Subsidized Mammals: Understanding the mammalian interactions with garbage sites around Western- Rajaji Tiger Reserve, Uttarakhand

by

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Enrolment no: 50BB22A73018

Dissertation Thesis

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Under the supervision of

Dr Bilal Habib

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Wildlife Institute of India

AcSIR

2024

DECLARATION

I hereby declare that the work conducted under the thesis entitled **"Subsidized Mammals: Understanding the mammalian interactions with garbage sites around Western- Rajaji Tiger Reserve, Uttarakhand"**, is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Master's in Wildlife Science** at the **Academy of Scientific and Innovative Research**. This research work has been carried out under the guidance and supervision of **Dr. Bilal Habib, Scientist-F**, and co-supervision of **Dr. Bivash Pandav, Scientist-G & Dr. Shivam Shrotriya** of Wildlife Institute of India, Dehradun. The work has not formed the basis for the award of any other degree, diploma, or any other qualification. I also declare that the thesis embodies my own work, analysis, observation, understanding and the particulars given in it are true to the best of my knowledge.

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CERTIFICATE

This is to certify that the thesis by **Shashank Nagarale** entitled "**Subsidized Mammals: Understanding the mammalian interactions with garbage sites around Western- Rajaji Tiger Reserve, Uttarakhand**" is an original and independent research work submitted to the **Academy of Scientific and Innovative Research**, for the award of the degree of **Master's in Wildlife Science**.

Shashank Nagarale has put one semester of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

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shaped by human waste exists!"

"Beyond the natural landscapes and untamed species, a wild world shaped by human waste exists!"

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4. EXECUTIVE SUMMARY

1. Anthropogenic food subsidies in the form of garbage dumps are widespread across the globe. When such sites are found around protected areas/wildlife habitats, wildlife is observed to exploit these subsidies as food resources. Foraging on such human-derived foods may have a negative or positive impact on individual to community/ecosystem levels. It becomes important to know the species associated with garbage dumps when found around protected areas and understand the interactions happening at the garbage dumps. This study was conducted aiming to know the animals at risk and also increase our understanding of these novel setups.
2. I deployed 13 IR camera traps at total 10 garbage sites resulting in a cumulative effort of 437 trap nights at the garbage site. The camera trap data was processed using Megadetector & SpSeg packages in python. This data was used to get the Relative Abundance Index with respect to 437 trap nights. Sambar (RAI= 8.35) was the species with the highest visitations at the garbage site, followed by Indian crested porcupine (RAI= 2.70) and spotted deer (RAI= 2.15). Synanthropes like rhesus macaque (RAI= 1.78) and wild pig (RAI= 1.67) were the most visitors following spotted deer. I hypothesised that synanthropic species will have higher visitations because of distribution outside protected areas, followed by omnivores from the forest area as compared to herbivores and carnivores from the forest areas because of their ability to exploit larger variety of food resources. The data from this study rejected this hypothesis as forest dwelling species like sambar and Indian crested porcupine visited these sites more as compared to other synanthropes. Lesser visitations by omnivores like golden jackal, small indian civet, small indian mongoose; carnivore like common leopard along with scavenger striped hyena was a result of the less percentage of poultry waste (0.33% at only one site) in the garbage sites.

3. I collected data on variables such as distance of the garbage site from the protected area, human infrastructure and waterbody, also quantified the size of the garbage site in terms of perimeter, NDVI difference between the protected area and garbage site as a surrogate of vegetation cover, relative abundance of each species in the adjoining protected area and calculated the composite RAI values of human, dogs/cats and livestock as a disturbance measure . I quantified the garbage in broader categories using a 1 m^2 quadrat which was divided into smaller sets of 25x25 cm^2. A total of 39 plots were laid for all the garbage site. The categories quantified were food wrappers & food disposables, food materials, religious offerings, agriculture discards, dung plates, sanitary waste, construction waste, carcass & poultry waste, pharmaceutical waste, cloths and plastic and others. The relation between relative abundances within protected area and visitations at the garbage site was assessed using Spearman correlation test along with Wilcoxon test p-values. With the available dataset I used ANOSIM using 'vegan' package in R program v4.1.2 to investigate the effect by considering the dissimilarity of the communities between sites based on the RAI values of the species for each garbage site. Relative abundance from protected area was not related to visitation of the species at the garbage site. Out of the selected variables, the ANOSIM values suggested the effect of 'distance between garbage site and protected area' on forest species and synanthropes. The effect of the 'size of garbage site' on the species could not be tested as there was not much variation in the sizes of the garbage sites. Human, dogs/cats and livestock presence affected the forest species, suggesting their sensitivity towards disturbances, while synanthropes were found to have affinity with the NDVI difference between protected area and garbage sites (vegetation cover at the garbage site) and the 'percentage of food materials available in the garbage site'.
4. To understand the co-occurrences at the garbage site, I modified the probabilistic models for co-occurrences (Veech, 2013) to get pair-wise associations at the temporal scale of one

hour. A total 13 mammals avoided co-occurring with humans (and vehicle) while nine with livestock and dogs. Co-occurrences were found to be there between sambar and Indian crested porcupine at two out of three religious sites and at a household site, suggesting high tolerance levels to each other's presence at the garbage site to exploit the resources. One of the sites was visited by barking deer with spotted deer group/herd. This association by solitary living barking deer can be for foraging effectively by reducing vigilance efforts in a group.

1. INTRODUCTION:

Anthropogenic Food Subsidies (here after, AFS) are food that is available to animals through human presence (Oro et al., 2013). This can be directly made available in the case of feeding stations or may be available to animals unintentionally, like the waste dumps. AFS sites can be further categorised based on the constituents like crop residuals, waste dumps, fishing or slaughter discards, feeding stations, etc. These constituents can attract species depending on their dietary habits, and the distribution of these sites can be predicted on the spatial or temporal scale. Oro et al. (2013) compared various types of Predictable Anthropogenic Food Subsidies (PFAS) based on the distribution, amounts, human intentionality, biomes, trophic levels of animals using these sites and birds and mammals using these sites (Table 1).

Table 1: Percentage of mammal (n=21) and bird (n=29) species affected by different types of Predictable Anthropogenic Food Subsidies worldwide (Source: Oro et al., 2013).

Type of PAFS	**Distribution**	**Relative amounts of food**	**Human intentionality**	**Predictability**	**Biomes**	**Trophic levels**	**% taxa (birds-mammals)**
Dumps	Worldwide	Very high	No	Spatial and temporal	Terrestrial; nutrient transfer to coastal	From producers to top predators	21-29%
Fishing discards	Worldwide	High	No	Spatial and temporal	Marine; nutrient transfer to coastal	From producers to top predators	14-5%
Middens and restaurants	Worldwide and mainly in industrialised countries respectively	Locally medium	Only for restaurants (avian scavengers)	Mainly spatial	Terrestrial	Producers, secondary consumers and top predators	10-19%
Crop residuals	Mainly in industrialised countries	High	No	Spatial and temporal	Terrestrial	Mainly herbivores	21-38%
Bird feeders	Industrialised countries	Low and local	Yes	Spatial and temporal	Terrestrial	Herbivores	3-0%

Feeding stations for game species and tourism	Mainly in industrialised countries	Locally high	Yes	Spatial and temporal	Terrestrial and marine	Mainly herbivores	10-24%
Gut piles and carcasses from hunting	Where large wild game is practised	Locally high	No	Spatial	Terrestrial	Producers, secondary consumers and top predators	10-19%

Growing human population is generating large amounts of waste. A large chunk of solid waste (household, agriculture, animal husbandry, tourism sites, and others) is left unmanaged because of ill-planning and resource deficiency in management. Roads, urban and rural settlements, tourism hotspots, and industrial areas lead to the fly-tipping and illegal dumping of solid waste and this waste is often dumped along roads, riverbanks, forest areas, and fringes of the villages (Banerjee et al., 2019; Shahab & Anjum, 2022), which are accessible to wildlife present in the surroundings. Roads and railway lines also contribute to garbage accumulation along them. Developing countries have a higher generation of waste, which remains unmanaged and these are the countries which hold most of the world's biodiversity (Myers et al., 2000; Danielsen et al., 2003).

Dumps, referring to the unsegregated waste, are the most widely distributed and abundant AFS which are also exploited by all the trophic levels (Oro et al., 2013). To avoid ambiguity, I defined garbage sites/dumps in this study as locations where regular dumping of unsegregated household/agriculture /tourism waste occurs. This dumping can be illegal or under a legal structure. Such dumps around wildlife habitats become a common foraging site for wildlife, domestic and free-ranging animals with human presence (Figure 1).

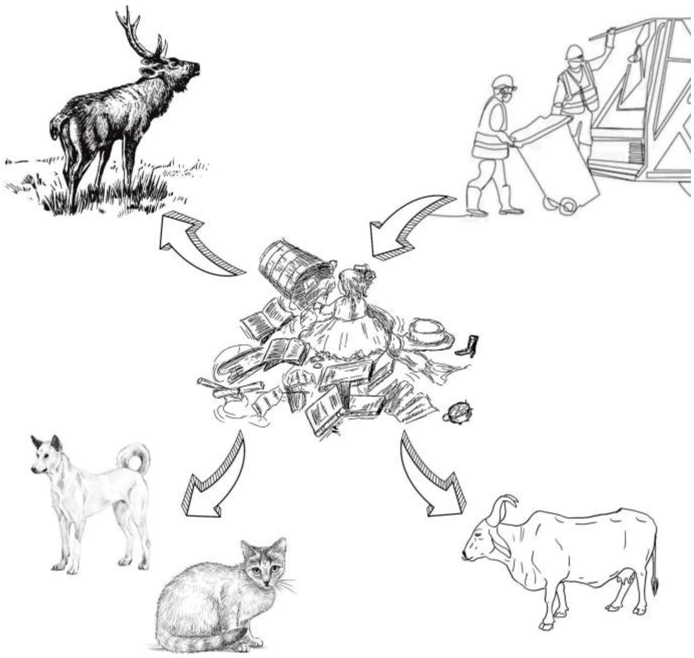

Figure 1: Representation of food resource flow at the garbage sites

For animals there is a risk of ingestion of human-derived materials which may be harmful. While, use of a common site by wildlife, livestock, free-ranging dogs/cats and humans may increase chances of zoonosis; subsidised wild populations may also have cascading effects on community or ecosystem levels because of fluctuations in populations or behaviour; increase in conflict of wild animals with humans can also a result of facilitation by AFS. Behavioural changes in terms of feeding, activity time and habituation to anthropogenic environments are also possible. Understanding species at risk and how species visits such sites gains importance.

1.1. Background:

I reviewed literature to understand the effects of a novel setup like a food subsidy act in a natural system. "Human subsidies; dumpsite; garbage disposal; landfill; waste management; urban wildlife; wildlife in landfills; wildlife response to waste" were the keywords used to search for literature on Google Scholar. I screened 58 published literature, out of which 3 were M.Sc./Ph.D. thesis published from 1980 to 2023. From the literature, Mammals (n = 33) and birds (n = 26) were documented more as compared to othertaxa. Reptiles and microbes were found to be the least studied (each, n = 1) (Figure 2).

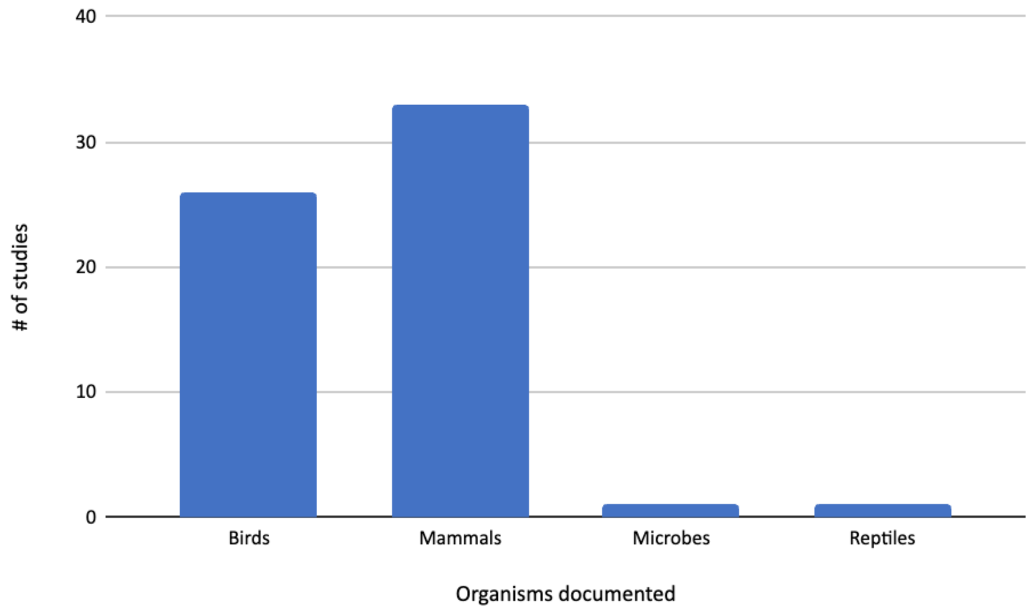

Figure 2: Number of studies documenting species associated with Anthropogenic food subsidies across the world from 1980 to 2023, obtained from Google scholar (n=58).

A total 24 unique mammalian species associated with human food subsidies were recorded. Based on dietary habits, the mammals reported were omnivores (n=11), carnivores (n=9), and herbivores (n=4). Oro et al. (2013) synthesized the effects of AFS on wildlife from individual to community/ecosystem levels (Figure 3).

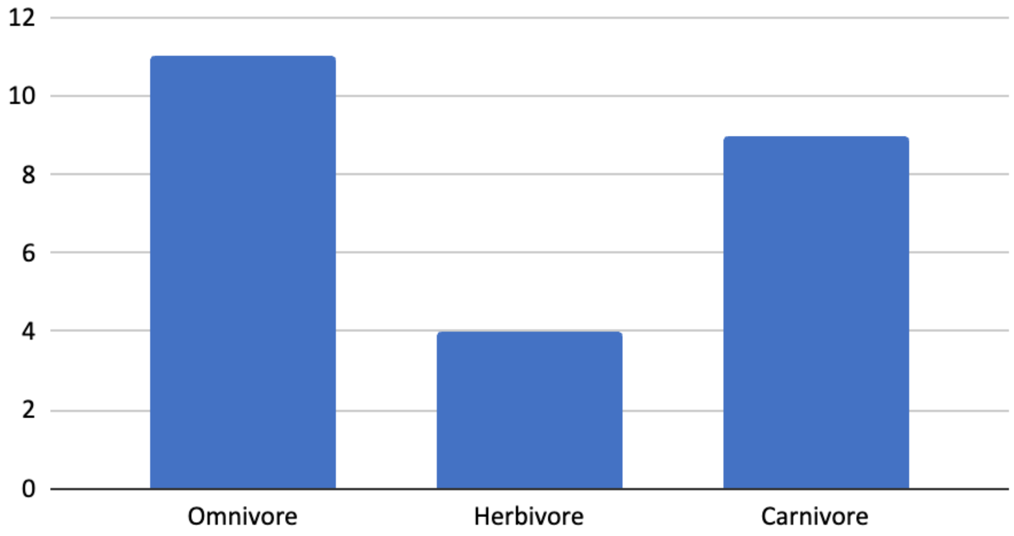

Figure 3: Number of mammals and their dietary habits documented associated to AFS based on the dietary habits across the world from 1980 to 2023, obtained from Google scholar (n= 24).

White Storks (*Ciconia ciconia*) was one of the most studied species, investigating the influence of AFS on hatching success and survivability of chicks (López-García et al., 2021), carriage of cephalosporin and colistin-resistant *Escherichia coli* in the droppings (Höfle et al., 2020) and landfill influence on densities and population decline after landfill closure (Bialas et al., 2021). Vultures are another group of species studied frequently. Human-derived waste from AFS was found in the diet of bird species like vultures (*Coragyps atratus, Cathartes aura* and *Vultur gryphus*) from Argentina and Andean Condors (*Vultur gryphus*) in Chile (Ballejo et al., 2021; Pavez et al., 2019). Ballejo et al. (2021) found a negative relation between presence of AFS in pellets of the vultures and distance from the AFS site. Kelp Gull (*Larus dominicanus*) from Argentina were found to show age specificity towards various types of human-derived waste (Frixione et al., 2023). For Lesser-backed Gulls (*Larus fuscus*), GPS tracking studies showed that the garbage sites reduced the foraging efforts of the gulls and helped them energetically (Langley et al., 2021). Black Kite (*Milvus migrans*) which show an association with landfills and other AFS while wintering Red Kite (*Milvus milvus*) were found to be less dependent on the landfills because of wild rabbits in the diet (Kumar et al., 2018; Vicente-

Hernández et al., 2023). Effects at community level were observed by (Boarman, 2003) where increase in Raven (*Corvus corax*) population increased the predation of the Desert tortoises (*Gopherus agassizii*). Various effects of AFS from individual to ecosystem level represented by Oro et al. (2013) in Figure 4.

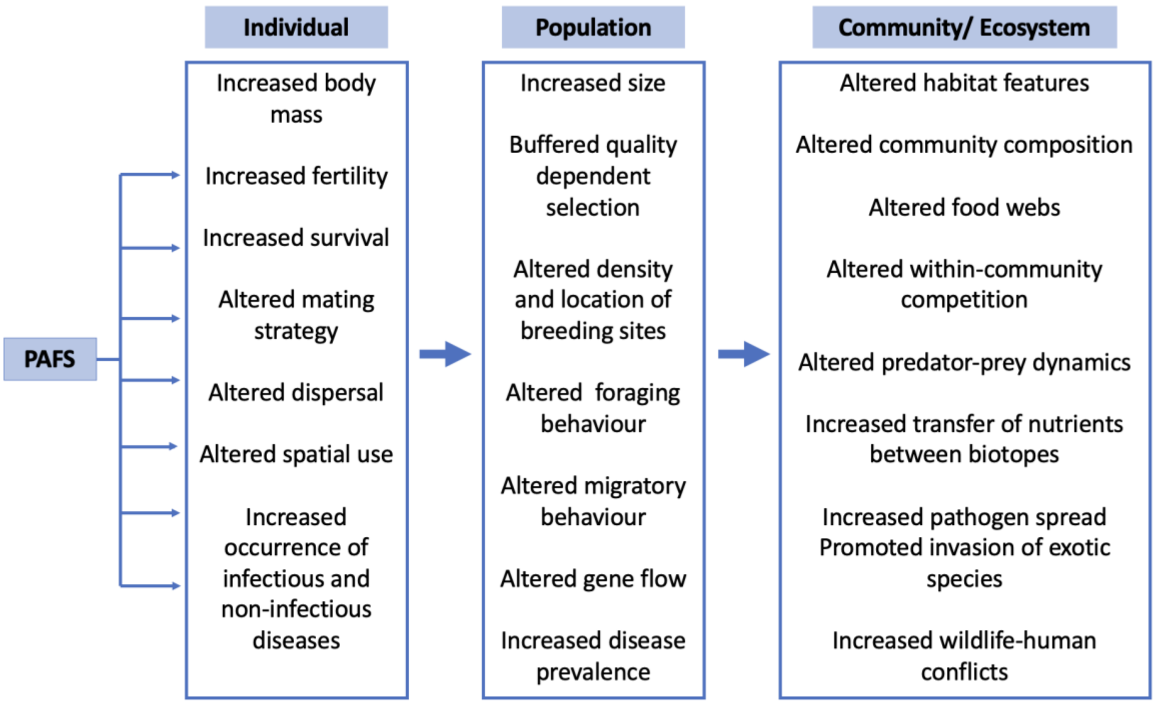

Figure 4: Flow of the effects of PAFS from individual to population and further to community and ecosystem level (Source: Oro et al., 2013).

Studies from India and Sri Lanka have documented presence of human-derived waste in the diets of the Asian elephants (Katlam et al., 2018; Liyanage et al., 2021). Katlam et al. (2020) recorded the ingression of plastics deep inside forest areas by Asian elephants from their dung, while Liyanage et al. (2021) documented the response of the elephants to the unloading of the garbage at a site which suggests the increased tolerance of elephants to human presence for the waste subsidies. Gray wolves (*Canis lupus*) from Spain and USA were associated with carcass dumps (Lagos & Bárcena, 2015; Petroelje et al., 2019). Lagos and Bárcena (2015) documents the reduction in carrion feeding by the gray wolves in Spain because of an increase in wild prey population. The presence of food subsidy like carcass dumps had an impact on the home ranges of the gray wolves in Michigen, USA (Petroelje et al., 2019). Golden jackals from Croatia (Škrivanko et al., 2013), and red foxes (*Vulpes vulpes*) from India were also documented consuming human-derived materials sourced from dump sites(Ghoshal et al., 2016; Reshamwala et al., 2018). Ghoshal et al. (2016) compared the presence of human-derived materials and livestock to the number of houses and Reshamwala et al. (2018) observed a positive association between the relative occurrence of this meso-predator with the presence of human-derived materials. Reshamwala et al. (2018) found Red foxes and the percent of AFS in their diet to be affected by the dog presence.

Garbage sites are known to have negative and positive effects on different species, which further alter the community structure, leading to cascading effects (Boarman, 2003; Oro et al., 2013; Newsome & Van Eeden, 2017). Species adapting to the synanthropic behaviour, which garbage dump sites may facilitate, may lead to conflict, as in the case of dingoes (*Canis lupus dingo*) in Australia, Polar bears (*Ursus maritimus*) in the Arctic region, and Gray wolves (*Canis lupus*) in Turkey (Burns & Howard, 2003; Chynoweth et al., 2016; Frixione et al., 2023).

Zoonotics is another component of interest where wildlife and human and livestock interactions may lead to disease spread forward and back. The ten most studied diseases at wildlife-livestock interfaces were avian influenza, rabies, salmonellosis, bovine tuberculosis, trichinellosis, Newcastle disease, brucellosis, leptospirosis, echinococcosis, and toxoplasmosis and Figure 5 is a representation of publications on the various studies related to wildlife-livestock interfaces (Wiethoelter et al., 2015). AFS sites have potential where the interface between wildlife, livestock, free ranging animals (dogs & cats) and humans may increase.

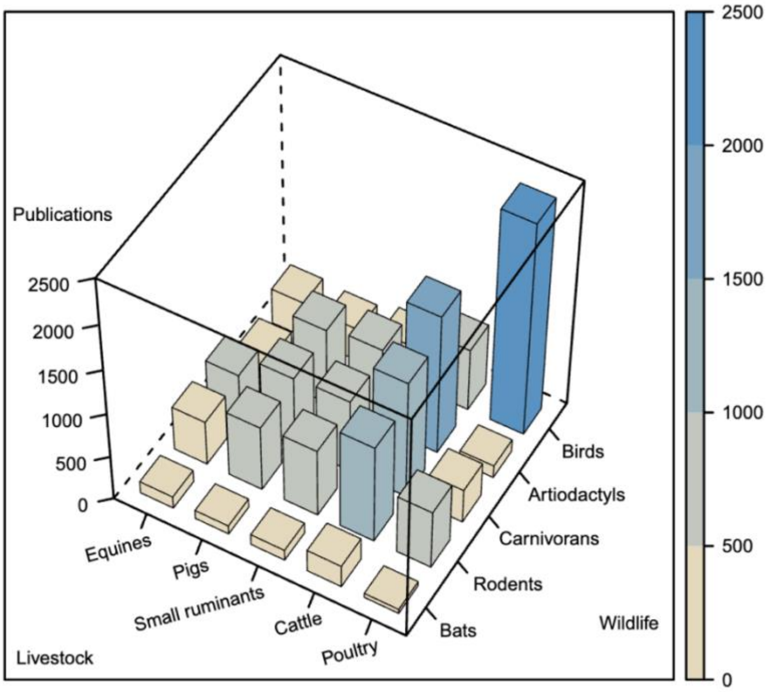

Figure 5: Prominent wildlife–livestock interfaces reported in scientific literature. Scaled to number of publications with only one disease (n = 13,293) (Wiethoelter et al., 2015)

Studies on garbage sites are not found to be directional. Studies conducted on white storks in different parts of Europe shows the positive and negative effects of AFS on its ecology. Responses by wildlife to AFS differ from species to species as for gulls, a positive effect was reported in terms of fecundity whereas for white storks there was no such effect. As Polis et al. (1997) mentions that effects on trophic levels depends on the web configuration and the roles of the species. A species may be completely dependent on the AFS or can visit these sites for supplementary food. Species which are highly dependent on the AFS may show effects in short time, while, for less dependent species these effects may be delayed over a time period.

India, as a developing nation with growing population, generates approximately 1.6 lakh tons of waste every day (CPCB, 2021). Managing this waste becomes difficult, resulting in only 70% of the waste collection. As a bio-diverse nation with wildlife habitats facing issues of fragmentation, smaller protected area sizes and degradation, only 5% of the geographical area is protected. Because of smaller protected areas, a significant proportion of wildlife thrives outside of protected areas, for example, 35% of Indian tigers are reported outside protected area network. If present in such areas, garbage sites become a attractant for wildlife. These readily available food sources may have a detrimental impact on wildlife, like a shift in diet, which may disrupt the ecological food webs. Garbage sites in the corridor and areas of wildlife movement may affect the activity time and movement of the animals. As such sites are located near human settlements, there are higher chances of the interface between human and wildlife, which may lead to an increase in the conflict cases. While interactions between wildlife and livestock are less studied in India, garbage sites can be responsible for an increased overlap between them, resulting in the exchange of zoonotic pathogens. Combined effect of a growing human population, mismanagement of waste, and limited protected areas creates a need for the study of such novel setups. Hence, understanding species associated with garbage sites, factors influencing their visitations and knowing populations at risk gains importance. This study will be helpful in identifying the species visiting the garbage sites and to understand the factors influencing the visitations and also how wild mammals visit these sites with respect to humans, livestock and free-ranging animals such as dogs and cats.

1.2. Objectives & hypotheses

Objective 1: To compare mammalian visitations at the garbage site

Hypothesis**:** *Synanthropic species may visit the garbage site more as compared to omnivores, carnivores and herbivores from the forest area.*

I divide the species found in the study area into synanthropes and forest (dwelling) species. Synanthropes are the species which are facilitated by human activities and hence which are distributed in human-dominated landscapes. Rhesus macaque (*Macaca mulatta*), nilgai (*Boselaphus tragocamelus*), golden jackal (*Canis aureus*) and wild pig (*Sus scrofa*) are grouped in synanthropes as they are associated with human subsidies on the edges. Synanthropes will be the most frequently visiting species followed by omnivores from the forest, which will visit the garbage site more as compared to carnivores and herbivores from the forests. With distribution outside the protected area, synanthropes like golden jackal, rhesus macaques and wild pigs will be dependent on these garbage sites, and hence will visit these sites more. Nilgai are recorded as dependent on subsidies like agriculture and hence may not visit the sites as often as the three mentioned above. I hypothesize that the omnivores from forests like common palm civet (*Paradoxurus hermaphroditus*), small indian civet (*Viverricula indica*), grey mongoose (*Herpestes edwardsii*), leopard cat (*Prionailurus bengalensis*), Indian crested porcupine (*Hystrix indica*), yellow-throated marten (*Martes flavigula*), Indian hare (*Lepus nigricollis*) and a scavenger like striped hyaena (*Hyaena hyaena*) from forests will be attracted more to the garbage dump sites as compared to carnivores and herbivores because of their generalist diet which may facilitate them to exploit these resources. Bengal tiger (*Panthera tigris tigris*) and common leopard (*Panthera pardus fusca*) act as apex predators and spotted deer (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), and Terai langur (*Semnopithecus hector*) are the herbivores in the landscape.

Objective 2: To investigate the influence of variables on visitation of the species

Hypotheses:

Table 2: Variables which may influence the visitations of the species at the garbage site

Sr. No.	Variable/Influencing factor		Association/ Effect	Reference/ Rationale
1	Distance between garbage site and protected area (wildlife habitat)		Negative	Panek & Bresiński, 2002; Ballejo et al., 2021; López-García et al., 2021
2	Size of the garbage site		Positive	Smith et al., 2023
3	Composition of garbage site according to the source	Percentage of food wrappers, food waste, plastic, flowers and organic offerings (religious) in the garbage site	Different across categories	Burns & Howard, 2003; Ghoshal et al., 2016; Katlam et al., 2018; Liyanage et al., 2021; Frixione et al., 2023
4	Distance between garbage site and human infrastructure		Positive	Panek & Bresiński, 2002
5	Difference in NDVI between garbage site and nearest protected area		Negative	NDVI difference can be a surrogate of the vegetation cover. Higher the vegetation cover around garbage site may lead to higher visitations
6	Relative abundances of human + dogs + cats + livestock at garbage site		Negative	Wild mammals may avoid human, dogs/cats and livestock because of disturbances and hence higher the RAI for all may lead to lower visitations
7	Distance to water body		Negative	Water as a resource is important for the species. Closer the water body may lead to higher visitations
8	Relative abundance from adjoining protected area		Positive	Higher abundnaces in protected area may lead to higher visitations to the garbage site

Objective 3: To investigate mammalian co-occurrences with respect to humans, livestock and free-ranging dogs and cats at garbage sites

Hypothesis: *Synanthropes and forest species may have a negative influence because of human, livestock, dogs and cat.*

Forest species and synanthropes will be avoiding humans, dogs and cats and livestock because of their sensitivity towards disturbances. Except for Rhesus macaque, as the mode of acquiring food for them is with direct interface with humans.

2. METHODOLOGY

2.1. Study Area:

2.1.1. Location:

Declared in 1983, Rajaji Tiger Reserve is situated in the upper Gangetic region between the Yamuna and Sharda rivers. This area is an important part of the Rajaji-Corbett Tiger Conservation Unit (RCTCU) of the Terai-arc landscape, which was also designated as the 11th Elephant Reserve in the country under the title- Shivalik Elephant Reserve (Johnsingh & Negi, 2003). The Ganges separates the Rajaji Tiger Reserve into two regions: Western- Rajaji Tiger Reserve (WRTR) with 571 km^2 and Eastern- Rajaji Tiger Reserve (ERTR) with 579 km^2. The WRTR has extent 30.248623° N to 29.938195° N, 77.878570° E to 78.249541° E (Figure 6).

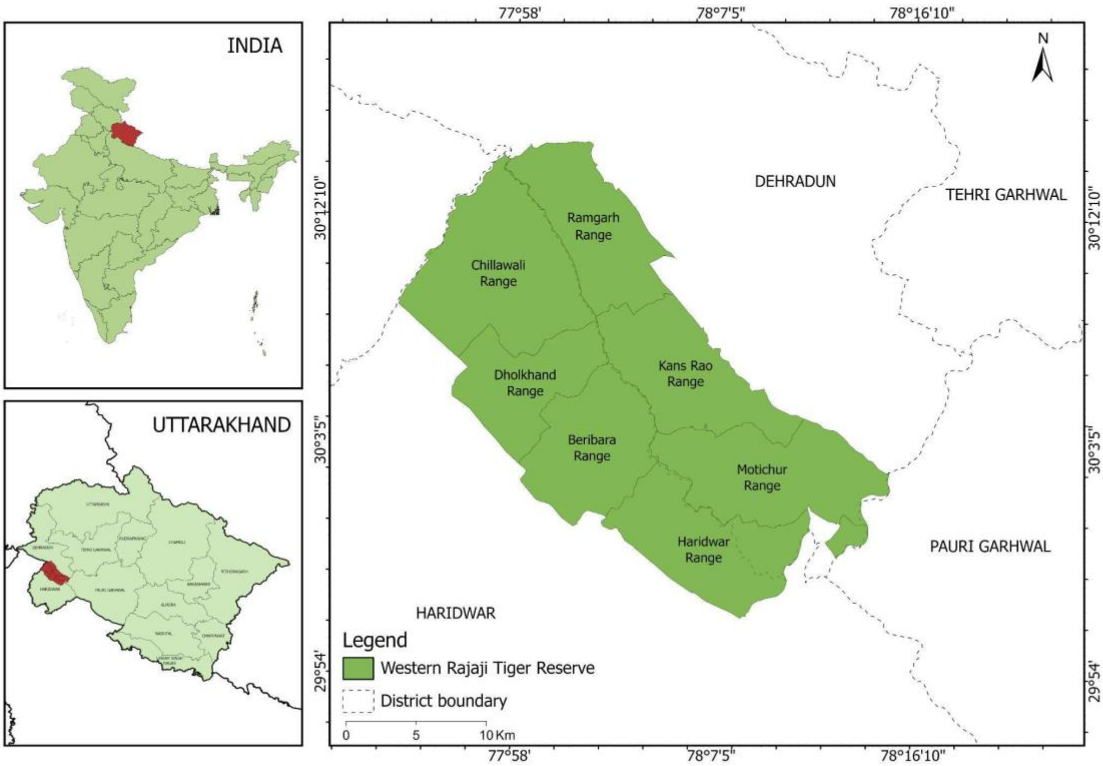

Figure 6: Location map of Western part of Rajaji Tiger Reserve, Uttarakhand

2.1.2. Physical features:

According to the Champion & Seth (1968) forest type classification, sub-tropical moist deciduous forests and dry deciduous forests are found in this region. The canopy is dominated by Sal (*Shorea robusta*) on the northern slopes, while on the southern slopes mixed forests of Sal with other dominant trees such as *Terminalia alata*, *Terminalia anogeissiana, Lagerstroemia parviflora, Holoptelia integrifolia, Ehretia aspera, Aegle marmelos* are found. Many south-flowing rivers and streams, which dry in late winter before the monsoon arrives, are characteristic to this landscape and are called 'raus' which supports the growth of grasses.

2.1.3. Mammalian assemblage:

In the Shivalik hills and Gangetic plain areas, Rajaji Tiger Reserve has observed higher leopard densities of 12.32 (SE - 1.01) per 100 km^2 (Qureshi et al., 2024). The three re-introduced tigers occupy the eastern ranges of the western part of Rajaji Tiger Reserve. Prey species like the barking deer (2.27 ± 0.32 ind/km^2), wild pig (4.82 ± 0.91 ind/km^2), Himalayan goral (1.61 ± 0.22 ind/km^2), spotted deer (16.32 ± 1.43 ind/km^2), sambar (8.85 ±0.61 ind/km^2), nilgai (1.33 ±0.91 ind/km^2), resulting in an overall prey density of 41.22 ± 6.65 ind/km^2 (Harihar et al., 2014). Other meso-predators found in WRTR are golden jackal, grey mongoose, yellow-throated marten, small Indian civet with striped hyena as a scavenger. Asian elephant is the only megaherbivore found. Rhesus macaque, Terai langur, common palm civet, and sloth bears are also present. The area also observes the movement of the Asiatic black bear in winter.

2.1.4. Human dimension:

The western part of Rajaji Tiger Reserve is surrounded by urban cities- Dehradun (n= 988007) in the north, Haridwar (n= 657829) and Rishikesh (n= 260343) in south-east of the park, with rural populations of 2.2, 3.3 and 1.3 lakhs respectively (Census of India,

2011) (Figure 7). The presence of Haridwar City acts as a barrier for various species like tigers, and the Ganges is a natural barrier for most of the species except Asian elephants (Johnsingh & Negi, 2003; Harihar et al., 2014). The BHEL township near Haridwar is an industrial area that borders the south-eastern WRTR. Agricultural lands and rural habitations surround the south-western boundary of the area. Two national highways pass through the WRTR, NH 307 (along the western boundary) and NH 34 (along the eastern WRTR). A network of minor roads on the northern and southern boundaries connects various villages. The presence of such urban and rural areas, railway lines and roads contributes to the illegal garbage dumping around WRTR. Species from different trophic levels with different feeding habits makes WRTR an appropriate study area to study the responses of different mammalian species to garbage sites.

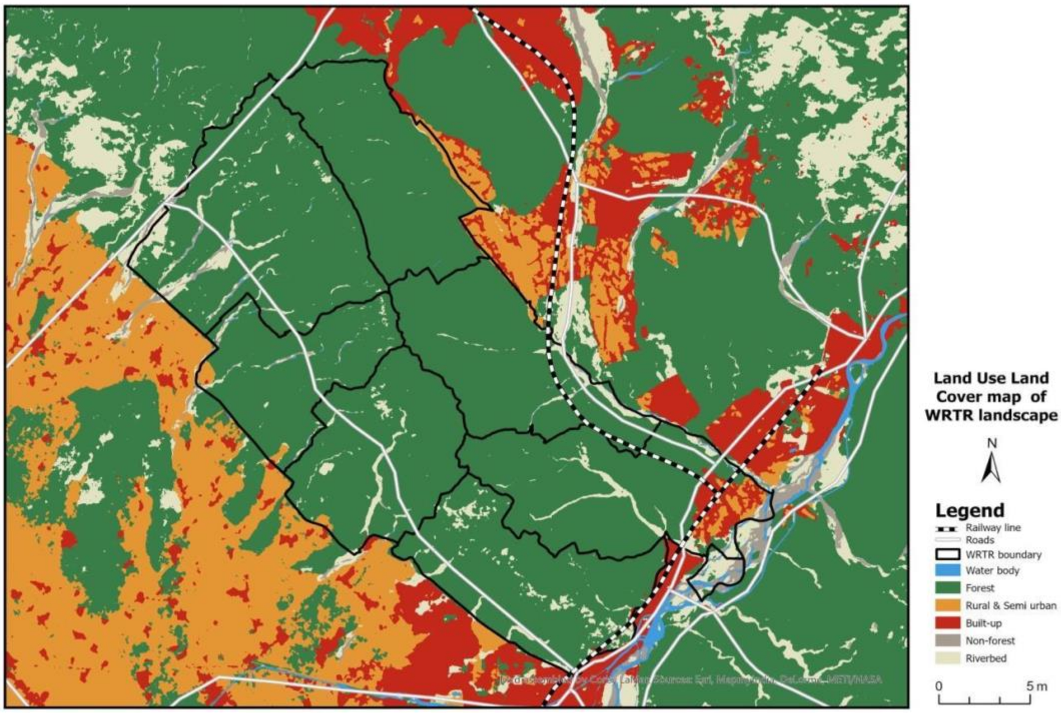

Figure 7: Land Use Land Cover map of Western part of Rajaji Tiger Reserve, Uttarakhand (Imagery data: Sentinel-2).

2.2. Study design:

2.2.1. Locating garbage dumps:

To locate garbage sites and confirm the presence of wildlife, a preliminary survey for garbage sites around WRTR was carried out in the months of December 2023 and January 2024. The availability of the garbage sites in the area and signs of spotted deer (*Axis axis*), wild Pig (*Sus scrofa*), nilgai (*Boselaphus tragocamelus*), Asian elephant (*Elephas maximus*) and sambar (*Rusa unicolor*) were noted during the survey. For a systematic mapping of these garbage sites, a buffer of 4km around WRTR was marked, and grids of 4 km^2 was layered on this buffer area using ArcGIS pro v3.1.4 (Figure 8). Each grid (n =72) was surveyed twice to locate garbage sites. To locate a garbage dump, the area was extensively surveyed and residents of the area were inquired about the presence of garbage sites and presence of wild mammals at these sites.

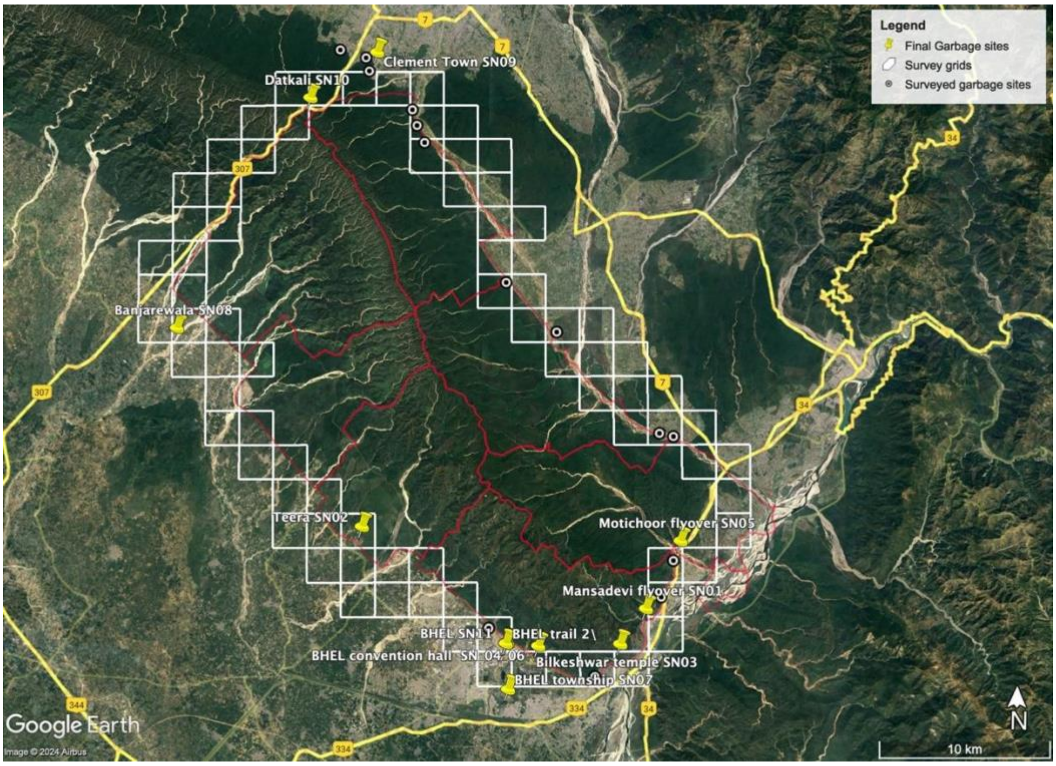

Figure 8: Map showing survey design for locating garbage sites around the western part of Rajaji Tiger Reserve, Uttarakhand

2.2.2. Objective 1: Comparing mammalian visitations at garbage sites

A total of 13 IR camera traps (Cuddeback) were deployed at 10 garbage sites at a height of ~45 cm from the ground, which were set to take images for all 24 hours. Two or more cameras were placed at larger sites to increase detections. To ensure the safety of the camera traps, cement poles were mounted near the garbage site and protective cages were drilled on the poles, in which the cameras were placed. For camera trap placement, I selected a site which was either an animal trail to the garbage site or where mammalian signs were higher. Mostly, areas with higher garbage amount were selected, as it was more visited by mammals (pers. obs.). The cameras at the dump were active between 12th January 2024 to 19th March 2024. The data from the camera traps was retrieved after 31-53 nights after deployment. This resulted in 437 trap nights of effort. The camera trap data was collected and processed to species level using python packages, MegaDetector v5 and SpSeg v1.0 further screened using Timelapse v2.3.1.0 (Beery et al., 2019; Microsoft 2022; Shrotriya et al., 2022). A record table of species visitation was created from the Timelapse output using CamtrapR package in R Statistical Software v4.1.2, given 30 minutes of interval of independence (Niedballa et al., 2016; R Core Team 2021). Relative abundance index (RAI) for each species was calculated using the formula (Carbone et al., 2001; O'Brien et al., 2003):

$$Relative\ Abundance\ Index = \frac{Total\ number\ of\ independent\ captures\ of\ the\ species}{Total\ number\ of\ trap\ nights} * 100$$

For each species the capture rates across sites were averaged. RAI values were averaged to get a mean RAI for species which was scaled with respect to the species having highest RAI value for comparison. The species were represented by various RAI values across sites, I grouped these species using hierarchical cluster analysis based on their presence at a site from a site-species presence absence matrix to know related species.

2.2.3. Objective 2: Estimating the influence of variables on visitation of the specie

I used Analysis of similarities (ANOSIM), as the number of sites (n=10) was not appropriate for Generalized Linear Models (Clarke, 1993; Somerfield et al., 2021). ANOSIM was run separately for two groups of species, i.e. forest dwelling and synanthropes with each variable. For the same, the variables were categorised based on the obtained data and ecological inferences (Table 3 & 4).

Table 3: Categorization of the variables used to test different hypothesis regarding the effect of the garbage sites on the presence of wildlife species around the western Rajaji National Park

Variable	Categories
Distance between garbage site and protected area (wildlife habitat)	Close (<100 m) & Far (>100m) Close (n= 4) & Far (n=6)
Size of the garbage site (Perimeter)	Small (<100m) & Large (>100m) Small (n=8) & Large (n= 2)
Distance between garbage site and human infrastructure	Close (<60 m) & Far (>60 m) Close (n= 4) & Far (n=6)
Difference in NDVI between garbage site and nearest protected area	Low (<5) & High (>5) Low (n=6) & High (n=4)
Relative abundances of human + dogs + cats + livestock at garbage site	Low (<10) & High (>10) Low (n= 4) & High (n= 6)
Distance to water body	Close (<350 m) & Far (>350 m) Close (n= 3) & Far (n=7)

Table 4: Waste type and corresponding constituents and the categories used to test different hypothesis regarding the effect of composition of the garbage sites on the presence of wildlife species around the western Rajaji National Park

*- Not used to test effect on the visitations

Category of waste	**Items**	**Categories**
Food wrappers & food disposables	Plastic food wrappers, aluminium foils used for food, disposable cups and dishes.	Low (<30) & High (>30) Low (n=4) & High (n=6)
Food	Food materials and kitchen waste.	Low (<0.1) & High (>1) Low (n= 8) & High (n= 2)
Plastic & others	Polythene bags, LDPE and HDPE materials, papers, footwear, rubber materials and metal materials.	Low (< 70) & High (>70) Low (n= 4) & High (n= 6)
Religious offerings	Flowers, fruits and leaves offerings.	Absent (0) & Present (0.80-1.32) Absent (n= 7) & High (n=3)
Agriculture discards*	Hay, leaves and agricultural weeds.	Low (<0.05) & High (>0.05) Low (n=8) & High (n=2)
Dung plates*	Dung plates	0.25 -3.75 % (number of sites= 3)
Sanitary *	Sanitary pads and diapers.	0.8 – 4.33% (number of sites =8)
Construction waste*	Bricks, cement blocks and Urinals.	0.2 – 1.25% (number of sites =4)
Carcass & Poultry waste*	Dead livestock and leftover waste from slaughterhouse.	0.33% (number of sites =1)

Pharmaceutical*	Medicine wrappers with/without contents	0.75- 1.4 % (number of sites =2)
Cloths*	Garments, leather bags, cloth bags, etc.	1.25 – 42.78% (number of sites = 10)

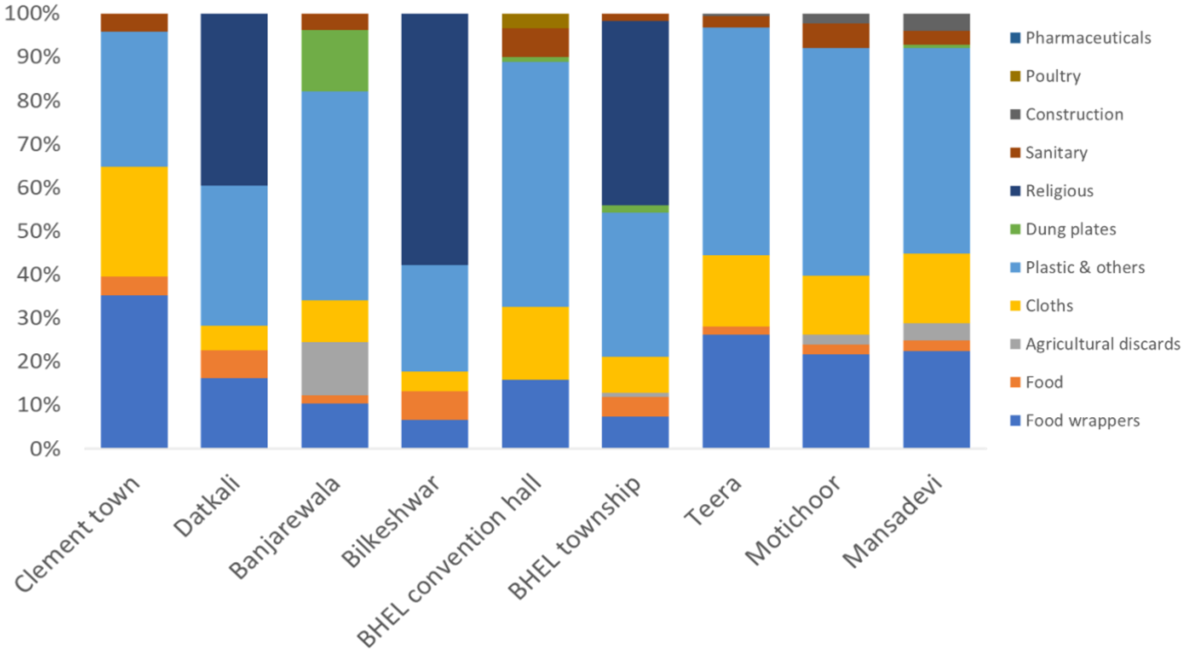

Figure 9: Graph showing percentage of composition of garbage sites

For different variables, the following data were collected:

Distance between garbage site and protected area and *distance between garbage site and human infrastructure:* Using ArcGIS pro software v3.1.4, these distances were measured in meters and which was categorised as high and low.

Size & Composition of garbage site: The size of the garbage sites was noted in terms of the perimeter of the site. I noted the presence of broader categories of waste in a 1 m^2 quadrat, which was divided into 25x25 cm^2 grids. I laid a minimum of 3 and maximum of 5 plots at a site to get representation of all the below-mentioned categories of waste. A total of 39 plots were laid, and the composition was categorised as Food wrappers & food disposables, Food, Plastic & others, Agriculture discards, Religious offerings, Dung plates, Sanitary, Construction waste, Carcass & Poultry waste, Pharmaceutical and Cloths (Table 4 & Figure A2).

NDVI difference between protected area and garbage site: The normalized difference vegetation index values were calculated using Landsat 8 data for the month of February 2024. A buffer of 100 meters around the garbage site and around camera traps placed within the protected area for SECR exercise was marked using ArcGIS pro v3.1.4. The average NDVI values of each camera trap from protected area were noted and were averaged for all the selected cameras from protected area corresponding to each garbage site. The difference between these average values was considered for the analysis.

RAI of Human, dogs+ cats and livestock: The camera trap data from the garbage sites were used to note the independent captures at 30 minutes interval for human, dogs and cats and livestock. The number of independent captures were pooled and were divided by 437 trap nights to get the composite RAI value. Also separate RAI values for human, dog+cats and livestock were also calculated.

Distance to waterbody: The distance to the waterbody was calculated by using MODIS data of 2022 on waterbodies.

I visualised these matrices of forest-dwelling species only with respect to the variables under the framework of Non metric Multidimensional Scaling using "vegan" package in R studio software v4.2.1. There was insufficient data for synanthropes for visualisation with respect to variables.

Relative Abundance from protected area: A 5 km buffer around the garbage site within the protected area was mapped using ArcGIS pro. Cameras were deployed in 2 km^2 grids on animal trails, streams, forest roads and dry stream to detect mammals within the protected area. For each garbage site photo capture number of each species from sites within 5km radius was converted to RAI values with respect to pooled camera trap nights of the selected cameras within the 5km radius (Figure 10).

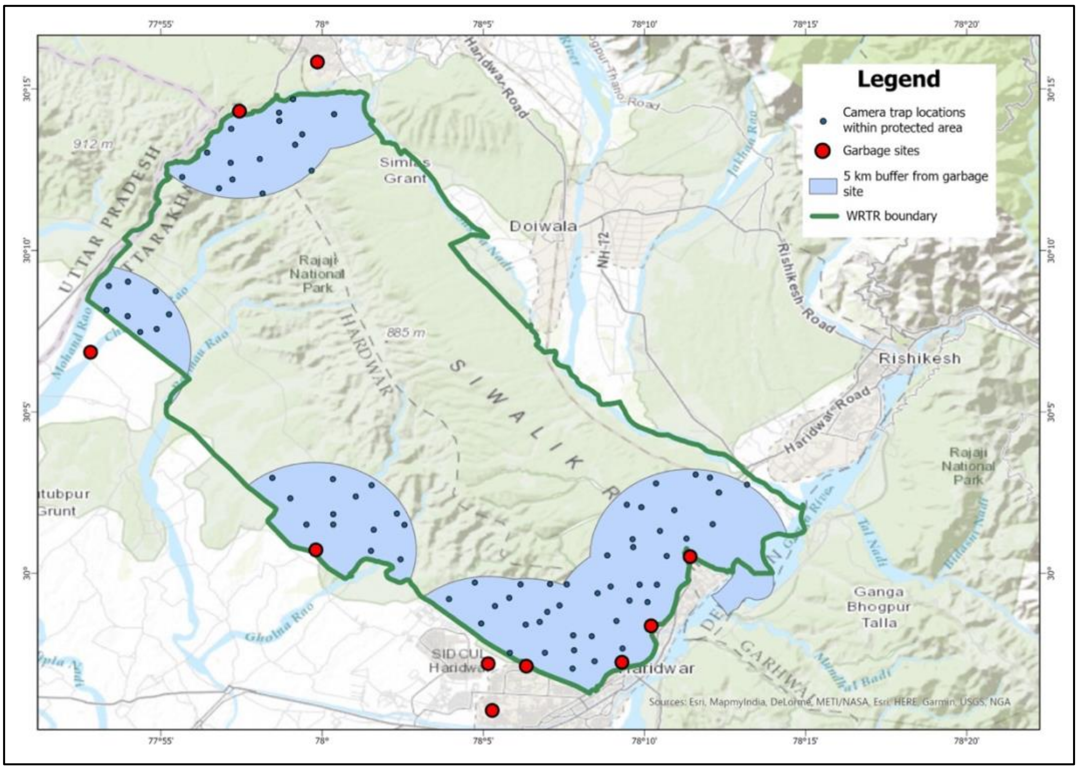

Figure 10: Map showing the camera traps (blue points) within the 5km buffer (shaded sky blue) inside the protected area from the garbage sites (red points)

2.2.4. Objective 3: Investigating mammalian co-occurrences with respect to free-ranging dogs and cats, livestock and human at garbage sites

To understand the co-occurrences of wild mammals with respect to other wild mammals, humans, free-ranging dogs and cats and with livestock at the garbage sites, I used the probabilistic models of co-occurrences (Veech, 2013). In this approach the probability of two species cooccurring at a site is calculated from a species-to-site presence-absence matrix. The associations between species are classified based on the probability of co-occurrences; into positive, negative and random. This model was modified to get site-event to species matrix of presence-absence. Site-event here refers to an event of a specified time period at a site. If a species is captured within this event at a site, then it is noted as present (1), if not then absent (0) for the site-event. This modification will provide the co-occurrence of the species at a specified temporal scale, so modifying the spatial co-occurrence viz. on a larger time scale like a camera trapping session to a shorter spatio-temporal scale. From the cooccur analysis, $P_{lt}<0.05$ and Plt<0.05 indicate negative and positive co-occurrence. I chose one hour to be the timescale based on the time spent by most of the species, which was around 30 minutes at the garbage site. The one-hour time scale is set to not miss any of the ecologically significant co-occurrences.

3. RESULTS

A total of 21 sites were located in the mapping survey, out of which 10 were selected for further camera trapping exercise based on their composition, distance from protected area, size (perimeter) and camera trap safety. The 10 selected garbage sites are listed with respective perimeter, distance from protected area and broader type of the garbage in Table 5.

Table 5: Total garbage sites located around WRTR and their characteristics (Bold – Selected for the study)

Site ID	Perimeter (m)	Distance from protected area (m)	Distance from human infrastructure (m)	Category of composition	Camera trap safety
a1	20	40	600	Household	No
a114	40	600	14	Household	No
a12	50	40	0	Household	No
a154	30	400	0	Household	No
a158	10	200	10	Household	Yes
a2	30	0	78	Religious	No
a20	20	0	20	Household	No
a26	30	0	25	Household	No
a27	20	22	10	Roadside	No
a60	20	200	79	Roadside	No
a71	10	10	44	Household	Yes
Banjarewala	40	2011	87	Household	Yes
BHEL convention hall	58	13	128	Household	Yes
BHEL landfill	20	1027	117	Household	Yes
BHEL township	105	3074	136	Household	Yes

Bilkeshwar	61	0	8	Religious	Yes
Clement town	70	0	42	Religious	Yes
Datkali	60.9	0	105	Religious	Yes
Mansadevi	42	127	9	Household	Yes
Motichoor	36	108	68	Household	Yes
Teera	27	104	42	Household	Yes

From the camera trapping exercise, a total of 18 mammalian species were recorded along with birds. Out of 18 mammalian species I selected 16 species excluding rodents and northern palm squirrel (*Funambulus pennantii*) for the comparison in visitations. These species were common palm civet (*Paradoxurus hemaphroditus*), striped hyena (*Hyaena hyaena*), small Indian mongoose (*Herpestes auropunctatus*), barking deer (*Muntiacus vaginalis*), Terai langur (*Semnopithecus hector*), Asian elephant (*Elephas maximus*), golden jackal (*Canis aureus*), Nilgai (*Boselaphus tragocamelus*), leopard (*Panthera pardus*), Indian hare (*Lepus nigricollis*), small indian civet (*Viverricula indica*), wild pig (*Sus scrofa*), rhesus macaque (*Macaca mulatta*), spotted deer (*Axis axis*), Indian crested porcupine (*Hystrix indica*) and sambar (*Rusa unicolor*).

3.1. Objective 1: Comparing mammalian visitations at garbage sites

From the RAI values obtained for the selected 16 mammalian species, Sambar had the highest RAI value of 8.35. RAI for other mammals was scaled with respect to RAI of Sambar by dividing RAI of each species by 8.35 (Table 6). The rarest visitors to the garbage sites were common palm civet, striped hyena, small Indian mongoose and barking deer, with the lowest RAI values. Terai langur, Asian elephant, golden jackal, nilgai, common leopard, Indian hare and small Indian civet had average visitations. Sambar, spotted deer, wild pig and rhesus macaque had the most visitations as interpreted from the RAI values (Table 6). There were variations in RAI values of a species across sites and also species were found to be visiting selected garbage sites (Figure 11). The distribution of the selected garbage sites and the species visiting these garbage sites with respect to total captures is represented in Figure 12. No captures of yellow-throated marten, grey mongoose, and leopard cat were at the garbage sites. Yellow-throated marten and leopard cat are habitat specialists preferring high ridges and slopes in Rajaji Tiger Reserve which may be the reason for no captures.

Table 6: RAI values (437 trap nights) of 16 mammalian species in the study with scaled RAI values with respect to Sambar

Species	RAI	RAI w.r.t. Sambar	Species	RAI	RAI w.r.t. Sambar
Common palm civet	0.02	0.003	Leopard	0.71	0.085
Striped hyena	0.02	0.003	Indian hare	0.78	0.093
Small indian mongoose	0.05	0.005	Small indian civet	0.85	0.101
Barking deer	0.16	0.019	Wild pig	1.67	0.200
Terai langur	0.21	0.025	Rhesus macaque	1.78	0.214
Asiatic elephant	0.39	0.047	Spotted deer	2.15	0.258
Golden jackal	0.62	0.074	Indian crested porcupine	2.70	0.323
Nilgai	0.69	0.082	Sambar	8.35	1.000

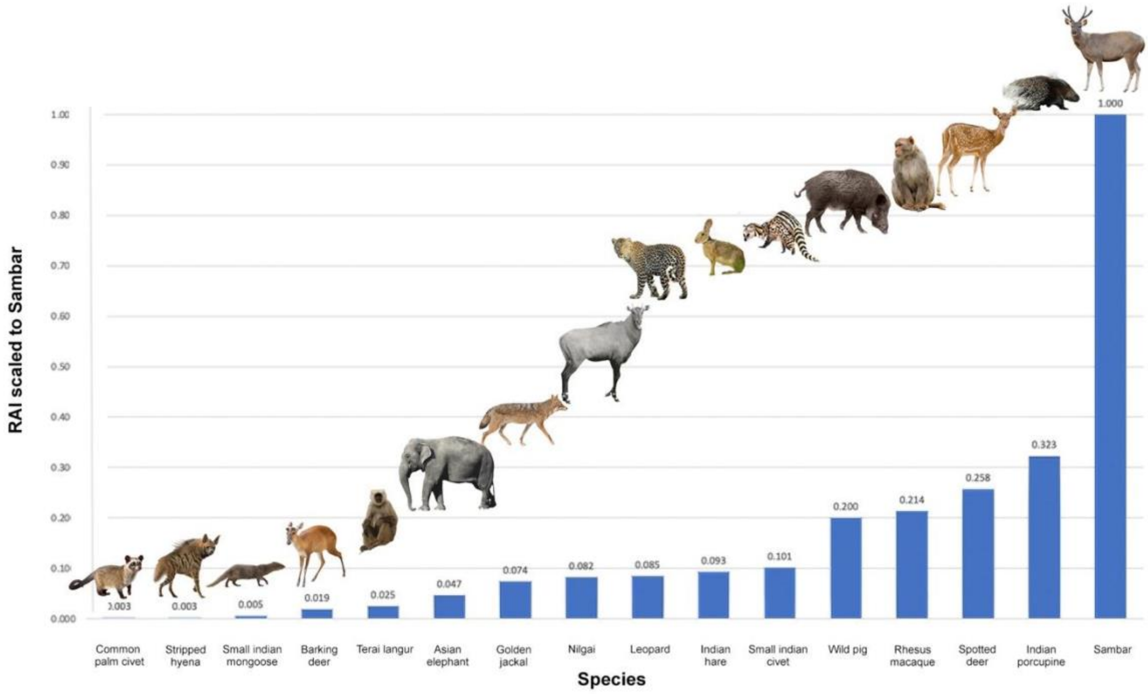

Figure 11: Graph showing Relative Abundance Index (scaled w.r.t. Sambar) of selected 16 species at garbage sites around western part of Rajaji Tiger Reserve, Uttarakhand

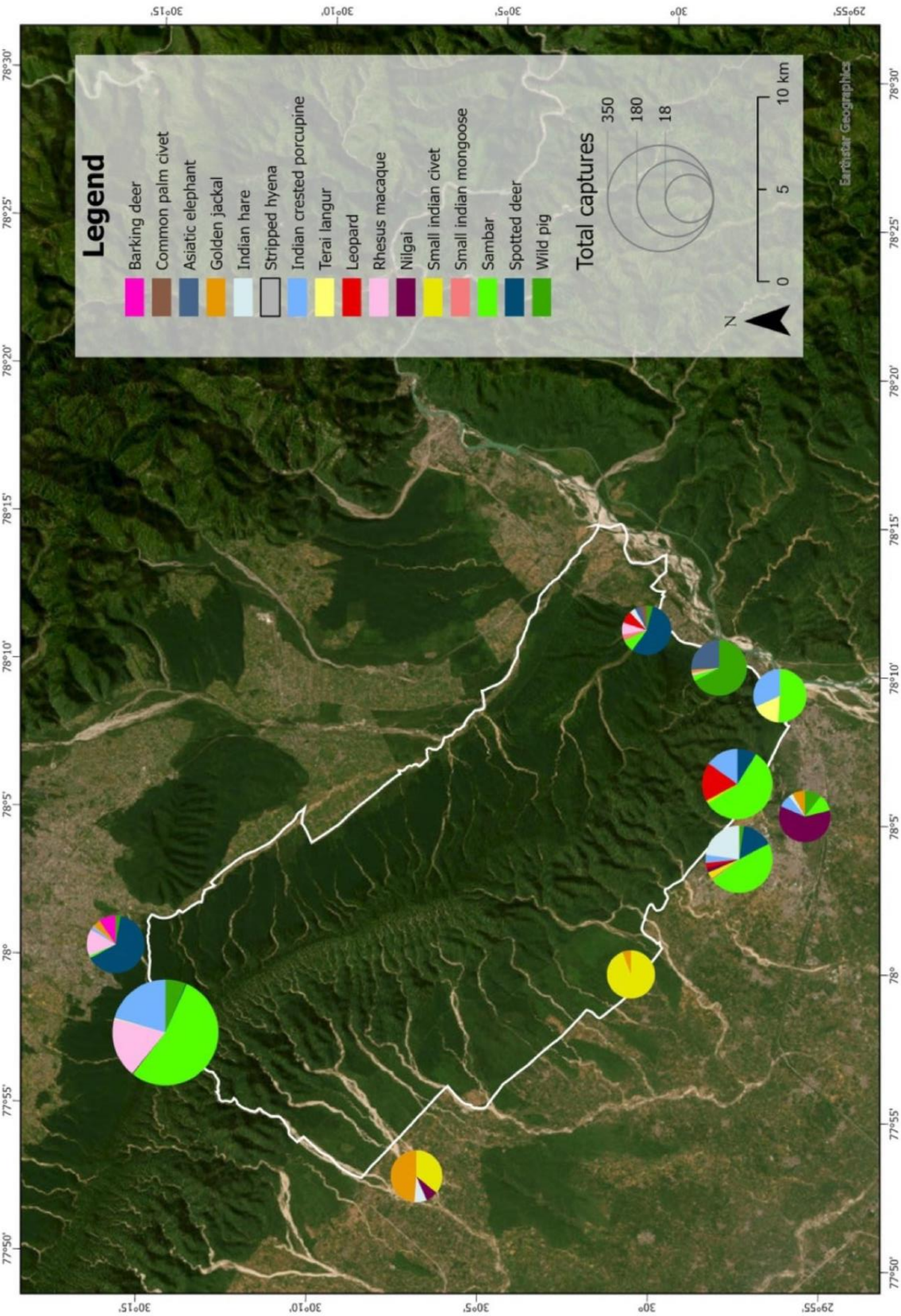

Figure 12: Map showing the distribution of garbage sites and species with respect to total number of captures at the garbage site (size of the pie chart)

Cluster analysis with based on the site-wise presence-absence data resulted in three major clusters based on the presence of species across sites. The species can be broadly grouped as common visitors which are Sambar, Indian crested porcupine and Spotted Deer; moderately common visitors like golden jackal, small Indian civet, Indian hare, nilgai, rhesus macaque, wild pig, common leopard, small Indian mongoose and Terai langur, while rare visitors were barking deer, striped hyena, common palm civet and Asian elephant (Figure 13).

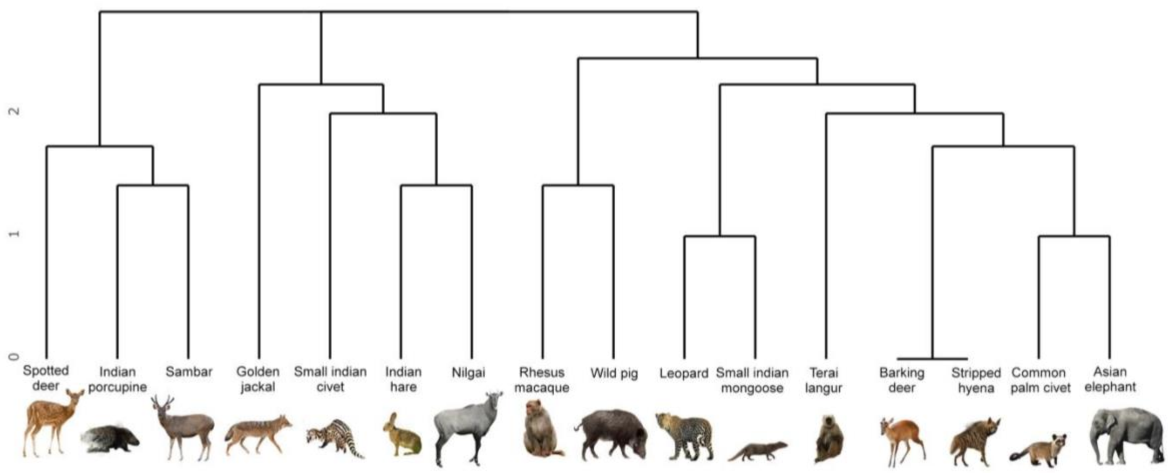

Figure 13: Dendrogram of the cluster of selected 16 species based on site-wise presence absence at garbage sites around western part of Rajaji Tiger Reserve, Uttarakhand

3.2. Objective 2: Estimating the influence of variables on visitation of the species

The relative abundance of a species at the garbage site and relative abundance of the same species within the adjoining protected area did not found to have a relation from the correlation test. Indian hare only was found to have a relation in the abundances at the garbage site and protected area. Golden jackal was not found within the 5 km radius from the garbage site. For all other species there was no significant correlation (>0.60) except for Wild pig, Asian elephant, small Indian mongoose, striped hyena and common palm civet which showed negative correlation suggesting that they had more visitations at the garbage sites than they were detected within the adjoining protected area (Table 7).

Table 7: Spearman correlation and Wilcoxon test values between RAI of species at garbage site and adjoining protected area

Species	Spearman correlation	Wilcoxon Test (p-value)
Golden jackal	Not found inside PA	
Indian hare	**0.72**	**0.08**
Leopard	0.54	0.01
Terai langur	0.51	0.02
Indian crested porcupine	0.48	0.38
Nilgai	0.48	0.28
Spotted deer	0.38	0.01
Sambar	0.29	0.01
Rhesus macaque	0.10	0.47
Barking deer	0.06	0.00
Small indian civet	0.02	0.10
Wild pig	-0.03	0.05
Asian elephant	-0.08	0.00
Small indian mongoose	-0.17	0.50
Hyena	-0.21	0.39
Common palm civet	-0.41	0.00

To evaluate the effect of variables on the species RAIs, I included selected variables (Table 3 & 4) to investigate their effect on the for which ANOSIM was carried out group-wise. The species were grouped based on the ecology as Forest dwelling and Synanthropes. The categories were binned based on the data and ecological understanding (Table 3 & 4). Significant effects of variables were found to be there on the visitations as per the ANOSIM R statistic value. This value ranges from -1 to 1 and a 0 value suggests the null hypothesis i.e.

there is no difference. A value closer to 1 suggest that there is effect of the variable on the values. The species were divided into two groups based on the ecology of the species as forest dwelling and synanthropes. According to ANOSIM R statistic values, I set the significance levels at $p < 0.10$ (90% confidence) to reject the null hypothesis that there is no effect of the variable on the community of mammalian species visiting the garbage sites based on the RAI values.

Significant differences were found for both the groups for the distance between the protected area and garbage site with 0.25 and 0.32 ANOSIM R statistic values for forest dwelling and synanthropes, respectively. For forest dwelling species, size of garbage site and composite RAI of human, dog/cat and livestock showed an effect with 0.38 and 0.17 ANOSIM R statistic values, respectively. Synanthropes also had an effect of NDVI difference between garbage site and protected area (0.22%) and of percentage food in the composition (0.50%) (Table 8).

The ANOSIM plots represents significant effects of distance of garbage site from protected area, size of garbage site, vegetation cover around garbage site and food amounts in the garbage on the mammalian community visiting the garbage site (Figure 14 to 18).

Table 8: ANOSIM values for each of the variables tested with two groups of species

Variable	Forest-dwelling		Synanthrope	
	ANOSIM R statistic	**Significance**	**ANOSIM R statistic**	**Significance**
Distance to protected area	0.25	**0.10**	0.32	**0.04**
Size of garbage site	0.38	**0.08**	0.05	0.37
NDVI difference between protected area and garbage site	0.06	0.27	0.22	**0.08**
RAI of (human + dog/cat + livestock)	0.17	**0.10**	0.02	0.33
Food	-0.31	0.91	0.50	**0.09**
Plastic & others	0.03	0.40	0.29	0.12
Religious offerings	-0.23	0.91	0.15	0.24
Food wrappers & disposables	-0.12	0.83	-0.10	0.72
Distance of site from human-infrastructure	0.03	0.36	0.11	0.20
Distance to water body	-0.13	0.62	-0.26	0.91

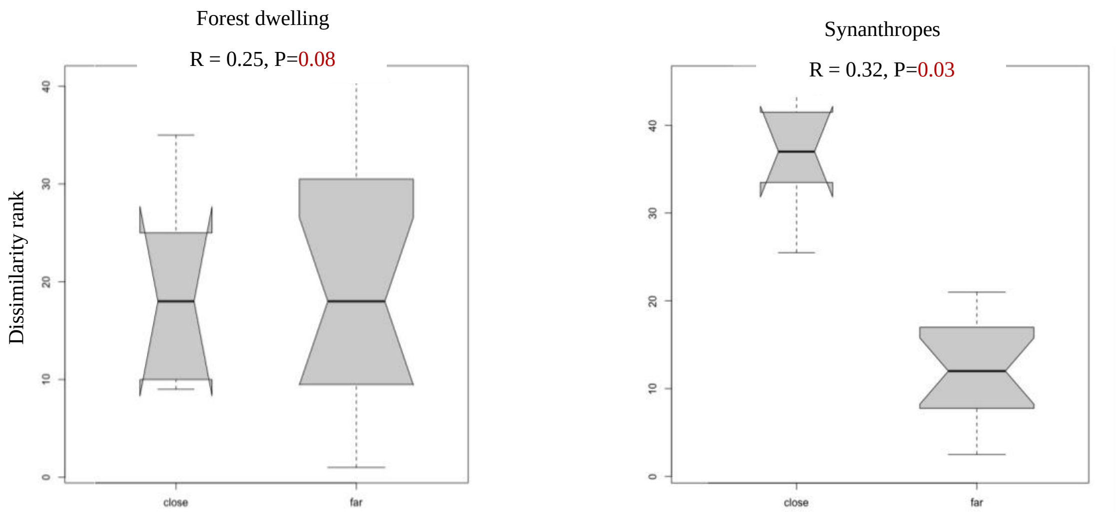

Figure 14 ANOSIM plots showing differences between communities of forest dwelling and synanthropes with respect to Distance between garbage site and protected (effect present) around western part of Rajaji Tiger Reserve, Uttarakhand

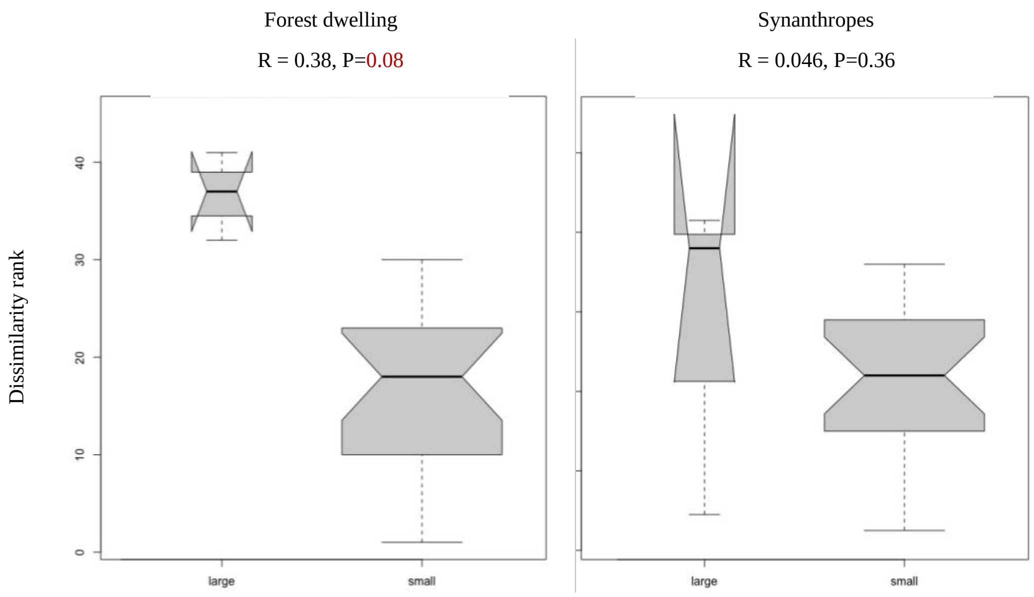

Figure 15: ANOSIM plots showing differences between communities of forest dwelling and synanthropes with respect to size of the garbage site around western part of Rajaji Tiger Reserve, Uttarakhand

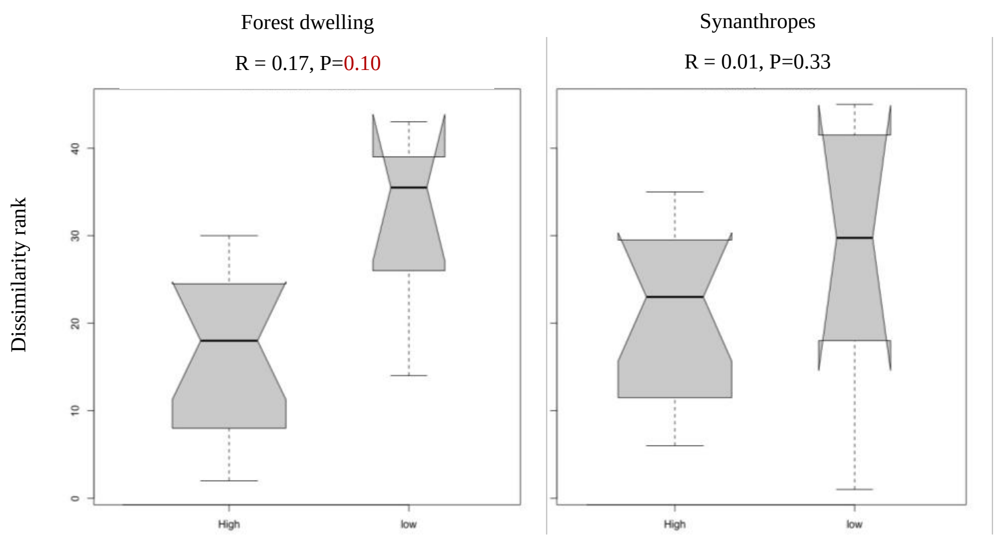

Figure 16: ANOSIM plots showing differences between communities of forest dwelling and synanthropes with respect to RAI of human, livestock, dog and cat at the garbage site around western part of Rajaji Tiger Reserve, Uttarakhand

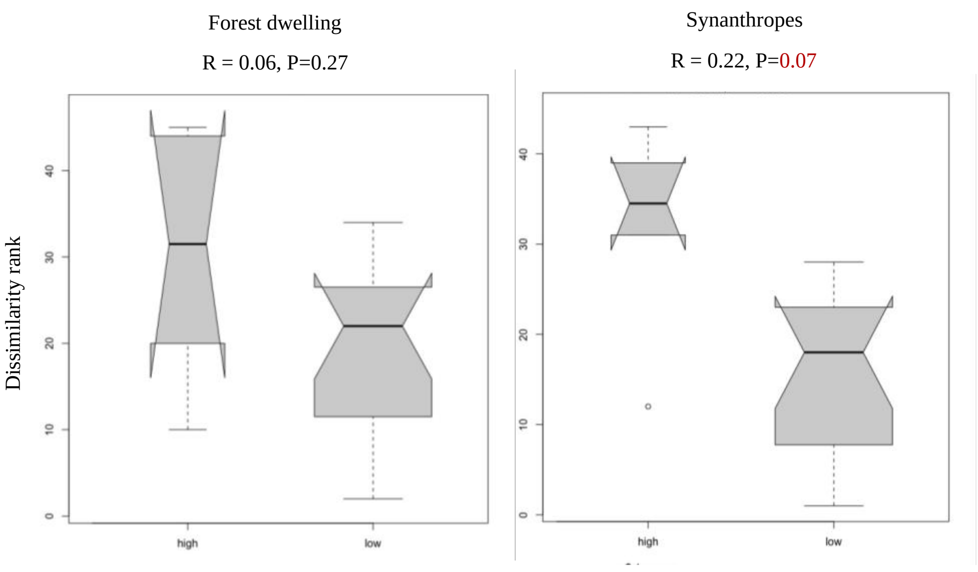

Figure 17: ANOSIM plots showing differences between communities of forest dwelling and synanthropes with respect to vegetation cover at the garbage site around western part of Rajaji Tiger Reserve, Uttarakhand

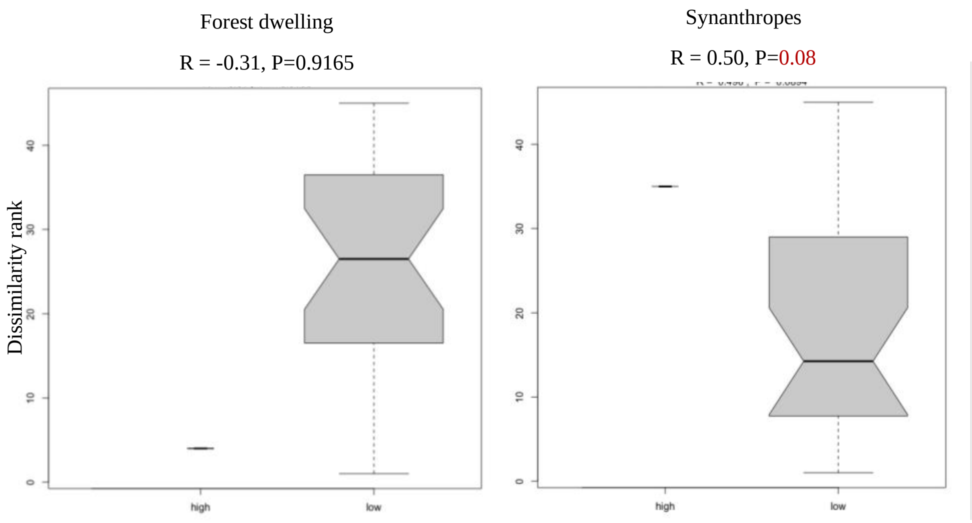

Figure 18 ANOSIM plots showing differences between communities of forest dwelling and synanthropes with respect to food amount in the garbage site around western part of Rajaji Tiger Reserve, Uttarakhand

3.3. Objective 3: Investigating mammalian co-occurrences with respect to free-ranging dogs and cats, livestock and human at garbage sites

A total 67 pairs of species (with vehicle) had significant associations out of 276 combinations, which were processed at a time scale of one hour (Figure 19 & 20). Most of the negative associations were by human, vehicle, dog, cow & buffalo towards various forest species (Figure 19). Out of 67 significant associations, 11 were Positive and 56 were Negative. Human (56.52%), Vehicle (56.52%), Cow (39.13%) and Dog (39.13%) had highest negative association with other species. Spotted deer (8.7%), Sambar (4.35%) and Indian crested porcupine (4.35%) had the most positive association. The lowest associations were found to be by Common palm civet, Striped hyena, Small Indian mongoose, Terai langur. This may be because of the low number of captures (Figure 19) The pairwise effects of the species were given in Table A2.

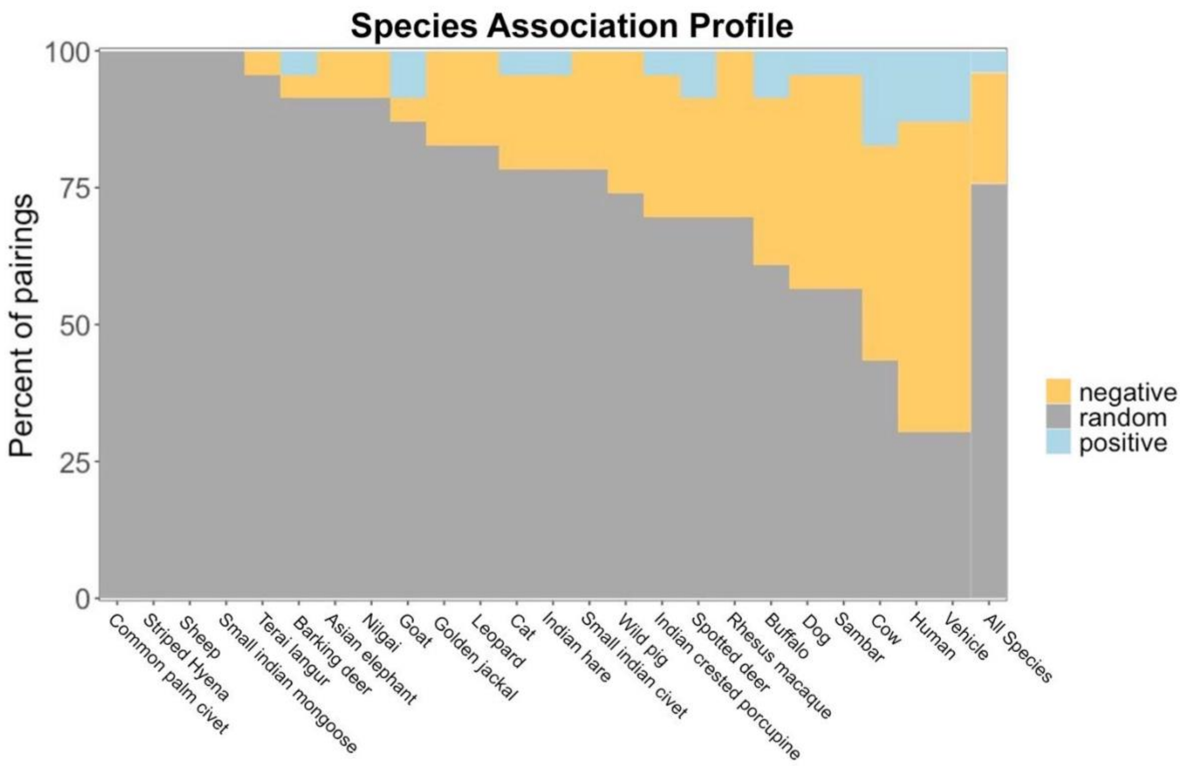

Figure 19: Species association profile for all species along with vehicle around captured at the garbage sites around western part of Rajaji Tiger Reserve, Uttarakhand

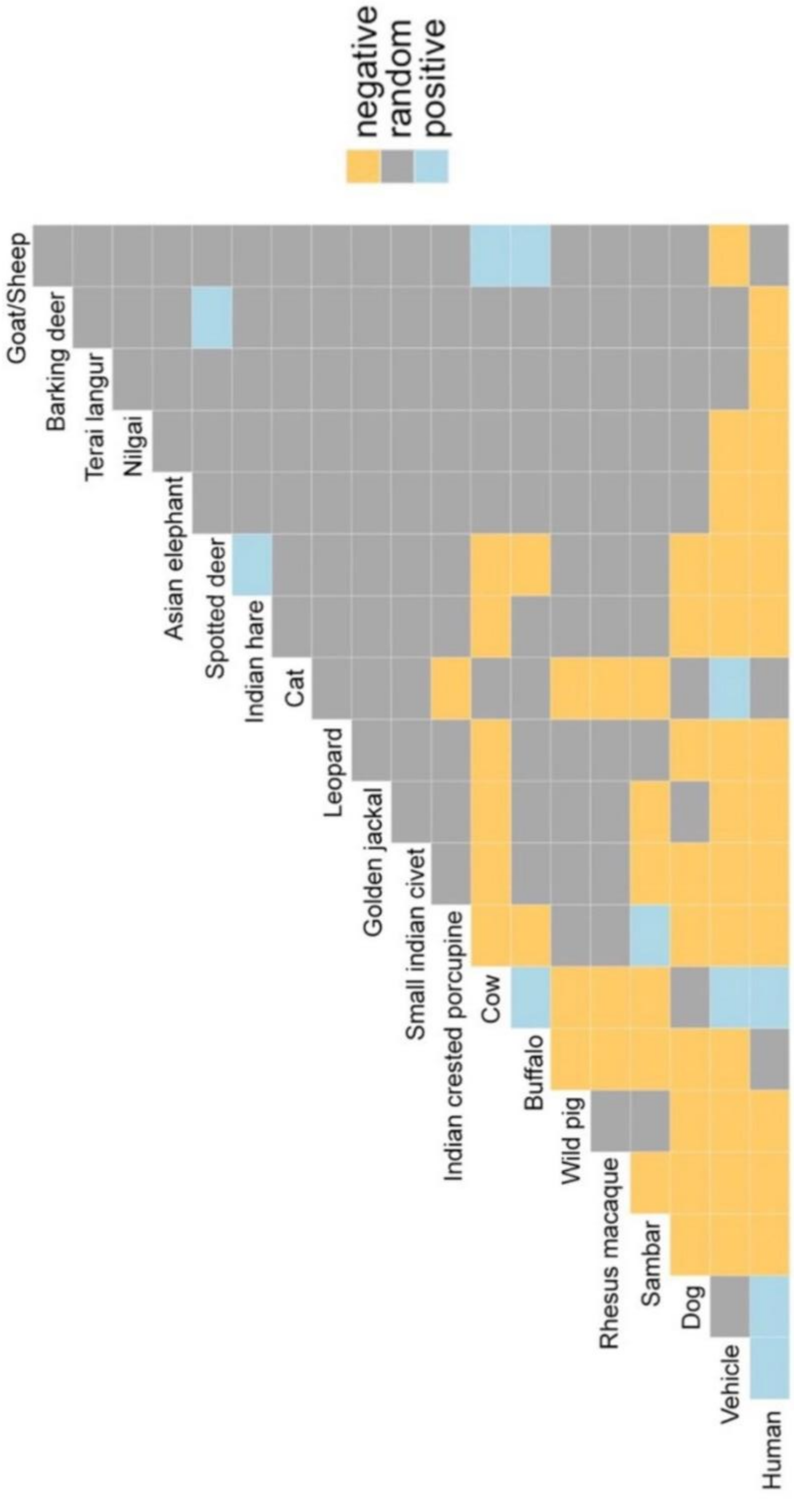

Figure 20: Species association matrix showing positive, negative and random associations between species as determined by probabilistic models for all the species along with vehicle visiting the garbage sites around western part of Rajaji Tiger Reserve, Uttarakhand. 67 pairs were analysed, of which 11 were positive (no antagonism), while 56 showed random (negative) distribution

4. DISCUSSION

4.1. Objective 1: Comparing mammalian visitations at garbage sites

From the results it is clear that visitations are irrespective of dietary habit, and the hypothesized concept that synanthropes will visit the garbage sites more followed by the forest dwelling omnivores as compared to carnivores and herbivores can be rejected. There were variations in the site-wise RAI values of the species (Figure A1). I observed lower visitations of carnivores, which can be because of the composition of the garbage site. Most of the garbage sites I sampled had either household waste or religious waste. In the process of quantification of garbage sites, I found very less presence of poultry discard (0.33% at only one garbage site) which could otherwise attract the carnivores towards the garbage sites. While the composition can be favourable for ungulates with moderate percentages of Food material and Food wrappers/disposables which are sources of supplementary food.

The expected species to visit these garbage sites more were Rhesus macaque and Golden jackal because of their omnivorous food habit and synanthropic behaviour. The results shows very less visitations for Golden jackal and moderate visitations for Rhesus macaque. For Rhesus macaque, the mode of acquiring food is different as compared to other foraging on garbage sites and natural food sources (Ganguly & Chauhan, 2018; Hasan & Hakim, 2024). Therefore, the camera traps might have missed their food sourcing from the garbage sites. A data collection method involving 24-hr direct observation could be applied to acertain that the macaque access the garbage sites but spent less time compared to species like ungulates. Golden jackals, which is also one of the synanthrope species, has a varied diet and along with the composition of the garbage site i.e. less slaughterhouse/poultry waste which resulted in less visitations (Škrivanko et al., 2013; Alam et al., 2015).

The forest dwelling species which are likely at higher risk of negative impacts of garbage sites are Sambar, Indian crested porcupine and Spotted deer due to their higher visitation and coverage of maximum sites. Synanthropes like rhesus macaque and wild pig which have higher visitations may have higher interface with humans and with both wild and domestic animals. This may facilitate the exchange of pathogens/diseases if any present. Negative interactions between human and elephant, e.g. property damage and chase by elephants, were observed at a site indicating the increasing tolerance levels of the species to human presence as studied by Liyanage et al. (2021) for Asian elephants in Sri Lanka (Figure A3). Tolerance of sambar to human presence was observed to be increased in the BHEL area where the landscape was mosaic with forest patches, human settlements and protected area close by with presence of garbage sites (Figure A4). Among the moderate visitors, common leopard was the only carnivore found visiting the garbage sites. No foraging by common leopard was noted from the captures as well as field observations, which may be a result of the composition with very less poultry discards.

Further, I noted the distance between the garbage site and the protected area to determine that how far animals are venturing for such food subsidies. Presence of forest dwelling species like the Sambar was found to be present at distances more than 3 km from the protected area, either suggesting the presence of population around the protected area or movement of species from protected area to such sites (Table 9).

Table 9: Table showing the species with the maximum distance between garbage site and protected area the species was captured around western part of Rajaji Tiger Reserve, Uttarakhand

Species	**Maximum distance of garbage site from protected area (m)**	**Species**	**Maximum distance of garbage site from protected area (m)**
Golden jackal	3074	Common leopard	1027
Indian hare	3074	Small indian mongoose	1027

Indian crested porcupine	3074	Spotted deer	1027
Nilgai	3074	Asian elephant	127
Sambar	3074	Common palm civet	108
Wild pig	3074	Barking deer	0
Small indian civet	2011	Striped hyena	0
Rhesus macaque	1217	Terai langur	0

4.2. Objective 2: Estimating the influence of variables on visitation of the species

The data in this study suggests that distance of garbage site from protected area and Human presence at a garbage site affects species visitations beyond composition (Figure 14 to 18). Comparing to previous studies on white stork, vultures and gulls the influence of distance of garbage site from the wildlife habitat for mammals can influence at finer scales (Panek & Bresiński, 2002; Ballejo et al., 2021; López-García et al., 2021).

No effect of the size of garbage site on the visitation of the wild mammals was found, perhaps because of the low variation in size in the dataset of this study. Only one site was comparatively larger than others (577m in perimeter). More data with variation in sizes of garbage dumps may explain the effect on the species visitations. A larger site like the BHEL landfill, with 577 m perimeter was found to have aggregations of sambar, spotted deer and nilgai while at smaller sites group wise visitation was observed viz. groups/herds of sambar visited the site one after the other which was a influence as observed in terms of Polar bears by (Smith et al., 2023).

Distance to human infrastructure didn’t show any effect on the visitations of the species which may suggest that species may be habituated to human infrastructures without any human activity at the site, as presence of human along with livestock, dogs and cats have an effect on the presence of the species. From this it can be considered that species get habituated to human-infrastructure when no human presence is observed at the site. Hence at night time, when human activity is low, wild mammals were found to be nocturnal visitors at the garbage site. The tolerance of the forest species to the human infrastructure tells about the increased tolerances of wildlife to humans which can lead to conflict as in case of Dingoes (Burns & Howard, 2003), Asian elephants (Liyanage et al., 2021) and Polar bears (Smith et al, 2023)

Presence of garbage sites may habituate forest species visiting such sites to human presence by a process as shown in Figure 21. Which suggest that at step 1, wildlife gets introduced to the subsidies and then adjust their activity time with respect to humans, dog/cats and livestock and hence get closer to human infrastructure following habituation with humans when there is no negative interaction/response from the human side. This process may be applicable for herbivores like Sambar and Spotted deer and carnivores like Common leopard in the study area except for Asian elephants. At a garbage site named Mansadevi, regular negative responses from humans towards elephants (shooting crackers & chasing elephants) were observed, yet elephants appeared to visit this site. This suggests that how important such sites can be for the ecology of Asian elephants around western Rajaji Tiger Reserve, Uttarakhand.

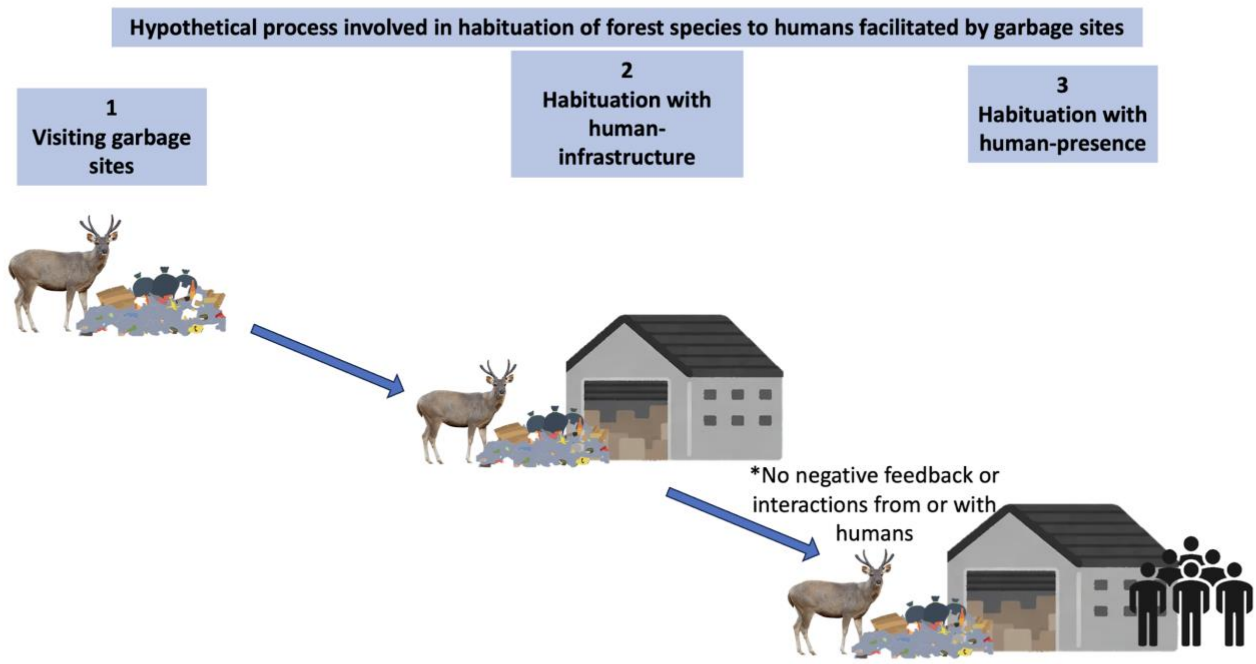

Figure 21: Hypothetical process involved in the habituation of a species visiting a garbage site

NDVI difference at the garbage site, which is here considered as a surrogate of canopy cover around the garbage site has a significant effect on visitations of forest dwelling species. Forest species appear to have no effect of the canopy cover at the site which suggests that forest species are becoming more tolerant to open spaces created by humans, and the chances of risking the movement in such open human-dominated places increases for exploitation of the AFS . For synanthropes, the case is opposite where canopy cover affects their visitations. The synanthropes occupy green spaces like forest patches outside protected wildlife habitats and forage on such sites, which may increase the requirement of a canopy cover for them around the garbage site. The exercise was performed in the season with no water scarcity and hence there was no significant effect of distance between garbage site and nearest waterbody.

Amount of Food wrappers and higher amount of Plastics and other materials didn't have effect on the visitations. While synanthropes showed significant differences with respect to food in the garbage site (0.50%). This may suggest that synanthropes specifically visit these garbage sites for the food materials available showing their dependency on such sites while thriving in human-dominated landscapes.

The quantification process has given insights on the human-derived materials encountered by a visitor at a garbage site (Figure 9). Wild mammals would visit a garbage site and sniff for the materials available and further depending on the type of the materials, they would ingest it or lick for salts (Personal observation - Sambar, Spotted deer & Nilgai). In this process by only examining the site by sniffing animal may get exposed to pathogens present at the site. Presence of sanitary materials like sanitary pads and diapers creates a higher chance of zoonotic transmission if there are disease causing pathogens present. Around 8 out of 10 sites comprised of sanitary waste though in less percentage (0.8 % – 4.33%), ingestion of such materials while ingestion of food materials may affect at the individual and population level.

4.3. Objective 3: Investigating mammalian co-occurrences with respect to free-ranging dogs and cats, livestock and human at garbage sites

Negative co-occurrences between various wild mammals and human and vehicle were observed. Human (56.52%), Vehicle (56.52%), Cow (39.13%) and Dog (39.13%) had highest negative association with other species. 13 wild mammals were observed to avoid cooccurring with humans and vehicle while 9 with livestock and Dogs. Wild mammals were found to have a nocturnal activity pattern at the garbage site to avoid humans.

Sambar and Indian crested porcupine, which were one of the most visiting the species at the garbage site, showed positive co-occurrences. They were found co-occurring together at religious sites (2/3) and at a household waste site. Clumped resources like garbage sites can force two or more species to co-occur together to exploit these resources making them tolerant of each other which may not be the case within the protected area. Another positive co-occurrence at the garbage site was found to be between Barking deer and Spotted deer at only one site. Barking deer is a forest dwelling and is found sensitive to disturbances. Barking deer was found to be visiting the garbage site with Spotted deer group which might have benefitted in reducing efforts in vigilance and forage effectively (Ghosal & Venkataraman, 2013; Neupane et al., 2022). Such type of commensal behaviour can be beneficial for a species to exploit such resources. Such co-occurrences can increase the chances of inter-species pathogen exchange.

4.4. Limitations & way forward:

This study includes data from the garbage sites and does not compare it with the protected areas. Comparing activity of these mammals at the garbage site with the activity of the animals within the core areas will show the change in ecology of various species.

The number of garbage site was a limitation in estimating the effect of the variables on the visitation rates. Data on visitations of these mammals in different seasons could help estimate the effect of the variables on the visitations of the species in a more meaningful way.

Studies on habituation of species because of such subsidies is required to know its effect on the overall community.

Further studies in the western part of Rajaji Tiger Reserve, Uttarakhand are required focusing on the zoonotic side by also including humans to investigate the effect of zoonosis. Investigating health issues of the frontline staff like ragpickers and garbage collectors gains important to know the effect by such common-use sites of wildlife, livestock, dogs/cats and humans.

4.5.Conclusion:

Based on my results I conclude that species visitation at a garbage site is specific to the garbage site characteristics like the location of the garbage site with respect to the protected areas/wildlife habitats; human infrastructures; presence of human, dogs/cats and livestock at the site and also the composition of the garbage sites.

Herbivores from the forest were the most visiting species followed by synanthropes, carnivores and omnivores. Mammals visited the garbage site irrespective of the abundances in the PA. Forest dwelling species visit sites closer to their habitat with less anthropogenic activity. Synanthropes require vegetation cover around the garbage site and higher food amounts. Mammals are tolerant to human-infrastructures. Clumped resources like the garbage can facilitate co-occurrences of two or more species from same trophic level.

Species visiting these garbage sites can be grouped into three as common visitors, moderately common visitors and rare visitors. Common visitors have more chances of direct and indirect interface with humans as compared to other visiting species which may lead to negative interactions like conflict or diseases. Forest species and synanthropes show specific requirements at the garbage site with insights as the canopy cover requirement and percentage food in the garbage site.

However, my study opens up more questions as to whether species visiting the garbage site or other AFS sites are a function of competition within the wildlife habitats which leads them to venture outside in the disturbed areas? How far do these species go into protected areas? Do such sites act as a source of disease to be spread in human locality and protected areas/wildlife habitats? There is a requirement to study diseases and changing mammalian behaviour because of such sites so to understand and answer many such questions.

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6. APPENDICES

Table A1: Number of captures of all species with vehicle at different garbage sites around western part of Rajaji Tiger Reserve, Uttarakhand

S.N.	Species/Vehicle	Number of captures	S.N.	Species/Vehicle	Number of captures
1	Human	1438	16	Other	50
2	Dog	832	17	Goat	37
3	Vehicle	576	18	Small indian civet	37
4	Cow	504	19	Indian hare	34
5	Sambar	365	20	Common leopard	31
6	Birds	195	21	Nilgai	30
7	Indian peafowl	192	22	Golden jackal	27
8	Buffalo	126	23	Asian elephant	17
9	Indian porcupine	118	24	Terai langur	9
10	Cat	116	25	Barking deer	7
11	Spotted deer	94	26	Rodents	5
12	Rhesus macaque	78	27	Sheep	2
13	Northern palm squirrel	78	28	Common palm civet	1
14	Wild pig	73	29	Striped hyena	1
15	Jungle fowl	62	30	Small indian mongoose	1

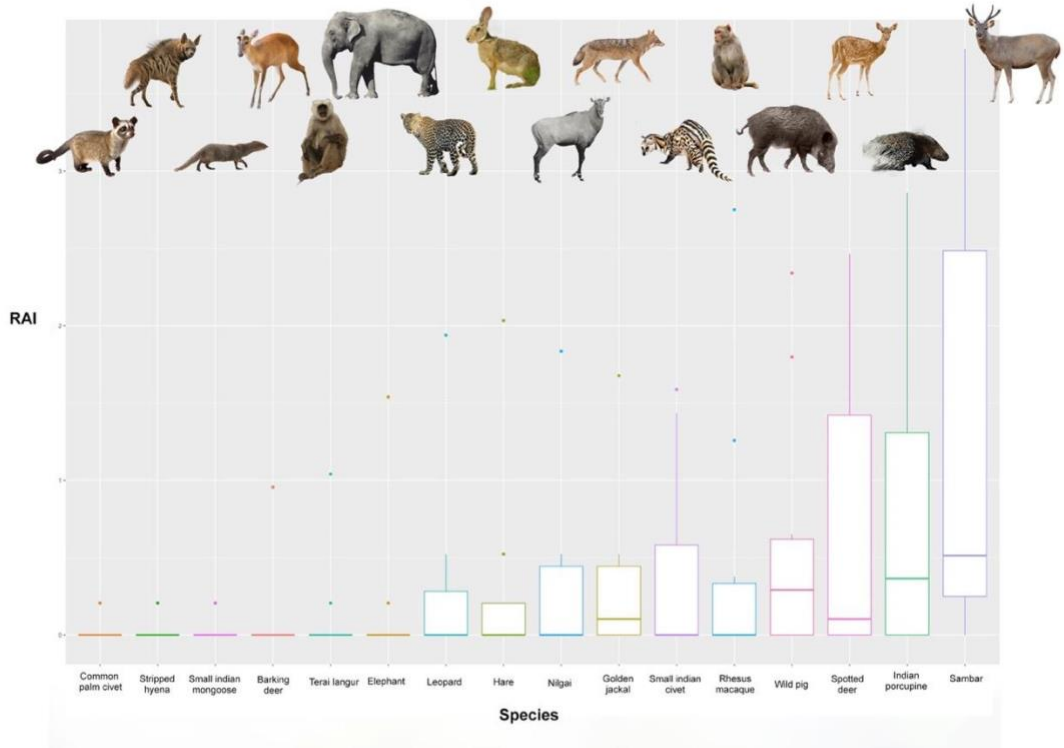

Figure A1: Species with variation in RAI values across garbage sites around western part of Rajaji Tiger Reserve, Uttarakhand

Figure A2: Photographs from the quantification process of garbage sites. From top to bottom- Quadrat at a household waste site, Quadrat at a religious waste site and Sampling at a household waste site.

Figure A3: Asiatic elephant and damage caused by it near Mansadevi- garbage site

Figure A4: Sambar habituated to traffic and human infrastructure in BHEL area

Figure A5: Co-occurrences of Sambar and Indian crested porcupine at religious waste(left) and household waste site (right)

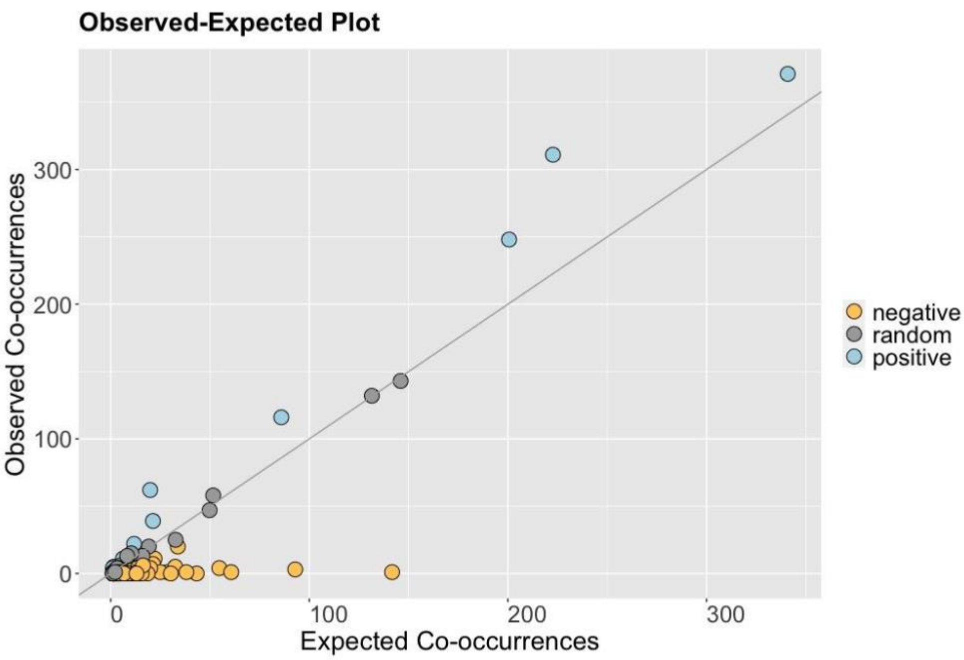

Figure A6: Observed-Expected Plot of positive, negative and random co-occurrences

Table A2: Pairwise probability table obtained from probabilistic model of co-occurrences

S.N.	Species 1	Species 2	Effects	S.N.	Species 1	Species 2	Effects
1	Barking deer	buffalo	-0.0001	139	Asiatic elephant	Vehicle	-0.0011
2	Barking deer	Common palm civet	0.0000	140	Asiatic elephant	Wild pig	0.0006
3	Barking deer	Cow	-0.0004	141	Goat	Golden jackal	-0.0001
4	Barking deer	Dog	-0.0004	142	Goat	Indian hare	-0.0002
5	Barking deer	Cat	-0.0001	143	Goat	Striped hyena	0.0000
6	Barking deer	Asiatic elephant	0.0000	144	Goat	Indian porcupine	-0.0005
7	Barking deer	Goat	0.0000	145	Goat	Terai langur	0.0000
8	Barking deer	Golden jackal	0.0000	146	Goat	Common leopard	-0.0001
9	Barking deer	Indian hare	0.0000	147	Goat	Rhesus macaque	-0.0004
10	Barking deer	Striped hyena	0.0000	148	Goat	Nilgai	-0.0001
11	Barking deer	Indian porcupine	-0.0001	149	Goat	Human	-0.0011
12	Barking deer	Terai langur	0.0000	150	Goat	Sambar	-0.0012
13	Barking deer	Common leopard	0.0000	151	Goat	Sheep	0.0000
14	Barking deer	Rhesus macaque	-0.0001	152	Goat	Small indian civet	0.0002
15	Barking deer	Nilgai	0.0000	153	Goat	Small indian mongoose	0.0000
16	Barking deer	Human	-0.0011	154	Goat	Spotted deer	-0.0004
17	Barking deer	Sambar	-0.0003	155	Goat	Vehicle	-0.0021
18	Barking deer	Sheep	0.0000	156	Goat	Wild pig	-0.0003
19	Barking deer	Small indian civet	0.0000	157	Golden jackal	Indian hare	-0.0001
20	Barking deer	Small indian mongoose	0.0000	158	Golden jackal	Striped hyena	0.0000
21	Barking deer	Spotted deer	0.0014	159	Golden jackal	Indian porcupine	-0.0004

22	Barking deer	Vehicle	-0.0005	160	Golden jackal	Terai langur	0.0000
23	Barking deer	Wild pig	-0.0001	161	Golden jackal	Common leopard	-0.0001
24	buffalo	Common palm civet	0.0000	162	Golden jackal	Rhesus macaque	-0.0003
25	buffalo	Cow	0.0152	163	Golden jackal	Nilgai	-0.0001
26	buffalo	Dog	-0.0050	164	Golden jackal	Human	-0.0042
27	buffalo	Cat	-0.0003	165	Golden jackal	Sambar	-0.0012
28	buffalo	Asiatic elephant	-0.0003	166	Golden jackal	Sheep	0.0000
29	buffalo	Goat	0.0012	167	Golden jackal	Small indian civet	0.0002
30	buffalo	Golden jackal	-0.0004	168	Golden jackal	Small indian mongoose	0.0000
31	buffalo	Indian hare	-0.0005	169	Golden jackal	Spotted deer	0.0000
32	buffalo	Striped hyena	0.0000	170	Golden jackal	Vehicle	-0.0018
33	buffalo	Indian porcupine	-0.0016	171	Golden jackal	Wild pig	-0.0003
34	buffalo	Terai langur	-0.0001	172	Indian hare	Striped hyena	0.0000
35	buffalo	Common leopard	-0.0004	173	Indian hare	Indian porcupine	0.0003
36	buffalo	Rhesus macaque	-0.0012	174	Indian hare	Terai langur	0.0000
37	buffalo	Nilgai	0.0003	175	Indian hare	Common leopard	-0.0001
38	buffalo	Human	0.0023	176	Indian hare	Rhesus macaque	-0.0003
39	buffalo	Sambar	-0.0051	177	Indian hare	Nilgai	0.0002
40	buffalo	Sheep	0.0000	178	Indian hare	Human	-0.0046
41	buffalo	Small indian civet	-0.0005	179	Indian hare	Sambar	0.0000
42	buffalo	Small indian mongoose	0.0000	180	Indian hare	Sheep	0.0000
43	buffalo	Spotted deer	-0.0014	181	Indian hare	Small indian civet	-0.0001

44	buffalo	Vehicle	-0.0040	182	Indian hare	Small indian mongoose	0.0000
45	buffalo	Wild pig	-0.0011	183	Indian hare	Spotted deer	0.0010
46	Common palm civet	Cow	0.0003	184	Indian hare	Vehicle	-0.0019
47	Common palm civet	Dog	0.0003	185	Indian hare	Wild pig	-0.0003
48	Common palm civet	Cat	0.0000	186	Striped hyena	Indian porcupine	0.0000
49	Common palm civet	Asiatic elephant	0.0000	187	Striped hyena	Terai langur	0.0000
50	Common palm civet	Goat	0.0000	188	Striped hyena	Common leopard	0.0000
51	Common palm civet	Golden jackal	0.0000	189	Striped hyena	Rhesus macaque	0.0000
52	Common palm civet	Indian hare	0.0000	190	Striped hyena	Nilgai	0.0000
53	Common palm civet	Striped hyena	0.0000	191	Striped hyena	Human	-0.0001
54	Common palm civet	Indian porcupine	0.0000	192	Striped hyena	Sambar	0.0000
55	Common palm civet	Terai langur	0.0000	193	Striped hyena	Sheep	0.0000
56	Common palm civet	Common leopard	0.0000	194	Striped hyena	Small indian civet	0.0000
57	Common palm civet	Rhesus macaque	0.0000	195	Striped hyena	Small indian mongoose	0.0000
58	Common palm civet	Nilgai	0.0000	196	Striped hyena	Spotted deer	0.0000
59	Common palm civet	Human	0.0002	197	Striped hyena	Vehicle	-0.0001
60	Common palm civet	Sambar	0.0000	198	Striped hyena	Wild pig	0.0000
61	Common palm civet	Sheep	0.0000	199	Indian porcupine	Terai langur	-0.0001
62	Common palm civet	Small indian civet	0.0000	200	Indian porcupine	Common leopard	-0.0004

63	Common palm civet	Small indian mongoose	0.0000	201	Indian porcupine	Rhesus macaque	-0.0010
64	Common palm civet	Spotted deer	0.0000	202	Indian porcupine	Nilgai	0.0000
65	Common palm civet	Vehicle	0.0003	203	Indian porcupine	Human	-0.0156
66	Common palm civet	Wild pig	0.0000	204	Indian porcupine	Sambar	0.0037
67	Cow	Dog	0.0002	205	Indian porcupine	Sheep	0.0000
68	Cow	Cat	0.0003	206	Indian porcupine	Small indian civet	-0.0005
69	Cow	Asiatic elephant	-0.0010	207	Indian porcupine	Small indian mongoose	0.0000
70	Cow	Goat	0.0017	208	Indian porcupine	Spotted deer	-0.0001
71	Cow	Golden jackal	-0.0016	209	Indian porcupine	Vehicle	-0.0067
72	Cow	Indian hare	-0.0017	210	Indian porcupine	Wild pig	0.0002
73	Cow	Striped hyena	-0.0001	211	Terai langur	Common leopard	0.0000
74	Cow	Indian porcupine	-0.0057	212	Terai langur	Rhesus macaque	0.0003
75	Cow	Terai langur	-0.0005	213	Terai langur	Nilgai	0.0000
76	Cow	Common leopard	-0.0017	214	Terai langur	Human	-0.0010
77	Cow	Rhesus macaque	-0.0034	215	Terai langur	Sambar	-0.0004
78	Cow	Nilgai	0.0004	216	Terai langur	Sheep	0.0000
79	Cow	Human	0.0171	217	Terai langur	Small indian civet	0.0000
80	Cow	Sambar	-0.0183	218	Terai langur	Small indian mongoose	0.0000
81	Cow	Sheep	-0.0001	219	Terai langur	Spotted deer	-0.0001
82	Cow	Small indian civet	-0.0022	220	Terai langur	Vehicle	-0.0006
83	Cow	Small indian mongoose	-0.0001	221	Terai langur	Wild pig	-0.0001
84	Cow	Spotted deer	-0.0042	222	Common leopard	Rhesus macaque	-0.0003

85	Cow	Vehicle	0.0109	223	Common leopard	Nilgai	-0.0001
86	Cow	Wild pig	-0.0031	224	Common leopard	Human	-0.0044
87	Dog	Cat	-0.0028	225	Common leopard	Sambar	0.0003
88	Dog	Asiatic elephant	-0.0009	226	Common leopard	Sheep	0.0000
89	Dog	Goat	-0.0005	227	Common leopard	Small indian civet	-0.0001
90	Dog	Golden jackal	-0.0010	228	Common leopard	Small indian mongoose	0.0000
91	Dog	Indian hare	-0.0035	229	Common leopard	Spotted deer	0.0000
92	Dog	Striped hyena	-0.0001	230	Common leopard	Vehicle	-0.0015
93	Dog	Indian porcupine	-0.0099	231	Common leopard	Wild pig	-0.0003
94	Dog	Terai langur	-0.0006	232	Rhesus macaque	Nilgai	0.0001
95	Dog	Common leopard	-0.0029	233	Rhesus macaque	Human	-0.0099
96	Dog	Rhesus macaque	-0.0052	234	Rhesus macaque	Sambar	-0.0032
97	Dog	Nilgai	-0.0009	235	Rhesus macaque	Sheep	0.0000
98	Dog	Human	0.0109	236	Rhesus macaque	Small indian civet	-0.0004
99	Dog	Sambar	-0.0325	237	Rhesus macaque	Small indian mongoose	0.0000
100	Dog	Sheep	-0.0002	238	Rhesus macaque	Spotted deer	-0.0009
101	Dog	Small indian civet	-0.0030	239	Rhesus macaque	Vehicle	-0.0047
102	Dog	Small indian mongoose	-0.0001	240	Rhesus macaque	Wild pig	-0.0007
103	Dog	Spotted deer	-0.0087	241	Nilgai	Human	-0.0043
104	Dog	Vehicle	-0.0011	242	Nilgai	Sambar	-0.0009
105	Dog	Wild pig	-0.0057	243	Nilgai	Sheep	0.0000
106	Cat	Asiatic elephant	-0.0003	244	Nilgai	Small indian civet	0.0002

107	Cat	Goat	-0.0005	245	Nilgai	Small indian mongoose	0.0000
108	Cat	Golden jackal	-0.0004	246	Nilgai	Spotted deer	-0.0004
109	Cat	Indian hare	-0.0001	247	Nilgai	Vehicle	-0.0020
110	Cat	Striped hyena	0.0000	248	Nilgai	Wild pig	0.0001
111	Cat	Indian porcupine	-0.0015	249	Human	Sambar	-0.0508
112	Cat	Terai langur	-0.0001	250	Human	Sheep	-0.0003
113	Cat	Common leopard	-0.0004	251	Human	Small indian civet	-0.0056
114	Cat	Rhesus macaque	-0.0011	252	Human	Small indian mongoose	-0.0001
115	Cat	Nilgai	-0.0004	253	Human	Spotted deer	-0.0134
116	Cat	Human	-0.0010	254	Human	Vehicle	0.0319
117	Cat	Sambar	-0.0035	255	Human	Wild pig	-0.0109
118	Cat	Sheep	0.0003	256	Sambar	Sheep	0.0003
119	Cat	Small indian civet	-0.0005	257	Sambar	Small indian civet	-0.0015
120	Cat	Small indian mongoose	0.0000	258	Sambar	Small indian mongoose	0.0000
121	Cat	Spotted deer	-0.0010	259	Sambar	Spotted deer	0.0017
122	Cat	Vehicle	0.0064	260	Sambar	Vehicle	-0.0216
123	Cat	Wild pig	-0.0010	261	Sambar	Wild pig	0.0017
124	Asiatic elephant	Goat	-0.0001	262	Sheep	Small indian civet	0.0000
125	Asiatic elephant	Golden jackal	-0.0001	263	Sheep	Small indian mongoose	0.0000
126	Asiatic elephant	Indian hare	-0.0001	264	Sheep	Spotted deer	0.0003
127	Asiatic elephant	Striped hyena	0.0000	265	Sheep	Vehicle	-0.0001
128	Asiatic elephant	Indian porcupine	-0.0002	266	Sheep	Wild pig	0.0000

129	Asiatic elephant	Terai langur	0.0000	267	Small indian civet	Small indian mongoose	0.0000
130	Asiatic elephant	Common leopard	-0.0001	268	Small indian civet	Spotted deer	-0.0004
131	Asiatic elephant	Rhesus macaque	-0.0001	269	Small indian civet	Vehicle	-0.0024
132	Asiatic elephant	Nilgai	-0.0001	270	Small indian civet	Wild pig	-0.0003
133	Asiatic elephant	Human	-0.0025	271	Small indian mongoose	Spotted deer	0.0000
134	Asiatic elephant	Sambar	-0.0007	272	Small indian mongoose	Vehicle	-0.0001
135	Asiatic elephant	Sheep	0.0000	273	Small indian mongoose	Wild pig	0.0000
136	Asiatic elephant	Small indian civet	-0.0001	274	Spotted deer	Vehicle	-0.0037
137	Asiatic elephant	Small indian mongoose	0.0000	275	Spotted deer	Wild pig	-0.0004
138	Asiatic elephant	Spotted deer	0.0002	276	Vehicle	Wild pig	-0.0047