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CHAPTER -1
Introduction

Monitoring ungulate population in India is mostly conducted by using distance sampling. However many ungulate species are difficult to enumerate and observe because of their rarity, small size, elusive behaviour or nocturnal habits, or because of dense vegetation cover (Stuart & Stuart 2000). Hence, methods based on indirect observation such as pellet-group counts are being developed for monitoring ungulate population trends across the landscape. The world's largest monitoring programme "Monitoring Tigers, Co-predators, Prey and their habitat in India." uses pellet based index to monitor trends in ungulate populations. In addition to monitoring population trends fecal studies are very useful for estimating animal habitat use, niche overlap and segregation, age group classification, sex etc. (Ball 2010, Morden *et. al.*, 2011, Rouco *et al.*, 2012). The study of fecal pellets of terrestrial mammals brings out biological and ecological data such as the species presence, diet, behaviour, territory and home-range use, which can be applied for conservation projects. It also provides vital information about activity centres, (Walker 1996), health parameter of individual species, the role of seed dispersion (Fragoso & Huffman 2000, Williams *et al.*, 2000) and potential enteroparasitosis dynamics (Patton et al. 1986, Page et al. 2001). It therefore becomes imperative to identify pellets of sympatric ungulate species correctly. Identification of pellet groups correctly with respect to species, age and sex have inherent problems. Pellet morphometry if done accurately may help in removing many ambiguities. As a non-invasive method, it constitutes an important tool for identifying and studying sympatric ungulate species. Although the new biotechnological techniques allow more accurate data, the diagnosis based on morphometric analyses permits the primary identification of the taxonomic group origin to support the best choice of subsequent analyses.

Morphometry means study of the measurement of the external features of an object so as to ascertain its characteristics. Fecal morphometry involves measurement of the length, breadth, width, volume etc. of the collected pellets. It also takes into account the comparison of shapes and sizes of indents and tips present in the fecal pellets. The criteria's may be used to differentiate between various sympatric species, to study the uniformity and symmetry of pellet sizes within the group, to study habitat use, sex of the ungulate species and disintegration with respect to time.

A study conducted by Hibert *et al*., 2008 on ten sympatric ungulate species of Western Africa has developed simple field criteria for distinguishing between pellets. From the mean of measurements of pellet groups from different species a discriminant analysis was performed by Hilbert *et al.*, 2008 to pinpoint and characterize the most useful morphological criteria for separation between them. The mean diameter of pellets and the mean indent depth within each pellet group has proved to be the two most valuable variables for species segregation. Once pellet groups have been identified, their density and spatial distribution may provide useful information on the use of space and habitat of sympatric species, over given periods. Variation in pellet shape and size in tropical ungulates also depends on seasonal variation in diet (Stuart & Stuart, 2000; Chame, 2003).

The objective of this study is to identify morphometric character which can discriminate between pellet groups of sympatric ungulate species and identify potential sources of error in our classification matrix. In India one study on Manipur brow-antlered deer classified highlighted the fact that fecal pellet measurements varied with respect to age and sex class. Prior to this study which is to be undertaken in Tadoba Andhari Tiger Reserve (TATR) studies regarding pellet morphometry have been restricted to mostly Africa and Europe. The study would help us determine the various morphometric criteria which can be used to identify the various sympatric species in TATR. So considering the immense possibilities which are associated with the subject of pellet morphometry this study will be conducted to answer the question whether it is possible to differentiate pellets of sympatric ungulate species based on morphometric criteria, and if yes what is the accuracy of this method.

CHAPTER -2
Literature Review

Pellet Morphometry is a science whose potential is yet to be realized by researchers and scientists throughout the globe. But a few studies conducted in various parts of the world have thrown some light to the fact that pellet morphometry if put to good effect may provide us answers to many questions which are quite intriguing.

Putman R. J., (1984) was the first to elucidate the importance of feces and their significance on the study of elusive animals. He pointed out that a lot of ecological information may be deduced from an analysis of fecal decomposition.

Khan *et. al.,* (1993) studied whether fecal pellet measurements of Manipur Brow-Antlered Deer (*Cervus eldi eldi*) varied with respect to sex and age classes. In this study measurements were made of fecal pellets for captive brow-antlered deer from different age and sex classes. Pellet measurements increased linearly with increase in age, except for length and width measurements in males. Differences in dimensions were statistically significant between sexes and some age classes.

Chame, M., (2003) did a review on morphometric summary and description of fecal shapes and measurements available in the literature published in North America, Eastern and Southern Africa, Europe and from Brazil and concluded that shape and diameters are the best characteristics for taxonomic identification. Feces were assembled in 9 groups that reflect the order, sometimes the family, and even their common origin.

Sanchez, *et al.,* (2004) studied that the various morphometric criteria namely length, width, length to width ratio and volume of pellets in 3 different categories (adult males, adult females and yearlings) of mule deer (*Odocoileus hemionus*). They were able to distinguish via discriminant function and fuzzy clustering techniques the age and sex of individuals. To determine a priori the identity of the pellet samples and to evaluate the accuracy of their methods, they obtained samples from individuals in captivity. The discriminant function allowed us to correctly assign 100% of adult males, 91.66% of adult females, and 75% of yearlings to an age class, using previous information.

The fuzzy clustering method enabled them to correctly distinguish 100% of adult males, 83.3% of adult females, and 75% of yearlings. The methods were based upon different assumptions.

Southgate R., (2005) conducted a study to find out whether age classes of greater bilby (*Macrotis lagotis*) had any relationship on the track and fecal pellet size. The gait length and width and faecal pellet diameter of bilbies were examined to determine whether these measures could be used to accurately identify different age classes of individuals in the field. There was a good relationship between gait width+length and animal size that allowed the identification of three age classes: immature–independent individuals <500 g, mature females and small males 500–1200 g, and large males >1700 g. The relationship between pellet diameter and animal size was not as strong and faecal pellet diameter was suitable to identify only immature–independent individuals. An application of these measurements to a bilby population in the Tanami Desert indicated that immature individuals were limited to the central half of their current distribution whereas medium-sized individuals were distributed throughout.

Hibert *et al*., (2008) have studied that morphometric criteria of fecal pellets can be used to identify the sympatric ungulate species in West African Savanna. Hibert et al.,(2008) have tried to develop simple field criteria for distinguishing between pellets among ten sympatric West African ungulates. The pellet groups of six of the ten designated species could be identified with a minimum misclassification error .A discriminant analysis was performed, using the mean of measurements of pellet groups from different species to pinpoint and characterize the most useful morphological criteria for separation between them. The mean diameter of pellets within each pellet group proved to be the most valuable variable for species segregation, whilst the second axis separated species by mean indent depth. The pellet groups of six of the ten designated species could be identified with a minimum misclassification error. Once pellet groups have been identified, their density and spatial distribution may provide useful information on the use of space and habitat of sympatric species, over given periods.

Ball M.C., (2010) has concluded from the study that fecal pellet size can be used to differentiate age classes in Caribou. It came to light that by using feces from known age Caribou, pellet length distinguished calf and yearling age classes from adult animals. However pellet width could only discern the calf age class.

Hibert *et. al.,* (2010) studied the aging of ungulate species in semi-arid landscapes of Africa. In semi-arid areas, ambient conditions conserve the pellets during the dry season. Thus, dating of accumulated pellet groups should be helpful in approximating the numbers of ungulates present during any chosen part of the dry season. The aims of this study were to confirm that the decay rate of pellet groups was low during the dry season, to identify the major causes of decay and to test the usefulness of criteria, easily measurable in the field, in dating pellets. Every month during the dry season pellet groups of five African savanna ungulates were collected fresh and deposited on bare ground at an experimental site. The levels of hardness, cracking, scattering, attack by insects and shade of colour of the pellets were monitored until the rainy season started. As expected, only a few pellet groups decayed completely during the dry season. The pellets shade of colour was the best criterion to date them. We discuss pellet colour as an original tool for monitoring the trends in ungulate use of target areas in semi-arid environments.

Morden *et. al.,* (2011) have concluded from their research that fecal pellet size can be used as a critical parameter to differentiate age classes in female Svalbard reindeer (*Rangifer tarandus platyrhynchus).* Using fecal samples collected from Svalbard reindeer population in the winters of 2008 (N=158) and 2009 (N=161) they investigated and validated the feasibility of using fecal pellet sizes to differentiate between female calves, yearlings and adults. It was found that pellets from adult females were longer than those from calves, and pellets from adults and yearlings were clearly wider than those from calves. With an accuracy of 91% correct classification, it was possible to show that a combination of fecal pellet dimensions (length, width and depth), rather than a single dimension alone, can allow managers to clearly differentiate between age classes if pellets already identified as being from females are used. He also found a positive relationship between live weight and pellet size of the reindeer. Combined with DNA analysis to identify the gender of the animal that produced the fecal pellet, this information may provide important population parameters and be a valuable tool for the monitoring of various ungulate species including wild reindeer.

Rouco *et. al.,* (2012) studied whether it was possible to differentiate between animals from different age classes on the basis of pellet size. Estimating population age structures by faecal pellets sizes is a commonly used field method in some mammal species. They examined the validity of this method in European rabbits based on 1113 pellets from 226 animals with known age, by measuring the intra-individual variation in pellet size and studying the explained variance of calibration curves describing the relation between pellet size and individual age. In addition, they applied a simulation model in order to estimate the accuracy of this method. Pellet size showed a high intra-individual variation and was only moderately correlated with the animals' age. Modeling revealed that the population age structure assessed by this method deviated considerably from the given structure, indicating a systematic estimation error. They concluded that this method can lead to strongly biased results, restricting its validity. They also provided estimation errors, which might be considered if estimates of age structure in wild rabbits populations based on faecal diameters are conducted.

Present study undertaken in Tadoba Andhari Tiger Reserve, (TATR) Maharashtra will be a very significant one from the research perspective as pellet morphometry is a concept which can add to the existing knowledge for better conservation and management of species. This is the first study on pellet morphometry in India barring a solitary work conducted on brow antlered deer by Khan *et. al.,*in 1993. Studies regarding pellet morphometry have been restricted to mostly the African continent and Europe, so it needs to be introduced in India also. The study will also give us vital inputs regarding habitat use, food habits, resource use amongst others which is of paramount importance from the conservation and management view point.

CHAPTER-3
Study Area

TATR (Tadoba-Andhari Tiger Reserve) represents a pristine and unique habitat for wildlife in Maharashtra, state in Central India. It is the second tiger reserve in the state. It contains some of the best forest tracks and is endowed with rich biodiversity. TATR is situated in the district of Chandrapur, eastern edge of Maharashtra.. The area lies between 20°04'-28°025' N and 79°13'-79°33' E (). The geographical area of the Tiger Reserve is 625.40 km^2 out of which Tadoba National Park comprises 116.55 km^2 while Andhari Wildlife Sanctuary covers 508.85 km^2. Tadoba National Park which was established as the first national park of Maharashtra, form the core northern zone of TATR. In the year 1986, the Government of Maharashtra established the Andhari Wildlife Sanctuary, which consists of two ranges Moharli and Kolsa, which form the central and southern zones of the Tiger Reserve respectively. The name 'Tadoba' is the name of the God "Tadoba" or "Taru", praised by the tribal people who live in the dense forests of the Tadoba and Andhari region, while the Andhari River that meanders through the forest gives the 'Andhari' name. The region was given its present status in February 1994. The TATR covers for tehsils namely Chandrapur, Bhadrawati, Chimur and Warora. A picturesque Tadoba Lake is located in the central part of Tadoba National Park.

3.1 Climate

The study area experiences subtropical climate with three distinct seasons i.e. summer, monsoon and winter. Climate is characterized by hot and prolonged summer from March to June while winter is short and mild from December to February respectively Rainfall is well distributed during southwest monsoons. The monsoon arrives in mid-June and continues till September.

3.2 Temperature

The maximum recorded temperature is 49.2 degree Celsius and the minimum in the year is 3 degree Celsius. Temperature rises rapidly after February till May which is the hottest month of the year. The mean maximum and minimum temperature is about 42 degree Celsius and 24 degree

Celsius respectively in May. After October both day and night temperature decreases till December which is the coldest month of the year.

3.3 Humidity

The air is generally dry except during the southwest monsoon season when the humidity exceeds 70%. The summer months are driest when the relative humidity in the afternoon is between 20-25%. The winds are generally light.

3.4 Precipitation

The bulk of rainfall i.e. 92% is received from June to September. The average number of rainy days is approximately eighty. The average rainfall is 1175mm.

3.5 Geology and Soil

Vindhyan sandstones occur in almost all the areas, which consist of sandstone, shales and limestone. The prominent rocks are the grained vitreous sandstone. Broad geological divisions, can be made for TATR based on the deposition of the rock types. In north, a small part of detrital mantle consists of alluvial deposits. In south western side, the Gondwana sediments expose the Kamathi formations and Lamteas at the surface. Archaen metamorphic rocks as patches are present along the north-east corner and in the western border. The soil in the greater part is sandy with stretches of yellow brown and black loam. True black cotton soil is found in the plains except where forests are heavily degraded. On the slopes the soil layer is thin and vegetation is sparse. The tops of the hillocks are mostly barren with exposed rocks.

3.6 Topography

The area is mostly undulating and hilly in the north. The southern part of TATR ia mostly plain. The Chimur hills start from the east of Chimur and run southwards with gradually diminishing height. In the basin of hills lies Tadoba Lake which has a spread of 120 hectares approximately. The highest elevation points in the study area reaches 380 m above mean sea level.

3.7 Drainage Pattern

There are two main rivers draining TATR namely Erai river in the western half and Andhari, the main river in the eastern half. Both these rivers are flowing from north to south and their course seems to be controlled by the major boundary fault. Since the area is undulating there are numerous streams passing through. Andhari river originates in eastern part of the National Park and flows down southwards joining Wainganga, a tributary of river Godavari. Erai is fed by the Bhanushkhandi nala, which originates from the western part of the National Park. The streams are seasonal and have flowing water only till the end of November. Other important surface water bodies in the area are Tadoba and Kolsa lake.

3.8 Biodiversity

General Account of Flora

TATR has southern tropical dry deciduous forest – 5A/16 (Champion and Seth 2005). Fairly large area is dominated by *Tectona grandis.* The main associates associates of Teak (*Tectona grandis*) are Bija (*Pterocarpus marsupium*), Dhaora (*Anogeissus latifolia*), Ain (*Terminalia tomentosa*), Mahua (*Madhuca indica*), Tendu (*Diospyros melanoxylon*), Salai (*Boswellia serrata*), and Sehna (*Lagerstroemia parviflora*). Bamboo (*Dendrocalamus strictus*) forms the middle storey in almost all communities and in certain cases under storey also. The area includes both Angiosperms and Pteridophytes comprising 667 species, 393 genera and 110 families (Malhotra and Moorthy,1992). A total of 85 species of trees, 43 species of herbs and shrubs, 23 species of climbers and 35 species of grasses have been reported by the Forest Department. The undergrowth is generally rich after monsoon but ephemeral in nature.

General Account of Fauna

A total of 42 mammals have been checklisted in the study area. Tiger (*Panthera tigris*) is a keystone species and major management inputs are focused towards its conservation. Other carnivores include Leopard (*Panthera pardus*), Striped hyaena (*Hyaena hyaena*), Wild dog (*Cuon alpinus*), Jungle cat (*Felis chaus*) and Desert cat (*Felis sylvestris ornata*). Rusty spotted cat (*Prionailurus rubiginosa*), Jackal (*Canis aureus*) and a Wolf (*Canis lupus*) occur in the western fringe of TATR. Sloth bear (*Melursus ursinus*) also occur in fairly large numbers. Major herbivores of TATR are Gaur (*Bos gaurus*), Sambar (*Cervus unicolor*), Chital (*Axis axis*), Barking deer

(*Muntiacus muntjac*), Nilgai (*Boselaphus tragocamelus*) Chowsinga (*Tetraceros quadricornis*), Wild pig (*Sus scrofa*) and Langur (*Presbytis entellus*). There are 195 species of avifauna recorded in the area. There are 3 endangered species of reptiles namely, Marsh crocodile, Indian Python and Common Indian Monitor.

3.9 Socio Economic Environment (People)

There are six villages inside TATR which lie in the Andhari Wildlife Sanctuary. These villages are completely dependent on TATR for their requirements of fuel wood, grazing of their livestock etc. The area is dominated by Gond and Mana tribes. Gonds have rich history in the area. Once the rulers of the southern Vidarbha area they were pushed into the forests by repeated invasions by Marathas. Gonds and Manas mainly survive on the products derived from trees like Tendu and Mahua in the forest. Due to increase in population in past few years, expansion of habitation has been observed there by changing the land-use pattern which in turn has affected the forested landscape. The main sources of livelihood are agriculture, minor forest produce and labour works, if available in the lean season. The cattle population most of which is unproductive is traditionally considered as symbol of social status.

The dissertation work was carried out mainly in the Tadoba Range especially in the following areas like the Grasslands of Navegaon and Pandarpauni, Tadoba Reservoir and dry deciduous forests of Jamunbodi, Vasant Bandhara and Kala Amba.

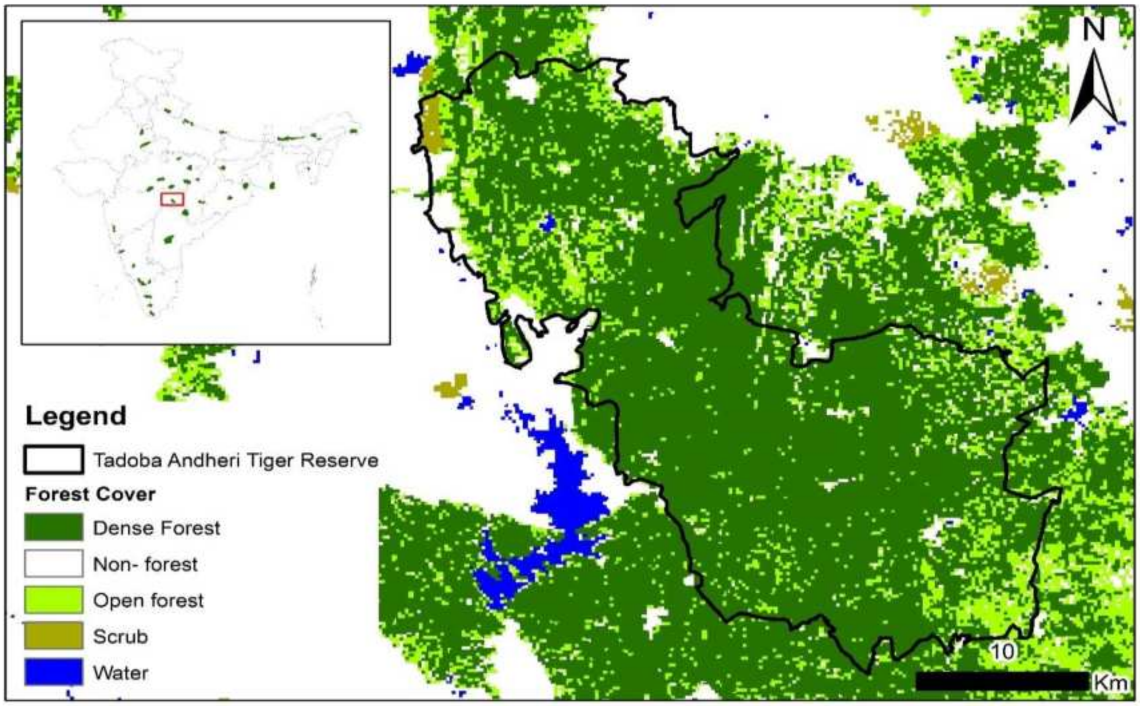

Figure 3.1: Location Map of Tadoba Andhari Tiger Reserve (TATR),Maharashtra Forest Density

Plate 3. 1: Habitat of Ungulates (Tadoba Reservoir)

Plate 3.2 : Pandarpauni Grassland interspersed with Zizyphus trees and Basant Vandhara showing dry deciduous type of vegetation a characteristic of TATR.

CHAPTER-4
Study Period and Study Species

4.1 Study Period:

The study was conducted from mid-February to 1st week of April 2014 in Tadoba Andhari Tiger Reserve (TATR) Maharashtra. Feces are less regular and less recognizable during the rainy season (Chame 2003) on account of rainfall and insect infestation on them. Size variation is more frequent among herbivores because of the alteration in the quality and amount of food ingested in different seasons. Food characteristics also affect fecal consistency. Fibrous plants maybe the only food found during dry periods or in arid environments, so animals produce hard and more compact feces. During rainy periods or in tropical rainforest ecosystems**,** the larger consumption of green leaves, sprouts**,** and fruits produce soft, large**,** and aggregated feces. Thus, the dry season is the best for conducting pellet counts and analyses to minimize confusion. For this reason, most feces collection will be performed from February to April. The study was conducted in TATR landscape to evaluate morphometric variation in pellets of 3 sympatric ungulate species.

4.2 Study Species:

4.2.1 Nilgai *(Boselaphus tragocamelus)*

IUCN threat category – Least concern.

Distribution and Home Range – The Nilgai is found only in the Indian Peninsula from the base of the Himalayas to Mysore. It does not occur in eastern Bengal, or Assam or on the Malabar coast.

Size – The height of the males ranges from 130 – 140cm. but may extend upto 150cm. Females are comparatively more smaller. The average length of the horns is 20cm but the maximum recorded length is 29.8cm.

Distinctive Characteristics – The animal is somewhat horse like in build with high withers and low rump. The adult bull has got a coarse iron-grey coat a white ring

Plate 4.1: Nilgai Male and Female

below each fetlock and two white spots in each cheek. The coat of young bull or cow is tawny. Irrespective of sex they have dark manes and the males wear a distinctive tuft of stiff black hairs on the throats. The bulls have stout cone like horns. They are distinctly keeled, triangular at the base and circular towards the tips.

Group Size and Composition – Nilgai are partially social in their habits (Roberts 1977), although congregations and group size are rare. According to Dinerstein (1980), Nilgai occurs in groups ranging from one to ten individuals. According to Schaller (1967, nilgai groups change constantly but three distinct kinds of groups are discernable:

(i) One or two cows with young calves,
(ii) Three to six adult and yearling cows with calves, and
(iii) Males groups varying in number from two to eighteen.

Habitat – Nilgai occur in arid areas, scrub, dry deciduous forests and agricultural areas, but avoid dense forest and deserts. They are both browsers and grazers. Their usual haunts are hills sparsely dotted with trees, or level or undulating plains covered with patches of grass or scrub.

Food Preferences – Nilgai feed on the fallen leaves and fruits of *Zizyphus mauritiana*, fallen flowers of *Butea monosperma*, fallen pods of *Acacia nilotica*, *Acacia catechu* and *Acacia leucophloea,* and fallen leaves of *Anogeissus pendula* along with grass and browse. They have a special preference towards freshly fallen flowers of Mahua tree (*Madhuca indica*). Nilgai also feed on crops in the field and cause damage to the farmers.

Dung Piles – Nilgai have acharacteristic habit of defecating repeatedly in the same location, resulting in the formation of large fecal piles or lavatory sites of nearly a meter in diameter (Brander 1923, Dharmakumarsinghji 1959, Schaller 1967). The social significance of this phenomenon is not yet clear but Schaller (1967) suggested that these piles might function as territorial markers.

Threats and Conflict with Human beings - Considered an agricultural pest in parts of India and, although legally protected in India, legislation has been amended to permit hunting when crop damage becomes excessive.

4.2.2 Chital or Spotted Deer (*Axis axis*)

IUCN threat category – Least concern

Distribution and Home Range - The Chital occurs over 8–30ºN in India (including Sikkim), Nepal, Bhutan, Bangladesh, and Sri Lanka. The western distribution boundary is formed by eastern Rajasthan (e.g. Sariska, Ranthambore, and Keoladeo Ghana) and Gujarat (e.g. Sasan Gir). The northern boundary runs along the bhabar-terai belt of the foothills of the Himalaya from Uttar Pradesh and Uttaranchal through Nepal, northern West Bengal and Sikkim to western Assam and the forested valleys of Bhutan below 1,100 m above sea level. The eastern boundary runs through western Assam (Golapara and Kamrup district) to the Sunderbans of West Bengal (India) and Bangladesh. Sri Lanka is the southern limit (Gee 1964; Schaller 1967). Chital occur throughout the rest of peninsular India sporadically in the forested areas, but in Bangladesh, it now occurs only in the Sundarbans, having vanished from the central, north-east and south-east regions.

Size – A well-built stag stands 90cm at the shoulder and weighs about 85 kgs (Prater 1971). Maximum height recorded for a chital stag is 101cm and the length of the antler would be 85cms and in case of South India it is about 80cm long.

Distinctive Characters – The Chital is perhaps the most beautiful of all deer. Its coat is bright rufous-fawn profusely spotted with white at all ages and at all seasons. Old bucks are more brownish in colour and darker. The lower series of spots on the flanks are arranged in longitudinal rows and suggest broken linear markings. The graceful antlers have three tines, a long bow tine set nearly at right angles to the beam and two branch tines at the top.

Plate 4.2: Chital Male, Female and Fawn

Group and Size Composition – Chital are essentially social animals, rarely seen as solitary individuals. The basic social unit among chital is a matriarchal family group, normally consisting of an adult female, her offspring from the previous year, and a fawn (Ables 1974). The usual herd is composed of two or more such family units and is often accompanied by individual deer of mixed sex and age-classes. Chital is expected to exhibit a fission-fusion system or fluid-group formation and dissolution (Schaller 1967, Mishra 1982, Barette 1991). Depending on various circumstances, a chital group may consist of 1-150 individuals (De and Spillit 1977, Eisenberg and Lockhart 1972, Fuchs 1977, Krishnan 1972, Schaller 1967).

Habitat – Chital thrive in a variety of habitats, but avoids extremes such as dense moist forests and open semi-desert or desert. Moist and dry deciduous forest areas, especially adjoining dry thorn scrub or grasslands appear to be optimal, and highest densities of Chital are reported from these habitats. Short grasslands of the terai, swampy meadows and glades adjoining forest areas, coastal dry evergreen forests, mixed forests or plantations with Teak Tectona grandis and Sal Shorea robusta are also used. Chital is particularly frequent in grassland–forest interface, edge, and other ecotones (Krishnan 1972). Eisenberg and Seidensticker (1976) opined that dry deciduous habitats with scrub is the favoured habitat, while Karanth and Sunquist (1992) found mixed forests with teak plantations, moist deciduous patches and swampy grasslands to support predators such as Tiger Panthera tigris (Moe and Wegge 1994).

Food preference – Chital are known to feed on more than 160 species of plants (Schaller 1967, Johnsingh and Sankar 1991). Schaller (1967) showed that graze formed the bulk of the feed of chital. Rodgers (1988) had categorized chital as a generalized feeder, with a diet consisting of grasses, forbs and leaves of woody plants.

4.2.3 Sambar (*Cervus unicolor*)

IUCN threat category – Vulnerable.

Distribution and Home Range – The Sambar extends from India and Sri Lanka east along the southern Himalayas (including Nepal and Bhutan) through much of south China (including Hainan Island) to Taiwan. Further south it occurs in Bangladesh, throughout mainland South-east Asia (Myanmar, Thailand, Lao PDR, Cambodia, Viet Nam, West Malaysia) and many of the main islands of the Greater Sundas (excepting Java). The typical race *Cervus unicolor unicolor* is native of Srilanka. The Indian race *Cervus unicolor niger* is confined to India. The Malay race *Cervus unicolor equinus* extends from Assam eastwards.

Size – The Sambar is the largest Indian deer and carries the grandest horns; height at shoulder nearly 5ft. (150cm), average about 140 cm. A full grown stag weighs 225 – 320 kgs. The finest heads come from the forests of Narmada and Tapi and from Madhya Pradesh generally. The record from Bhopal tapes 129.2 cm. Nowadays 95 cm is good in North India and 90 cm in the South. The antlers of the Malay Sambar are close-set, more rugged and massive, the average length being 65 cm and a head over 75 cm is considered good.

Distinctive Characters – The typical forest deer of south-eastern Asia is the Sambar. The coat is coarse and shaggy. In the hot weather much of the hair is shed. The general colour is brownish with a yellowish and greyish tinge. The under parts are paler. Females are lighter in tone. Old stags tend to become very dark, almost black. The antlers are stout and rugged. The brow tine is set at an acute angle with the beam. At its summit, the beam forks into two nearly equal tines. In some heads the outer, in others the inner, tine is longer. The full number of points are developed in the fourth year.

Plate 4.3 : Sambar Male, Female and Fawn

Group Size and Composition – Sambar are essentially a non-social species. In Sambar the typical group is small, numbering fewer than six individuals (Schaller 1967). The characteristic social unit is one hind and one fawn or one hind, one yearling and one fawn (Schaller 1967, Kelton 1981, Downes 1983). Family groups usually travel in a single file led by the adult female (Kelton 1981). During the rut, dominant stags are frequently seen with hinds and occasionally with other stags who may challenge the dominant stag for breeding opportunities (Lewis et al. 1990). However, the average group size of Sambar is reported to be 4 – 5 individuals (Jerdon 1874 and Prater 1971).

Habitat - No large Indian ungulate has adapted itself to a wider variety of forest types and environmental conditions than has Sambar (Schaller 1967). Sambar occurs in a wide array of habitats ranging from the thorn and arid forests, the moist and dry deciduous forests, the pine and oak forests, and the evergreen and semi-evergreen forests. However forested hill-sides, preferably near cultivation, are the favourite haunt of the Sambar. It is also seen that Sambar take to water readily and swim with the body submerged, only the face and the antlers showing before the surface. This fact has been illustrated with a photo provided in the plate.

Food preference – Sambar have been observed to feed on more than 139 species of plants (Schaller 1967, Johnsingh and Sankar 1991). The food requirements of Sambar are less specialized than those of other deer (Schaller 1967). Young green grasses are the preferred forage of Sambar but browse is often important during seasons when green grasses are scarce. Richardson (1972) reported that the diet of Sambar varied from large amount of browse in the dry season to an almost complete dependence on grass and herbaceous plants in the wet season. This flexibility of Sambar diet from graze to browse has enabled a wide distribution of the species.

Chapter-5
Materials and Methods

5.1 Field Data Collection and Measurements

During the study period, pellets of animals actually observed defecating were collected & position marked using GPS (Global Positioning System). The site of collection of pellets was decided at random wherever the species in question i.e. Chital (*Axis axis*), Sambar (*Cervus unicolor*) and Nilgai (*Boselaphus tragocamelus*) were observed. Whenever the concerned species was observed I, waited for a few hours at a safe distance so as not to cause any disturbance to them. I tried to observe what the animal was doing, determining its sex (from the presence or absence of antlers or horns) and estimating the herd size. The observation was done for a time period ranging between one to one and a half hours so that the animals could get time to graze which is essential for defecating. After the elapsing of the above mentioned time period I along with my field assistant went to the spot where the animals were observed grazing or roaming about.

Figure 5.1: Collecting Nilgai pellets from Navegaon Grassland, TATR

The areas were marked by encircling the spot with pebbles or stones or twigs and inserting a small stick adjacent to the spot. For those pellet groups which were to be kept for periodic observation after every 5 days to a period to 20 days a red ribbon was tied around the stick to avoid confusion. The latitude and longitude of the spot was ascertained using GPS. Five pellets from each marked pellet group was collected for morphometric measurements after they are completely dry. Sun drying is of paramount importance as without this if fresh pellets are collected then it will be difficult to measure them as they will get disfigured. For appropriate sun drying the fresh pellets were kept in the open for a period between 2-3 days after which they were collected for measurement. For each of the ungulate species at least 100 plus boxes of pellets were collected so as to get significant results and reduce the chances of any bias or error which might be incorporated if lesser number of pellet groups were collected. On the label of the boxes the identity of the animal, habitat, location, box number and probable age of the species was noted down by me using a marker pen to prevent confusion and chaos. We collected fecal pellets from different habitats ranging from grassland to area adjacent to water body to mixed forest as well as bamboo or teak forests to see if any difference exists with respect to pellet morphometry. Marked pellet groups in the field were visited after every five days for the next 20 days to evaluate the age of the pellets groups based on colour change, cracking, hardness, scattering and disintegration. After first visit regular visits after every 5 days were made to record data on the above mentioned indicators.

The pellets which were kept inside the sample boxes had to be checked regularly to find out whether any fungal or bacterial growth was there or not. When fungal or bacterial growth was observed in the boxes it was concluded that the pellets were not completely dry and had to be subjected to drying for a day or two. So these precautions had to be kept in mind for conducting the study. After the collection and drying of the pellets were over the pellets had to be measured using a digital Vernier Calipers (Mitutoyo) for the various parameters.

Figure 5.2: Showing a digital vernier calipers (Mitutoyo) and how measurements are recorded

Using callipers, the maximum length (maximal distance between each extremity) maximum width or diameter and depth at 90 degree rotation from W. Volume of the pellets were calculated using the product of the three measurements (L*W*D). We also recorded easily observable characteristics such as the presence and sizes of tips and indents, and the uniformity and symmetry of pellet shapes within the group. An indent is formed on one side of the pellet by the imprint of another pellet in the digestive tract. To record the sizes of tips and indents, I distinguished various classes in accordance with the species under study as described in the Figure (Fig. 6.11). The measurements of the above mentioned parameters and the various comments provided on account of the tips, indents and shapes were recorded in standard datasheets.

5.2 Data Analysis

All analyses were performed using the R statistical package in its 2.2.1 version (R Development Core Team, 2004).Significance levels for statistical tests were fixed at 5%. Linear discriminant analysis with the discrimin function of the ade4 package of R was used to identify the best morphological variables to segregate species. The analysis provided successive orthogonal axes such that the total variance carried by these axes was equal to one for each axis, and that the between species variance was maximal. We investigated whether those criteria were sufficient to reclassify all species using the lda function of the MASS package of R, which gives the same discrimant functions as discrimin.

The discriminating power of the variables was tested with a one-way ANOVA to check whether variation of each variable was well explained by the species seen as a factor, i.e. whether the inter-species variation contributed strongly towards overall variation. The variable regularity was discarded as almost all pellets in each pellet group for each species were regular in shape. The scatterplot graphs were plotted to find out which variables were co-related among each other and thus would be crucial for discriminating the pellets. Discriminant Function Analysis (DFA) was used to investigate the pellet discrimination among the 3 sympatric species. Press's Q statistic (Press's Q statistic = $[N-(Nk)]^2/N(K-1)$, where N is the total sample size, n is the number of observations correctly classified and K is the number of groups/species in this case) was used as a classificatory power of the discriminant function when compared to the results expected from a chance model.

Chapter-6
Results and Discussion

6.1 General Characteristics of Pellet Groups:

From the pellets which were collected in Tadoba Andhari Tiger Reserve (TATR) during the study period 510 were Chital pellets (*Axis axis*), 510 were Sambar (Cervus unicolor) and 515 were that of Nilgai (*Boselaphus tragocamelus*). The pellets so collected were of different age classes and they were measured to find out the parameters of Length, Width, Depth and Volume. The table below shows the Mean and Standard Deviation (S.D.) of the pellets of the three sympatric ungulates so collected.

Table 6.1: Mean and Standard Deviation of Length, Width, Depth and Volume of Pellets of the three sympatric ungulates in TATR

Species/Statistic		**Length(cm)**	**Width(cm)**	**Depth(cm)**	**Volume(cm^3)**
Chital	Mean	1.32	0.88	0.82	1.01
	S.D.	0.23	0.15	0.15	0.41
Sambar	Mean	1.81	1.24	1.19	2.66
	S.D.	0.22	0.08	0.08	0.56
Nilgai	Mean	1.74	1.36	1.23	2.95
	S.D.	0.31	0.22	0.19	1.02

As is evident from the table (Table 6.1) provided above the mean length of all the Chital pellets collected was 1.32cm, that of Sambar was 1.81 cm and that of Nilgai was 1.74cm. So one can conclude that the pellets of Sambar and Nilgai are comparatively longer than that of Chital. Likewise when one tends to focus on the width aspect it is seen that the decreasing order of pellet width arrangement is: Nilgai(1.35cm) > Sambar(1.23cm) > Chital(.88cm) So when we shift our attention to the depth parameter the decreasing order pellet width arrangement is: Nilgai(1.23cm) > Sambar(1.19cm) > Chital(.82cm). The volume parameter also varies in the same way as the width and depth parameter across the 3 sympatric species.

6.1.1 Measurement of Chital Pellets:

The box plot (Fig. 6.1) of chital depicts the sample distribution over 4 different morphometric parameters the data of which was collected in TATR. It is observed that in case of length the data is distributed mainly within the range of .75cm (Lower inner fence) to 1.95 (Upper inner fence). The median is 1.3cm (50th percentile). The 25th percentile is from .75cm to 1.2cm and the 75th percentile is from 1.5cm to 1.95cm. A large portion of data lies in 25th percentile and in 75th percentile. Some outliers are present at the bottom and one is present at the top which show that a few data points are present which remains outside the range of the box plots and can be counted as exceptions. In case of width and depth parameter the box plots are quite similar to each other. The median in case of width and depth is .9cm to .85cm respectively. In case of width and depth outliers are present at the bottom of the box plots. The extremes of the box plot for width parameter ranges from .6cm to 1.2cm and 0.55cm to 1.15cm for width and depth respectively. As in the case of length majority of the sampled data lies between 25th and 75th percentile for both width and depth parameters. The range for the volume parameter is quite extensive with the extremes ranging from .4cm to 2.0cm respectively. This has happened because the volume parameter takes into account all the other 3 parameters.

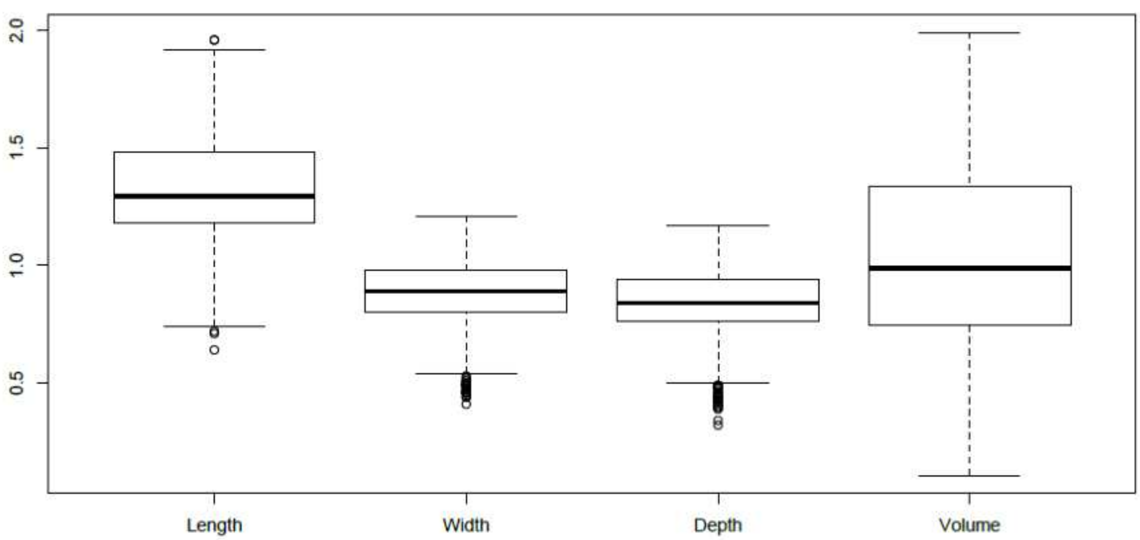

Figure 6.1: Box plot of Chital measurements

The mean of the volume parameter is 1.05cm and and the 25th percentile is .73cm and the 75th percentile is 1.4cm.

6.1.2 Measurement of Sambar Pellets:

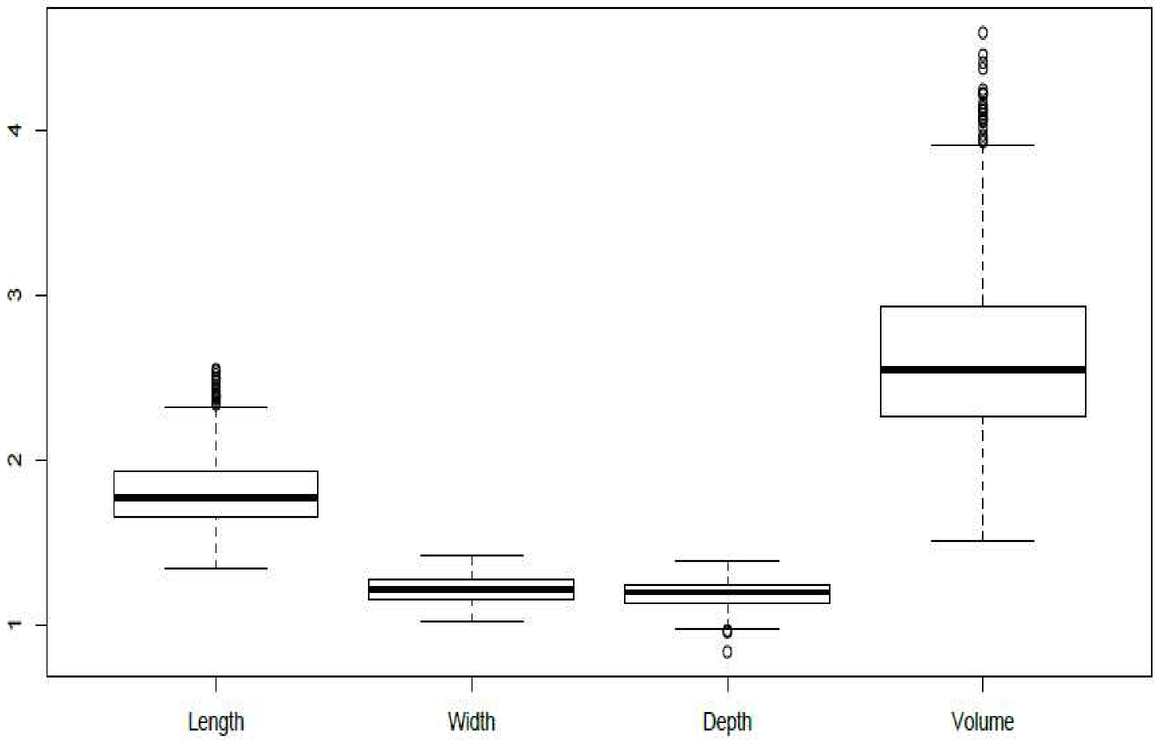

Figure 6.2: Box plot of Sambar measurements

The box plot (Fig. 6.2) of Sambar depicts the sample distribution over 4 different morphometric parameters the data of which was collected in TATR. In case of length parameter of Sambar it can be said that the range of the lower inner fence to the upper inner fence is from 1.35-2.3cm. The median of the data set is 1.75cm (50th percentile). The 25th percentile ranges from 1.35cm to 1.65cm. 1.9cm to 2.3cm range is for the 75th percentile. Some outliers are present above the 2.3cm range which signifies that they are outside the specified range and that they are exceptions.

In case of width and depth parameter the box plots are quite similar to each other. The median of the width and the depth parameter is 1.2cm and 1.15cm respectively. The extremes of the box plot for width parameter ranges from 1.0cm to 1.45cm and that of depth parameter is .95cm to 1.40cm. As in the case of length majority of the sampled data lies between 25th and 75th percentile for both width and depth parameters. Presence of a few outliers can be observed in case of depth parameter.

As in the case of volume parameter the median of the data set is 2.6cm. The extent of the data set is from 1.65cm to 4.0cm with the presence of a few outliers.

6.1.3 Measurement of Nilgai Pellets:

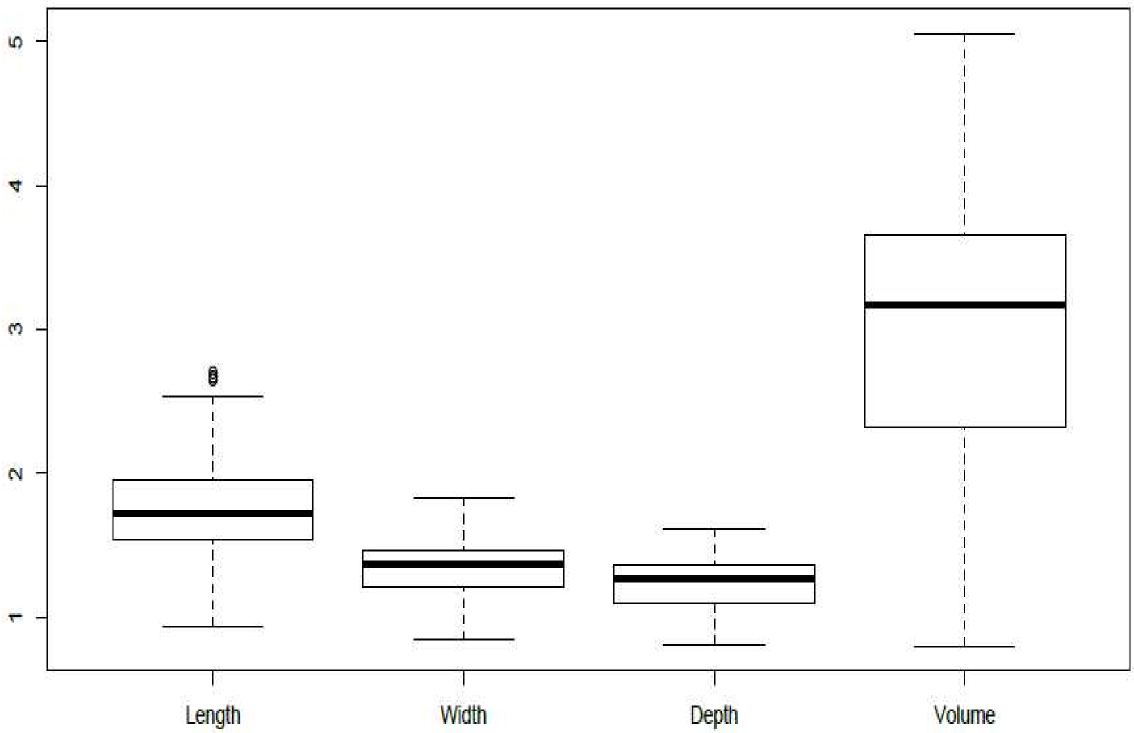

Figure 6.3: Box plot of Nilgai measurements

The box plot (Fig. 6.3) shown above depicts 4 morphometric measurements of Nilgai. In case of length parameter of Nilgai it can be said that the range of the lower inner fence to the upper inner fence is from .8-2.6cm. The median of the data set is 1.7cm (50th percentile). The 25th percentile ranges from 1.35cm to 1.5cm. 1.95cm to 2.6cm range is for the 75th percentile. Some outliers are present above the 2.6cm range which signifies that they are outside the specified range and that they are exceptions.

In case of width and depth parameter the box plots are quite similar to each other. The median of the width and the depth parameter is 1.35cm and 1.3cm respectively. The extremes of the box plot for width parameter ranges from .8cm to 1.9cm and that of depth parameter is .75cm to 1.7cm. As in the case of length majority of the sampled data lies between 25th and 75th percentile for both width and depth parameters.

As in the case of volume parameter the median of the data set is 3.2cm. The extent of the data set is from .75cm to 5.1cm with the presence of a few outliers.

6.1.4 Variation of Depth across species

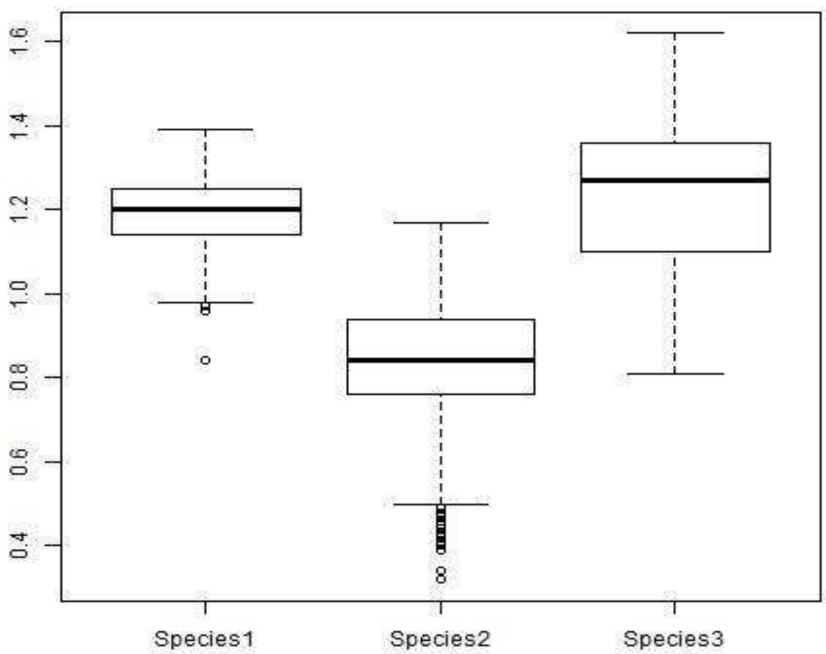

Figure 6.4: Variation of Depth across species. (Species 1 – Sambar, Species 2 – Chital and Species 3 – Nilgai)

As is evident from the from the box plot (Fig. 6.4) the depth parameter when used to differentiate between 3 sympatric species does a decent job in discriminating between the pellets. The median value for depth of species 1 i.e. Sambar is 1.2cm whereas for species 2 i.e. Chital is 0.85cm and for species 3 i.e. Nilgai is 1.28cm. Also as observed from the box plot the range of extremes of values for Nilgai is 0.8cm to 1.65cm and that for Sambar is comparatively less i.e. .96 to 1.38cm. This aspect can be used to separate the pellets. Presence of outliers are seen in case of Chital and Sambar species which may be termed as exceptions.

6.1.5 Variation of Length across species

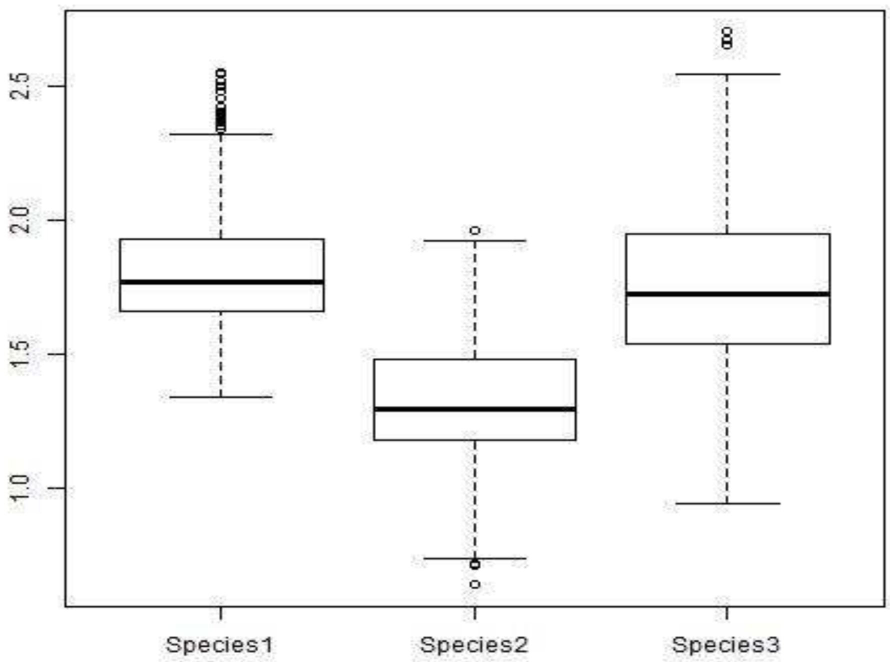

Figure 6.5: Variation of Length across species.

As is evident from the from the box plot (Fig. 6.5) the length parameter when used to differentiate between 3 sympatric species does not accurately discriminate between the pellets. The median value for depth of species 1 i.e. Sambar is 1.77cm whereas for species 2 i.e. Chital is 1.3cm and for species 3 i.e. Nilgai is 1.75cm. Also as observed from the box plot the range of extremes of values for Nilgai is 0.96cm to 2.54cm and that for Sambar is comparatively less i.e. 1.35cm to 2.35cm. However length very accurately can be used to differentiate between the pellets of Chital and Nilgai and between Chital and Sambar species. This aspect of can be used to separate the pellets. Presence of outliers are seen in case of Chital and Nilgai species which may be termed as exceptions.

6.1.6 Variation of Volume across species

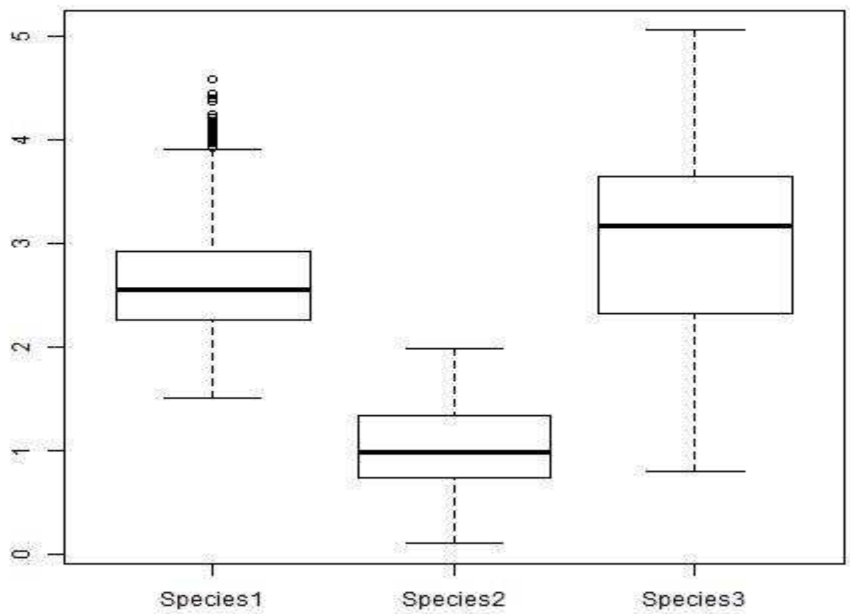

Figure 6.6: Variation of Volume across species. (Species 1 – Sambar, Species 2 – Chital, Species 3 – Sambar)

From the box plot (Fig. 6.6) involving variation of volume parameter when used to differentiate between 3 sympatric species does accurately discriminate between the pellets. The median value for depth of species 1 is 2.55cm whereas for species 2 is 1.05cm and for species 3 is 3.1cm. Also as observed from the box plot the range of extremes of values for Nilgai is 0.76cm to 5.1cm and that for Sambar is comparatively less i.e. 1.6cm to 3.95cm. So volume can be used to differentiate very accurately between the pellets of Chital and Nilgai, between Chital and Sambar species and also between Nilgai and Sambar. The range of volume of Sambar pellets is comparatively lesser than that of Nilgai which can be exploited to find out the differences and to discriminate between the pellets.

6.1.7 Variation of Width across species

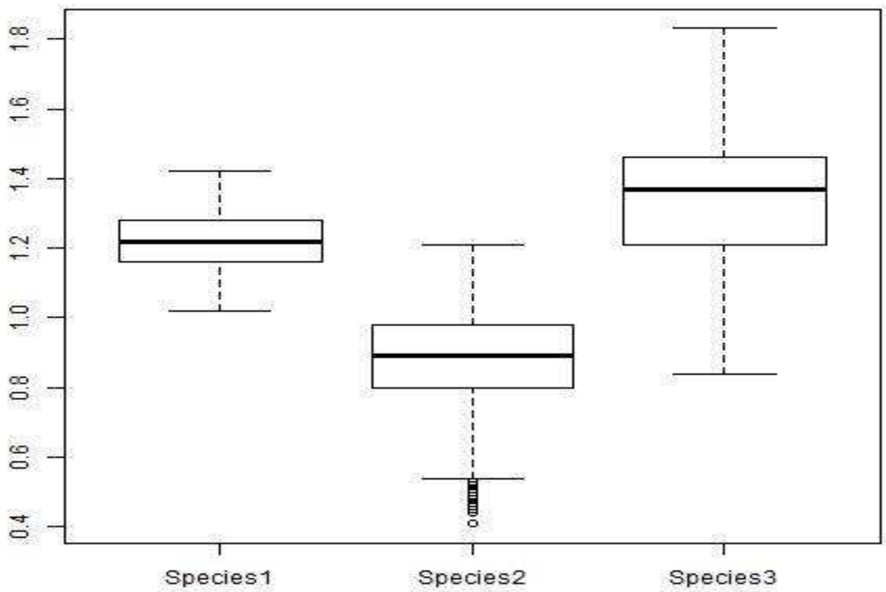

Figure 6.7: Variation of Width across species. (Species 1 – Sambar, Species 2 – Chital, Species 3 – Sambar)

As is evident from the from the box plot (Fig. 6.7) the width parameter when used to differentiate between 3 sympatric species does a decent job in discriminating between the pellets. The median value for depth of species 1 is 1.22cm whereas for species 2 is 0.87cm and for species 3 is 1.37cm. Also as observed from the box plot the range of extremes of values for Nilgai is 0.82cm to 1.82cm and that for Sambar is comparatively less i.e. 1cm to 1.45cm. This aspect can be used to separate the pellets of Sambar and Nilgai. Chital pellets can be easily differentiated from Nilgai and Sambar by using this width parameter. Presence of outliers are seen in case of Chital species which may be termed as exceptions

6.1.8 Scatterplot

The scatter diagram graphs pairs of numerical data, with one variable on each axis, to look for a relationship between them. If the variables are correlated, the points will fall along a line or curve. The better the correlation, the tighter the points will hug the line.

Table 6.2: Showing Correlation Matrix

Parameter	Length	Width	Depth	Volume
Length	1.000	.395	.373	.734
Width	.395	1.000	.893	.821
Depth	.373	.893	1.000	.809
Volume	.734	.821	.809	1.000

The scatterplot graph of Chital, Nilgai and Sambar helps us to find out what kind of relationship exists between the variables length, width, depth and volume and how are they correlated. As seen in the case of all 3 species the length v/s width is not at all co-related and the plotted points do not stick or fall along the line which would have strengthened its case but on the contrary it is distributed in a haphazard manner in the graph and is skewed. The correlation value of length v/s width graph also bears testimony to this being at low of 0.395 (Table 6.2). So we can infer that the length and width are the 2 parameters which can be correlated.

Likewise, between length v/s depth the plotted points are distributed throughout the graph which is pointed out by the very low correlation value 0.373. Thus these 2 parameters are not correlated and should not be used for differentiating the pellets which might lead to unnecessary error or bias. However, length v/s volume is a lot better as in comparison to length v/s width and length v/s depth graph as the points are more properly distributed along the line even though it is skewed to some extent. The correlation value of 0.734 is a proof of this fact.

Now when I look at the width v/s depth graph it is found that it is generally the same for all the 3 study species, as the plotted points adhere to the line closely. So we can infer that the variables of width and depth are positively correlated which is even justified by the highest value of correlation observed that is 0.893.

In case of Nilgai the plotted points are a bit waywardly distributed as in comparison to Chital and Sambar. The only visible flaw in the graph is its skewness is not totally removed and it continues to persist. As we focus our attention on the width v/s volume graph it is observed that the plotted points lie closely to the line and they are positively correlated which is proved by a high correlation value of 0.821 though this value is slightly lower than the width v/s depth graph. When we focus our attention on the last remaining graph i.e. depth v/s volume graph we find that it is also positively correlated but with a slightly lesser value i.e. 0.809, although there is a higher degree of skewness when compared to width v/s depth and width v/s depth graph.

The scatterplot graph of various morphometric measurements for Chital, Sambar and Nilgai is shown in the figures 6.8, 6.9, & 6.10.

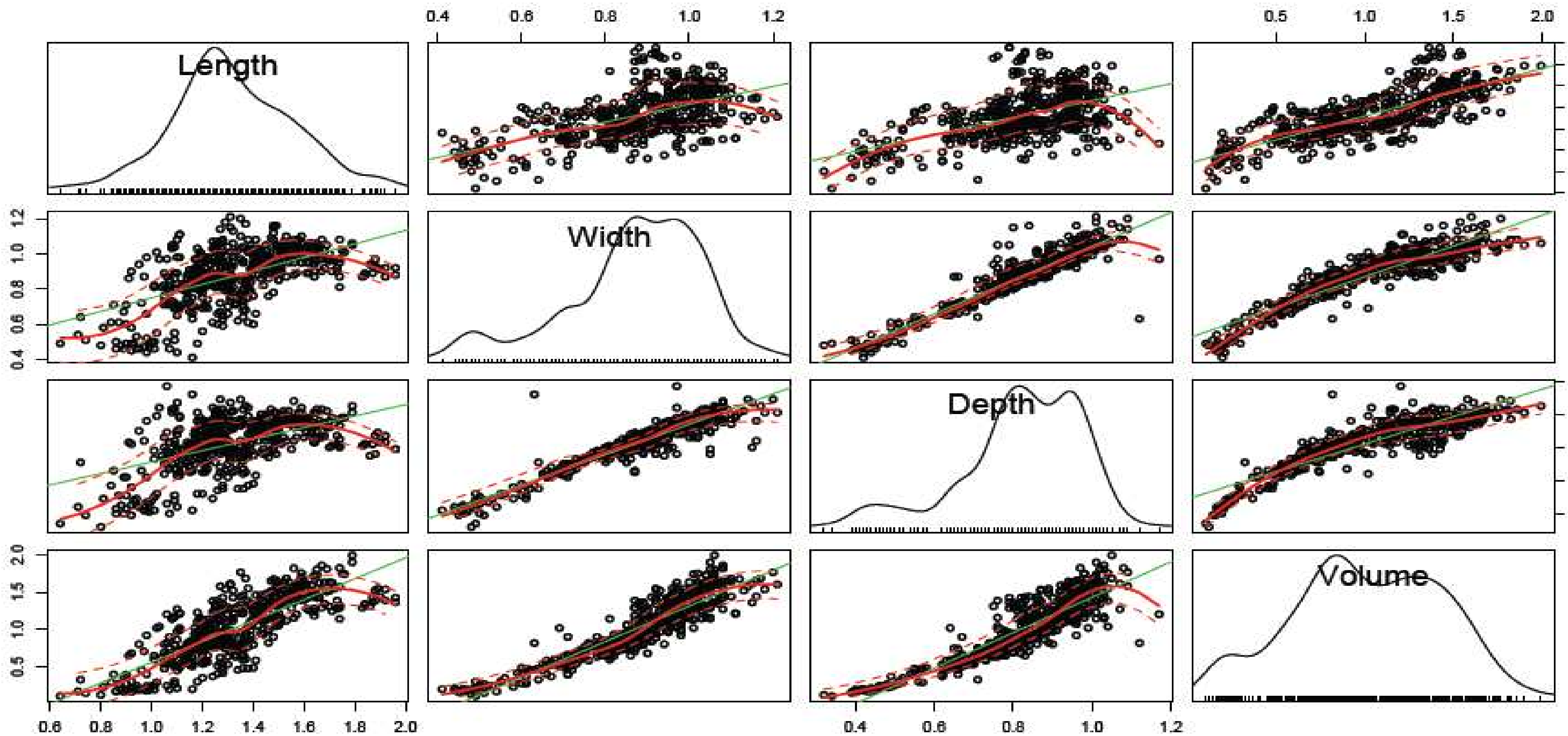

Figure 6.8: Scatter plot of Chital showing Correlation of various morphometric measurements

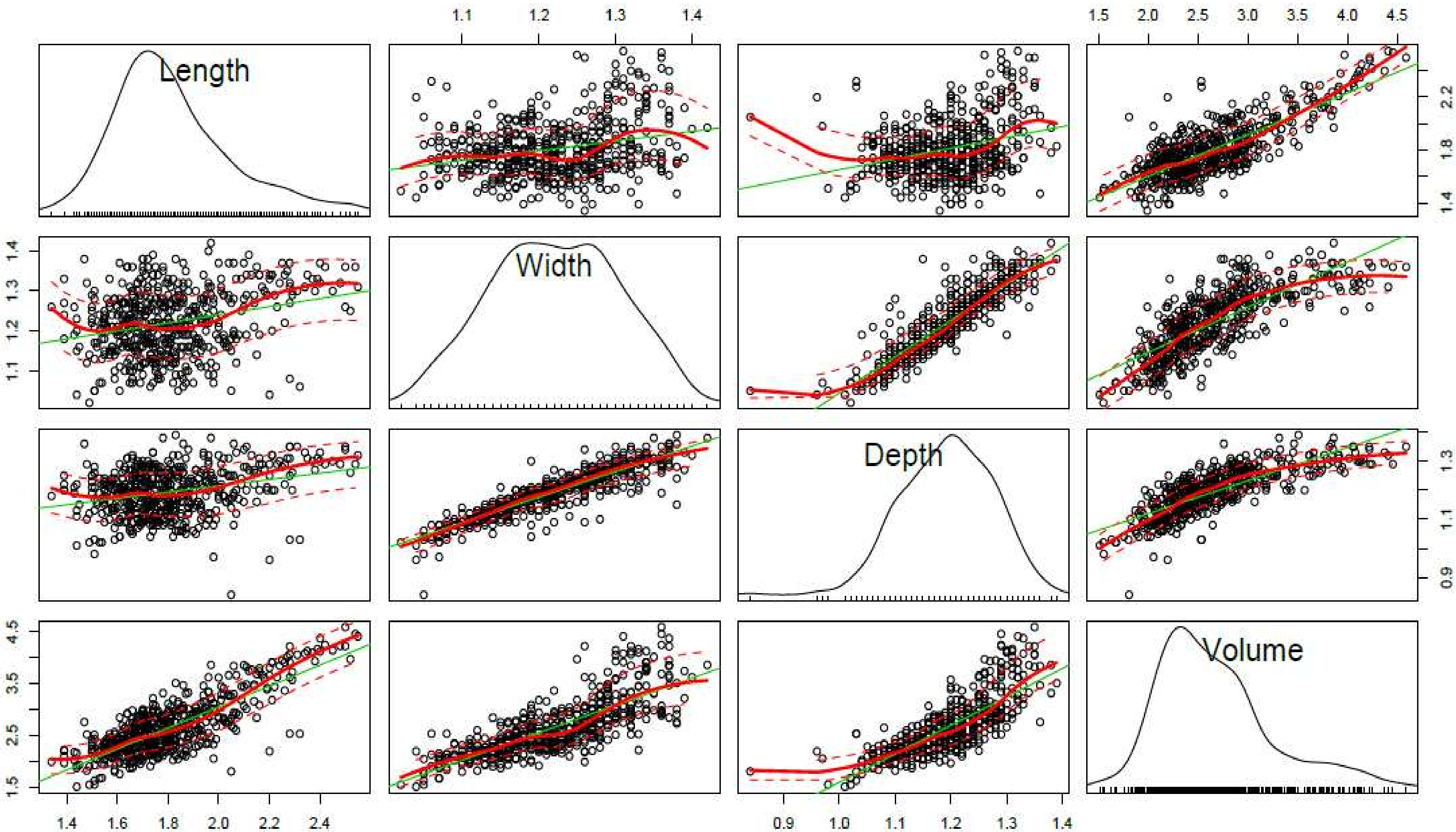

Figure 6.9 : Scatter plot of Sambar showing Correlation of various morphometric measurements

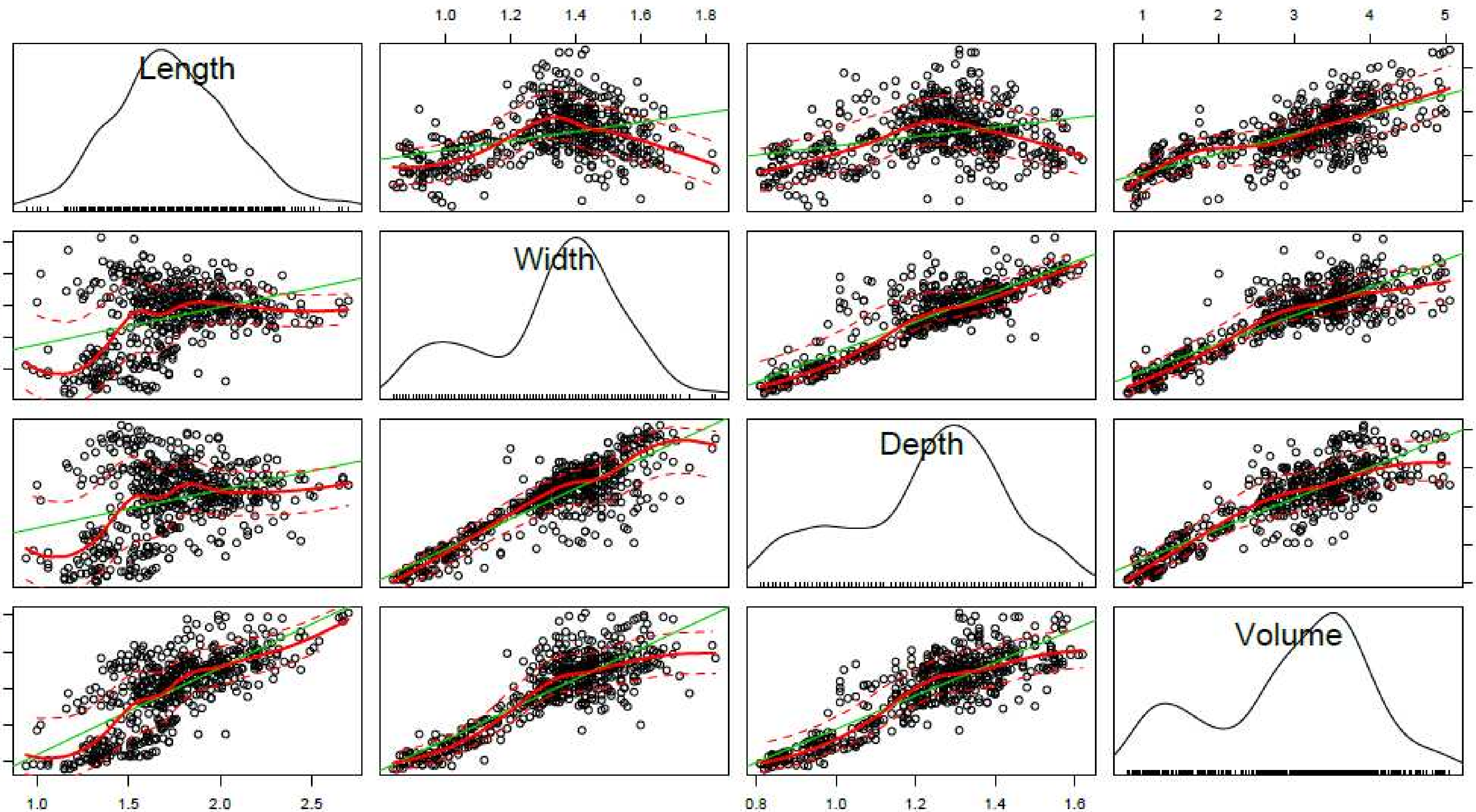

Figure 6.10: Scatter plot of Nilgai showing Correlation of various morphometric measurements.

6.1.9 Indents and Tips

Indents and tips are an intrinsic part of the pellets of the ungulate species inhabiting our country. A tip is nothing but a pointed portion found in the anterior portion of the pellet whereas an indent is basically a depression found on the posterior end formed by the imprint of another pellet in the digestive tract.

Table 6.3 : Frequency and Percentage of Different Types of Tips and Indents in three Sympatric Ungulate Species

Species	Tip/Indent Type		Frequency	%
Sambar	Indent	Very Small	20	19.6
		Small	65	63.72
		Medium	10	9.80
		Long	0	0
		No Indent	7	6.86
	Tip	Very Small	0	0
		Small	61	59.80
		Medium	29	28.43
		Long	0	0
		No Tip	12	11.76
Chital	Indent	Very Small	13	12.74
		Small	78	78.47
		Medium	2	1.96
		Long	0	0
		No Indent	9	8.82
	Tip	Very Small	0	0
		Small	15	14.70
		Medium	85	83.33
		Long	0	0
		No Tip	2	1.96
Nilgai	Indent	Very Small	71	68.93
		Small	14	13.59
		Medium	3	2.91
		Long	2	1.92
		No Indent	13	12.62
	Tip	Very Small	1	0.91
		Small	23	22.33
		Medium	60	58.25
		Long	3	2.91
		No Tip	16	15.53

Generally it is observed that the characteristics of indents and tips of the pellets is different for different species. So certain benchmark or basis needs to be provided with to simplify the differentiation process and make it easier to the layman to identify pellets on the basis of tips and indents.

It is seen that the tip “small” is a characteristic of Sambar species as is evident with it having a higher percentage i.e. 59.8% of pellets belonging to that characteristic. Similarly the “small” indent is a characteristic of Sambar species as it has it has a higher frequency of occurrence i.e. 63.72%. Likewise the characteristic indent and tip remark for Chital species is “small” and “medium” respectively with frequency of occurrence being 78.47% and 83.33%. For Nilgai pellets the characteristic comment for indent and tip is “very small” and “medium” respectively. The frequency of occurrence of “very small” indent is 68.93% and that of “medium” tip is 58.25%. So based on the data from the table (Table 6.3) we can differentiate between the pellets based on tips and indents.

6.1.10 Shape

We have found that the shape criteria is a very vital parameter to differentiate and segregate the pellets. It has been observed that Nilgai pellets are of diverse shapes i.e. 7 different ones (Table 6.5) whereas the Chital (Table 6.4) and Sambar (Table 6.6) pellets are of 3 distinct shapes. Because of the presence of 7 different types of shapes it can be rightly said that identifying Nilgai pellets is comparatively more difficult than Chital and Sambar. The difficulty of correctly identifying Nilgai has been emphasized by its comparatively lower original and cross validated classification results.

Table 6.4: Different shapes of Chital pellets

Shape	Frequency	%
1	384	75.29
2	89	17.45
3	37	7.25
Total number of pellets	510	100%

Table 6.5: Different shapes of Nilgai pellets

Shape	Frequency	%
Shape 1	39	7.57
Shape 2	41	7.96
Shape 3	98	19.02
Shape 4	166	32.23
Shape 5	126	24.46
Shape 6	28	5.43
Shape 7	17	3.30
Total	515	100%

Table 6.6 : Different shapes of Sambar pellets

Shape	Frequency	%
1	156	30.58
2	297	58.235
3	57	11.17
Total	510	100%

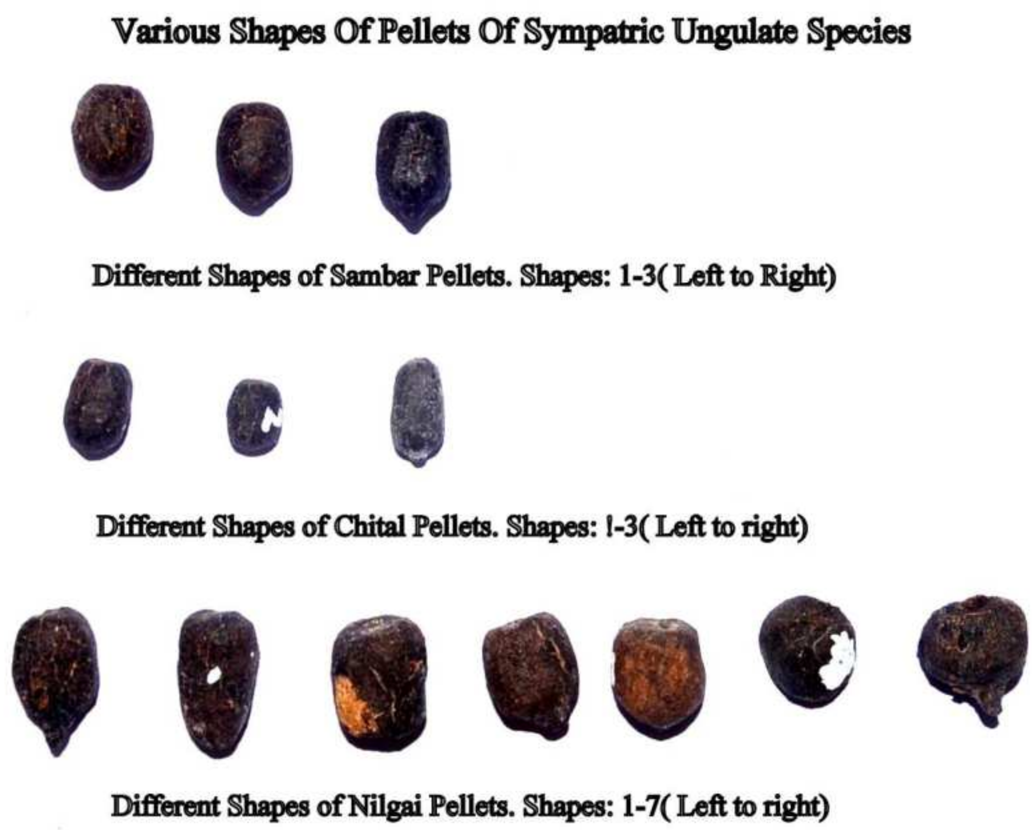

Figure 6.11; Various shapes of pellets of Sambar, Chital and Nilgai

6.2 Discriminant Function Analysis (DFA)

Discriminant function analysis is used to determine which continuous variables discriminate between two or more naturally occurring groups. Discriminant function analysis is (MANOVA) multivariate analysis of variance reversed. In MANOVA, the independent variables are the groups and the dependent variables are the predictors. In DA, the independent variables are the predictors and the dependent variables are the groups.

Table 6.7: Showing DFA 1 and DFA 2 values for length, width, depth, volume,Wilk's Lambda, Chi-square test, significance, eigen value and canonical correlation.

	DFA 1	**DFA 2**
1) Length	**1.247**	**5.028**
2) Width	**1.931**	**-7.340**
3) Depth	**4.063**	**12.575**
4) Volume	**-0.083**	**-2.307**
5) Wilk's Lambda	**0.286**	**0.777**
6) Chi-square Test	**1917.703**	**386.295**
7) Significance	**0.000**	**0.000**
8) Eigen value	**1.720[a]**	**0.287[a]**
9) Canonical correlation	**0.795**	**0.472**

[a] First 2 canonical discriminant functions were used in the analysis.

Discriminant Function Analysis (DFA) was used to investigate the difference between pellets of Sambar, Chital and Nilgai. The relative location of the case variables was plotted against the case variables i.e. length, width, depth and volume to conclude for pellet identification and differentiation.

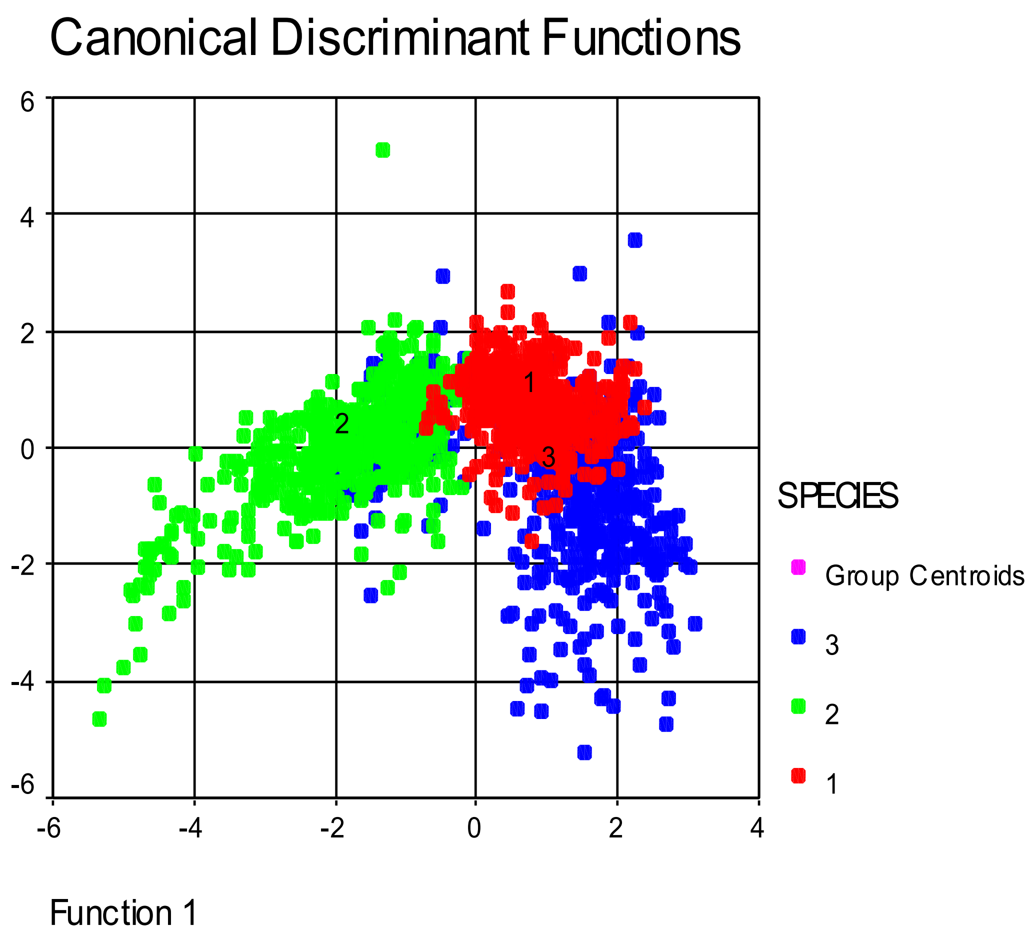

Figure 6.12 : Graph showing Canonical Discriminant Functions of 3 sympatric ungulate species when plotted against Function 1 and Function 2.

Group 3 – Sambar, Group 2 – Chital, Group 1 – Nilgai.

All the variables were taken into consideration to extract differentiation between between the response of DFA to the various measured variables. Press's Q statistic

(Press's Q statistic = $[N-(Nk)]^2/N(K-1)$, where N is the total sample size, n is the number of observations correctly classified and K is the number of groups/species in this case) was used as a classificatory power of the discriminant function when compared to the results expected from a chance model. The Press's Q obtained in my case was 277.50 which is a significant result(N = 1535, n = 1229, K = 3) . All the analysis were performed using R statistical package in its 2.2.1 version. (R Development Core Team 2004) following Zar (1999).

Table 6.8; Classification Results[b,c]

		Species	Predicted Group Membership			Total
			1.00	2.00	3.00	
Original	Count	1.00	446	2	62	510
		2.00	32	472	6	510
		3.00	122	82	311	515
	%	1.00	87.5	.4	12.2	100
		2.00	6.3	92.5	1.2	100
		3.00	23.7	15.9	60.4	100
Cross-validated[a]	Count	1.00	445	3	62	510
		2.00	32	472	6	510
		3.00	122	82	311	515
	%	1.00	87.3	.6	12.2	100
		2.00	6.3	92.5	1.2	100
		3.00	23.7	15.9	60.4	100

[a.] Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

[b.] 80.1% of original grouped cases correctly classified.

[c.] 80% of cross-validated grouped cases correctly measured.

6.3 Linear Discriminant Function

Linear discriminant function 1 (Fig. 6.13) separates Sambar (Group 1) whose minimum and maximum values range from -1 to +2 and Chital (Group 2) whose minimum and maximum values are -5 to 0 respectively but there is overlap between group 1 and group 2. The maximum and minimum values of Nilgai ranges from -2 to + 2. But as is evident from the graph there is a high degree of overlap between Sambar (Group 1) and Nilgai (Group 3), so the degree of differentiation is considerably less. Still I believe that Groups 1 and Group 3 can be differentiated on account of their minimum and maximum values and the height of their respective histograms/peaks are different across different regions. However even though there exists a certain degree of overlap between Chital (Group 2) and Nilgai (Group 3) the LDA 1 values can be used to differentiate between with a reasonable degree of precision.

But contrary to LDA 1, LDA 2 (Fig. 6.14) when applied to the 3 sympatric species it is found that it is unable to differentiate between them clearly. Some subtle differences can still be observed between Sambar (Group 1) and Nilgai (Group 3). When one looks closely at the values of Sambar especially around the range -1 to 0 it is seen that that -1 region has a value of 0.6 but in case of Nilgai the value around that range is is practically half than that of Sambar.

When we compare the two functions i.e. LDA1 and LDA2 we can say that LDA1 is better placed than LDA2 to differentiate between the 3 Groups under study.

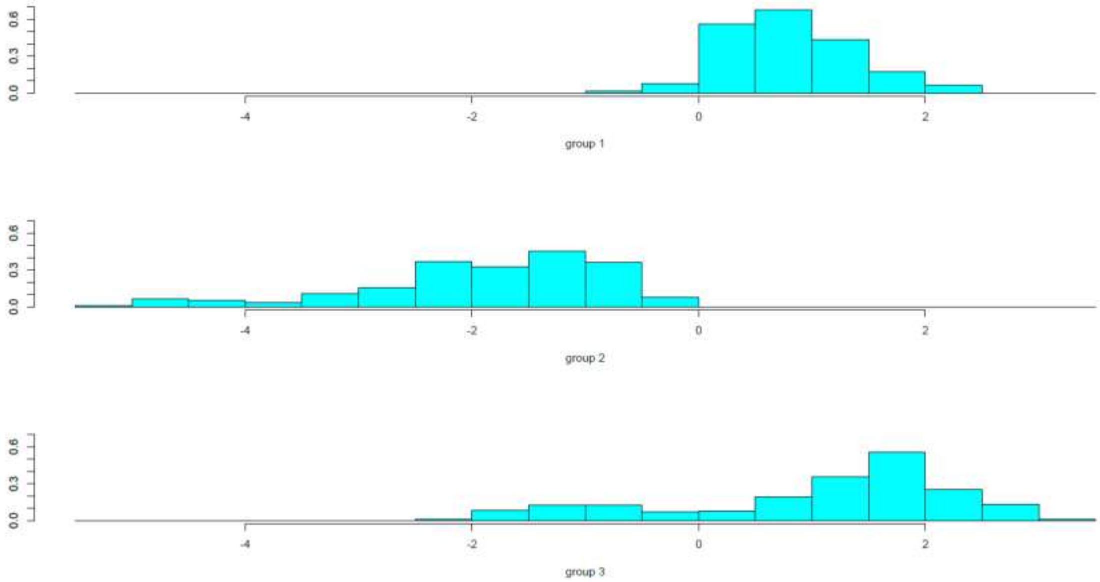

Figure 6.13: Histogram showing LDA 1

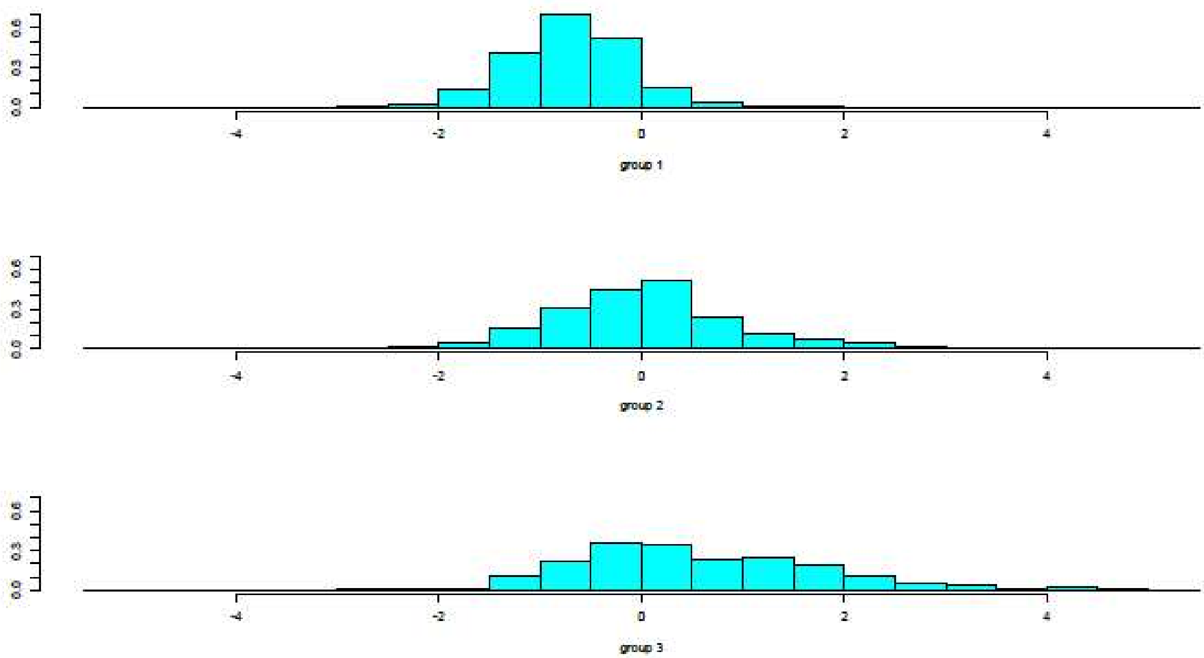

Figure 6.14: Histogram showing LDA 2

6.4 Change of physical characters of pellets

In semi-arid areas, ambient conditions conserve the pellets during the dry season. Thus, dating of accumulated pellet groups is helpful in approximating the numbers of ungulates present during any chosen part of the dry season. So in the study conducted by me in TATR, I tried to find out what changes were brought about in the pellets on account of exposure to sun, moisture and other physical factors by monitoring the pellets in the field after a regular time interval of every 5 days. Generally when fresh pellets are observed in the field it is seen that their color shade is dark and wet, with a glossy patina. (Fig. 6.15) They have a smooth surface (cracking of pellets) and are very soft (hardness) and are generally not scattered. Moreover they do not show any chances of insect attack. On the fifth day it was observed that the glossy exterior of the pellets were lost and that it had a dried surface. Thin hairline cracks had started appearing on the pellets and that they were harder than the 1st day observation. When observed on the 10th day it was found that the pellets showed a light brown colour and wider cracks were observed in them. The pellets had become really hard. On the 15th day (Fig. 6.16) it was found that the pellets were getting a darker shade of brown and prominent cracks were observed in them. However from the point of view of disintegration or infestation on account of insect zero to least cases were observed. This was also emphasized by the fact that it was summer.

Figure 6.15: Fresh Nilgai pellets obtained from Navegaon Grassland. Day 1 observation.

Figure 6.16: Nilgai Pellets when observed after every 5 day interval in Navegaon Grassland.

Chapter – 7
Conclusion

The pellet morphometric study conducted by me in Tadoba Andhari Tiger Reserve, Maharashtra was a significant one from the research point of view because it made me throw light on areas previously not explored with respect to the Indian subcontinent. The study involved devising simple field criteria so as to differentiate between the three sympatric species with reference to external characteristics of pellets.

When I focus my attention on the aspect of tips and indents I have observed that in case of indents the comment type "very small" is found to a greater extent in case of Nilgai (68.93%) and followed closely by sambar (19.60%) and chital (12.74%). In case of comment "medium" tip is found in the decreasing order in the following manner: Chital(83.33%)>Nilgai(58.23%)>Sambar(28.43%) (Table 6.3). After analising the shape criteria it was found that it could play a vital role in the identification of pellets. It was observed that Nilgai pellets were of diverse shapes i.e. of 7 different types whereas chital and sambar pellets were of 3 different shapes only (Fig. 6.11). So the effiency of correctly identifying Nilgai pellets was comparatively lower as in comparison to chital and sambar.

During the analysis of pellets when the respective scatterplot graphs were plotted it was noticed that of all the 4 morphometric parameters under study only 3 i.e. width,depth and volume could be correlated with a reasonably higher degree of correlation as is evident from the correlation table. Canonical Discriminant Function also plays a crucial role in identifying and segregating the pellets (Fig. 6.12). The discriminant dunction exceeded the classification accuracy at a significant level of 0.01 (Press's Q = 277.50 > 6.63). It was observed that with canonical correlation O.795 (DFA 1) and 0.472 (DFA 2) the percentage of correct classification was 80%. The DFA 1 was statistically significant at a level of $p<0.001$ and DFA 2 was not signifant.

When linear discriminant analysis was performed and the histograms were obtained it could differentiate between Sambar (Group 1), Chital (Group 2) and Nilgai (Group 3) for DFA 1 but the same was not possible for DFA 2 (Fig 6.14 & 6.15).

The accauracy of classifying the pellects od three sympatric ungulates species correctly was aroung 80% (Table 6.8). Therefore it can be concluded the study provides original criteria that compliment the knowldege for the identification of ubgulates faecal pellets durug dry season. This study need to be extended to include other species in India to develop morphometric crteria for idetification of ungulates species. If pellets are identified correctly used the morphometric criteria's, the feasibility of using pellet groups as indices for monitoring the abunadnce of ungulate populations in various habitats acros India will become more conclusive. The study needs to be extended further to develop criteria for all ungulates species in India.

Chapter -8
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