MORPHOLOGICAL AND MORPHOMETRIC CHARACTERS OF WILD MAMMAL FECES: IS IDENTIFICATION AND DESCRIPTION

Dissertation report submitted to Goa University in partial fulfillment of the requirement for the degree of Master's of Science in Zoology by

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Morphological and morphometric characteristics of wild mammal feces: its identification and description

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, **"Morphological and morphometric characteristics of wild mammal feces: its identification and description"** is based on the results of investigations carried out by me in the Zoology at the School of Biological Sciences and Biotechnology, Goa University, under the Supervision of Dr. Nitin Sawant and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will be not being responsible for the correctness of observations / experimental or other findings given the dissertation.

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This is to certify that dissertation report **"**Morphological and morphometric characteristics of wild mammal faeces: its identification and description**"** is a bonafide work carried out by Ms. Disha Dipak Pagi under my supervision in partial fulfilment of the requirements for the award of the degree of Master's Degree in Zoology in the Discipline Zoology at the School of Biological Sciences and Biotechnology, Goa University.

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PREFACE

The genesis of this study emerged from an experience encountered during our practical examination in Wildlife Conservation and Management. While preparing for the examination on the topic of indirect evidences to identify mammal, we faced a notable challenge – the lack of comprehensive resources on the morphological and morphometric characteristics of mammal feces. Despite conducting the thorough research, the limited availability of data constrained our ability to gather knowledge about the topic. The pivotal moment occurred during the examination when our professor presented a variety of pellets from different ungulate species. Although each pellet had unique morphological characteristics, our inability to identify the correct mammal species emphasized the crucial necessity for extensive data and research in this field.

It was this encounter that made me bridge this knowledge gap and contribute to the scientific understanding of mammal fecal morphology. The goal was well-defined: to conduct a thorough research that would provide a detailed dataset, thus enabling upcoming students, researchers, wildlife enthusiast and conservationists to effectively identify mammal species through their fecal characteristics. I hope that the findings presented herein will serve as a valuable resource and catalyst for further exploration in this vital field.

ACKNOWLEDGMENT

I am deeply thankful for the guidance and mentorship provided by my respected guide Dr. Nitin Sawant for supporting and providing me with insightful and unceasing ideas while preparing my dissertation. I have been able to successfully complete my dissertation work due to the constant support, motivation and help provided by him.

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ABBREVIATIONS USED

Entity	Abbreviation
Wildlife sanctuary	WLS
National park	NP
Mean diameter	MD
Mean length	ML
Mean width	MW

ABSTRACT

Scatology, the scientific study of feces, provides invaluable insights into various aspects of wildlife ecology, including donor animal identification, prey-predator dynamics, habitat preferences, and dietary habits. While advancements in biotechnology offer precise data collection methods, documenting the morphometric characteristics of wild mammal feces remains fundamental for species identification. This study focused on documenting the morphometric characters of wild mammal feces across six protected areas in Goa, India. Over a 10-month period from May 2023 to March 2024, fecal samples from 19 mammal species were meticulously recorded, analyzing dimensions such as length, width, shape, color, and other distinctive features. Statistical analyses were employed to elucidate significant differences in fecal pellet dimensions among various mammal species. The unpaired t-test revealed statistically significant differences in the mean length and width of fecal pellets/segments among four mammal species. Similarly, statistical analyses conducted on 15 mammal species using the Mann-Whitney U test yielded consistent results. Further investigation compared the mean length and mean diameter of pellets between spotted deer and goat, demonstrating a significant difference in measurements. Additionally, the Kruskal-Wallis test, employing Dunns multiple comparison test, was performed to assess differences in pellet measurements among four ungulate species – spotted deer, sambar deer, barking deer, and four-horned antelope. The data indicated a statistically significant difference in pellet length among the compared species, while no significant difference was observed in mean pellet diameter between spotted deer vs. sambar deer and barking deer vs. four-horned antelope. This comprehensive analysis contributes to the understanding of wildlife fecal morphology, providing valuable data for species identification and conservation efforts in the region.

Keywords

Feces, wild mammals, morphometric and morphological characters.

CHAPTER 1

INTRODUCTION

1.1 Background

Tracking is probably the oldest science (Liebenberg 1990), detecting the presence of wildlife and understanding their activities in a given area relies on observing various direct and indirect cues. Often, it proves challenging to identify the diverse array of animals inhabiting an area, hindering studies on population densities and interactions, such as predator-prey dynamics.

By looking at various signs left by these organisms we can get useful information to hunt or avoid them. As a non-invasive technique, tracking mainly acts as an important way of studying the endangered animals and those which are difficult to observe and trap.

Direct evidence encompasses firsthand observations such as visually sighting the animal, hearing its vocalizations, or encountering physical remains such as the entire body or distinct body parts like skin, hair, nails, antlers, and teeth. However many organisms declare their presence through various indirect evidences such as the tracks, foot impression, droppings, gnaw-marks on the barks of trees, scratches on trees and burrows (Seber 1982; Stokes & Stokes 1986; Boyce 1988). Recently such indirect pieces of evidences from Indian forests have been used to study the population density, prey-predator relations and diet habits (Karanth & Sunquist, 1995; Jathanna et al., 2003; Kushwaha et al., 2004; Bargali et al., 2004 & Reddy et al., 2004).

One of the important evidence among them is the feces or the droppings of an animal. Feces are the most evident and easily recognizable signs (Liebenberg 2000). In most of the mammal species the fecal sample is morphologically unique, serving as a distinct indicator, whether they are carnivores like leopards, jungle cats, and wild dogs, or herbivores such as porcupine, Sambar, rabbits etc.

Scatology is defined as a science that studies feces (Seton, 1925) and the research on this subject is steadily growing since 1970s (Putman 1984, Halfpenny & Biesiot 1986, Kohn 1997).Fecal analysis can provide various insights, including the identification of the animal (Seton 1925, Camardella et al. 2000), activity pattern (Walker, 1996), diet composition (Johnson & Hansen 1978, Johnson & Aldred 1982, Emmons 1987, 1997, Inagaki & Tsukahara 1993, Chinchilla 1997, Santos & Hartz 1999, Kauhala & Auniola 2001), seasonal dietary variations (Corn & Warren 1985, Aragona & Setz 2001), prey species inventory (Floyd et al. 1978, Emmons, 1987, Camardella et al. 2000), seed dispersion role (Fragoso & Huffman 2000, Williams et al. 2000), health status, and dynamics of enteroparasitosis (Patton et al. 1986, Page et al. 2001).

Researchers have been using fecal counting methods for population estimation (Neff, 1968).The identification of feces from wild mammals plays a crucial role in understanding the ecological dynamics of the region. It is pivotal for ecological research, aiding in the assessment of species diversity, dietary habits, and habitat interactions.

It is very essential to maintain the original shape of the feces so as to ensure accurate identification. Various natural and anthropogenic factors, such as exposure to heat, desiccation, or rapid decomposition in humid and rainy environments, can lead to disintegration of the original fecal shape over time. Additionally, fragmentation by other animals like dung beetles and termites, who often consume herbivorous feces, is also another factor that prevents fecal preservation (Stuart & Stuart 1998). Carnivores, such as spotted hyenas consuming Lion and fresh wild dog scat, can also affect the original shape (Stuart & Stuart 1998).

In principle, it is possible to distinguish scat/dung/pellets of the major herbivores and carnivores of the area studied by the size and shape of it and thus species specific scat/dung/pellet count can be made (Jayson & Esa, 1997; Davison et al., 2002).

The feces mainly consist of semi-digested and undigested parts of various animals and plants. The herbivorous feces generally contains semi digested parts of roots, barks, seeds, berries and sometimes grasses. Whereas the carnivore scat primarily includes the bones, feathers, scales, teeth, hair, claws etc.

Size has always been a prime criterion for scat identification, and many naturalists have positively stated, based on size, that the scat was deposited by a leopard. The size and amount of feces produced by each individual vary with age, the type of ingested food, and its absorption capacity (Bang & Dahlström, 1975). Herbivores experience a higher frequency of size variation due to changes in the quality and quantity of food consumed during different seasons.

Size varies less among carnivores (Stuart & Stuart, 1998). Food characteristics additionally impact the consistency of feces. In dry periods or arid habitats, animals may consume primarily fibrous plants, resulting in the production of firm and compact feces. Conversely, during rainy periods or in tropical rainforest ecosystems, animals tend to consume higher amounts of green leaves, sprouts, and fruits, leading to the formation of softer, larger, and more aggregated feces.

Mammal feces have a social communication role (Gorman & Trowbridge, 1989). When deposited in a random manner, they reveal the home range of either an individual or a group, as observed in certain ungulates, rodents, and primates. They are used as territorial marks when deposited in small volumes in prominent places such as trail junctions, rocks, trunks, or termite nests (Marcia Chame, 2003).

Feces are used as strategic sensorial marks by all Carnivore family members except Hyaenidae (Gorman & Trowbridge, 1989; Estes, 1991; Romo, 1995; Aragona & Setz, 2001). The secretion generated by the anal gland in carnivorous animals adheres to the feces while they are being

excreted. The secretion of each species has a characteristic and complex odor, supplying intra and inters specific information on an individual's territory, sex, reproductive state, and movements (Gorman & Trowbridge, 1989).

By elucidating these distinctive features, the research aims to facilitate accurate fecal analysis, providing valuable insights into the ecological roles of mammals and contributing to broader conservation and biodiversity efforts.

1.2 Aim and Objective

The aim of this study is to examine the morphological and morphometric characters of wild mammal feces; its identification and description from the 6 protected areas of Goa.

Objectives of this study are: -

1. To study the morphological and morphometric characters of wild mammal feces and to differentiate between the herbivore and carnivore depending upon their fecal morphology.
2. To develop the visual or morphological guide for field researchers to identify mammal species based on their fecal characteristics.

1.3 Hypothesis

There are significant differences in the morphological and morphometric characters of wild mammal feces depending upon their feeding habits.

1.4 Scope

This study will provide a comprehensive catalogue for identifying the wild mammals based on their fecal morphology and morphometry, offering valuable information for researchers, conservationists and wildlife enthusiasts and also its practical application in wildlife management and conservation strategies.

CHAPTER 2

LITERATURE REVIEW

Over the span of decade very little research has been carried out concerning the Identification of wild mammal feces based on their morphology and morphometry. Nagy and Gilbert, (1968) through their work referred that, scatology developed from basic morphometric description to more sophisticated chemical analyses.

As per the work of Bang and Dahlström, (1975), the size and the amount of feces produced by each individual varies with age, the type of ingested food, and its absorption capacity.

Putnam,RJ in 1984 asserted that Carnivore feces are a valuable source of information for researchers who seek to answer questions of distribution, diet, health, population status, genetic diversity, breeding condition, stress levels and much more of their study animals.

Halfpenny,J (1986) stated that traditional scat-identification criteria have been based primarily on morphology and size has always been a prime criterion for scat identification.

According to Gorman and Trowbridge, (1989) mammal feces have a social communication role to play. Liebenberg L (1990) in his book “The art of tracking: the origin of science” has quoted feces as the most evident and most easily recognizable sign.

In 1995 Romo MC, from his work inferred that Feces are used as strategic sensorial marks by all Carnivora family species except Hyaenidae.

Bjune, (2000), worked on the Pollen analysis of feces as a method of demonstrating seasonal variations in the diet of Svalbard reindeer and observed that fecal components may include feathers, bones, teeth, claws, scales, arthropod chitin, seeds and plant tissues, pollen grains, as well as mucus, cells, and a significant amount of living and dead bacteria.

An important breakthrough to this research was in the year 2003 when a researcher, Marcia Chame published her work providing morphometric analysis and identification of 9 similar fecal groups. Her work provided the pictorial representation of various terrestrial mammal feces along with its morphometry.

As India is concerned very little work has been done with respect to Identification of wild mammal feces. In 2008 Abi Tamim Vanak et al, published their work as Identification of scat of Indian fox, Jungle cat and Golden Jackal based on morphometry. Their study indicated no differences in scat diameter between the Golden Jackal and Jungle Cat, while the Indian Fox scats were smaller in diameter.

CHAPTER 3
METHODOLOGY

3.1 Study area

Goa, with an area of 3,702 km^2 is a state located on the southwestern coast of India. It is one of the smallest but biodiversity rich state of India. Geographically, it is distinguished from the Deccan highlands by the presence of the Western Ghats. The total forest cover of Goa is 1424.46 sq. km. There is diversity in the forests due to the variation in altitude, aspect, soil characters, slope etc. It is majorly covered by the semi evergreen and moist deciduous forest type mainly towards the Western Ghats. Within this location, an extensive assortment of amphibians, reptiles, birds, and mammals reside. Additionally, a noteworthy occurrence of endemic species is observed among these creatures. Goa prides itself on hosting a diverse collection of more than 40 mammalian species. During these expeditions, one may have the opportunity to observe remarkable creatures including leopards, deer, leopard cats, Indian civets, gaurs, sloth bears, Indian porcupines, pangolins, slender loris, wild boars, giant squirrel, flying squirrel, wild dog, jackal and mongooses.

The present compressive study has been carried out throughout the 6 protected areas of Goa namely the Cotigao wildlife sanctuary, Netravali wildlife sanctuary, Bhagwan Mahavir wildlife sanctuary, Bondla wildlife sanctuary, Mhadei wildlife sanctuary and Mollem National park.

Cotigao wildlife sanctuary

The sanctuary is spread over an area of 85.65 km2 and located adjacent to the Anshi Tiger reserve of Karnataka. This sanctuary showcases a diverse range of plant and animal species. Predominantly, the vegetation in this particular region consists of the moist-deciduous category, which is occasionally interspersed with areas containing semi-evergreen and evergreen patches. The noteworthy among are Black (melanistic) panther, Sloth Bear, Painted Bat, wild dogs and variety of other faunal diversity.

Netravali wildlife sanctuary

Netravali Wildlife Sanctuary, situated in the Sanguem Taluka, covers an area of 211.05 km2. In the region, one can find a predominantly moist deciduous forest type with patches of semi-evergreen forest located in the valleys. The high altitude areas in the hills feature natural grassy patches that serve as an ideal habitat for grazing population. This area boasts a rich diversity of flora and fauna and is home to Leopard, giant Squirrel, and Mouse Deer.

Mollem National Park and Bhagwan Mahavir Wildlife Sanctuary

Bhagwan Mahavir Wildlife Sanctuary and Mollem National Park, encompassing a total area of 240 km^2 constitute the largest contiguous wildlife protected region in Goa, primarily characterized by the semi-evergreen and evergreen type. The wildlife in this sanctuary includes large mammals such as Leopard, Sloth Bear, Gaur, Sambar and Barking deer, while also hosting a diverse array of birds and butterflies.

Bondla wildlife sanctuary

Bondla wildlife sanctuary is situated in the Ponda taluka of northern Goa. It is the smallest wildlife sanctuary in the state, spread over an area of just 8 sq. km. It is among the most visited sanctuaries of the state. Besides the sanctuary there is a small zoo, botanical garden, park and nature interpretation centre. The forest is covered with moist deciduous vegetations. One can spot a number of animals here including the Gaur, leopard, jungle cat, spotted deer, sambar deer, gaint squirrel etc.

Mhadei wildlife sanctuary

Mhadei Wildlife Sanctuary is the Northern most sanctuary of the state. It is one of the recently declared Wildlife sanctuaries of the Goa. It is spreads over an area of 208 km2 and is named after the Mhadei River which flows across this Sanctuary. The sanctuary is a contiguous tiger corridor to Bhimgad Wildlife Sanctuary and Anshi Dandeli Tiger Reserve of Karnataka. The favorable climatic conditions of the sanctuary ensures the presence of several distinct forest types including West Coast Tropical Evergreen Forest, Southern Moist Deciduous Forest and Subtropical Hill Forest in this Sanctuary and supports rich diversity of flora and fauna.

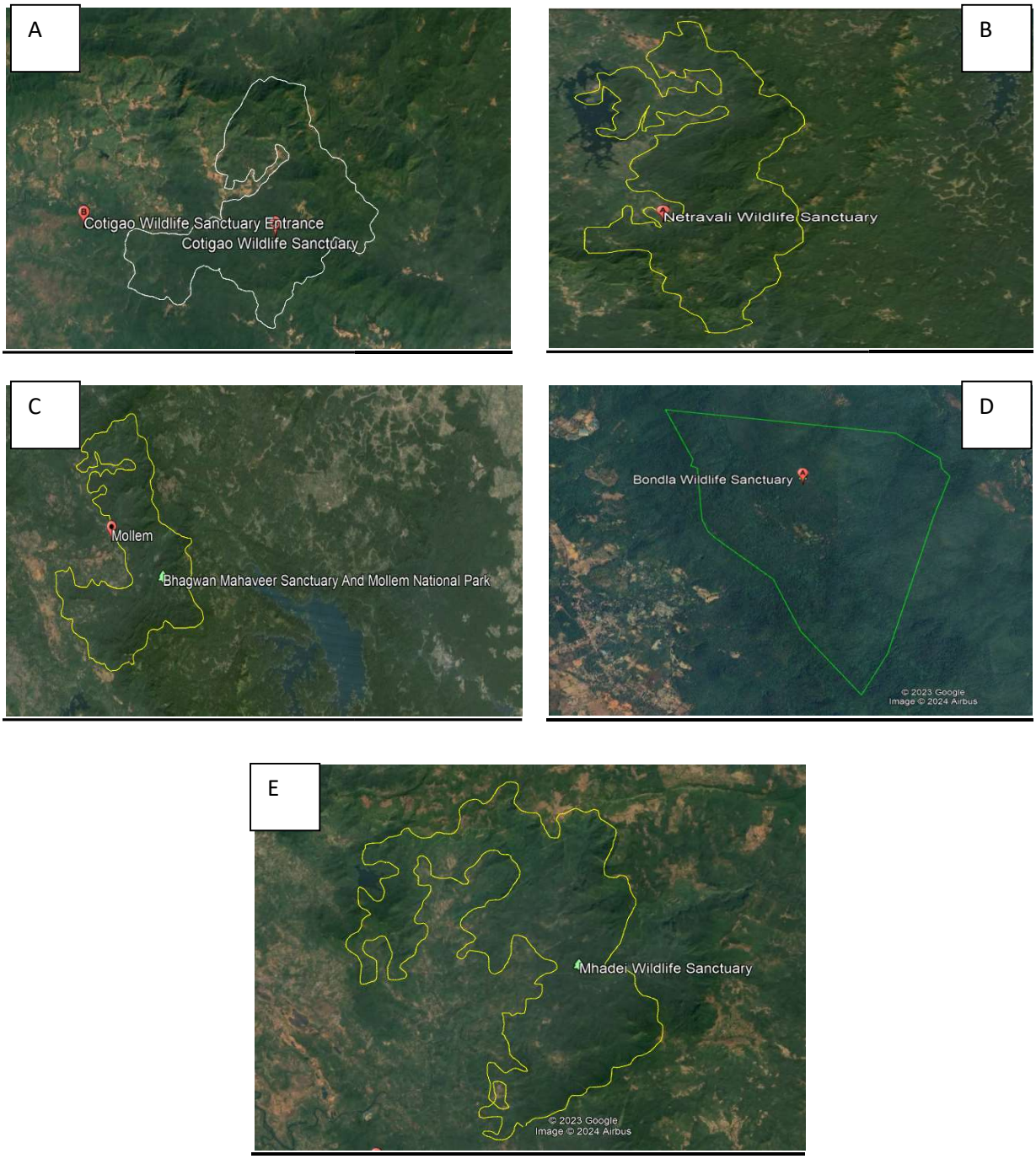


Figure 1: Protected areas of Goa (source; Google Earth Pro)

A: Cotigao WLS B: Netravali WLS C: Bhagwan Mahavir WLS and Mollem NP
D: Bondla WLS E: Mhadei WLS

Sampling

The fecal samples were searched through opportunistic sampling (Sensu Frenzel 1974) along the travel routes used by the animals (paths, trails, and dirt roads). The presence of other discerning signs around the feces such as the pugmarks, hoofmark, scratches, urine etc. along with the scat's location e.g. under a tree, open area, on trail etc; were also taken into account in order to get the correct identity of the donor species.

Scat collection

A total of 25 fecal samples (n=25) from each mammal were collected from the different study sites. Each sample at the time of collection was placed individually in a labeled zip lock plastic bag to avoid contamination. To prevent further degradation the samples were air-dried in the field and the lab.

Photography

Photographs were taken on Nikon D5600 with 15-75mm lens by placing a measuring ruler or pen along with the GPS location of every scat collected as geo-references to show points of collection.

Morphometric and morphological analysis

All the measurements were recorded using a Mitutoyo digimatic Vernier caliper. For the morphological analysis several characters such as: - the general shape of the sample, whether it is segmented or in the form of pellets, if the scat is tapered at one end, flattened, curved on one end, or tapered at both ends. Furthermore, assessment of the morphometric characters such as the

total size of the scat, including its length and diameter/width, as well as the number of segments, was done. Also the numbers of the pellets were noted down.

Data analysis

All the collected field work data were processed using MS excel and Graphpad prism. Graphpad prism was used to calculate the Descriptive statistics (mean, standard deviation) and other statistical tests (t test, Mann-Whitney U test and Kruskal-Wallis test). Significance level for statistical tests was fixed at 0.05.

Figure 3.2: Photographs of (A) Digital Vernier calliper. (B) While taking measurements. (C) Measuring ruler. (D) Specimen inside the zip lock bag along with the collection details. (E) Gloves.

CHAPTER 4
ANALYSIS AND CONCLUSION

4.1 Observation

Documentation of morphological and morphometric characters of 19 wild mammal species was done during the study period of 10 months from May 2023 to March 2024. The character included the general shape of the feces, size, texture and the color.

Other then the morphological and morphometric characters there are also other evidence that needs to be taken into account which could be present in vicinity of the fecal sample, such as the footprints, urine traces, scratch marks on the tree trunks, destruction termites hill, eaten fruits etc. because most of these animals leave at least some or the other evidences nearby which helps to get the correct identity of the species. For example, the members of the feline family such as the jungle cat and leopard have the habit of defecating along the trail either in the middle or on the sides, in order to mark their territory. Depending upon the size of the fecal sample you can easily distinguish between them.

In case of the wild dogs there is the high change of getting many fecal samples together or in the vicinity of each other. Since they live in a pack and spend most of their time together, their scat is encountered in groups.

The scat of carnivore animals such as the leopard, jungle cat and wild dog appears white or grey in color, mainly due to the high composition of calcium in that diet.

In case of the Asian palm civet and the sloth bear there is not distinct shape of the scat as such mainly due to the high composition of fruits and berries in their diet. Many a times the one may find the scat of palm civet with complete seeds in it giving it an undefined shape. Sloth bear also has the similar habit. Most of the time the shape of their scat changes depending upon what they have eaten and it becomes difficult to identify it. During the availability of the foods they will

feed on wide variety of fruits including the wild fig, jackfruit and cashew and their scat then will contain the seeds of these fruits. During the dry season when the food becomes scar, they feed on the bark of the tree, termites etc. The composition of the food also varies according to the altitude. These animals play a very important ant role in the process of pollination.

Sometimes one may encounter a scat that is either present as a single oval mass with the visible tiny bones and fur or a spread out mass containing clearly visible bones, crab exoskeleton etc. This type of the scat is usually of owl. There are high changes of confusing this with the scat of other carnivore species.

1. HOUSE MOUSE

Morphometric and morphological characters of the feces.

Size: - Mean length (ML) is 1.094±0.2973 and mean width (MW) is 0.5709±0.08397.

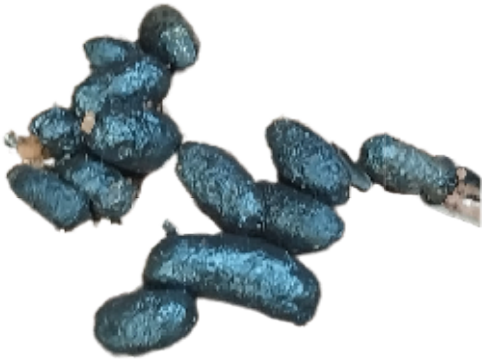
Shape: - These are small elongated pellets having pointed ends and similar in appearance to that of dark grains of rice.

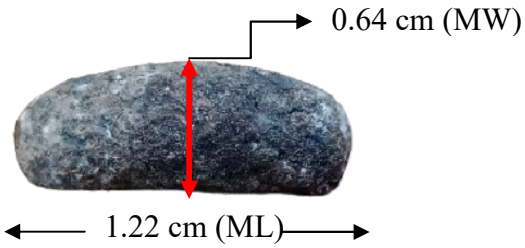
Color: - When fresh these pellets are black in color. Over the time they will start to turn brown and finally fading to grey.

Note: - Most of the times a film of fungus cover these pellets when the moisture content is high. Usually present 6-7 in numbers

Figure 4.1.1: Photographs of the House mouse's faecal sample taken during the field visit.

2. BLACK RAT





Morphometric and morphological characters of the feces.

Size: - Mean length is 1.220± 0.3271 and mean width is 0.6431± 0.08910

Shape: -Elongated capsule like pellets with slight curve or shape similar to that of banana.

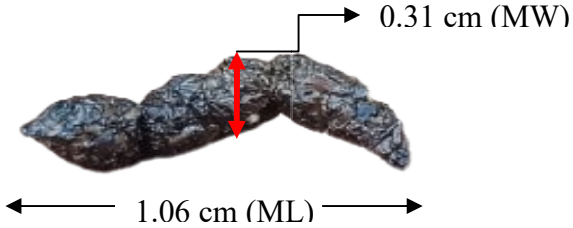
Color: - The fresh pellets are usually brown in color and later after drying they turn black or grey.

Note: - Their droppings can be found almost everywhere, taking from bathroom, garden, kitchen, garage etc. Pellets are more than 10 in number.

Figure 4.1.2: - Photographs of the faecal sample taken during the field visit.

(B) Shape of the pellets resembling similar to that of the banana.

3. BAT



Morphometric and morphological characters of the feces.

Size: - Mean length (1.061±0.2116) and width (0.3139±0.04002).

Shape: - They are small elongated pellets, pointed at one end.

Color: - Usually black and brown in color with white speckles in between.

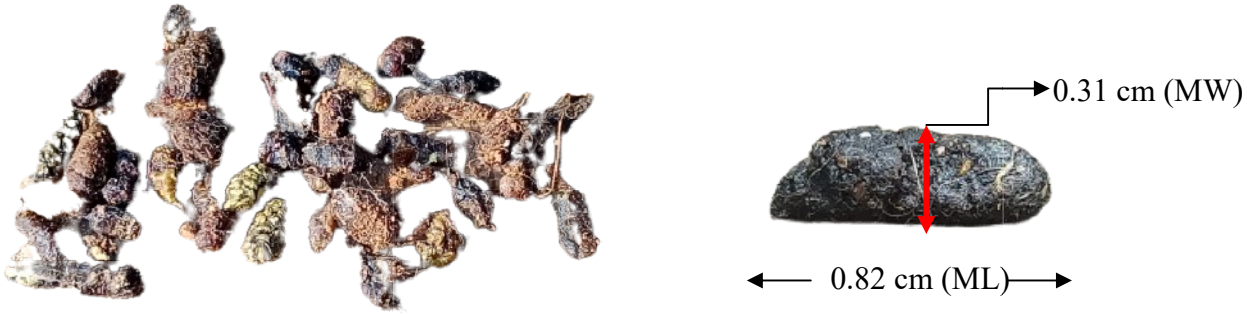
Note: - The droppings of bat tend to be found in piles usually below the attic where these flying mammals rest during the day. Bats often defecate while leaving the area they live in.

The shinny freckles found within their feces are usually the remains of undigested insect wings.

Figure 4.1.3: Photographs of the faecal sample of Bat taken during the field visit.

(A) Attic below where these animals rest. (B)Close up of the area. (C) Shinny freckles visible are the undigested insect parts.

6. INDIAN PALM SQUIRREL



Morphometric and morphological character of the feces

Size: - Mean length (0.8275±0.2336) and mean width (0.3142±0.05412).

Shape: - These are tiny pellets similar to that of the bat.

Color: - Color may vary from dark brown to black.

Note: - Pellets are found mostly below the tree where these animals rest or the place where they spend most of their time.

Pellets are difficult to locate since they fall on the ground and gets camouflaged with the color of the soil.

Figure 4.1.4: Photographs of the faecal sample of Palm squirrel taken during the field visit. (A) Pellets found below the chiku tree. (B) and (C) Close-up of the pellets.

7. MALABAR GIANT SQUIRREL

Morphometric and morphological characters of pellets

Size: - Mean length (1.628±0.2808) and mean width (0.9048±0.1085).

Shape: - Cylindrical, elongated, sometimes spherical in shape with blunt ends.

Color: - When fresh it is greenish yellow and brown in color. After drying it appears completely dark chocolate brown.

Note: - When crushed it has a texture similar to the saw dust.

Pellets are found mainly below the resting or the feeding area.

They are round 6-8 in number.

Figure 4.1.5: Photographs of the faecal sample of Malabar gaint squirrel taken during the field visit.

(A) and (B) are freshly defecated pellets. (C) Pellets after drying has a texture similar to the

8. INDIAN BLACK NAPED HARE

1.18 cm (ML)

Morphometric and morphological characters of feces.

Size: - Mean length 1.184±0.1184.

Shape: - Spherical or rounded and sometimes flattened. Some may be slightly squashed.

Color: - Golden or light yellow in color.

Texture: -When crushed they have similar texture to that of the saw dust.

Note: - They are usually 8-10 in numbers.

The pellets are found mainly in the open grounds or plateau where the hay is dominant.

Figure 4.1.6: Photographs of the faecal sample of Black napped hare taken during the field visit.
(A) Fresh pellets, having golden yellow color. (B) Pellets, after drying for longer period. (C)Crushed pellets having texture similar to that of the sawdust.

9. INDIAN CRESTED PORCUPINE

Morphometric and morphological character of the feces

Size: - Mean length 2.823±1.147 and mean width 1.014±0.1448

Shape: -They are usually oblong elongated pellets, curved on one side while tapered at other.

Color: - When fresh the pellets are glossy black in color; after drying the color fades into the lighter shade or sometimes brown.

Texture: - Softer when fresh, hardens after drying with visible remains of the plant matter.

Note: - Porcupines feeds mainly on tubers, roots, bark of the tree because of which their pellets contain the fibrous matter. The pellets are found along the trail or under the tree.

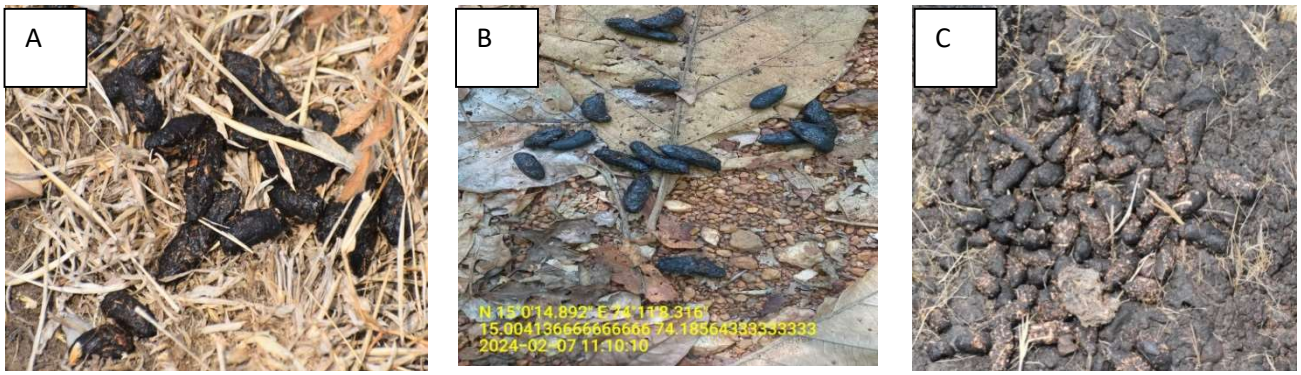
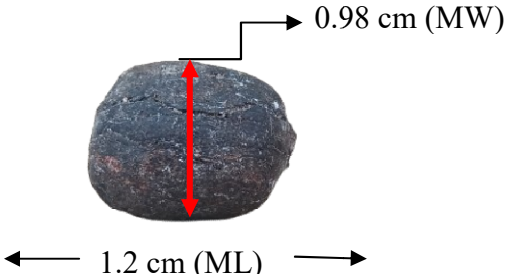


Figure 4.1.7: Photographs of the faecal sample of Indian crested porcupine taken during the field visit.

10. SPOTTED DEER



Morphometric and morphological character of the feces

Size: - Mean length is 1.297±0.07416 and mean diameter is 0.9860±0.1365

Shape: -The fecal pellets are cylindrical in shape, with a rounded base and a tapering apical point. There is presence of indents.

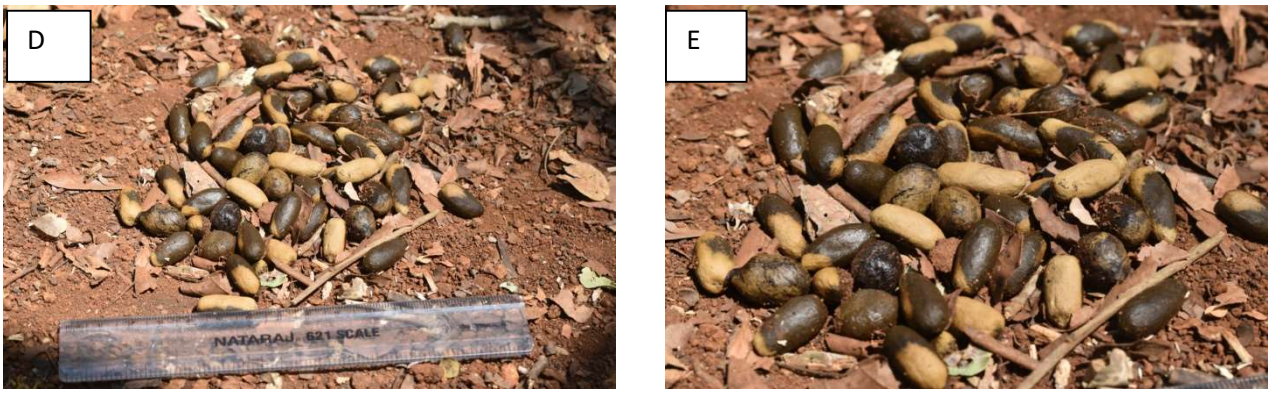
Color: - black in color with greenish ting when fresh. Complete black after drying.

Note: - The pellets are found mainly along the trail or the area where these animals graze and rest.

The adult male pellets are much larger and rounded.

The pellets are usually more than 25 in number.

Figure 4.1.8: Photographs of the faecal sample of spotted deer taken during the field visit from different study sites.



Sometimes the colour of the pellets may change depending upon their diet.

Figure 4.1.9: Pellets of spotted deer have distinct shape on both the ends.

(F) One end is pointed which can be referred to as **pimple** while (G) the other end has a depression / concave surface which can be called as **dimple.**

11. SAMBAR DEER

Morphometric and morphological character of the feces

Size: - Mean length of the pellets is 1.504±0.1304 and mean diameter is 1.023±0.08140.

Shape: - The pellets are barrel shaped and sometimes elongated. The base of the pellet is indented while the top is slightly tapered or pointed.

Color: - Dark green when fresh and black after drying.

Pellets are usually more than 20 in number.

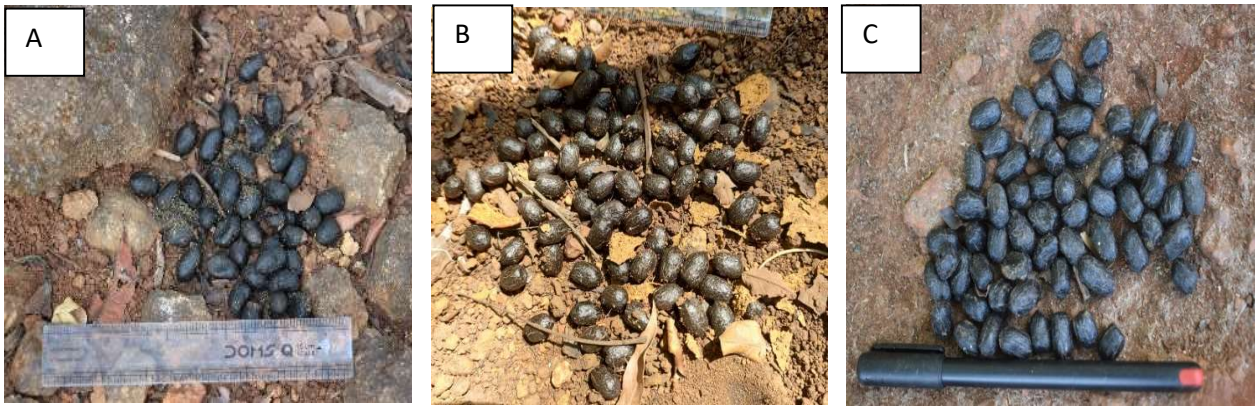


Figure 4.1.10: Photographs of the faecal sample of Sambar deer taken during the field visit.

12. BARKING DEER

Morphometric and morphological characters of the feces.

Size: - Mean length of pellet is 1.004±0.1605 and mean diameter is 0.5929±0.0909.

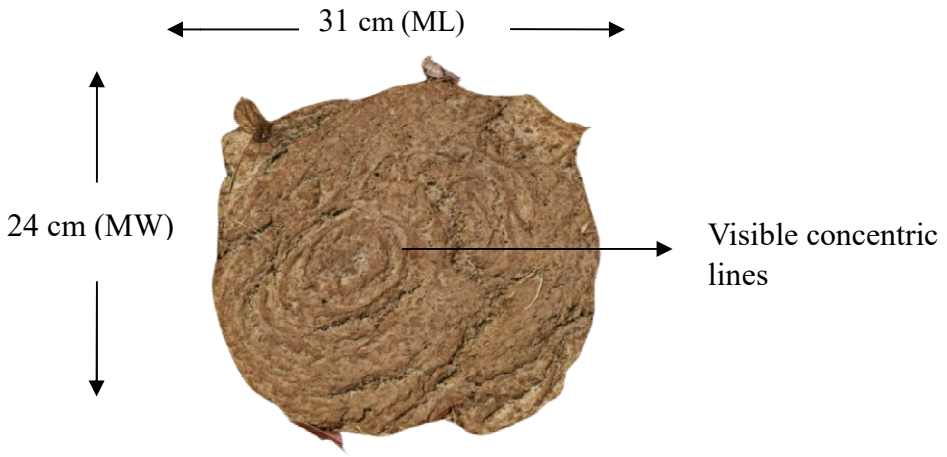
Shape: - The fecal pellets are elongated and crinkled. The pellets taper at both the ends giving a spindle shape, the tips may vary from being long and hook like to blunt.

Color: - The color is often dark brown to black.

Note: - The pellets are usually found in the deep forested areas mainly because of the shy nature of the animal.

Figure 4.1.11: - Photographs of the faecal sample of barking deer taken during the field visit.

13. GAUR



Morphometric and morphological characters of the feces.

Size: - Mean length is 31.10± 4.743 and mean width is 24.32± 4.378.

Shape: - It is a large pile of dung, mostly flattened. Often on the upper surface of the dung there are visible concentric lines.

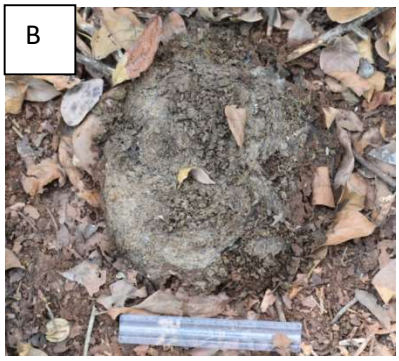
Color: - Dark green, brown or black in color when fresh. Unlike the cow dung which turns somewhat black after drying, the dung of a Gaur after drying gets in to a lighter shade of brown.

Texture: - Can be somewhat coarse and fibrous, depending on what the animal has been eating.

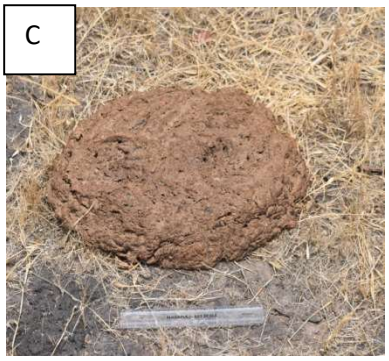
Most of the time, it contains visible plant material.

A

B



C



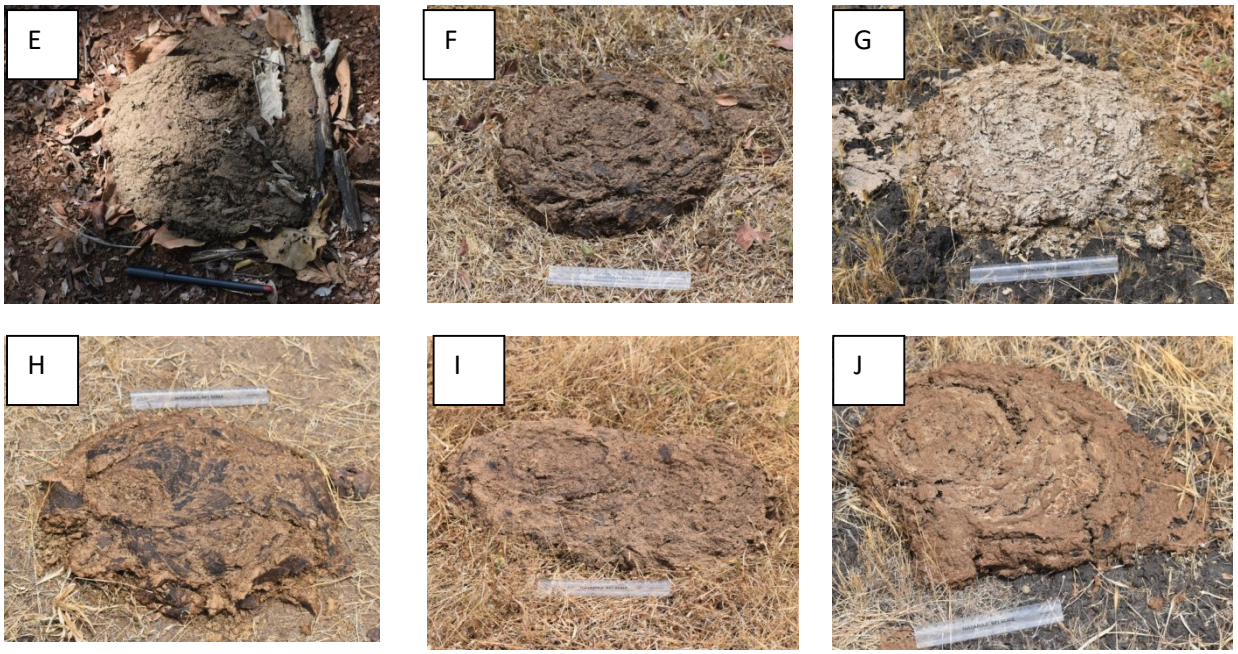
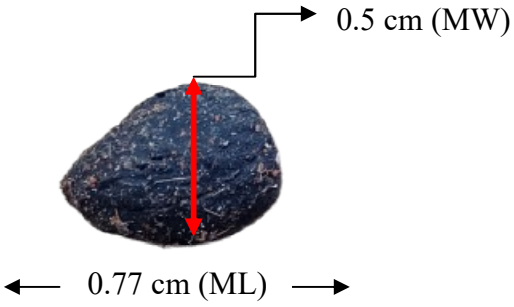


Figure 4.1.12: - Photographs of the faecal sample of Gaur taken during the field visit from different study sites.

(D) Multitude of dung pile encountered at a particular area on a plateau indicating it to be the resting or grazing ground of these animals (Photographs taken at Mhadei wildlife sanctuary).

14. FOUR HORNED ANTELOPE



Morphometric and morphological character of the feces

Size: - Mean length of the pellets is 0.7763±0.04764 and the mean diameter is 0.5086±0.02738.

Shape: - They vary in shape being ovoid or elongated in shape.

Color: - The color is often dark brown to blackish.

Note: - These were the smallest encountered ungulate pellet.

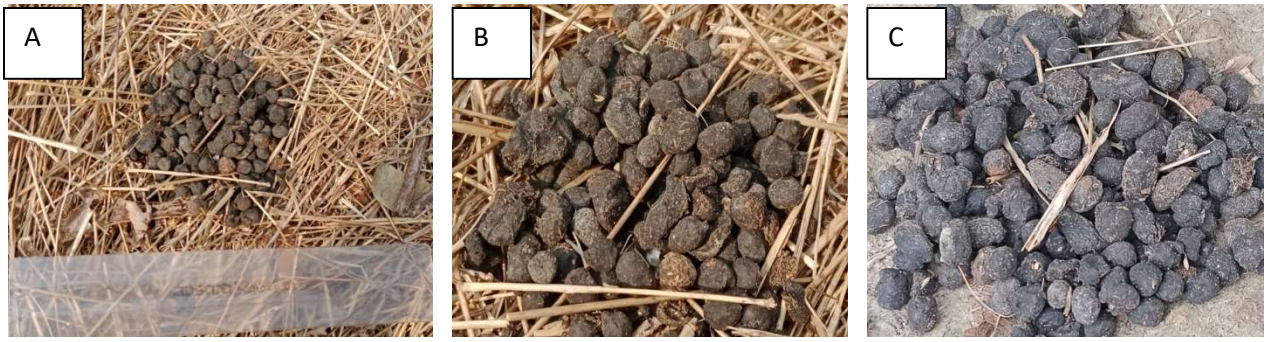
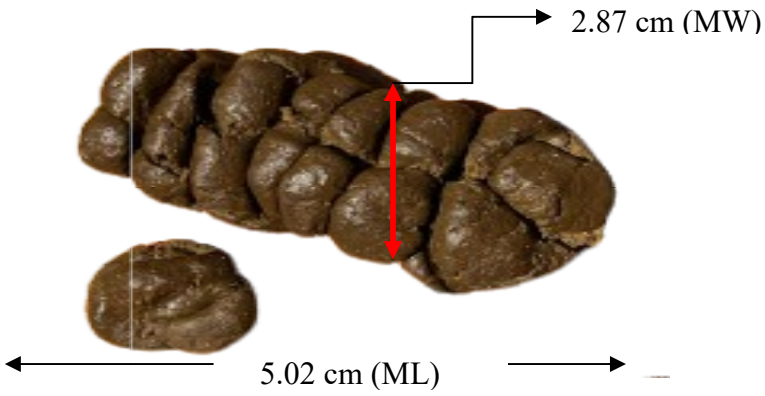


Figure 4.1.13: Photographs of the faecal sample of 4 horned antelope taken during the field visit.

15. HANUMAN LANGUR



Morphometric and morphological characters of feces

Size: - Mean length (5.025 ± 2.363) and mean width (2.875 ± 0.6500).

Shape: - It is like a small tube, but not perfectly round. Tiny rosette shape pellets are present alongside. Less defined shape, possibly due to a diet high in fruits and leaves.

Color: - When fresh, greenish brown in color. After drying completely, the upper side is appears to be silvery gray while the bottom side is black.

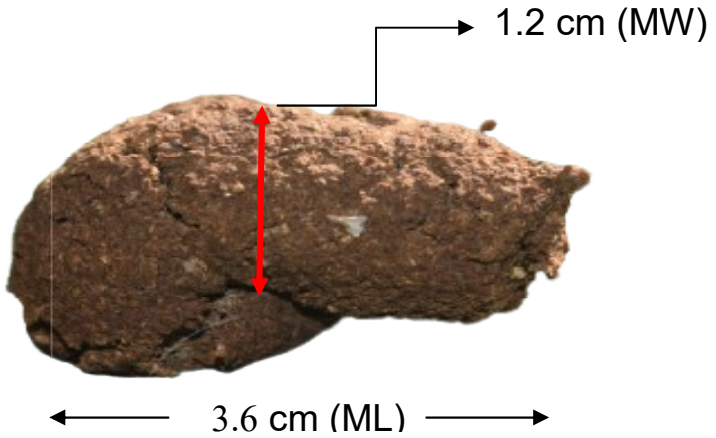
Texture: - Can vary depending upon the diet, but often softer when fresh due to high plant matter content.

Note: - There is the presence of fine undigested fiber material. Monkeys often defecate from trees, so the pellets are found in piles on the ground below.

Figure 4.1.14: -Photographs of the faecal sample of Langure taken during the field visit.

(A) Fresh sample. (B) Tiny rosette shaped pellets (C) Sample after drying for longer period of time.

16. INDIAN GRAY MONGOOSE



Morphometric and morphological characters of feces

Size: - Mean length 3.695±0.8148 and mean width 1.246±0.3222.

Shape: - It is generally tiny sausage shaped.

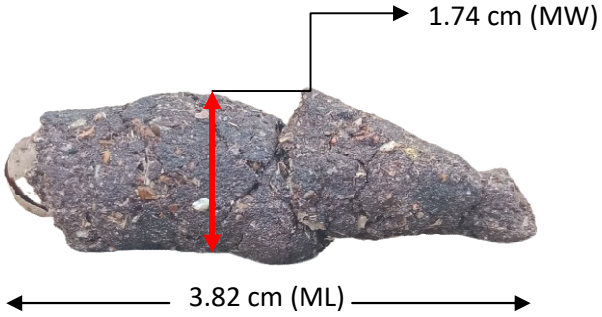
Color: - It's generally dark colored, ranging from dark brown to black.

Note: - Since mongooses are omnivorous, their scat may contain fur, bones, insect parts and seeds depending upon what they have eaten.

After dying it has a texture similar to that of soil and a strong distinct odor..

Figure 4.1.15: - Photographs of the faecal sample of grey mongoose taken during the study period.

17. ASIAN PALM CIVET



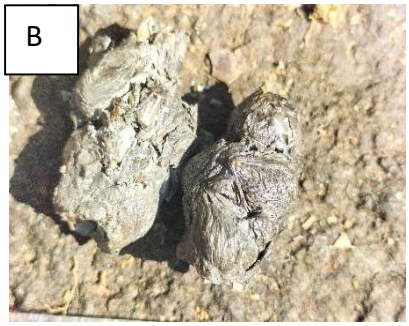
Morphometric and morphological characters of the feces.

Size: - Mean length of each segment is 3.825±1.743 and mean width is 1.743±0.4000.

Shape: - The scat may be elongated, sausage shaped or sometimes uneven due to the presence of large number of seeds and berries.

Color: - It is usually black or brown in color but the color may defer depending upon what the animal has fed.

Note: - Their scat contains large amount of seeds and berries and the composition may vary according to the season and the availability. It is mainly found on the rocks or under the tree.



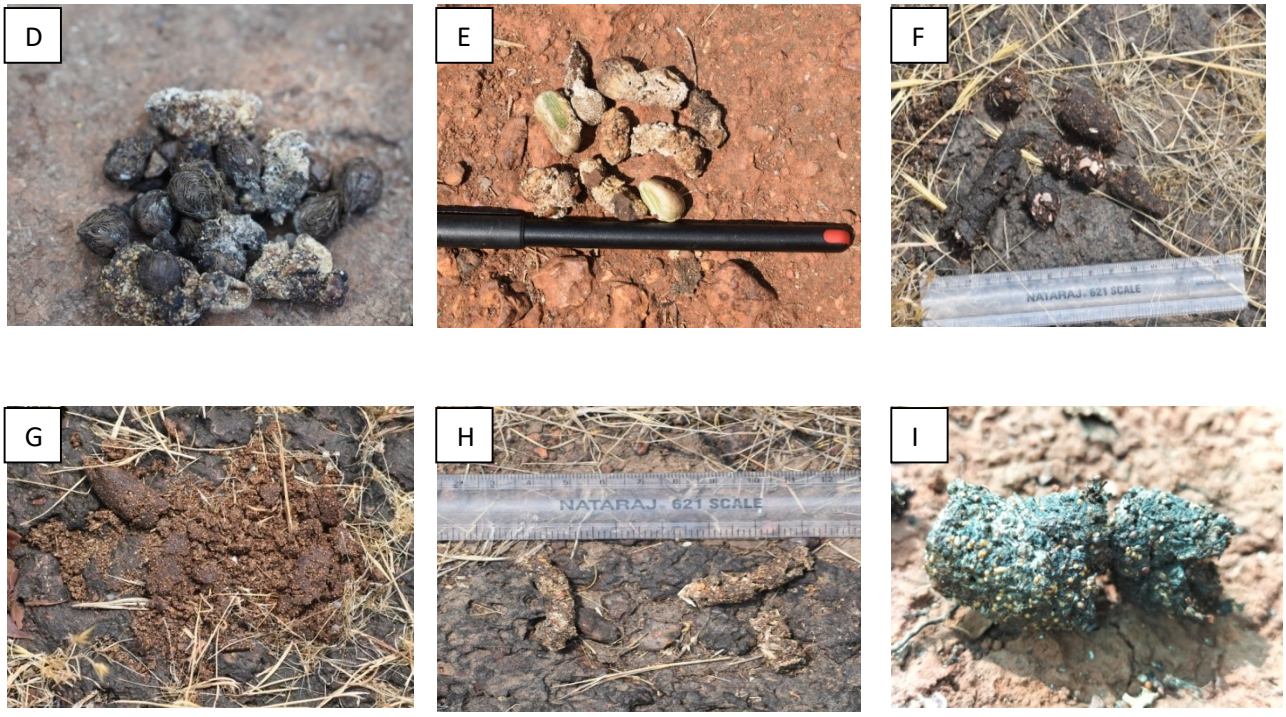
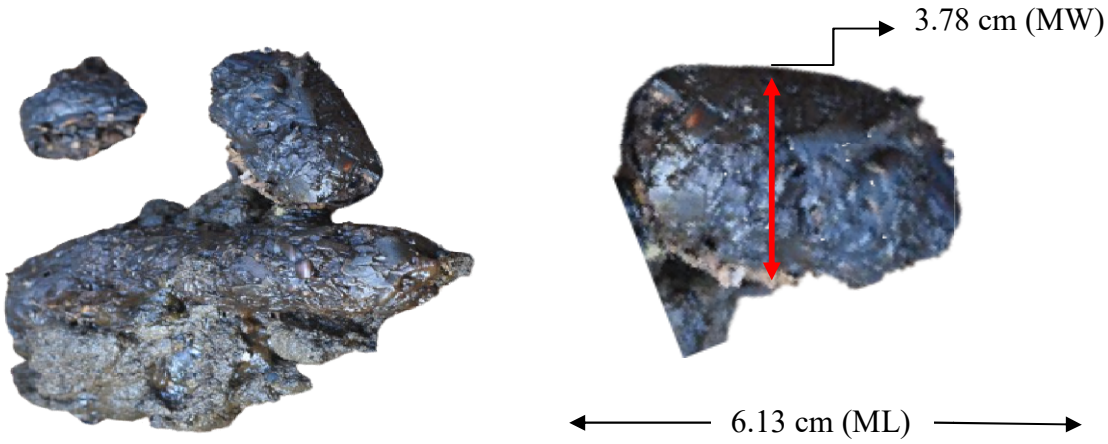


Figure 4.1.16: - Photographs of faecal sample of Asian palm civet taken during the field visit. Majority of their scat contains seeds and berries, indicating how important role they play in process of seed dispersal.

18. SLOTH BEAR



Morphometric and morphological characters of the feces.

Size: - Mean length 6.132±2.839 and mean width 3.787±0.3790.

Shape: - Their scat is elongated sausage shaped; sometimes irregularly shaped due to the presence of high fruit content.

Color: - When fresh black in color, after drying it turns into the shade of brown.

Texture: - Fresh scat is always softer in texture with the visible seeds, termite exoskeleton and other plant matter. After drying it turns into the harder form.

Note: - Majority of their diet contains the fruits, berries and honey. The composition may vary depending upon the season, availability of the food and the altitude. During the drier season their scat mainly contains undigested remains of the termites and the bark of the tree.

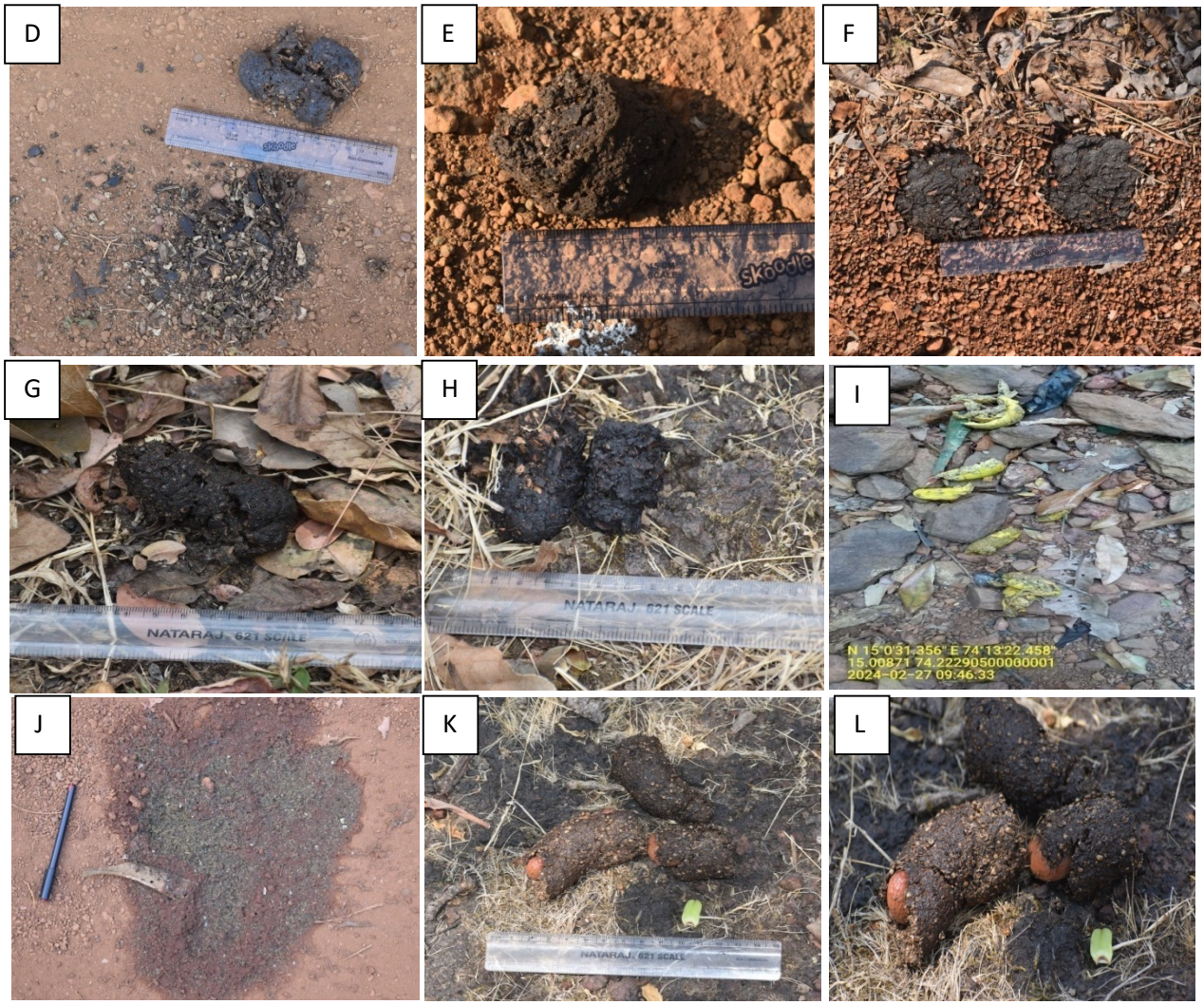


Figure 4.1.17: A-L Majority of their scat contains the fruits and berries which are easily visible in the photographs. (I) scat containing the undigested remains of cashew fruits. (J) Scat having the liquidly texture, containing large amount of tiny seeds.

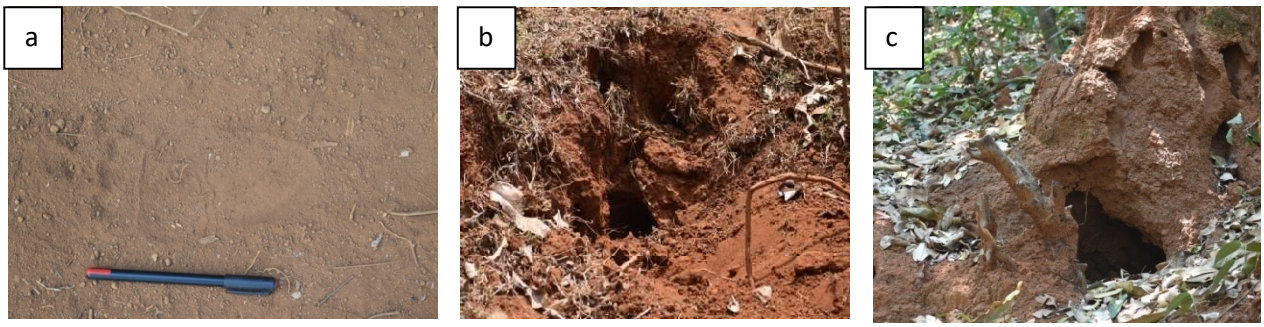


Figure 4.1.18: Other indirect evidences such as the footprint (a), destruction of the termite hill (b) and digging of the ground (c) by the sloth bear found in and around the vicinity of the scat.

19. INDIAN WILD DOG (DHOLE)

Morphometric and morphological characters of feces.

Size: - Mean length 3.241±1.257 and mean width 1.961±0.5548.

Shape: - The scat is cylindrical in shape and segmented. Present as a separate individual fragment like mini sausages.

Color: - Black in color when fresh, grayish white after drying.

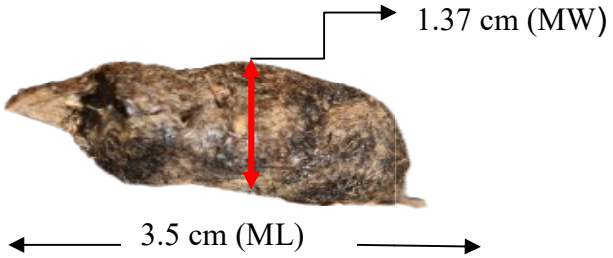
Note: - Unlike leopards, whose scat typically resembles as singular cohesive mass, wild dogs commonly deposit their feces as discrete, individual fragments.

Since they live in a pack, they have the habit of defecating together as a strategy to mark their territory. The scat contains the large amount of hair, bones, claws etc highlighting the animal's carnivorous diet.

Figure 4.1.19: Photographs of the faecal sample of wild dog taken during the field visit.

(A) Fresh scat encountered during the field work. (B) How the scat appears after drying. (C) Scat with the visible prey hair and bones.

20. JUNGLE CAT



Morphometric and morphological characters of the feces.

Size: - Mean length each segment (3.500±1.305) and mean width (1.376± 0.2875).

Shape: - It is sausage- shaped and sometimes cylindrical. The scat may be segmented and have a pointed end.

Color: - It is usually dark grey or black in color.

Note: - It contains visible fur, bones, insect exoskeleton from the prey the cat has consumed.

Unlike the domestic cats which tend to bury their scat, jungle cats often leave their scat in conspicuous locations, like along the trail, on the rock or under the trees. According to the literature this is thought to be a way of communicating with the other jungle cats.

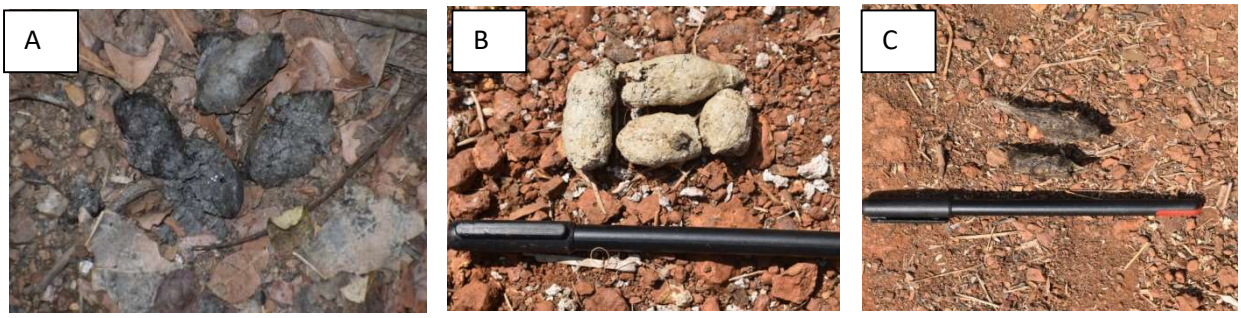
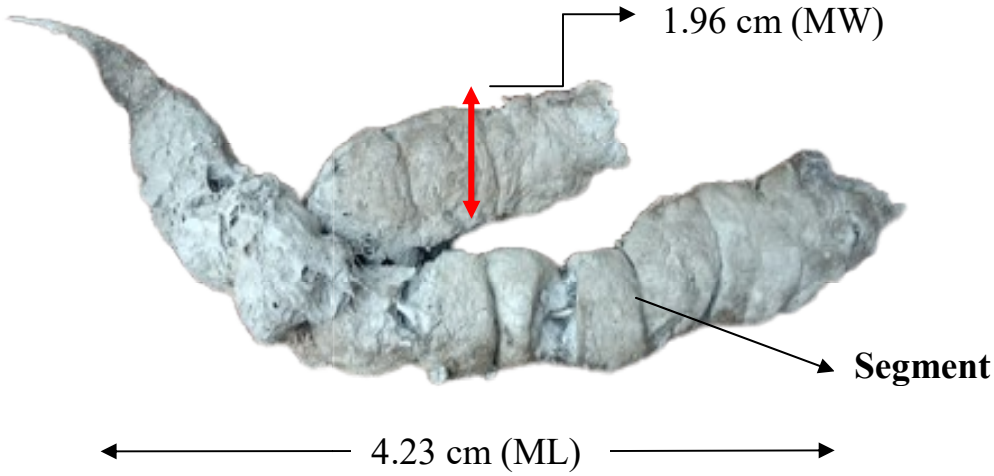


Figure 4.1.20: Photographs of the faecal sample of jungle cat taken during the field work from different study sites.

21. INDIAN LEOPARD



Morphometric and morphological characters of the feces.

Size (segment): - Mean length (4.231±2.080) and mean width (1.967±0.8100).

Number of segments varies from 4-8.

Shape: - It is elongated or sausage shaped, with well demarcated segments. It is curved at one end while tapered at the other.

Color: - Brownish grey when fresh and white or dark grey after drying.

Note: - Leopards mainly defecate along the side or middle of the trail in order to mark their territory. The scat contains large amount o fur, bones hair, teeth and claws.

After drying for longer period of time due to their segmented form, each segment detaches from the main body and appears as an individual form.

The fresh scat has a musty odor.

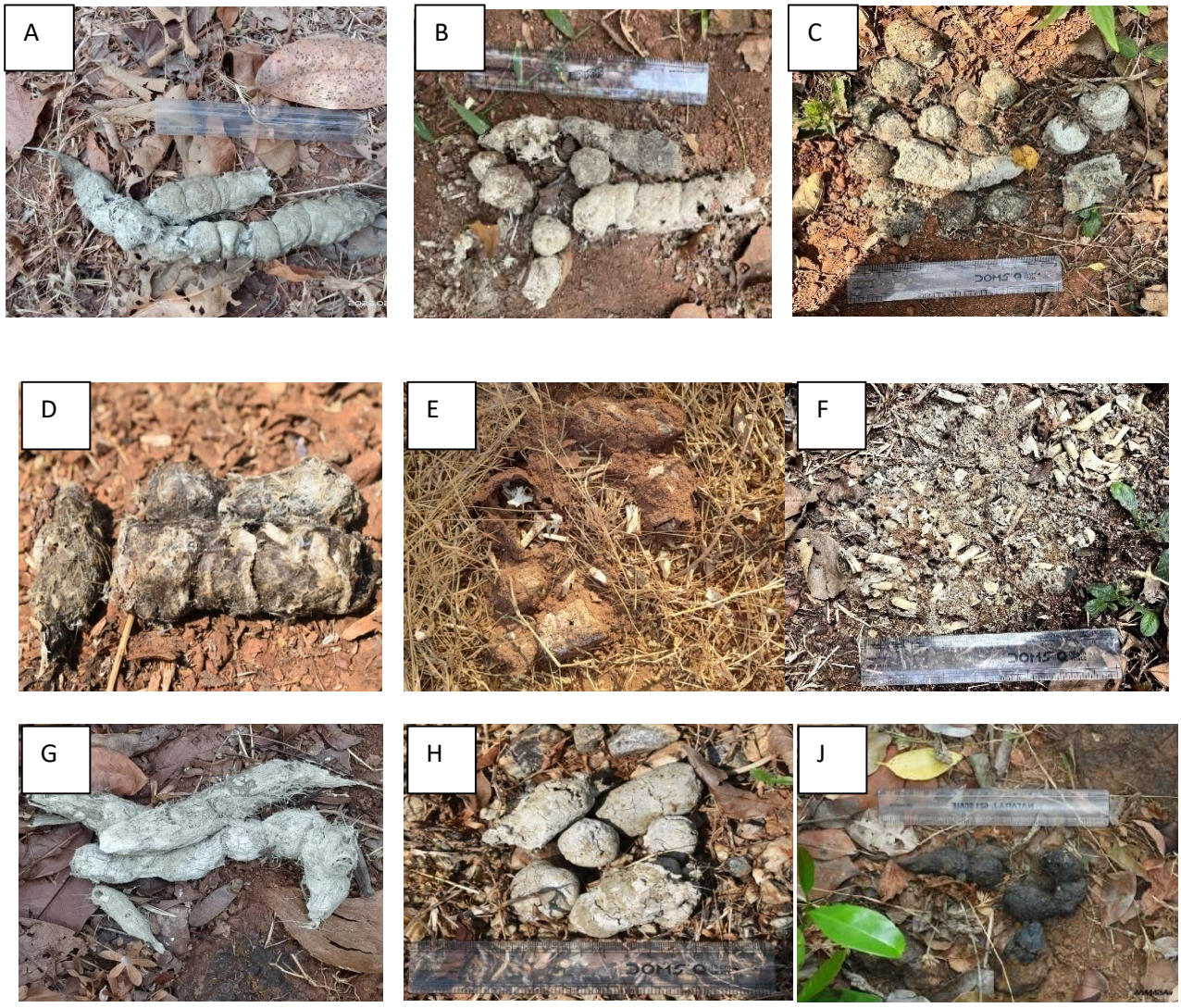


Figure: 4.1.21: Photographs of the faecal sample of leopard taken during the study period

(A) Fresh elongated sausage shaped scat with well demarcated segments. (B) And (C) After drying for longer period of time, the segment detaches from each other (D-F) The scat containing the visible remnants of their prey, like the fur, bones, claws and teeth.

MAMMAL	IMAGE	SHAPE	SIZE	COLOUR
House mouse		Elongated pellets having pointed, similar in appearance to that of dark grains of rice.	ML±SD= 1.094±0.2973 MW±SD= 0.5709±0.083.	When fresh these pellets are black in color.
Black rat		Elongated capsule like pellets with slight curve or shape similar to that of banana.	ML±SD= 1.220± 0.3271 MW±SD= 0.6431±0.0891	The fresh pellets are brown in color and after drying they turn back or grey.
Bat		They are small elongated pellets, pointed at one end.	ML±SD= 1.061±0.2116 MW±SD= 0.3139±0.0400	Usually black and brown in color with white speckles in between.
Malabar gaint squirrel		Cylindrical, elongated, sometimes spherical in shape with blunt ends.	ML±SD= 1.628±0.2808 MW±SD= 0.9048±0.1085	When fresh, greenish yellow or brown, after drying it appears completely dark brown

3 striped palm squirrel		These are tiny pellets similar to that of the bat.	ML±SD= 0.8275±0.2336 MW±SD= 0.3142±0.054.	Color may vary from dark brown to black.
Black napped hare		Spherical or rounded and sometimes flattened. Some may be slightly squashed.	ML±SD= 1.184±0.1184	Golden or light yellow in color.
Indian crested porcupine		They are usually oblong elongated pellets, curved on one side while tapered at other.	ML±SD= 2.823±1.147 MW±SD= 1.014±0.1448	Glossy black when fresh, after drying the color fades into the lighter version.
Spotted deer		Cylindrical in shape, with a rounded base and a tapering apical point. Sometimes the bottom side may be squashed or flat	ML±SD= 2.823±1.147 MD±SD= 1.014±0.1448	Black in color with greenish ting when fresh. Complete black after drying
Sambar deer		Barrel shaped and sometimes elongated. The base of the pellet is flattened to a concave surface while the top is slightly tapered or pointed.	ML±SD= 1.504±0.1304 MD±SD= 1.023±0.08140	Dark green when fresh and black after drying.

Barking deer		Pellets are elongated and crinkled, tapering at both the ends giving a spindle shape	ML±SD= 1.004±0.1605 MD±SD= 0.5929±0.0909	The color is often dark brown to black.
Gaur		It is a large pile of dung, mostly flattened. Often on the upper surface of the dung there are visible concentric lines.	ML±SD= 31.10± 4.743 MW±SD= 24.32± 4.378	Dark green, brown or black in color when fresh
4 horned antelope		They vary in shape being ovoid or elongated in shape.	ML±SD= 0.7763±0.0476 MD±SD= 0.5086±0.0273	The color is often dark brown to blackish.
Hanuman langur		It is like a small tube, but not perfectly round. Tiny rosette shape pellets are present alongside.	ML±SD= 5.025 ± 2.363 MW±SD= 2.875 ± 0.65.	Greenish brown in color when fresh, black after drying.
Indian gray mongoose		It is generally tiny sausage shaped.	ML±SD= 3.695±0.8148 MW±SD= 1.246±0.3222.	It's generally dark colored, ranging from dark brown to black.

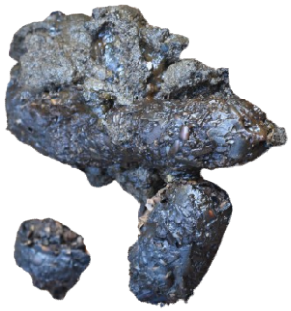
Asian palm civet		The scat may be elongated, sausage shaped or sometimes uneven due to the presence of large number of seeds and berries.	ML±SD= 3.825±1.743 MW±SD= 1.743±0.4000.	Black or brown in color but may upon what the animal has fed.
Sloth bear		Their scat is elongated sausage shaped; sometimes irregularly shaped due to the presence of high fruit content.	ML±SD= 6.132±2.839 MW±SD= 3.787±0.3790.	When fresh, black in color, after drying it turns brown.
Wild dog		The scat is cylindrical in shape and segmented. Present as a separate individual fragment like mini sausages	ML±SD= 3.241±1.257 MW±SD= 1.961±0.5548.	Black in color when fresh, grayish white after drying.
Jungle cat		It is sausage- shaped, sometimes cylindrical. It may be segmented and have a pointed end.	ML±SD= 3.500±1.305 MW±SD= 1.376± 0.2875.	It is usually dark grey or black in color.
Leopard		It is elongated or sausage shaped, with well demarcated segments. It is curved at one end while tapered at the other.	ML±SD= 4.231±2.080 MW±SD= 1.967±0.8100	Brownish grey when fresh and white or dark grey after drying.

Table 4.1: - Comparison between the morphometric and morphological characters of different mammal species.

Figure 4.1.22: - Difference between the herbivore and carnivore based on their faecal morphology.

4.2 Result

Analysis of morphological and morphometric characters of 19 mammal species was done during the study period of 10 months from May 2023 to March 2024. The data produced was analyzed using different types of statistical tests.

Table 4.2.1 shows the results of the unpaired t test carried out between the mean length (n=25) and mean width (n=25) of the fecal sample of 4 different mammal species. The calculated p value for the Malabar giant squirrel, Gaur and Indian leopard is p = >0.0001**** whereas for the wild dog it is 0.0003*** which is less than the accepted threshold for statistical significance (0.05) indicating that the mean length and the width of fecal sample are statistically significantly different.

Species	Length (Mean±SD)	Width (Mean±SD)	Unpaired t test p value
Malabar giant squirrel	1.628±0.2808	0.9048±0.1085	<0.0001****
Gaur	31.10± 4.743	24.32± 4.378	<0.0001****
Wild dog	3.241±1.257	1.961±0.5548	0.0003***
Indian leopard	4.231±2.080	1.967±0.8100	<0.0001****

Table 4.2.1: - Descriptive statistics and result of unpaired t test carried out between the mean length and width of fecal pellets /segments of different mammal species. p = >0.0001**** for Malabar giant squirrel, Indian bison and Indian leopard whereas for the wild dog it is 0.0003***. (*** p< 0.001, **** p< 0.0001).

Table 4.2.2 shows the results of Mann Whitney test performed on the mean length and mean width of the fecal pellets/segments of 15 mammal species and the observed p value of each mammal is (p= >0.0001***) which indicates that both the mean length and width are statistically significantly different from each other.

Sr. No	Species	Length (Mean±SD)	Width/diameter (Mean±SD)	p value
1	Bat	1.061±0.2116	0.3139±0.04002	<0.0001****
2	House mouse	1.094±0.2973	0.5709±0.08397	<0.0001****
3	Black rat	1.220± 0.3271	0.6431± 0.08910	<0.0001****
4	Three striped palm squirrel	0.8275±0.2336	0.3142±0.05412	<0.0001****
5	Indian black napped hare	1.184±0.1184	-	<0.0001****
6	Indian crested porcupine	2.823±1.147	1.014±0.1448	<0.0001****
7	Spotted deer	1.297±0.07416	0.9860±0.1365	<0.0001****
8	Sambar deer	1.504±0.1304	1.023±0.08140	<0.0001****
9	Barking deer	1.004±0.1605	0.5929±0.0909	<0.0001****
10	4 horned antelope	0.7763±0.04764	0.5086±0.02738	<0.0001****
11	Hanuman langur	5.025±2.363	2.875±0.6500	<0.0001****
12	Indian grey mongoose	3.695±0.8148	1.246±0.3222	<0.0001****
13	Asian palm civet	3.825±1.743	1.743±0.4000	<0.0001****
14	Sloth bear	6.132±2.839	3.787±0.3790	<0.0001****
15	Jungle cat	3.500±1.305	1.376± 0.2875	<0.0001****

Table 4.2.2: - Descriptive statistics and results of Mann Whitney test performed between the mean length and mean width of fecal pellets/segments of different mammal's species (p= 0.0001****).

Table 4.2.3 displays the results of an unpaired t test conducted between the mean length of pellets from spotted deer and goat, and a Mann Whitney U test for comparing mean width of the pellets from the same. The obtained p-value for the t test is (p= >0.0001****) and for the Mann Whitney test is (p=0.0004***) indicating a statically significant difference (p= <0.0001****) in ML and MW of the pellets between spotted deer and goat.

Sr no.	**Measurements**	**Species**		**Statistical Tests**	
		Spotted deer n=25	Goat n=25	Unpaired t test p value	Mann Whitney test p value
1	Length (Mean±SD)	1.297±0.07416	1.209±0.09690	0.0004***	
2	Diameter (Mean±SD)	0.9860±0.1365	0.804±0.1136		<0.0001****

Table 4.2.3: - Descriptive statistics, result of unpaired t (<0.0001****) test and Mann-Whitney U test (0.0004***) performed between the mean length and width of pellets from spotted deer and Goat. (*** p< 0.001, **** p< 0.0001).

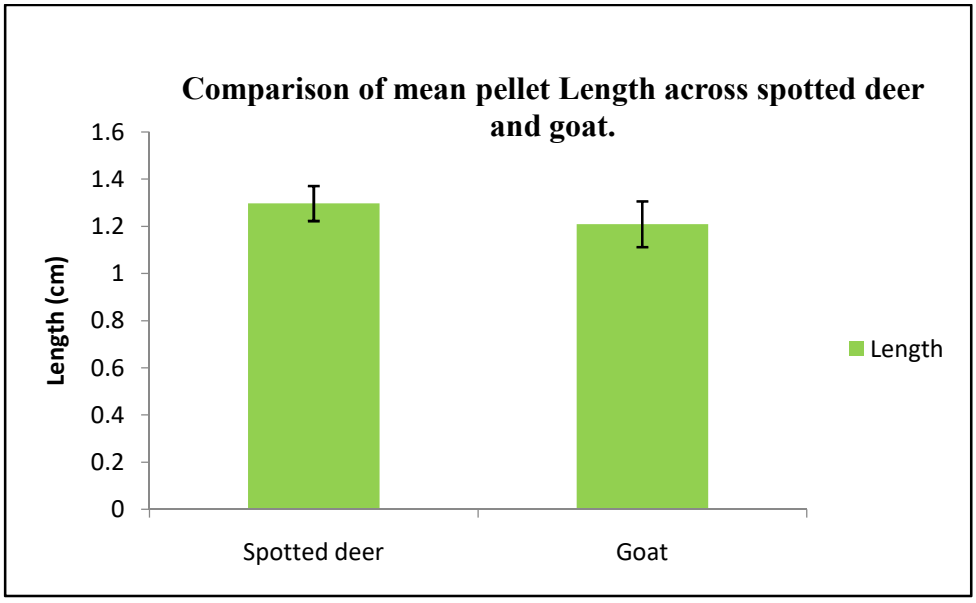


Figure 4.2.1: - Graph showing the comparison of mean pellet length across spotted deer and goat.

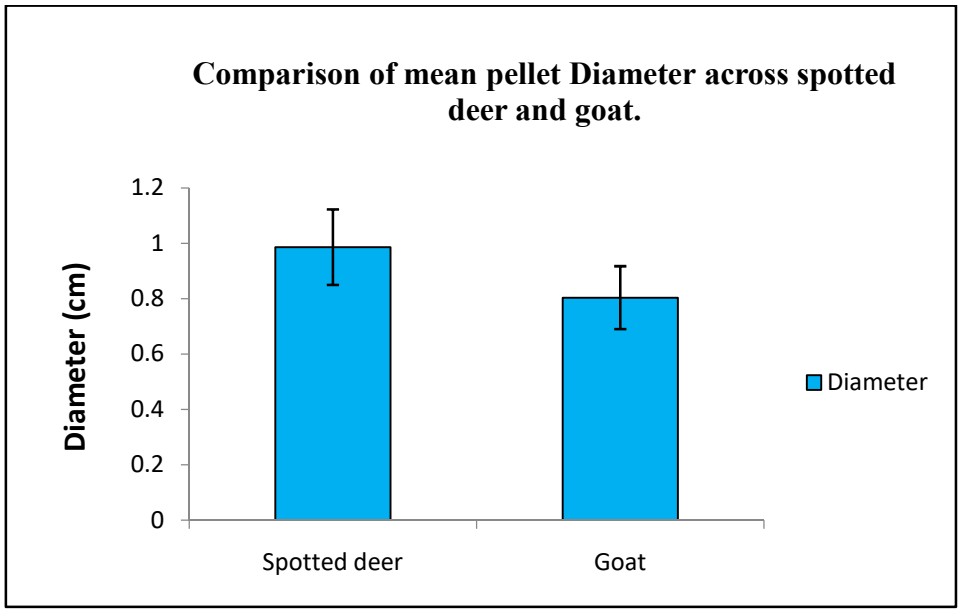


Figure 4.2.2: - Graph showing the comparison of mean pellet diameter across spotted deer and goat.

Table 4.2.4 shows the results of Kruskal-Wallis test (Dunn's multiple comparison tests) performed to compare the mean length of pellets from 4 different ungulate species namely the Spotted deer, Sambar deer, Barking deer and Four-horned antelope respectively. The observed p value for the compared mean length of pellets between the Spotted deer vs Sambar (p= 0.0494*), Spotted deer vs. Baking deer (p= 0.0148*), Spotted deer vs. Four-horned antelope (p= <0.0001****), Sambar vs. Baking deer (p= <0.0001****), Sambar vs. Four-horned antelope (p= <0.0001****) and Baking deer vs. Four-horned antelope (p= 0.0177*) suggests a statistically significant difference (p=<0.05) between the compared measurement dimensions.

Dunn's multiple comparisons test	Mean rank diff.	Significant ?	Summary	Adjusted P Value	
Spotted deer vs. sambar	-21.68	Yes	*	0.0494	A-B
Spotted deer vs. baking deer	24.84	Yes	*	0.0148	A-C
Spotted deer vs. 4 horned antelope	49.24	Yes	****	<0.0001	A-D
Sambar vs. baking deer	46.52	Yes	****	<0.0001	B-C
Sambar vs. 4 horn antelope	70.92	Yes	****	<0.0001	B-D
Baking deer vs. 4 horned antelope	24.40	Yes	*	0.0177	C-D

Table 4.2.4: - Results of Dunn's multiple comparison tests performed between the mean lengths of the pellets from 4 ungulates species. (*p<0.05, **p<0.01, ***p<0.001)

Table 4.2.5 shows the results of Kruskal-Wallis test (Dunn's multiple comparison tests) performed to compare the mean diameter of pellets from different ungulate species namely the Spotted deer, Sambar deer, Barking deer and Four- horned antelope respectively. The observed p value for the compared mean diameter of pellets between the Spotted deer vs. Sambar (p= >0.9999), Spotted deer vs. Baking deer (p= <0.0001****), Spotted deer vs. Four-horned antelope (p= <0.0001****), Sambar vs. Baking deer (p= <0.0001****), Sambar vs. Four-horned antelope (p= <0.0001****) and Baking deer vs. Four-horned antelope (p= 0.1654). This suggests that, there is a statistically significant difference (p=<0.05) between the mean diameters of pellets from Spotted deer vs. Barking deer, Spotted deer vs. Four-horned antelope, Sambar vs. Barking deer, Sambar vs. Four-horned antelope. Whereas it should no significant difference between the pellet diameter from Spotted deer vs. Sambar(>0.9999) and Barking deer vs. Four-horned antelope (0.1654).

Dunn's multiple comparisons test	Mean rank diff.	Significant?	Summary	Adjusted P Value	
Spotted deer vs. sambar	-8.320	No	ns	>0.9999	A-B
Spotted deer vs. barking deer	36.52	Yes	****	<0.0001	A-C
Spotted deer vs. 4 horned antelope	54.60	Yes	****	<0.0001	A-D
Sambar vs. barking deer	44.84	Yes	****	<0.0001	B-C
Sambar vs. 4 horned antelope	62.92	Yes	****	<0.0001	B-D
Barking deer vs.4 horned antelope	18.08	No	ns	0.1654	C-D

Table 4.2.5: - Results of Dunn's multiple comparison test performed between the mean diameters of the pellets from 4 ungulates species. (**** p<0.0001)

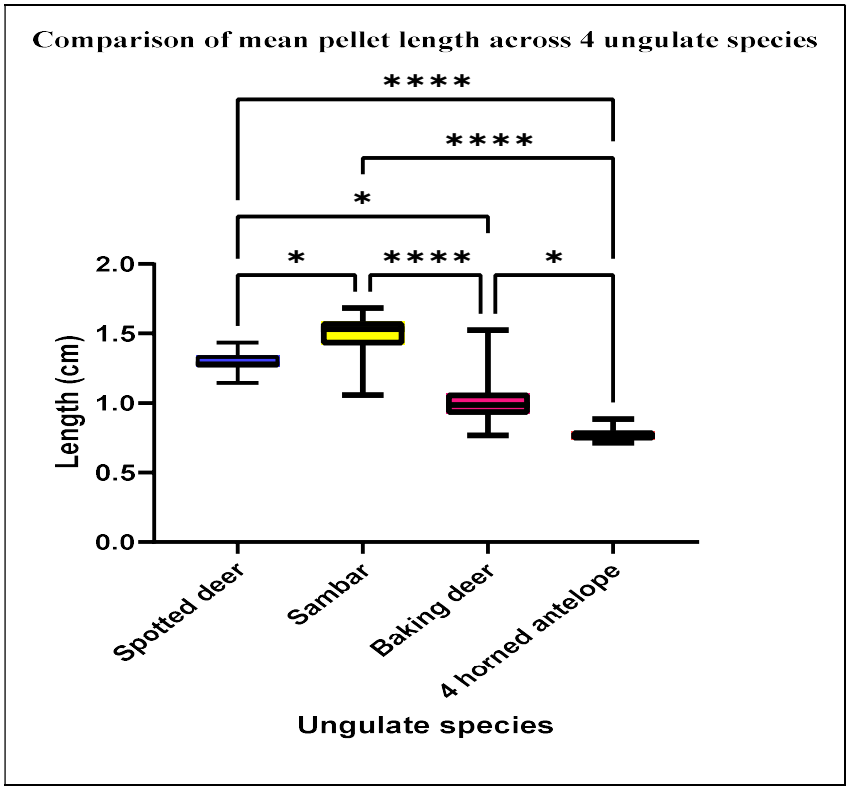


Figure 4.2.3: - Graph showing the results of Dunn's multiple comparisons test between mean pellet lengths across ungulate

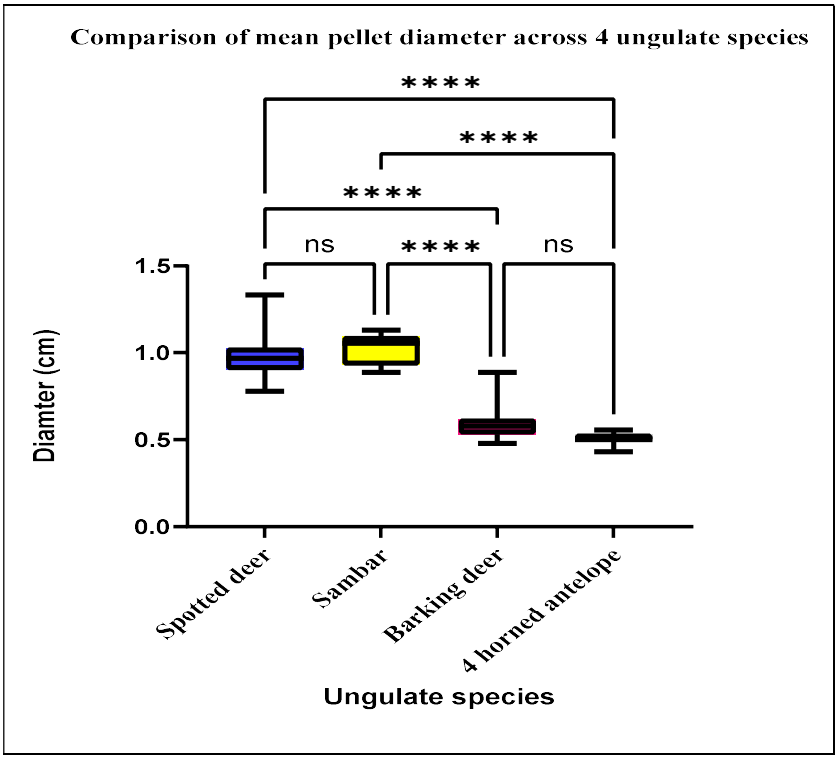


Figure 4.2.4: - Graph showing the results of Dunn's multiple comparison tests between mean pellet diameters across ungulate

4.3 Discussion.

The primary objective of the study was to document the morphological and morphometric characters of wild mammal's feces: its identification and description from the 6 protected areas of Goa. Over the period of 10 months, documentation of the fecal characters of 19 mammalian species was recorded. The morphometric, morphological characters and other notable signs were taken into account. Marcia Chame in 2003 described the terrestrial mammal feces into nine groups which were characterized by fecal morphometry, general pattern of shape and size.

While fecal size is subject to variation based on factors such as animal age and dietary preferences, it is possible to establish standardized size parameters for characterization purpose (Chame, 2003).

The morphology, particularly the shape, serves as the primary diagnostic indicator for identifying the origin of feces, aligning the statement made by Seton (1925).

Present study finding reveal that there is statistically significant difference between the mean length and width/ diameter of fecal sample of each mammal species.

Comparison between the fecal pellets of goat and spotted deer revealed a statistically significant difference.

Comparison between pellets of four different ungulate species namely Spotted deer, Sambar deer, Barking deer and four- horned antelope revealed a statistically significant difference between the pellet length and diameter across the species, except no significant differences were reported for comparison between Spotted deer and Sambar, Barking deer and four-horned antelope.

Yogananda et al in 2003 reported that during the non-fruiting season, the scat of sloth bear is composed greatly of insects diets mainly the termites and ants and during the fruiting season, it contains fruits as similar observation was made during the study.

After analyzing the morphometric and morphological characteristics of fecal pellets from various mammal species, the data produced, accepted the hypothesis, there are significant differences in the morphometic and morphological characters of wild mammal feces. The observed differences in the pellet length and width of different species may be possibly due to variations in the diet, digestive physiology and habitat preferences.

4.4 Conclusion

The study on the morphological and morphometric characters of wild mammal feces in Goa, India has provided valuable insights into fecal morphology and its significance in wildlife ecology and conservation biology.

Through analysis of fecal pellets from diverse mammalian species, including herbivore and carnivore significant variations in size, shape and other attributes have been identified. This morphological and morphometric characteristics offer valuable information for species identification.

Furthermore, the study highlights the potential utility of fecal morphology as a non-invasive tool for wildlife monitoring and conservation efforts. By understanding the distinct morphological features of fecal pellets, researchers can better assess species diversity, population dynamics and ecosystem health. This knowledge contributes to more effective conservation strategies aimed at preserving biodiversity and habitat integrity in the region.

Given the limited research in this area, there is ample opportunity for further exploration. Future studies could delve into additional aspects such as the trichotaxonomy, dietary analysis and habitat preferences of wild mammals, thereby enhancing our understanding of ecosystem dynamics and species interaction.

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APPENDIX II

Photographs of regurgitated owl pellet.