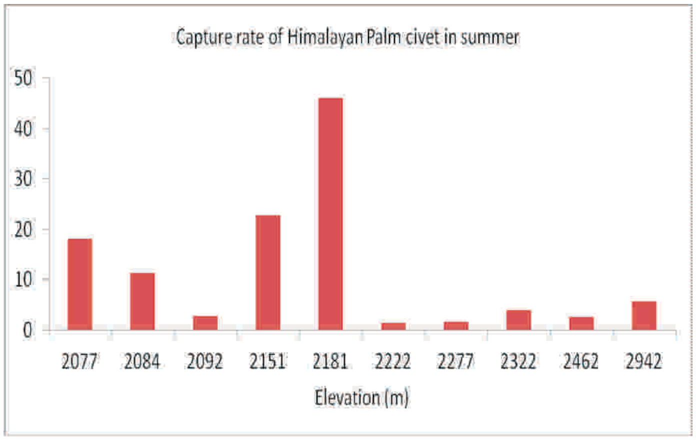

Fig.3.5: Photo capture rate per 100 trap nights at different elevations for Himalayan palm civet in summer 2017.

red fox uses more of the ridge areas between 2000-3600m in both seasons whereas in case of leopard cat the intensity of site usage is towards river with more skewness towards lower elevation in winters. Yellow throated marten showed specific site preference in winters rather being more distributed in summers. Site usage is highly specific in case of Himalayan palm civet as it had captures from very particular locations in summer and also went undetected in winters. This kind of site preference of small carnivores reveals the spatial segregation they undergo owing to resource availability according to season and its utilization as per requirement. As there are studies on resource utilisation by sympatric carnivores being large or small, temporal and spatial segregation of the animals has

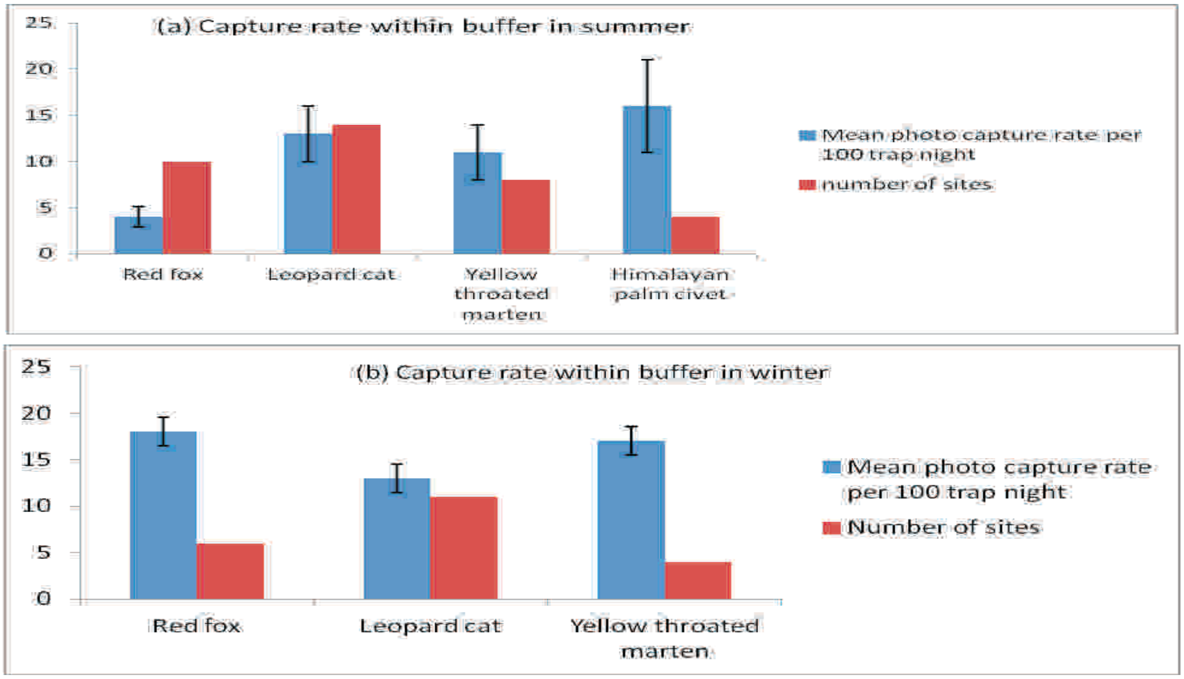

Fig. 3.6: Mean photo capture rates per 100 trap nights of small carnivores and its corresponding number of camera trap sites within 500m from river in (a) summer and (b) winter 2017.

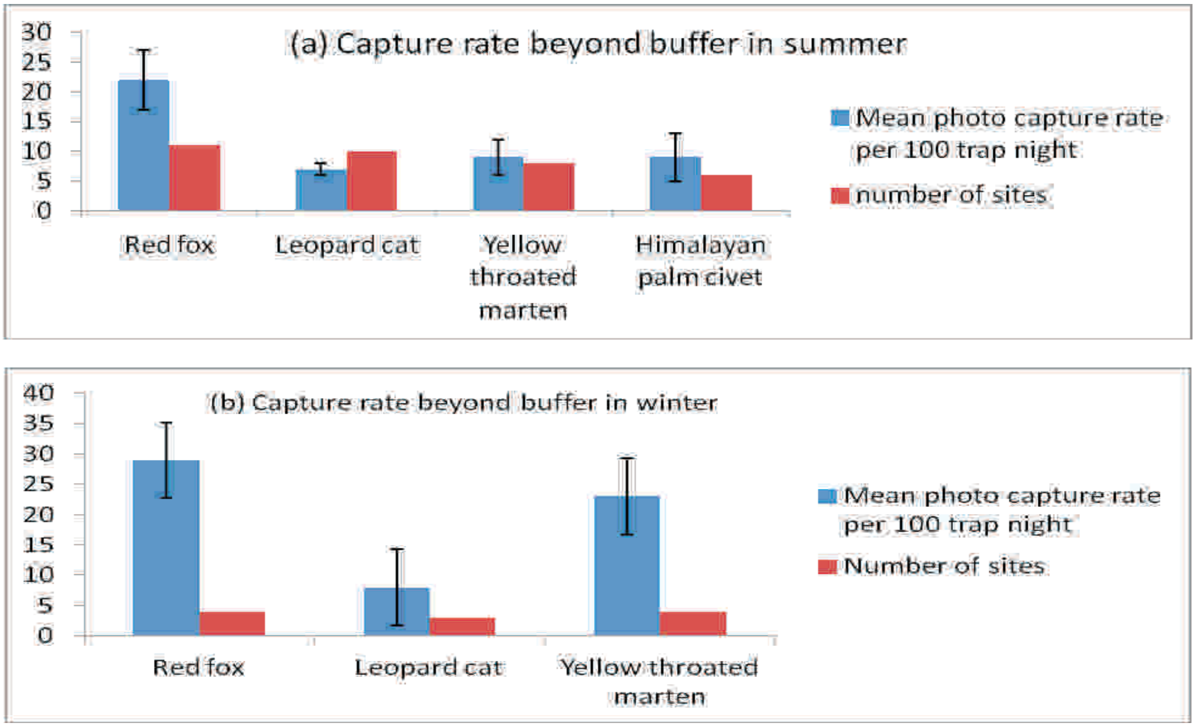

Fig. 3.7: Mean photo capture rates per 100 trap nights of small carnivores and its corresponding number of camera trap sites beyond 500m from river in (a) summer and (b) winter 2017.

been cited as the important feature in all cases. This indicates the niche partitioning or overlapping is highly governed by the habitat variables and other environmental factors.

CONCLUSIONS & RECOMMENDATIONS

Study of carnivore communities along gradient has been an area of interest across the world but not much explored yet in the Himalayan system, specifically on the smaller carnivores. The gradient being a platform of food resources, macro and microclimatic conditions, shelter, anthropogenic disturbances, geographical features, etc. shapes the size and dynamics of the existing carnivore population. This study focusing on the small carnivore communities along the elevation gradient have been able to provide baseline information on the current pattern of small carnivore space use along riverine system. It was also possible detect the seasonality in the habitat use along elevation. As it is evident from the two seasons (summer and winter 2017) study that small carnivores show variation in site usage intensity, it would be interesting to investigate the habitat variables driving such kind of pattern i.e. the ecological factors responsible for a spread out distribution of animals in summer and a reduced distribution in winter. Once the key components controlling the small carnivore communities along the elevation gradient of GHNPCA are identified we can arrive at a better understanding of the overall scenario and to plan conservation management strategies for this group of mammals.

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THE WILDLIFE SOCIETY
Leaders in Wildlife Science, Management and Conservation

Certificate of Attendance

October 19, 2020

This certificate recognizes **Meghna Bandyopadhyay**'s attendance at The TWS 2020 Annual Conference - A Five Day Virtual Conference Experience on September 28 – October 2, 2020. Meghna also presented a talk titled - *Vertical Changes in Small Carnivore Community Interactions in the Great Himalayan National Park, Himachal Pradesh*.

If you have any questions, please contact The Wildlife Society via phone at (301)897-9770 ext. 315 or via email to agajare@wildlife.org.

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ASSOCIATION FOR
TROPICAL BIOLOGY
AND CONSERVATION

ATBC2019
Antananarivo
Madagascar

CERTIFICATE OF ATTENDANCE

This is to certify that

Meghna Bandyopadhyay

Has participated in the **56th Conference of the**
ASSOCIATION FOR TROPICAL BIOLOGY AND CONSERVATION
July 30 - August 3
CCI Ivato, Antananarivo, Madagascar

Lúcia LOHMANN
ATBC Executive Director

Hajanirina RAKOTOMANANA
Event Chairman

ATBC2019
Antananarivo
Madagascar

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Best Presentation Award

This is to certify that

Meghna Bandopadhyay

has been awarded **Third Prize** for presentation made during the 4th Himalayan Research Seminar held on August 21, 2019 at the Wildlife Institute of India.

In recognition thereof, this **Certificate** is hereby awarded on this 27th day of August, 2019 at Dehradun.

Director

Rawat
Dean

Sinha
Research Coordinator

NATIONAL MISSION ON HIMALAYAN STUDIES (NMHS)

Himalayan Researchers Consortium (HRC)-2019

May 16–17, 2019

Certificate of Paper Presentation

This is to certify that **Ms. Meghna Bandyopadhyay** from **Wildlife Institute of India (WII), Dehradun, Uttarakhand** has participated and made Presentation on the theme"**Biodiversity Conservation and Management"** in the **"3rd Himalayan Researchers Consortium (HRC)-2019"** held during May 16-17, 2019 at **GBPNIHESD, HQs Almora**, Uttarakhand, India.

(Er Kireet Kumar)
Scientist 'G', GBPNIHESD
Nodal Officer, NMHS-PMU

(Dr. Ranbeer S. Rawal)
Director, GBPNIHESD
Kosi-Katarmal, Almora

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Best Presentation Award

This is to certify that

Meghna Bandopadhyay

has been awarded **Second Prize** for her presentation made during the 3rd Himalayan Research Seminar held on September 10, 2018 at the Wildlife Institute of India.

In recognition thereof, this **Certificate** is hereby awarded on this 20th day of September, 2018 at Dehradun.

Director

GS Rawat
Dean

B Sinha
Research Coordinator

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Best Presentation Award

This is to certify that

Meghna Bandopadhyay

has been awarded **Third Prize** for her presentation made during the 2nd Himalayan Research Seminar held on September 1, 2017 at the Wildlife Institute of India.

In recognition thereof, this **Certificate** is hereby awarded on this 6th day of September, 2017 at Dehradun.

Director

Dean

Research Coordinator