Habitat Occupancy by Tiger Prey Species Across Anthropogenic Disturbance Regimes in Panna National Park, Madhya Pradesh, India

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By

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CERTIFICATE

This is to certify that this dissertation entitled *"Habitat Occupancy by Tiger Prey Species Across Anthropogenic Disturbance Regimes in Panna National Park, Madhya Pradesh, India"* embodies a piece of original research work carried out by Mr. Manu Verghese Mathai for the partial fulfilment of **Master of Science** degree in **Wildlife Science** of Saurashtra University, Rajkot. The research work was carried out under our supervision at the Wildlife Institute of India between November 1998 and June 1999. We also certify that this work has not been submitted for any other degree of any other university.

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ABSTRACT

Effect of anthropogenic disturbance on habitat occupancy by tiger prey species was studied in Panna National Park (PNP), Madhya Pradesh. The study was conducted between November 1998 and April 1999. Line-transect method and pellet-count technique were used to estimate prey species abundance. Abundance estimates were used as a measure for intensity of habitat use by the species.

The density estimates from line transects are associated with high coefficient of variation, which is largely a function of the small sample size resulting form extremely low densities in much of the study area. Ordination of habitat parameters grouped transects based on habitat quality, structure, anthropogenic disturbance and topography. Anthropogenic disturbance was found to be an important factor influencing habitat quality and differential use of habitats by animals.

Sambar (*Cervus unicolor*) associated strongly with low disturbance hill habitats and poorly with relocated village sites and disturbed plateau transects. Results from line transect and pellet count method concurs in the case of Sambar. Chital (*Cervus axis*) were very localised in their distribution being strongly restricted to secondary successional stages and ecotones between relocated village sites and woodland. Nilgai (*Boselaphus tragocamelus*) was a generalist in terms of habitat occupancy. In case of Nilgai the two methods complement each other with the information they provide. The information from pellet–group counts was found to reflect patterns not detected by direct sampling methods like line transects.

Chinkara (*Gazella gazella benneti*) was strongly associated with the disturbed areas, largely because of the openness, but was also found in the undisturbed areas. Wild pig (*Sus scrofa*), like Nilgai, was a generalist, but showed preference for fringe areas of forest adjoining

agricultural fields. Langur (*Presbytis entellus*) showed a marked preference for hill habitats and did not differentiate between disturbed and undisturbed hill habitats. Langur also showed the strongest association with water.

The distribution of preferred tiger prey, Sambar and Chital is localised. Nilgai, which is distributed throughout the study area, is found in habitats not favourable for tigers. Such a distribution pattern is likely to only support dispersing and transient animals. Therefore habitat management should be aimed at maintaining and expanding habitats suitable for the cervids.
Disturbance in the form of livestock grazing and woodcutting are largely responsible for the poor habitat quality. Such habitat disturbance is intimately connected with the socio–economic and cultural circumstances of the people, both near and far, and therefore efforts to conserve the tiger have to turn to these aspects rather than being limited to the biological aspects of the animal.

1. INTRODUCTION

"India is remarkable for the variety of its large mammals, a richness in species exceeded by few countries in the world" George Schaller (1967). Schaller goes on to conclude in the introduction to his landmark work *The Deer and the Tiger,* "In India perhaps more than in most countries, the basic problem of animal and human ecology are intimately related, and a solid body of facts is desperately needed if conservation and management practices satisfactory to man, his livestock, and the wildlife are to be initiated in time to save the last from complete extermination..."

India today, thirty two years after Schaller (1967) wrote his introduction still faces the same dilemma, the lives of millions of people on one hand and our biological heritage on the other, which, to say the least is a precarious situation. These conflicts of interest are most visible in and around our Protected Areas (PAs) which, being perhaps the last repositories of our biological diversity are of great conservation importance. And being an important source of biomass resources for the sea of humanity that surrounds them, they are subject to intense human pressures. A crisis compounded by the fact that PAs occupy as little as 6.75% of the country's land area (State of the Forest Report, 1997) and the alarming rate at which the human population continues to grow.

Caughley (1994) formalised two important aspects of conservation biology, namely, the "small population paradigm" and the "declining population paradigm". The small population paradigm deals with the effect of small size of populations e.g. inbreeding depression and minimum viable population. This is a symptomatic approach to the problem, and hence by itself long-term permanent solutions will continue to evade us. On the other hand the declining population paradigm deals with the factors causing the decline of populations and its cure. This approach largely evades our attempts to generalise, because of the wide variety of processes and situations that contribute to it and the situations being very site specific. But it is this approach that needs more rigorous investigation to elevate the causes from mere conjectures to certainties.

Causes for decline and decimation of tiger and its prey populations are numerous. Schaller (1967) described two factors that have brought the large mammalian fauna to its present predicament, a predicament hauntingly reflected in the current state of our tiger population. Our despicable history of hunting for recreation and the indirect and less avoidable course of "habitat destruction", both of which are key elements in the declining population paradigm. Trophy hunting of large animals like in the old days has been brought under check following a series of wildlife protection laws. Nevertheless, poaching of both prey and predator continues, be it for food, oriental medicines or other illegal trade in wildlife parts (Siedensticker, 1997). Habitat degradation, on the other hand, which is largely a function of human influence, continues to work at its own steady pace affecting both the predator and the prey. Poaching combined with degradation and fragmentation of habitats of already depressed populations is likely to have disastrous effects on their viability and future survival (Seidensitcker *et al*. 1999)

Though tigers have been known to feed on a wide variety of animals (Schaller 1976) a marked preference for medium (31-175 Kg) to large (>176 Kg) sized ungulates has been documented by studies in different habitats. Schaller (1967), Johnsingh (1983) and Karanth & Sunquist (1995) have all found that medium to large sized ungulates comprise the bulk of the tiger's diet, of which Chital and Sambar between them constitute approximately 55% – 65%.

Therefore a viable and abundant prey population is a prerequisite for any viable population of tigers.

The tiger is the largest obligate terrestrial carnivore in any of the mammalian assemblages where it occurs and as such, preys on the largest ungulates found in these assemblages (Seidensticker 1997). Karanth & Sunquist (1992), Eisenberg & Seidensitcker (1976) and Schaller (1967) have all observed a positive correlation between tiger densities and prey biomass densities. The prey inturn depend entirely on the availability of suitable and productive habitats to maintain such viable and abundant populations.

However, habitat destruction or "elimination of habitat" (Schaller, 1967) is an ongoing process and it is here, in the cycle of events, that anthropogenic influences play a key role in modifying and often degrading the habitat by diverting a substantial quantum of the biomass towards human and livestock needs. Anthropogenic disturbances take the form of cattle grazing, lopping and cutting for fodder, fuelwood and other biomass requirements, fires, large-scale extraction of non-timber forest products (NTFPs) and drastic alterations in the physio-chemical quality of the terrain.

The direct effects of such disturbances include loss of cover, change in vegetation communities, species composition, forage abundance and quality (Dinerstein 1987); all of which have a direct effect on the ungulate habitat use (Dinerstein 1979a). The tiger, due to the obligate nature of its phylogenetic (Sunquist et al. 1999) and trophic position is most vulnerable to such alterations and deterioration of habitat, which affects the health of the prey populations (Karanth and Stith 1999). Karanth *&* Stith (1999), from modelling studies of tiger populations, have speculated that prey depletion is a major factor driving the current decline of wild tiger populations and hence a "significant constraint" on their recovery.

But, it has also been found that disturbances at various intensities need to be considered. At lower intensities disturbances like fire and other anthropogenic activities increase the amount of edge habitats, which is preferred by many ungulate species (Sunquist et al. 1999). Studies of grazing systems have shown that net primary productivity is the highest on marginally grazed sites, while lowest at heavily grazed sites (Pandey and Singh 1992). These findings suggest that an optimum level of disturbance is useful in maintaining the productivity and variety of habitats, which is favourable for the ungulates. Therefore a valuable extension to the body of work existing on ungulates from the subcontinent would be to understand how ungulate communities' habitat choice and occupancy relates to environmental heterogeneity that results from different intensities of anthropogenic disturbance.

1.1 LITERATURE REVIEW

Habitat Selection by Ungulates

Habitats can be compared to templates, moulding the shape of the community that occupies it and moreover much like the template it is moulded in return (Southwood 1987).

Central to the study of animal ecology is an understanding of the habitat the animal in question occupies or its habitat preferences. A geographical area may comprise a variety of habitats, and may be occupied by many species. If species are to be conserved, it is essential to know what factors are influencing their distribution. This can be achieved by relating distribution of animals to the characteristics of the geographical region (Ben-Shahrar 1988). A significant body of work on the distribution patterns of ungulate communities has been carried out on the West African ungulate fauna (Ben-Shahrar & Skinner 1988, Ben-Shahrar 1990), while the South-Asian ungulate assemblage has being left out largely when it came to quantitative work on habitat preference. Nevertheless invaluable information has been collected by many researchers beginning with Schaller (1967) and a long list following him who have been briefly reviewed below.

Large mammalian terrestrial herbivores tend to show peak densities in grassland, grass scrub and savannah biomes, with the lowest densities found in severely arid conditions or at the other extreme in tropical evergreen forests (Eisenberg 1980), although the specific reasons are different in both cases. As a generalization, consider a rainfall gradient from low to high, e.g. from dry thorn forest to moist deciduous forests, and further to tropical evergreen forests. The mammalian biomass increases along this gradient. After a point as the forest cover becomes continuous and the forest only supports little ground cover in terms of shrubs and grass, the ungulate biomass again falls (Eisenberg & Seidensticker 1976).

For instance, the dry deciduous and scrub forest of Gir support 383 kg/Km^2 of wild mammalian herbivore biomass (Berwick 1974). Later after the formation of the national park and under protection from grazing, Khan *et al.* (1996) from the same area reported a wild herbivore biomass of 2,746 Kg/Km^2. In comparison, the moist semi-deciduous forests and meadows of Kanha support 1780 Kg/Km^2, of wild herbivore biomass (Schaller 1967). The highest wild herbivore biomass of 2858 Kg/Km^2 has been reported from the gallery forests and alluvial flood plains of Kaziranga (Spillet 1967a). In comparison the tropical rain forest of Udjung Kulon in Java supports only about 492 Kg/Km^2 of ungulate biomass (Hoogerwerf 1970).

These differences are drastic enough to reflect the intrinsic differences in quality of the habitats in relation to ungulates. These differences indicate that though moisture availability is an essential factor, large herbivorous mammals in India and South-Asia attain peak densities in secondary successional forests that have an interspersion of grass, shrubs, low stature trees but not moist enough to support closed canopy woody vegetation seen in tropical evergreen forests, where most of the biomass is locked up in the trees making it inaccessible to terrestrial herbivorous mammalian forms (Eisenberg and Lockhart 1972).

The secondary seral woodland savannah stage is suitable to graze livestock too, and has been maintained largely by burning (Dinerstein 1976) and other forms of interference by man. In the absence of such practices the vegetation would progress to woodland, which is considered the climax for the Indian subcontinent given its seasonal rainfall regime (Puri et al. 1982). An added factor maintaining the secondary seral stage in the *terai* is the annual cycle of flooding (Dinerstein 1976). In the case of central India the role of fire and grazing have been critical in maintaining this stage of succession. With a *Terminalia- Butea- Diospyros* mixed deciduous forest emerging when protected form grazing (Tiwari 1954).

Eisenberg and Seidensticker (1976) reported that the ungulate biomass observed in South-Asia is considerably lower than that found on the plains of east Africa. Eisenberg (1980) attributes this largely to the fact that unlike the older east African herbivore assemblage the grazing herbivores have not diversified equally in the ungulate communities of south Asia. Recent studies (Khan *et al*. 1996, Karnath and Sunquist 1992, Karanth and Nichols 1998) from the Indian sub-continent however reveal much higher ungluates biomass estimates, approximating those form the savannah grasslands of east and central Africa (Hirst 1975) when contributions from species like elephant, hippopotamus and buffalo are excluded form the latter estimates. Even when biomass contribution by elephants, hippopotamus and buffalo are considered the estimates by Hirst (1975), of 10,000 to 20,000 Kg/Km^2, is in the range of what has been reported by Karnath and Sunquist (1992) from Nagarahole, 6,846 to 19,092 Kg / Km^2.

This is because of the vast improvement in habitat quality since the inception of Project Tiger in India in 1973 and the consequent protection that these parks and sanctuaries from grazing and other related forms of biomass extraction. Hence, inspite of the lower diversification of the grazers, these areas appear to be able to support equally high ungulate biomass as has been observed from the savannah of central and east Africa.

Karanth & Sunquist (1992) reported higher average group sizes of chital and higher densities of all other ungulate species and primates in moist and teak dominant habitats compared to the dry deciduous habitat at Nagarahole. This is contrary to what has been postulated by Eisenberg (1980). i.e. the dry deciduous forest with its woodland savannah vegetation structure would be expected to support a higher biomass of grazers than moist deciduous forests. Karanth & Sunquist (1992) suggest that the coarse nature and low nutritional quality of the grass during the dry season may be a factor reducing the carrying capacity of ungulates. Also dry deciduous forests are comparatively scarce in fruits and browse that characterise the dry season forage. Further the absence of fires, which historically had played an important role in maintaining grassland productivity, since the formation of the park has probably reduced the quality of the habitat for grazer species.

The studies of Dinerstein (1980), Eisenberg & Seidensticker (1976) and Karanth & Sunquist (1992) have all shown that the greatest ungulate biomass is reached in areas where grassland and forests form a mosaic with the interdigitation of many different vegetation types. Changing river courses, fire and anthropogenic disturbances have all contributed to increasing the edge habitat, which is preferred by many ungulate species (Sunquist *et al*. 1999).

1.2. OBJECTIVES

Panna National Park is representative of the dry deciduous forests in India that are characterised by intense human pressure. About 40 % of tiger habitats in India fall within such sub-optimal areas (Chundawat *et al*. 1997). Hence a clear understanding of the impact of human disturbances in such areas is imperative. Therefore this study was conceptualised with the following objectives.

1. To estimate relative prey abundance across a gradient of anthropogenically disturbed areas within Panna N.P.
2. To understand which of the habitat or disturbance variables or combination thereof are responsible for the observed habitat occupancy patterns of the prey species.

2. STUDY AREA

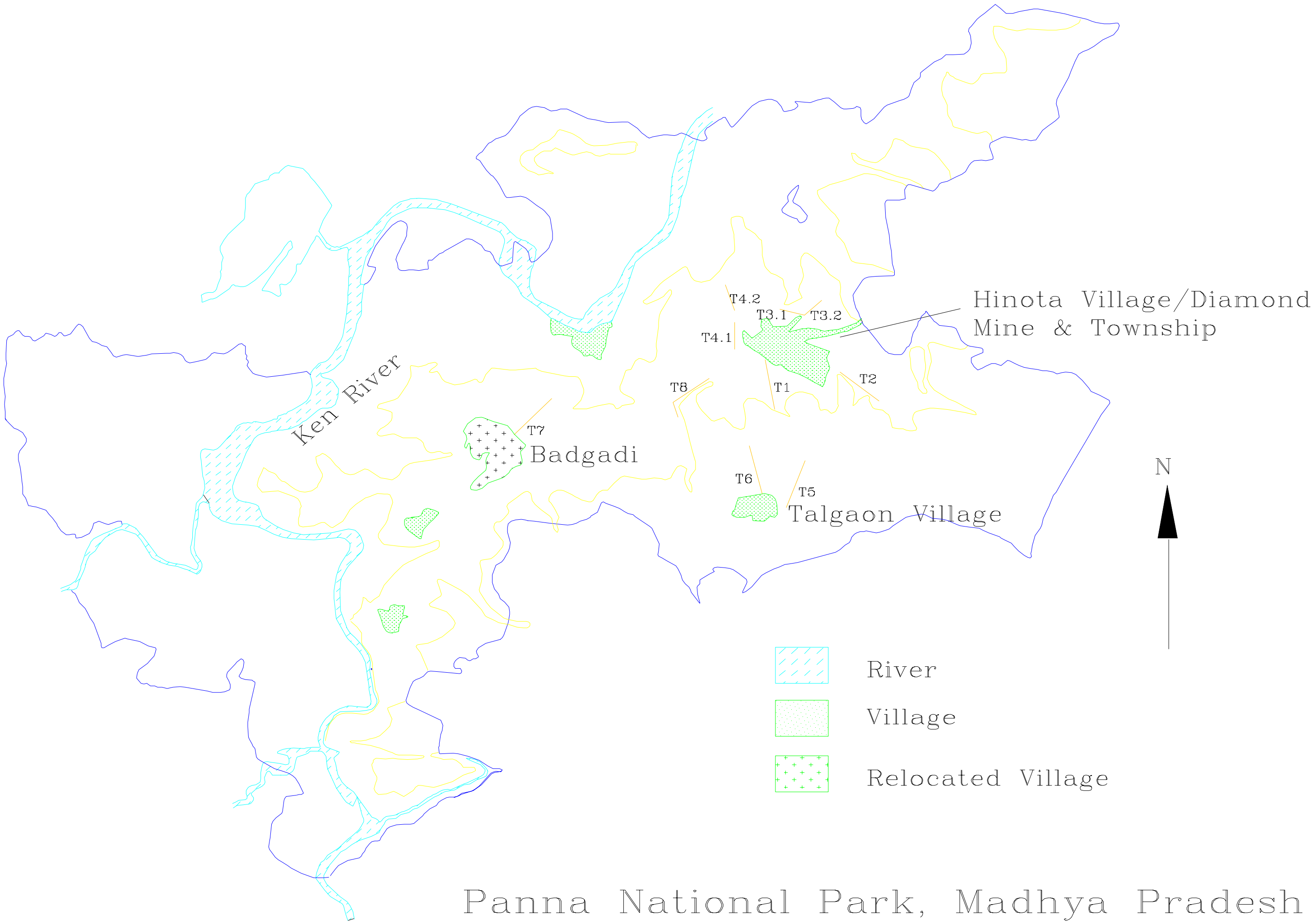
2.1 LOCATION

Panna National Park (Figure 2.1) is located in North Central Madhya Pradesh. The park occupies an area of $543Km^2$ spread over two districts, Panna and Chattarpur. It lies between 24^0 27^l and 24^0 46^l N and 79^0 45^l to 80^0 09^l E. The park is part of the Central Indian Highlands (Zone 7) according to the biogeographic classification of Rodgers & Panwar (1988).

2.2 CLIMATE

The calendar year can be approximately divided into three distinct seasons. The summer season from March to June, wet season from July to October and the winter season from November to February. The annual rainfall is approximately 1100 mm. This is the only source of water for large areas of the park. The maximum day temperature recorded till the end of May this year was 47^0 C, while the lowest nighttime temperature recorded during winter was 3^0 C. Ground frost is common in the moist and open grassland areas of the park during peak winter, mostly in the month of January. Usually a few winter and summer showers are in order. During the course of the present field study though there were only two brief wet spells. The first from 15th to 18th of November '98, caused by a cyclonic depression in the Bay of Bengal and the second, again due to a depression in the Bay, between the 3rd and 10th of February. But for these two brief spells the remainder of the period form 14th November '98 to 3rd May 1999, remained dry.

Figure 2.1: Map of Study Area:



2.3 TOPOGRAPHY

2.3.1 Escarpments

The park is a part of the Vindhya hill range. The topography of the park is unusual and unique. It can be termed as "Step" topography, with one plateau stepping down onto the lower plateau. The plateaus run approximately in the NE- SW direction. The transition from one plateau to another takes the form of steep escarpments, usually a steep fall ranging from 10-80 meters. The area along these escarpments is extremely rocky, have perennial water springs, plenty of caves and thick vegetation of various types, including Bamboo species (e.g. Dendroclalmus strictus) many shrubs species (e.g. Helicteris isora, Grewia sp.) and trees species at their bases. During the summer months when water is at a premium, these areas offer not only water but also shade, which is provided by trees which regenerate leaves early (e.g. Schleichera oleosa) and species which shed leaves late in summer (e.g. Soyamida febrifuga). In fact the only semblance of greenery to be seen anywhere in the park during the summer is along these escarpments. All these factors make these areas an extremely important habitat component for a host of wildlife species in Panna.

2.3.2 Plateau

From the base of one escarpment to the top of the next one is more or less flat land, crisscrossed by a network of 'monsoonal' streams, streamlets and their catchments. On a moisture gradient, moisture levels decrease as one moves away from the base of the escarpment towards the escarpment of the next lower plateau. PNP has three such plateaus or 'steps', the upper Talgaon plateau, the middle Hinouta plateau and the valley of the Ken River.

This study was carried out largely on parts of the middle Hinota plateau and a small area on the Talgaon plateau.

2.4 Drainage and Hydrological Regime

The entire area forms part of the catchments of the Ken River. The river as such passes briefly through the western part of PNP, which makes it restricted in access. The river, though it reduces a lot in summer is never completely dry. The springs along the escarpments are perennial and are fed by aquifers draining into crevices along the escarpments. The monsoon rains and any other precipitation are the only sources of water for a large part of the park. There are also a few tanks, both natural and manmade, spread around the park. Areas within the park that were previously inhabited or are being presently inhabited have some perennial source of water, which also makes these the most productive areas of the park. There are also a handful of streams that retain water from the monsoon flow till early summer.

2.5 People, Society and Land Use

The first impressions that one gets on visiting the area are the extremely low levels of social development. Levels of education and awareness are very low; hence avenues for employment are limited, or non-existent. Therefore, the only options available are some form of dependence on the biomass resources of the forest.

Under such circumstances it is no surprise that the park is subject to intense human pressure. There are over 47 villages within a 5 Km belt around the park and 13 villages within the park that are to a large extent are dependent on the park for their livelihood. Conservative estimates are that the livestock and human population within the park are about 9500 heads of livestock and about 6000 people (Forest Department records). The total cattle population of the dependent villages (enclaved and surrounding) is in the range of 37,500 and 50,000. Even these are likely to be conservative estimates. The human population is about 34,500 (Chaudhary 1996).

The major ethnic groups of the area are the Gonds (Rajgonds, Nandgonds and Saurgonds) and Khairuas among the tribes and the Yadavs among the non-tribals.

Cattle rearing is the predominant occupation of the people in this area. Agriculture, but for a handful of big farmers, is a subsistence occupation with most of the land holdings varying between 0.5 - 7.0 ha. which gets further divided into smaller and less economic holdings as the generations go by. A high "generation" turnover rate also characterises the demography of the region. Also agriculture is restricted to one crop a year for lack of water during the dry season. Being employed as daily wage labour and collecting and selling fuel wood and NTFPs are hence important sources of income for a substantial number of people. The dependence on the park for fuel wood reaches as far as Panna town and probably even further.

On the social development front, as with the whole of the Bundhelkand region, the vicinity of the park is a 'backward area' characterised by child marriage, lack of adequate family planning and strongly entrenched caste hierarchy.

In conclusion, a host of factors of societal origins keep the people dependent, with their dependence rising exponentially, on the forests.

2.6 Vegetation

The forest types within PNP belong to the following categories as per Champion and Seth (1968).

1. Southern tropical dry deciduous dry teak mix forest $5A/C_3$.

2. Northern tropical dry deciduous mixed forest – $5B/C_2$

3. Dry deciduous scrub forest.

4. *Boswellia* forest $5/E_2$

5. Dry bamboo brakes $5/E_9$

6. *Annogeissus pendula* forest $5/E_1$

2.7 Description of sampling transects

Transects use for sampling ungulates represent two very different topographic regimes, the hills or escarpments and plateau (c. f. figure on page X)

The two hill transects are **T2** and **T8**. Transect **T2** falls on the fringe of the park running along the escarpment bordering the nearby by Hinota township and diamond mine. The forest compartment along side this transect is open access forest. Like many areas along the hills this transect has numerous perennial springs dotting it. These are watering points for the large number of livestock that come out to graze from the nearby township. The ground layer of the vegetation is largely dominated by *Oscimum sp.* Grass cover is sparse along this transect. Signs of sloth bear feeding activity abound and leopard tracks have been found. The tree species composition of T2 is varied. The main species include *Terminalina tomentosa, Tectona grandis, Lagerstroemia parviflora, Annogeissus latifolia, Acacia catechu, Cochlosprermum religiosum* and *Diospyros melanoxylon.*

Transect **T8**, the second hill transect is different from **T2**, in terms of the under growth. Parts of T8 have extremely high grass growth and a high shrub and sapling diversity. Patches of *Dendrocalamus strictrus* are found along this transect. Unlike T2, this transect does not have any perennial springs, but there are seasonal sources of water within a radius of 2 Km form any point on the transect. T8 falls within the zone of influence of the erstwhile *Ram Kheriya* village, which was relocated out of the park in 1984. By virtue of its position today, it is a better-protected area protected from the pressures of grazing and lopping. Indirect evidences of tiger presence such as scats and pugmarks have been recorded on this transect. Teak appears to be the dominant tree species on this transect. Other tree species found include *Zizyphus xylopyrous, Lagerstroemia parviflora, Butea superba, Diospyros melanoxylon, Annogeisus latifolia* and *Schleichera oleosa*.

The remainder of the transects, namely T1, T 3.1, T 3.2, T 4.1, T 4.2, T 5, T 6 & T 7 were all plateau transects. The forest types represented by all transects on the plateau were broadly dry deciduous teak mixed forest, or dry deciduous mixed forest. Amongst the plateau transects, **T 7** is located near *Badgadi*, which is a relocated village site. This transect served as a control undisturbed transect to compare the other transects which are subject to different levels of disturbance.

Transect T1 represents an area along the border the park, which was an open forest until about four years ago. The larger part of the transect lies on flat area, but begins to rise slowly and concludes half way up the escarpment of Talgaon plateau. The dominant tree is again teak and mixed forest association of *Terminalia tomentosa, Lagerstroemia parviflora, Lannea coromandelica, Acacia catchu* and *Annogeissus latifolia.* Being on the periphery of the park this habitat is grazed and used for all other form of human use. The nearby perennial water spring is a major attractant for herders from far off villages who use it to water their livestock.

Transect 3 comprises of two parts, **T 3.1** and **T 3.2**. each of which is 1 Km in length. T 3.1 runs along the border of the Hinota town. It is a heavily grazed area with some patches even devoid of any grass or vegetation cover. This transect accounted for the maximum number of the Chinkara sightings. The area of the village immediately bordering this part of the forest are agricultural fields and crop raiding by Cinkara and the occasional Nilgai is not uncommon. Access to water on this transect is very good. A perennial stream has been check dammed for use by the village, water is always present. Teak dominates the transect with associates like *T. tomentosa, L. parviflora* and *D. melanoxylon.*

Transect 3.2 starts off from the end of T 3.1 and moves away from the village. This area is dominated by *L. parviflora,* teak, *Terminalia* association with the odd *A. catachu*, *A. latifolia* and *Maduca indica.* This transect too has weed infestation by *Oscimum sp.*, but not as intense as T2. The whole transect is intensively grazed and browsed. Due to proximity to the village disturbances are high in the habitat.

Transect 4.1 is largely Teak dominated, with *Terminalia* and *Lagerstroemia* associations. Inspite of its proximity to the village it is not an extensively grazed or disturbed area. Cases of cattle straying in are common but the magnitude of it is not as great as in the other areas. E. g. T 3.1, 3.2 & T2. Hence inspite of its proximity to the village the standing biomass of grass is high.

Transect 4.2 is characteristic of an area called the “Sathkatta jungle” or miscellaneous forest with the seven timber species, namely teak, *T. tomentosa, L. parviflora, A. latifolia, D. melanoxylon, Flacourtia indica* and *A. catechu.* The transect falls in a slightly more elevated area, which is rockier and has a drier regime and the area too is not intensively grazed by cattle.

A factor common to all transects discussed so far, except T 7, is the practice of lopping the branches of fodder tree species by goatherds.

Transect 5 & 6 sample an area surrounding a village ensconced within the park. These villages have grazing rights within the park. Access to water from these two transect is good. There is a perennial source of water, which is located in the village. Use of this by wild animals is largely restricted to the night, with cattle, and humans dominating the landscape during the day. Distance from the water source to the farthest point on the transect is approximately 3 Km.

Transect T5 is an open dry deciduous teak mix forest and intensively grazed area. Ground cover is largely depleted. Lantana is found in patches with open areas in between. Other tree species include *L. parviflora, Z. xylopyrous, Butea monosperma, Feronia alata, Acacia senegalensis* and *D. melanoxylon.* As with the other transects lopping is rampant in this area too.

Transect T 6. Starts off from just outside the revenue area of Talgaon village. The initial section on the transect is infested with *Lantana*. Unlike in the lantana patches found on transect 5 in this case they are very clumped and significantly reduce visibility. Further along the transect the intensity of *lantana* clumping reduces and more open areas are found. The tree species composition in the 1 to 1.5 Km stretch of the transect is largely a *Tectona – Butea* association, which gradually gives way to a *Tectona – Zizyphus – Diaospyros – Lagerstroemia* association. The few recordings of animals during the sampling were from this latter part of the transect. Grazing by cattle and goat is extensive with lopping of all browse species being practiced by goatherds.

2.8 FAUNA

The park supports a diverse large mammalian fauna. Besides the tiger (*Panthera tigris tigris*) other large carnivores include, Leopard (*Panthera pardus*), Striped hyena (*Hyaena hyaena*), Sloth bear (*Melursus ursinus*), Dhole (*Cuon alpinus*), and wolf (*Canis lupus*). Smaller carnivores are represented by Jungle cat (*Felis chaus*), Indian fox (*Vulpes bengalensis*), Common mongoose (*Herpestes sp.*) and Ruddy mongose and Ratel (*Mellivora capensis*). The wild ungulate assemblage consists of Sambar (*Cervus unicolor*), Chital (*Axix axis*), Nilgai (*Boselaphus tragocamelus*), Chinkara (*Gazella gazella*), Chousinga (*Tetracerus quadricornis*) and Wildpig (*Sus scrofa*). The most common primate species is the common langur (*Presbytis entellus*).

3. METHODS

3.1 Field Methods

The data collection effort was comprised of two components: -

1. Prey species population distribution, i.e. recording patterns in the distribution of prey species across a gradient of anthropogenic disturbances.
2. Habitat Evaluation, i.e. measuring a set of habitat and disturbance parameters to understand the processes behind the observed set of patterns.

3.1.1 Animal Population Distribution

Two methods were used to measure abundance estimates of prey species in the different areas, namely; The Line Transect Method (Burnham *et al.* 1980) and Pellet Group Count Technique (Bennett *et al.* 1940, Ebernhardt *et al.* 1956 and Neff 1968).

3.1.1.1 Line Transect Method

Ten line transects were laid (6 transects were 2 km. each and the 4 were 1 Km. each in length) in a stratified random manner, to sample fringe areas with villages on the periphery, areas surrounding a village ensconced well within the national park and areas from which human habitation has been relocated. Transects were cut and marked and points at 100 mts intervals were marked along transects. Transect walks were repeated for a minimum of 7 walks and a maximum of 9 walks per transect in both seasons viz. winter and early summer. Wild ungulate species seen on transect walks were recorded as species, sex and age (if possible), sighting time, sighting distance (ocular estimate) and sighting angle were recorded. All transect walks commenced within the first hour after sunrise and were walked by the same team of two observers. A distance of one kilometre was covered in approximately 40 minutes on all transect walks. Livestock was not systematically recorded on transect walks, because most of the cattle came out into the forest to graze only later in the day, by which time the transect walk was completed. Using transects to quantify livestock, as a disturbance variable, would have given us underestimate.

3.1.1.2 The Pellet-Count Method

This method was first described by (Bennet et al. 1940), and has since been improved (Ebernhardt et al. 1956) and established as a useful and reliable method for a wide variety of conditions. Neff (1968) provides an extensive review of the subject. The method has a number of important advantages over the direct observation method. It measures a permanent record of the presence of an animal i.e. its droppings. This method is suitable for areas which have a marked difference in temporal use by wild herbivores, or low ungulate densities, making them 'absent' during the transect walks.

Cairns et al. (1980) used this method as measure of the time spent in a particular habitat during a season. Edge et al. (1989) compared Pellet group and telemetry techniques to compare elk distributions. They found that of the pellet group technique could be used to identify key areas and estimate elk distribution relative to topographic and disturbance factors.

A limitation of the method is its lack of utility during the monsoon months on the subcontinent, or during moist and wet whether. Largely because of displacement of pellets during rains, heightened dung beetle activity and disintegration of pellets. Hence this method is ideally suitable for the dry months. Given the conditions of Panna, a dry deciduous habitat, with low ungulate densities and high livestock pressure, the use of pellet – count method was ideally suited for the present study. Also the duration of the study was during the dry season.

A total of 160 dung plots, measuring 60mts x 2mts each, were monitored 5 to 7 times, with the interval between counts varying between 10 to 30 days in winter to 20 days in summer. In the areas with tall grass the entire plot was cleared for ground visibility, so as to minimise error due to missing out pellet groups. The area cleared of grass is insignificant in relation to the area of the disturbance regimes being sampled. Hence the possibility that the availability of fresh shoots could bias dung deposition rates is unlikely. Further, the duration of the study being in the dry months does not favour extensive growth of new sprouts even if the ground has been cleared. Pellet groups belonging to different species were recorded on each visit and removed from these plots.

Dung and pellets of cattle and goat was also recorded and was used as a measure of livestock pressure. The total counts for all species were converted into deposition rate per 10 days, for the entire study duration. This data was further used in analysis and comparisons of habitat occupancy across disturbance regimes.

3.1.2. Habitat Evaluation

The ideal habitat evaluation scheme must consider the perceptions of the animal. Since this is unknown, the factors are selected subject to our understanding of the needs and requirements of the animal.

The habitat evaluation was comprised of three parts.

Quantifying vegetation parameters

Quantifying structural parameters

Quantifying disturbance parameters

3.1.2.1. Quantification of Vegetation Parameters

Point-Centred Quarter (PCQ) method: (Muller-Dombois 1974) was used to estimate tree density. Tree species and Girth at Breast Height (GBH) of the individuals was also recorded. Sampling points were laid at 100 metre intervals along transects. The distance to the nearest tree in each quarter was measured and the species and its GBH recorded. Five metre radius plots were laid at the same points used for the PCQ, for estimating shrub species composition and densities. Total counts of shrubs and saplings were carried out within these plots.

Standing weight of grass: Grass was collected from two randomly placed plots (0.5 x 0.5 mts.), one on either side of the line transect. The species present were recorded and the samples were stored till summer. They were further sun dried in summer for one complete day when shade temperatures were about 40^{o}c and then weighed.

Canopy cover: A rectangular hand mirror of 8x5 inches was grided 40 squares of 1sq in. each. The mirror was held perpendicular to the body, at waist height. Five readings were taken at each point. One at the centre and the remaining four at 10 steps away from the point in four directions perpendicular to each other. The number of squares with more than 50% cover was considered closed. The five values were pooled and an average for the sampling point was calculated.

Horizontal cover density: This was measured using a chessboard. Measurements were made in 4 perpendicular directions, at distances of 10, 20 and 30 meters away from the central point. The measures were made at three heights, of 0.5, 1.0 and 1.5 mts. from the ground at each distance. Only the black squares were considered, the number of visible squares of which were recorded. The number of black squares counted were later converted into proportion of the total number of black squares on the board (32). These visibility values for each height were pooled across the four perpendicular directions for each sampling point.

3.1.2.2. Quantification of Terrain and Structural parameters

Distance to water: Water holes, perennial springs and tanks near all transects were marked on 1:50,000-scale topographic sheet of the study area. Distances were further calculated from water sources to the line transects from these maps. Transects were marked on toposheets using GPS locations for the start and finish points or only GPS location of the starting point and the angular bearing of the transect.

The gradient for each sampling point was recorded as 'Flat', 'Mild Slope' or 'Steep'. This was a subjective measure based on the character of the general vicinity of the sampling point.

3.1.2.3 Quantification of disturbance parameters

Dung and pellet deposition for cattle and goat were monitored using the pellet plots described earlier. The intensity of lopping and cutting was measured by counting cut and lopped trees within the 5 mts. radius plot at each habitat sampling point.

3.2. Analytical Methods

Statistical analysis of data was performed using SPSS Version 8 (SPSS Inc., 1998). One-way ANOVA and Tukey's multiple comparison test according to Zar (1984) and Principal Component Analysis according to Gauch (1982) were used to study the data.

3.2.1. Prey Species Density Estimation

3.2.1.1. Checking for detectability bias of species between transects

One-way ANOVA was used to compare detectability (angular sighting distances) for each species on different transects.

3.2.1.2. Analysis of line transect data

After establishing that species detectability did not vary between transects all sightings of a particular species was pooled and effective strip widths for each species was estimated from the histogram of frequency of sightings against distance class intervals. 5 –10 % data was truncated in order to establish the strip widths. The strip widths were used to calculate densities as = n/2LW where n = no. of individuals sighted per walk within the fixed strip width, L = length of the transect and W = effective strip width.

Distance program was not used to estimate densities of individual species due to extremely low sample sizes (Table 4.1 A - H) on most transects. However density estimates using 'Distance' was attempted after pooling all sightings on a transect (irrespective of species). These results are tabulated in Appendix 1. As can be seen, even in this case, the estimates using the program are not reliable. Therefore the only solution to get reliable density estimates in such low-density habitats is to have a much higher sampling effort, an effort that was not possible in the duration of this study given the logistical constraints of a single researcher study effort.

3.2.2. Dung deposition rates on different transects

Species wise deposition rates for each plot were calculated as rate/10 days for the entire study period. One-way ANOVA and multiple comparison test (Tukeys' HSD) were used to check for differences in dung deposition rates between species and between transects.

3.2.3. Ordination of transects based on disturbance and habitat characteristics

All the plots were subject to Principle Component Analysis (PCA) to classify them into various categories based on habitat, disturbance and terrain variables. A one-way ANOVA with multiple comparison was used to test for significant differences between the habitats based on the PC 1 and PC 2 respectively. The dung deposition rates were correlated (Pearson) with respective PC scores to ascertain their relationships. Patterns in association of species with different disturbance regimes were arrived at by a multiple correlation with component scores for all the three main PCs correlated with dung or dropping deposition rates.

4. RESULTS

4.1 Density Estimation

4.1.1 Detectability bias of species between transects

Sambar, Nilgai and Wildpig showed no significant difference in detectability across transects (Sambar $F= .967$, $df =2$, $p \leq 0.39$, Nilgai $F = 1.918$, $df = 5$, $p \leq 0.11$ and Wildpig $F = 1.230$, $df = 1$, $p \leq 0.348$). Only Chinkara showed a significant difference ($F= 5.624$, $df = 5$, $p \leq 0.0001$). The difference was significant only between transect 4 and transect 7 in the case of Chinkara ($p \leq 0.0001$). Chital was not included in the test as it was sighted only on one transect.

4.1.2. Density estimates for different transects

Since detectability across transects was not different between species, the data was pooled to estimate strip width for each species. From the histograms of perpendicular distance against frequency of sightings (Fig. 4.1 A-E) the strip - widths for Sambar, Chital were set at 50 mts. and that of Nilgai and Chinkara at 80mts. In case of Wildpig the strip width was approximated to 40mts. The density estimates for individual species for the various transects is compiled in table 4.1 (A - H)

4.2. Dung Deposition Rates on different transects

The dung deposition rate of all species (Fig. 4.3 A-H) showed significant difference across transects. Sambar ($F = 14.764$, $df = 9$, $p \leq 0.0001$); Chital ($F = 3.529$, $df = 9$, $p \leq 0.001$); Nilgai ($F = 7.731$, $df = 9$, $p \leq 0.0001$); Wildpig ($F = 2.593$, $df = 9$, $p \leq 0.003$); Langur ($F = 7.238$, $df = 9$, $p \leq 0.0001$); Cattle ($F = 17.062$, $df = 9$, $p \leq 0.0001$); Goat ($F = 13.506$, $df = 9$, $p \leq 0.0001$); and Chinkara ($F = 23.208$, $df = 9$, $p \leq 0.0001$). The transect wise comparison of dung deposition rates for each species shows that Chital and Nilgai differs significantly only between T7 and all other transects (Chital, $F = 3.529$, $df = 9$, $p \leq 0.001$; Nilgai, $F = 7.731$, $p \leq 0.0001$, $df = 9$). Sambar differed between T8 and all other transects ($F = 14.764$, $p \leq 0.0001$, $df = 9$) and Langur shows similarity only between T2 & T8 ($F = 7.238$, $p \leq 0.822$, $df = 9$). Livestock (cattle and buffalo), showed significant difference between most transects (Table 4.2)

4.3 Ordination of Habitats

Principal Component Analysis (PCA) yielded a total of 11 distinct components. Of which the first three (habitat quality, disturbance and topography) accounted for 53.022 % of the variance of habitat evaluation data. The remaining eight components each of them accounted for less than 10 % of the variance and hence were not included in the analysis. Bartlett's test of sphericity ($p \leq 0.001$) proved that the correlation matrices were not identity matrices. KMO (Kaiser-Meyer-Olkin) measure of sampling adequacy was 0.655, which indicates sampling adequacy as well as validity of PCA.

The habitat quality axis (PC1) is positively associated with canopy cover, tree density, tree species richness, terrain and shrub and sapling diversity. The disturbance axis (PC2) was positively associated with Goat pellet and Cow dung deposition rates, woodcutting and lopping and negatively associated with grass weight. While visibility and terrain was associated positively and water negatively with topography (PC 3). (Table 4.3 A-C).

Habitat occupancy by ungulate community in relation to habitat quality and disturbance is depicted in Fig. 4.2. Chital and Sambar shows a localized distribution restricted to areas with low disturbance and better quality and structure. Nilgai, chinkara and wildpig are more widely distributed.

4.4. Species association with habitat variables

Transects showed significant differences in factor 1, the habitat quality component ($F = 10.437$, $df = 9$, $p \leq 0.0001$) and factor 2 the disturbance component ($F = 25.502$, $df = 9$, $p \leq 0.0001$). The individual comparisons between transects has been represented in Table 4.4 (A-B).

Component scores PC 1, 2, 3 were correlated with the dung deposition rates of all the study animals. From the correlation matrix (Table 4.5) Sambar and Langur shows a slight positive correlation with quality and structure (component 1), while Chital, Nilgai, Chinkara and Wildpig were negatively correlated with the same.

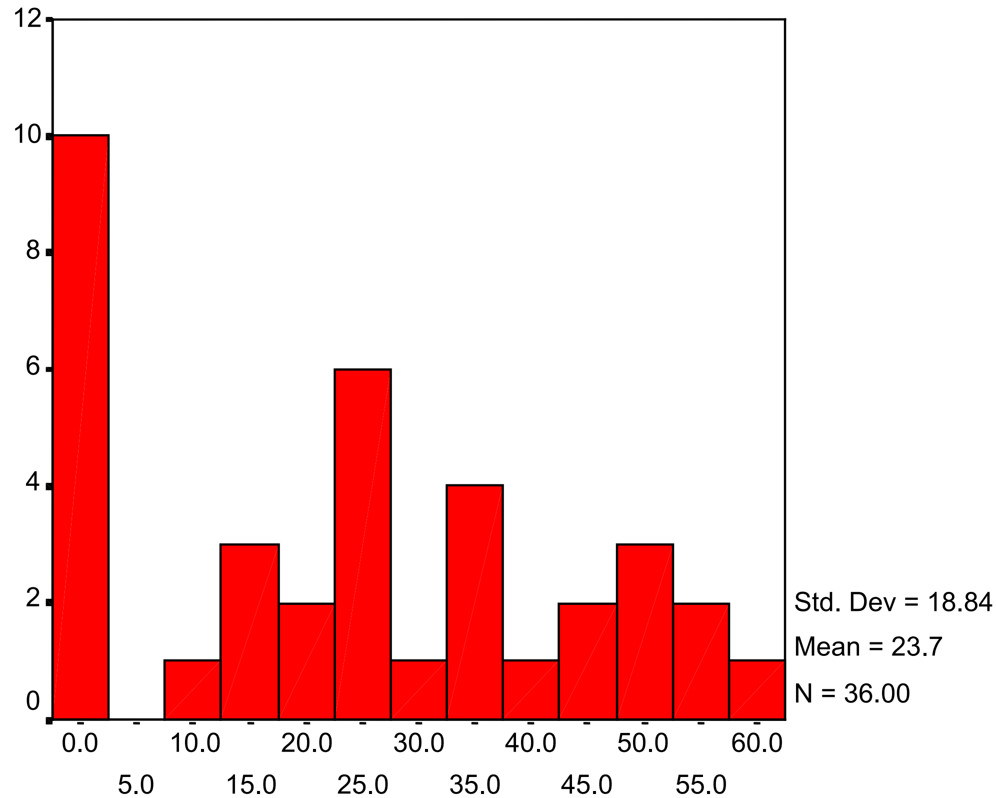
Sambar, Chital, Nilgai and Langur showed negative correlation with habitat disturbance (component 2), while chinkara and wildpig show a positive correlation.

Chital, Nilgai and Wildpig were negatively correlated with topography (component 3). While Chinkara, Langur and Sambar show a positive correlation with component 3.

The overall correlation coefficients are weak and hence p values are of little importance in deciding the correlation. Therefore the results of the correlation matrix should be looked at as merely suggesting trends in the association between various species and the habitats.

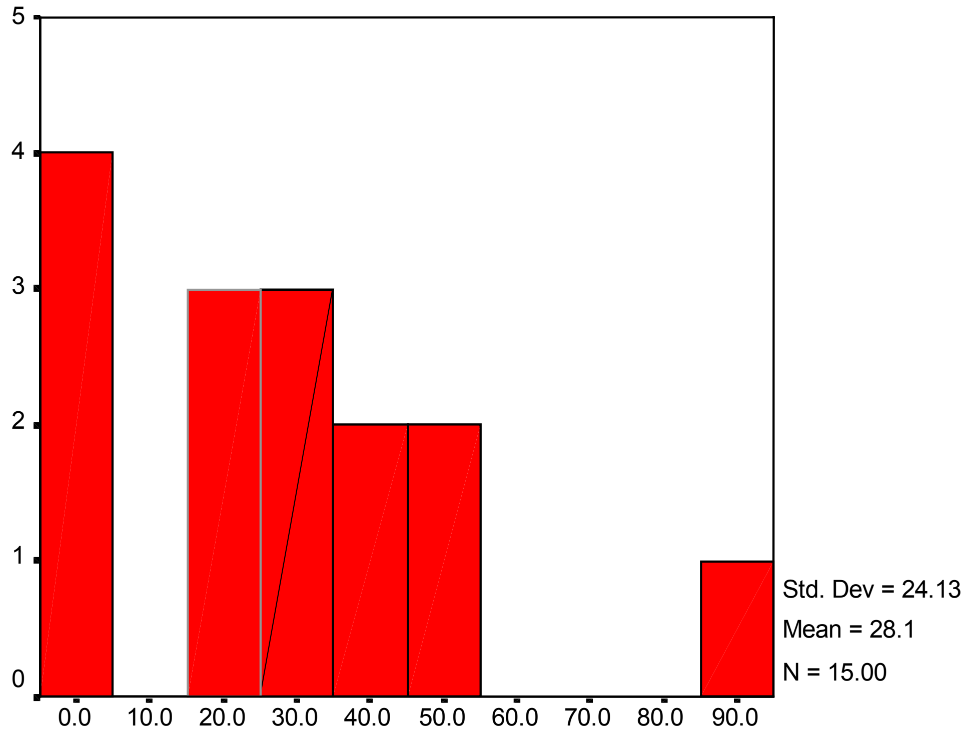
Sighting Distance of Ungulates in Distance Classes

Figure 4.1A Histogram of sighting frequency of Sambar in distance classes of 10mts



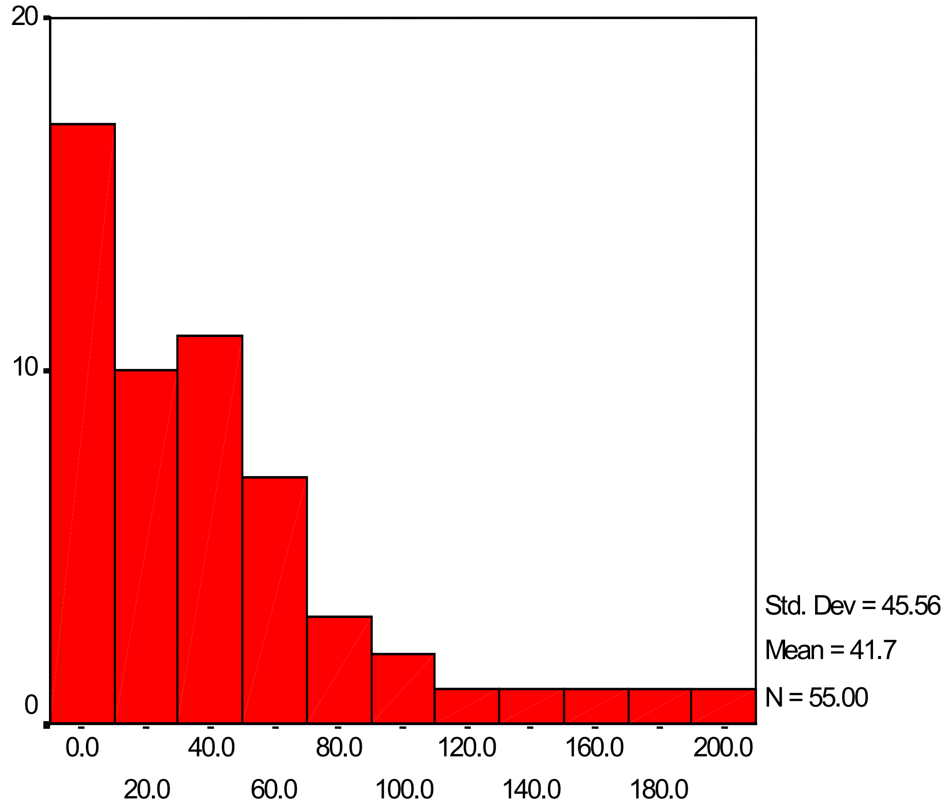
X – axis = distance classes of perpendicular sighting distance
Y – axis = frequency of sighting in each interval class

Figure 4.1B Historgram of sighting frequency of Chital in distance classes of 10mts



X - 10 mts. Class intervals of sighting distances
Y - axis   number of animals seen in each interval class

Figure 4.1 C Histogram of sighting frequency of Nilgai in distance classes of 10mts



X – axis = distance classes of perpendicular sighting distance
Y – axis = frequency of sighting in each interval class

Figure 4.1D Histogram of sighting frequency of Chinkara in distance classes of 10mts

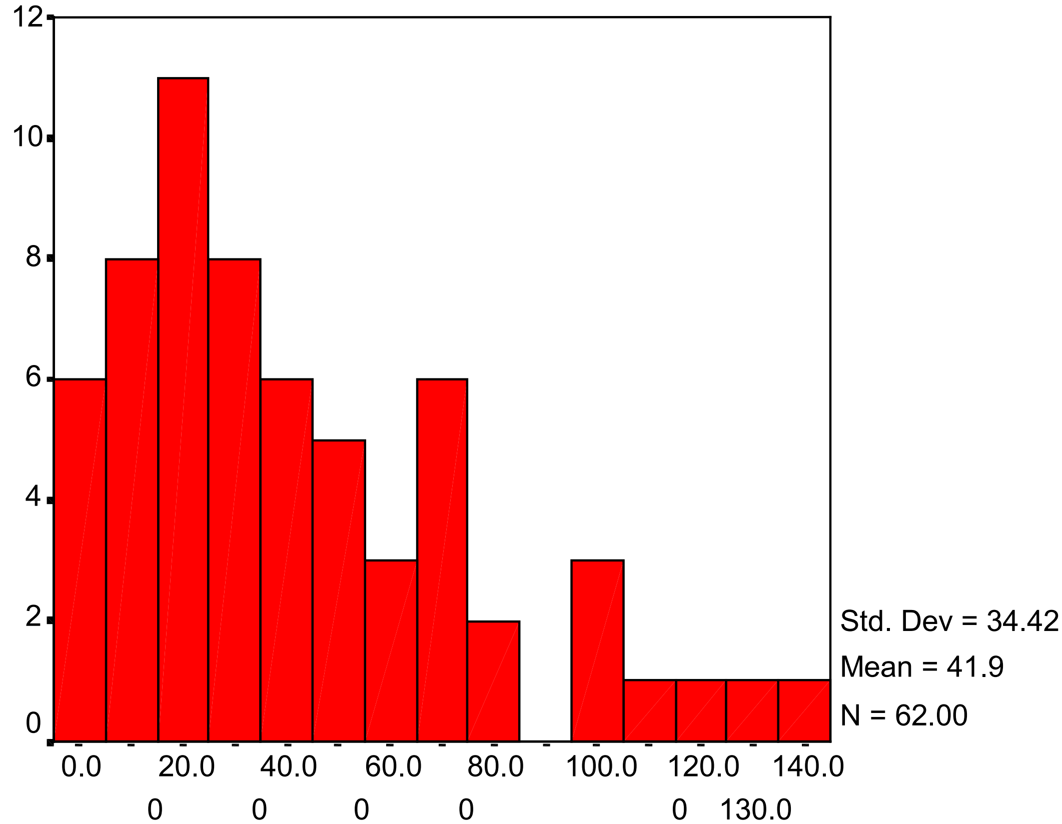
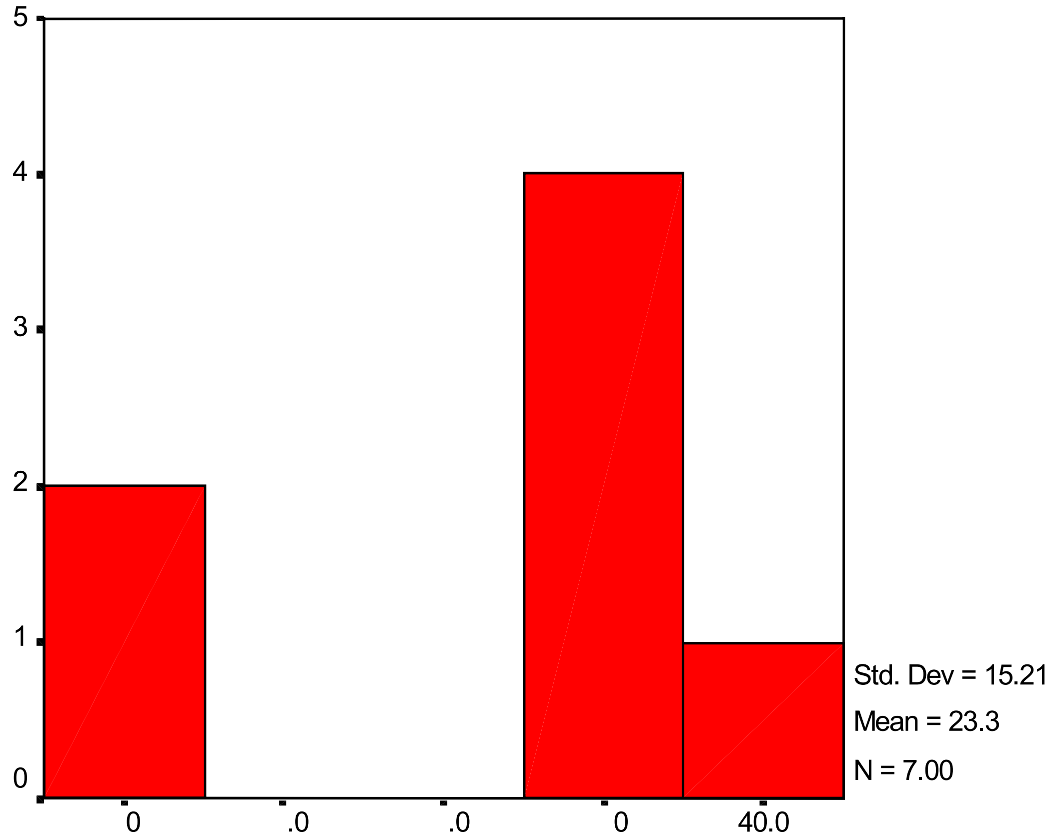


Figure 4.1E Histogram of sighting frequency of Wildpig in distance classes of 10mts



Densities of Ungulates in Panna National Park

Table 4.1 (A –H)

(A) *Densities of ungulates on transect # 1, Length = 2 Km, disturbed plateau.*

	Sambar	Chinkara	Nilgai
Density/ km^2	1.25 (8.75)	4.30 (7.031)	1.56 (3.125)
n	3 (14)	11 (20)	7 (11)
Effort (Km)	16	16	16
C.V	185.16 (151.96)	54.11 (102.9)	151.19 (141.5)

(B) *Densities of ungulates on transect # 2, Length = 2 Km, disturbed hill.*

	Sambar	Nilgai	Chinkara	Wildpig
Density/ km^2	0.63 (1.429)	1.17 (2.678)	0.39 (2.3623)	1.60 (2.75)
N	1 (2)	3 (6)	1 (2)	2 (3)
Effort (Km)	14	14	14	14
C.V	302.37 (264.6)	142.53 (141.75)	302.37 (264.58)	195.18 (183.59)

(C) *Densities of ungulates on transect #3.1 & 3.2 (Length of 3.1 = 1 Km & length of 3.2 = 1 Km) Disturbed plateau.*

Transect 3.1	Chinkara	Nilgai
Density/ km^2	8.49 (10.714)	0.44 (0.893)
N	18 (40)	1 (2)
Effort (Km)	14	14
C.V	46.17 (60.381)	264.58 (264.6)
Transect 3.2		
Density/ km^2	4.01 (5.80)	0.90 (0.90)
N	11 (16)	2 (2)
Effort (Km)		
C.V	132.55 (109.59)	170.78 (170.58)

**** Numbers within parentheses are individual densities, individuals encountered on transects and their associated CV's respectively; n = number of groups (individuals) encountered on transects.**

(D) *Densities of ungulates on transect #4.1& 4.2 (Length of 4.1 = 1 Km & length of 4.2 = 1 Km); Less disturbed plateau.*

Transect 4.1	Nilgai	Chinkara
Density/ km^2	3.13 (10.268)	3.570 (3.977)
N	7 (22)	8 (9)
Effort (Km)	14	14
C.V	81.64 (105.01)	78.72 (84.213)
Transect 4.2		
Density/ km^2	1.33 (1.33)	0.44 (0.44)
n	3 (3)	1 (1)
Effort (Km)	14	14
C.V	124.72 (124.72)	264.57 (264.575)

(E) *Densities of ungulates on transect #5 (Length of transect 5 = 2 Km.), Disturbed plateau.*

	Sambar	Nilgai	Chinkara
Density/ km^2	0.56 (1.111)	2.78 (4.16)	1.39 (2.083)
n	1 (2)	7 (12)	5 (7)
Effort (Km)	18	18	18
C.V	300 (300)	87.94 (140.31)	163.46 (167.71)

(F) *Densities of ungulates on transect #6 (Length of transect 6 = 2 Km), Disturbed plateau*

	Chinkara	Wildpig	Nilgai
Density/ km^2	1.04 (1.04)	0.35 (2.85)	0.69 (1.042)
n	3 (3)	1 (4)	2 (3)
Effort (Km)	18	18	18
C.V	150.0 (150.0)	300.0 (300.01)	198.0 (212.1)

**** Numbers within parentheses are individual densities, individuals encountered on transects and their associated CV's respectively; n = number of groups (individuals) encountered on transects.**

(G) *Densities of ungulates on transect #7 (length of transect 7= 2 Km.)*

Undisturbed plateau, relocated village site.

	Sambar	Chital	Nilgai	Wildpig	Chinkara
Density/ km^2	3.12 (5.62)	9.37 (22.5)	7.81 (11.72)	2.40 (9.74)	1.56 (1.17)
n	6 (17)	18 (49)	27 (49)	2 (11)	6 (9)
Effort (Km)	16	16	16	16	16
C.V	82.80 (129.6)	119.16 (126.8)	77.09 (114.7)	138.01 (227.9)	213.83 (282.84)

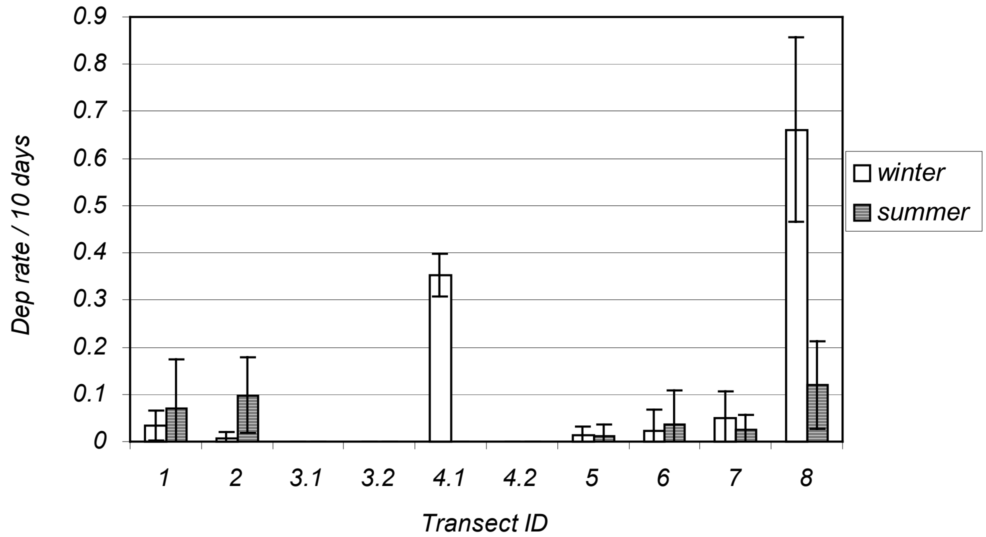
(H) *Densities of ungulates on transect #8 (length of transect 8 = 2 Km.)*

Undisturbed hill transects.

	Sambar
Density/ km^2	16.44 (30.63)
n	26 (53)
Effort (Km)	16
C.V	260.07 (93.36)

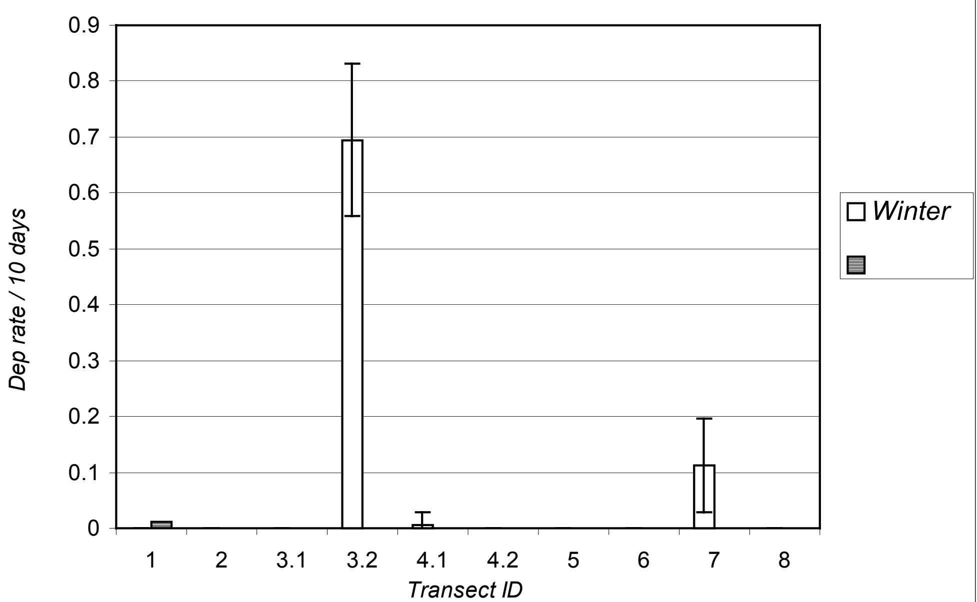
**** Numbers within parentheses are individual densities, individuals encountered on transects and their associated CV's respectively; n = number of groups (individuals) encountered on transects.**

Figure 4.3A - Pellet group deposition rate for Sambar, seasonwise. Error bars represent confidence intervals at (alpha = 0.05)



Transect No. 1, 3.1, 3.2, 5, 6 = Disturbed plateau habitat.
Transect No. 4.1, 4.2 = Less disturbed plateau habitat.
Transect No. 2 = Disturbed hill habitat.
Transect No. 8 = Undisturbed hill habitat.

Figure 4.3 B -Pellet group deposition rate for Chital across both seasons. Error bars represent confidence interval at (alpha = 0.05)



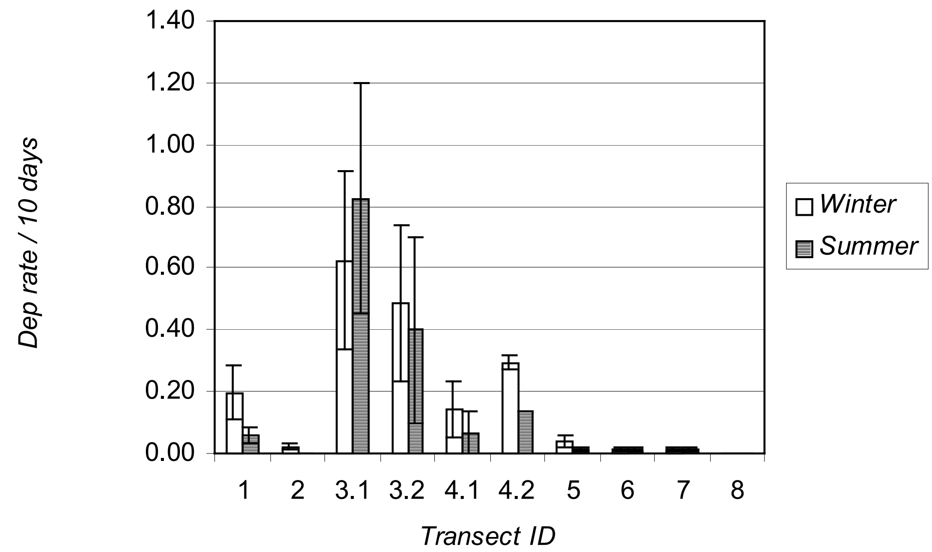


Figure 4.3 C- Pellet group deposition rate for Chinkara across both seasons. Error bars represent confidence interval at (alpha = 0.5)

Transect No. 1, 3.1, 3.2, 5, 6 = Disturbed plateau habitat
Transect No. 4.1, 4.2 = Less disturbed plateau habitat
Transect No. 2 = Disturbed hill habitat
Transect No. 8 = Undisturbed hill habitat.

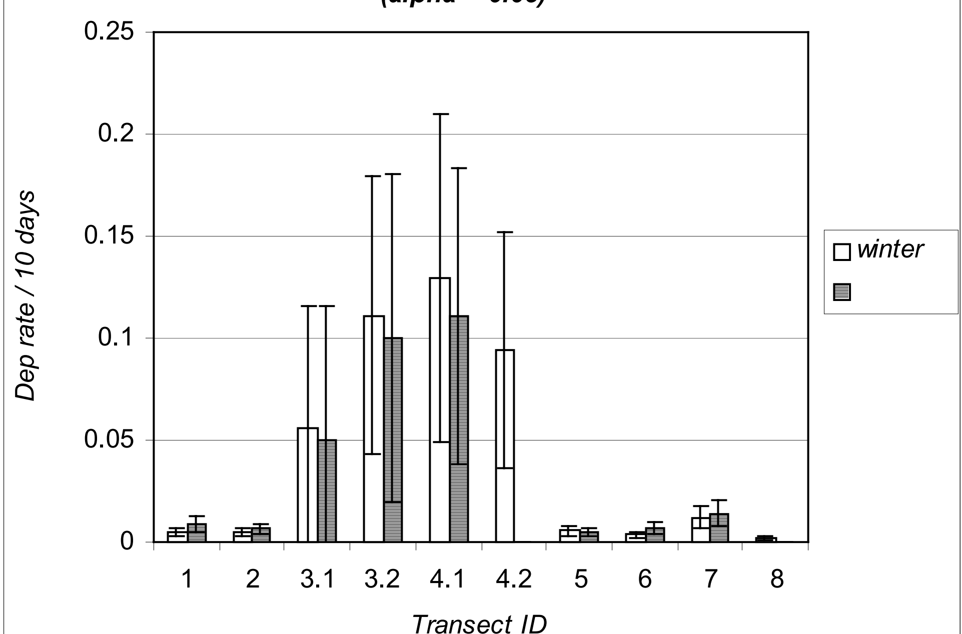
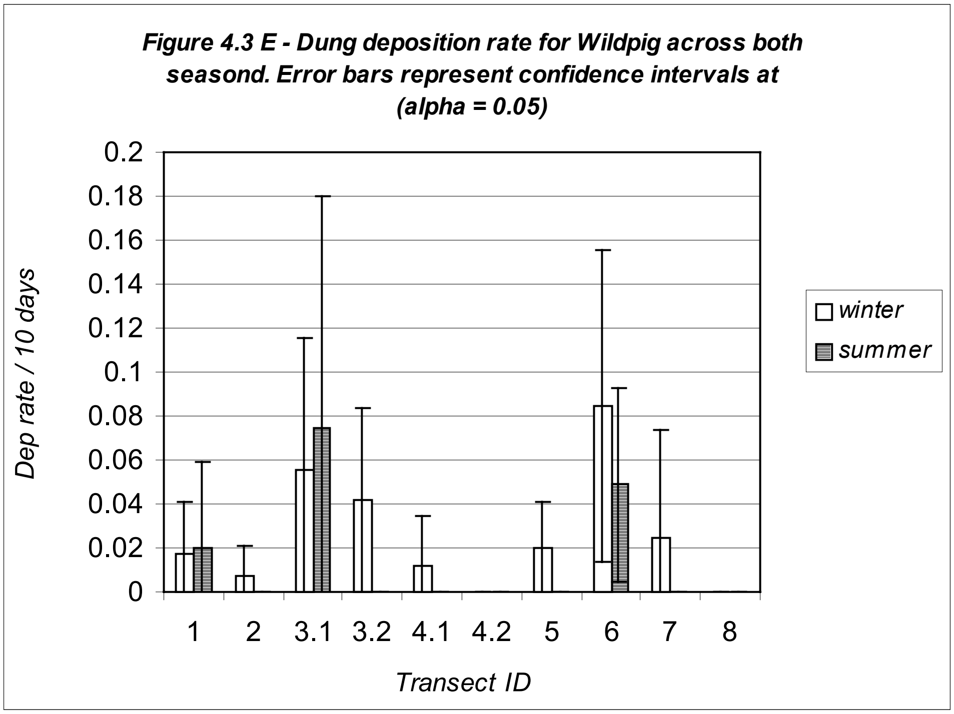
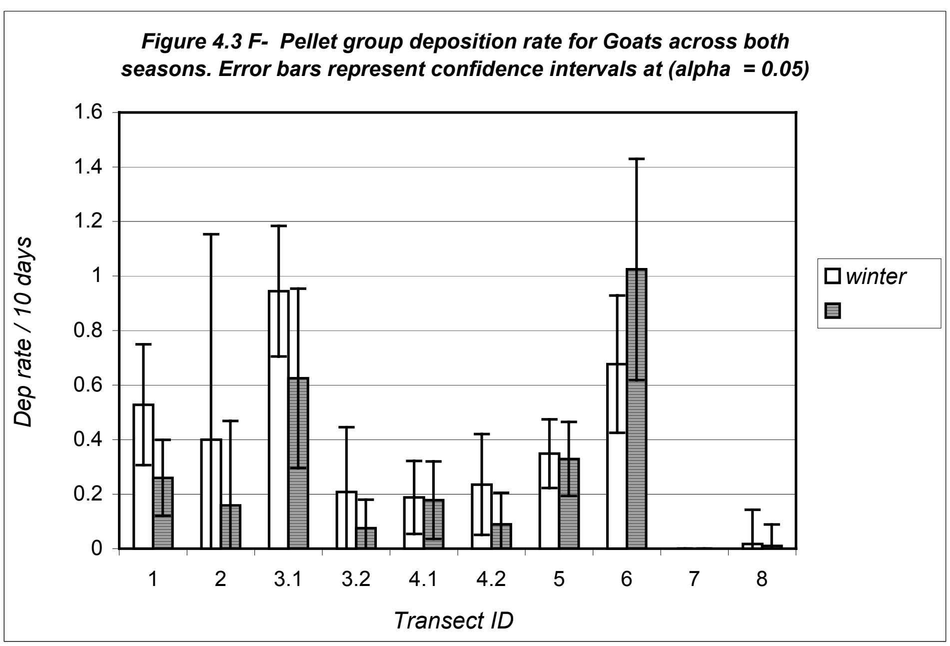
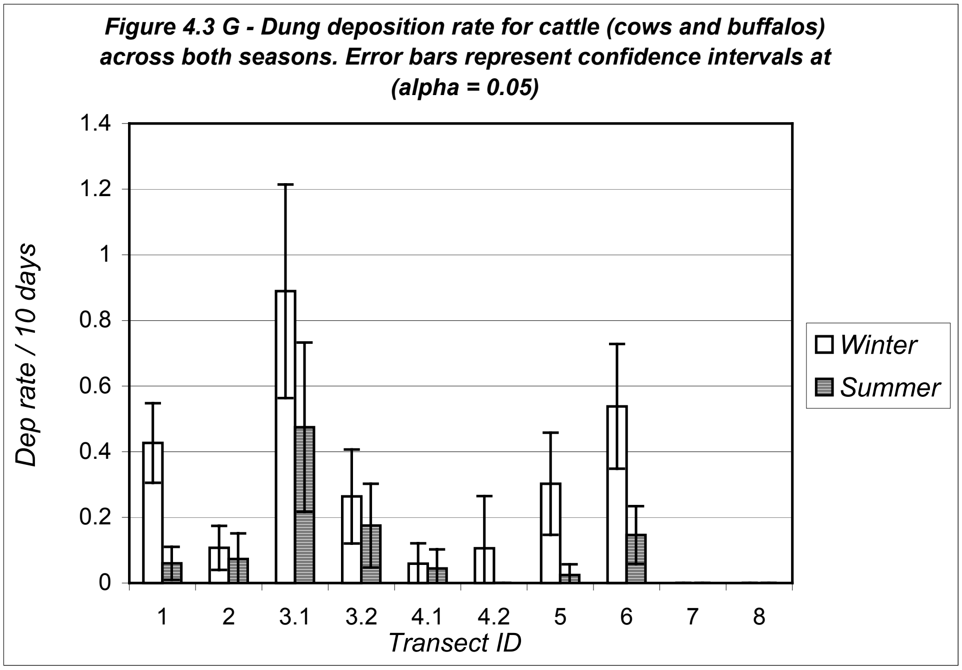


Figure 4.3 D - Pellet grout depostion rate for Nilgai acorss both seasons. Error bars represent confidence intervals at (alpha = 0.05)



Transect No. 1, 3.1, 3.2, 5, 6 = Disturbed plateau habitat.
Transect No. 4.1, 4.2 = Less disturbed plateau habitat.
Transect No. 2 = Disturbed hill habitat.
Transect No. 8 = Undisturbed hill habitat.





Transect No. 1, 3.1, 3.2, 5, 6 = Disturbed plateau habitats
Transect No. 4.1, 4.2 = Less disturbed plateau habitats.
Transect No. 2 = Disturbed hill habitat
Transect No. 8 = Undisturbed hill habitat.

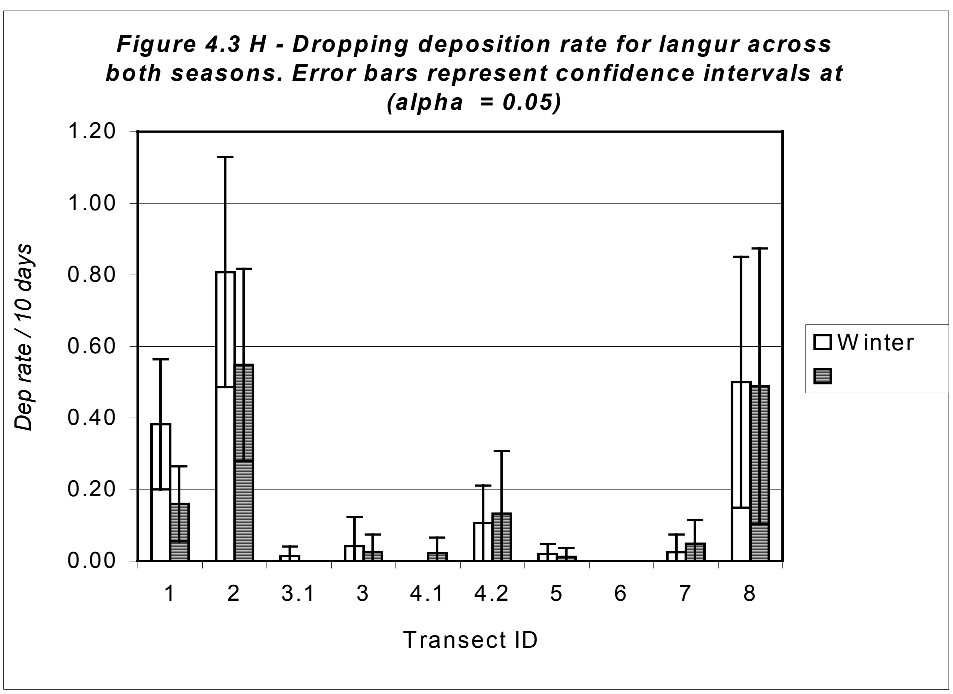


Table 4.2. Representing differences between pairs of transects with respect to dung deposition rate of cattle and Buffaloes

Transect ID	1	2	3.1	3.2	4.1	4.2	5	6	7	8
1			*						*	*
2			*					*		
3.1	*	*	-	*	*	*	*	*	*	*
3.2			*						*	*
4.1			*					*		
4.2			*					*		
5			*					*		
6		*	*		*	*	*	-	*	*
7	*		*	*				*		
8	*		*	*	*	*		*		

*** Significance difference (alpha = 0.1) between transects with respect to pellet deposition rates**

Table 4.3A: The component matrix showing correlation of variables with each component.

Variables	Component		
	1	2	3
Canopy cover	.767	.128	.270
Tree density	.780	-.033	0.051
Tree sp richness	.389	-.188	-.068
Distance to Water	.063	-.152	-.805
Woodcut	.160	.535	.198
Grass weight	-.135	-.631	-.277
Shrub density	.525	.113	-.025
Visibility	-.465	.154	.516
Goat pell. Dep. rate	-.100	.766	-.051
Cow	-.263	.752	-.233
Terrain	.422	-.158	.739

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 5 iterations.

Table 4.3 B The proportion for each variable explained by all the components

	Extraction
Canopy cover	.677
Tree density	.611
Tree spp. richness	.191
Distance to water	.675
Wood cut	.351
Grass weight	.492
Shrub density	.289
Visibility	.506
Goat pell. Dep.rate	.599
Cow dung dep. Rate	.690
Terrain	.750

Extraction Method: ***Principal Component Analysis.***

Table 4.3C Total Variance Explained by each of the 11 principle components

	Initial Eigenvalues			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.368	21.529	21.529	2.368	21.529	21.529	2.143	19.485	19.485
2	2.077	18.878	40.407	2.077	18.878	40.407	1.974	17.942	37.428
3	1.388	12.615	53.022	1.388	12.615	53.022	1.715	15.594	53.022
4	.929	8.448	61.470						
5	.881	8.012	69.482						
6	.795	7.223	76.705						
7	.724	6.586	83.291						
8	.639	5.805	89.096						
9	.440	3.999	93.095						
10	.424	3.851	96.946						
11	.336	3.054	100.000						

*Extraction Method**: Principal Component Analysis***

Figure 4. 4 A Ordination of transects based on habitat quality and disturbance characteristics on the principle component axes

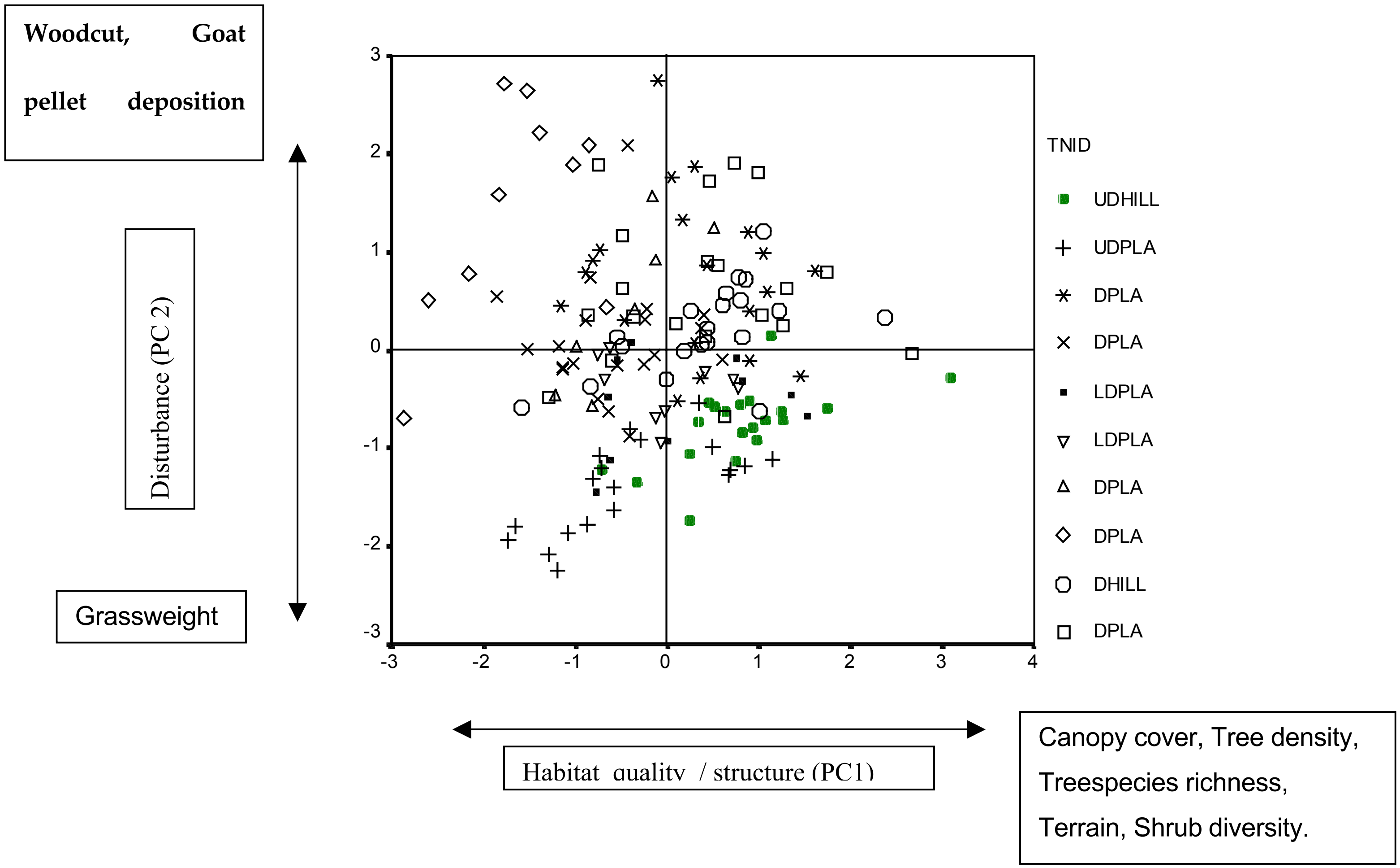


Figure 4.4 B – Ordination of transects based on habitat quality and structural characteristics on the principle component axes

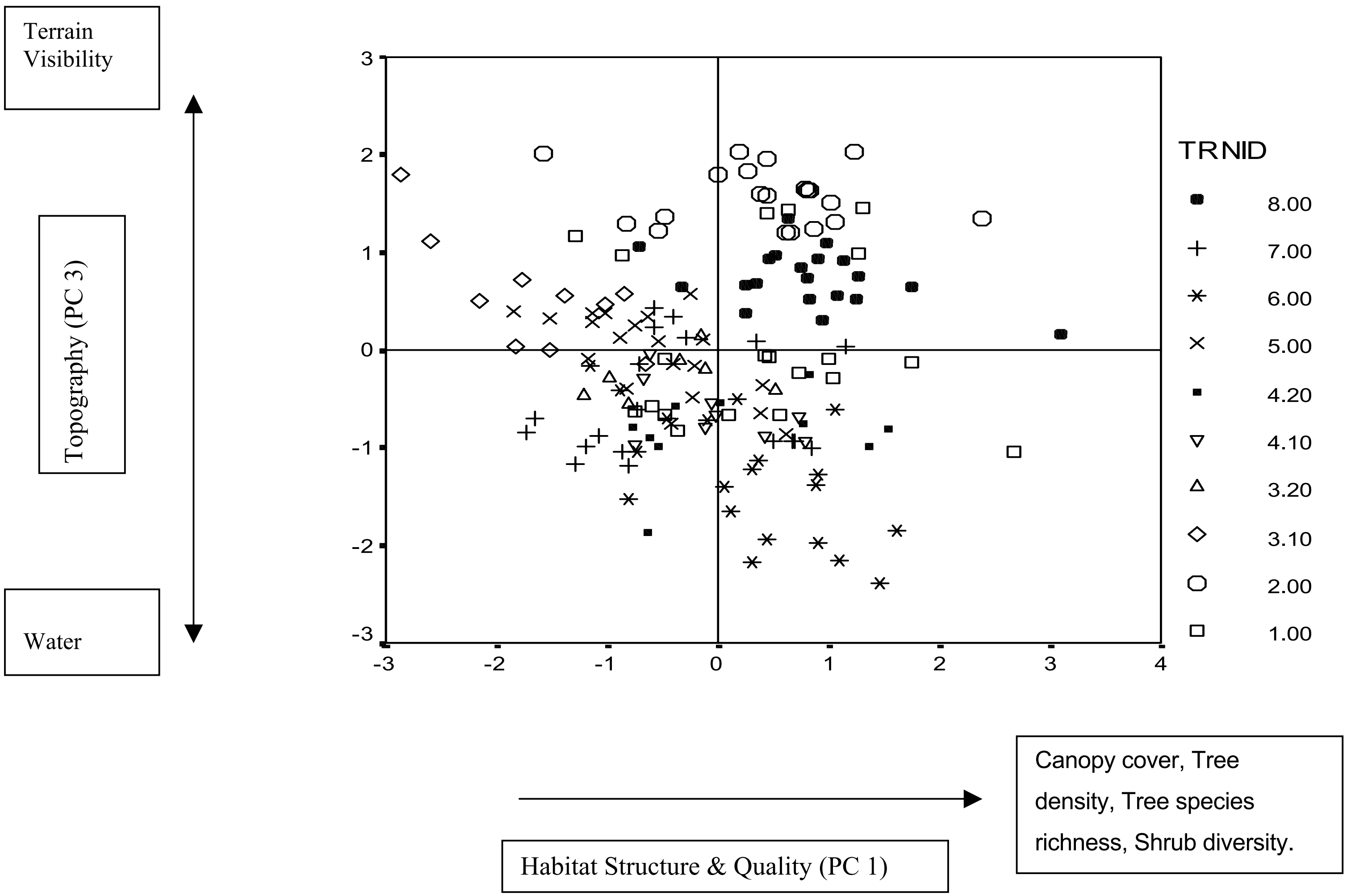


FIGURE 4.2. Diagram represents a composite picture of the extent of overlap between

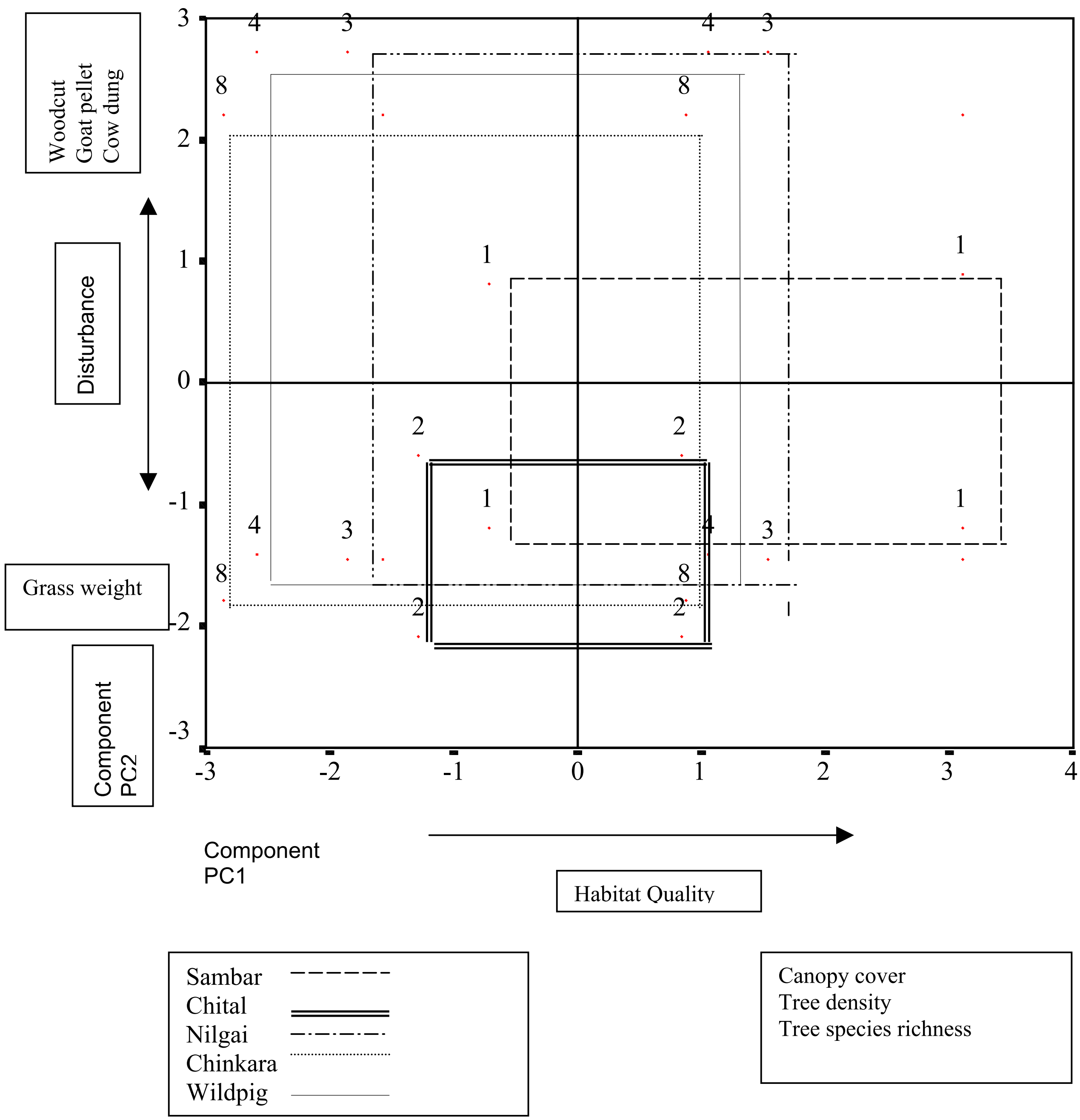


Table 4.4 - A

Multiple comparison between transects with reference to habitat quality and structure (scores for PC1)

TN ID	1	2	3.1	3.2	4.1	4.2	5	6	7	8
1	-		*				*		*	
2		-	*				*		*	
3.1	*	*	-	*	*	*	*	*	*	*
3.2			*	-						*
4.1			*		-					
4.2			*			-				
5	*	*	*				-	*		*
6			*				*	-		
7	*	*	*						-	*
8			*	*			*		*	-

* Significance at < 0.1
The above matrix is a representation of how transects differ from each other or group together with respect to the habitat structure and quality variables

Table 4.4 -B

Multiple comparisons between transects with reference to disturbance (scores for PC2)

TN ID	1	2	3.1	3.2	4.1	4.2	5	6	7	8
1	-		*		*	*			*	*
2		-	*			*			*	*
3.1	*	*	-	*	*	*	*		*	*
3.2			*	-		*			*	*
4.1	*		*		-			*	*	
4.2	*	*	*	*		-		*	*	
5			*				-	*	*	*
6					*	*	*	-	*	*
7	*	*	*	*	*	*	*	*	-	*
8	*	*	*	*			*	*	*	-

*Significant at < 0.1.
The above matrix is a representation of how the transects differ from each other or group together with respect to the disturbance variables

Table 4.5 Correlation matrix of dung and dropping deposition rate with factor scores of the first 3 principle components

SPECIES		*REGR factor score 1*	*REGR factor score 2*	*REGR factor score 3*
CHITAL	Pearson Correlation	-.055	-.202	-.133
	Sig. (2-tailed)	.498	.012	.100
	N	155	155	155
NILGAI	Pearson Correlation	-.097	-.165	-.032
	Sig. (2-tailed)	.228	.041	.694
	N	155	155	155
CHINKARA	Pearson Correlation	**-.342**	**.375**	.108
	Sig. (2-tailed)	.000	.000	.181
	N	155	155	155
WILDPIG	Pearson Correlation	-.145	.152	-.038
	Sig. (2-tailed)	.073	.058	.637
	N	155	155	155
LANGUR	Pearson Correlation	.217	-.034	**.487**
	Sig. (2-tailed)	.007	.679	.000
	N	155	155	155
SAMBAR	Pearson Correlation	**.353**	-.245	.188
	Sig. (2-tailed)	.000	.002	.019
	N	155	155	155

5. DISCUSSION

Does habitat occupancy of tiger prey species vary across a gradient of anthropogenic disturbance? The findings of this study reveal that different levels of disturbance have a significant effect on the habitat occupancy of the various species of tiger prey studied.

Sambar

Sambar (*Cervus unicolor*) is the largest cervid in Asia and is an element of the Indo-Malayan region (Corbett and Hill 1992). Having evolved largely in closed forested environments Sambar shows affinities to these attributes even in other biomes into which it has radiated. In Bandipur, Johnsingh (1983) observed that their abundance and distribution appear to be influenced by dense cover, water and by their ability to subsist on a wider variety of plants. Sambar is also known to use both open grassland and scrub areas as well as forested areas. The use of the former is largely restricted to the night when it comes out from its daytime rest sites to browse and graze (Eisenberg and Lockhart 1972). As compared to Chital, the other cervid studied, Sambar shows a wider variety of habitat use (See Fig. 4.2). Johnsingh (1983) observes that Sambar was the most widely distributed large prey species in his study area.

Data from the present study also reflects this variety in habitat use though the intensities of use vary between the different disturbance regimes considered. In Panna, amongst the areas sampled in the present study, the undisturbed hill transects with individual density of 30.63/sq.km was used most. The next lower densities were on the undisturbed plateau transect radiating from the relocated village site of Badgadi (5.65 individuals / sq. Km.). The general vicinity of the relocated village, with its interdigitation of grassland and woodland and also the presence of a perennial water source, provided an ideal area for ungulates. Density on the disturbed hill transect is 1.43/sq.km, while densities on the disturbed plateau transects on which

Sambar was recorded, are 8.75 / sq. km on T1 and 1.11/sq. km on T5, near Talgaon village. As already described in Section 2.7, T1 is comprised partly of a flat region which follows a gradual ascent toward the escarpment, the section of the transect where all the Sambar sightings of this transect was observed. The comparison between abundance of Sambar on the undisturbed hill and plateau transects brings out the strong affinity of Sambar to hilly terrain. This underscores the importance of protecting hill habitats in Panna for the Sambar population.

Preliminary work on food habits of tigers in Panna reported in Gogate and Chundawat (1997) show that Sambar is preyed upon at a higher proportion than its availability (P availability 0.32, P used 0.37) and that it also constitutes a substantial portion of the tiger's food (24.4% in terms of number). That is to say, it is not only a preferred prey but also a principal prey of tigers in Panna.

Chital

Chital (*Cervus axis*) presents an even more drastic distribution pattern. Of the gradient of disturbances considered chital were recorded through direct sightings only in one habitat, namely the undisturbed plateau transect at Badgadi (T 7) (Table 4.1 A – E). Data from pellet counts though (Table 4.3 B) reveals the presence of chital on four transects with the highest abundance on T 3.2, a disturbed plateau transect radiating form Hinota village that has no record of chital by the direct sighting method. The actual observations of all the pellet groups contributing to this observed deposition rate was made from one particular plot during one particular counting event. This count, on 30th January 1999, was conducted about 15 days following a fire in the region.

Interestingly Chital pellets were not recorded on any of the following counts on 3rd March, 23rd March and 11th April, nor on any of the counts prior to the fire. The fire prompted the sprouting of grass better forage quality. Moe and Wegge (1997) have reported that Chital have been reported to prefer burned plots to those that are neither cut nor burned. Burned plots also show drastic increases in Chital densities over a very short time when compared to cut areas.

However, another point one has to consider is the fall in the soil moisture as the dry season progresses and its impact on grass growth after fires that occur later in the season or the subsequent growth of grass after the first new sprouts have been cropped. MacNaughton (1985) reported from the Serengeti that fire only appears to have a weak stimulation of productivity in the wet season, immediately following a dry fire. Due to this ambiguity, it may be justified to consider the deposition rates observed on this transect (T3.2) as an odd event and exempt it from interpretations of habitat occupancy patterns. Keeping this ambiguity in mind, in this particular instance, we consider data of dung deposition rates only as indicators of the range of areas occupied and not as a comparison of intensity of use.

For a comparison of different habitats in terms of habitat occupancy by chital, density estimates reveal a clear preference for the undisturbed plateau T 7 (Fig. 2.1), which is a relocated village site evacuated in 1990. This transect shows a similarity with the disturbed plateau transects with respect to the habitat structure variables. On the habitat disturbance axis of the habitat ordination though, T 7 stands out in sharp contrast to all the other transects. From figure 4.4 A we see that it is the 'grass weight' variable that separates T7 from the rest of the transects that are similar to it in terms of the habitat structure. The high 'grass weight' on this transect is largely a function of the cessation of grazing pressure following the relocation of the village. Khan et al. (1996) have documented similar patterns in the case of Gir following the removal of a sizeable number of livestock. The agriculture fields of Badgadi have all been converted into grasslands and there is a very clear pattern of interdigitation of the forest and grassland that is a favourable habitat for chital. Eisenberg and Lockhart (1972) also make such an observation. Also being a past site of human habitation this area has a large number of unused wells dotting the entire area. A pond is also found in the area that was probably the village pond. Therefore both with respect to structure, quality and water availability Badgadi provides ideal conditions for Chital.

Gogate and Chundawat (1997) have found chital to be the most preferred prey in Panna (in terms of number) being utilised far in excess of its availability (prop. available = 0.06, prop utilised = 0.14, n=45). Karanth (1995) found that chital is not preferred though it forms the principal prey species. Johnsingh (1983) also found such a trend. It is only in the case of Panna that chital has been reported as the preferred prey whereas in all other cases so far chital has been reported to be the principal prey. This is probably explained by the absence of habitats suitable for the proliferation of chital. Hence in Panna there is a need to create and maintain such habitats. To this end, management plans could focus on maintaining the relocated village sites at a seral stage where the edge habitat due to the interdigitation of both grassland and woodland is maximised.

Nilgai

Nilgai (*Boselaphus tragocamelus*), unlike sambar and chital is not restricted to any particular habitat (Fig. 4.2). The results show considerable variation in abundance estimates of nilgai between different habitats and methods. From direct sightings (Table 4.1) the undisturbed plateau area of Badgadi shows the highest densities. While a consideration of dung deposition rates (Fig. 4.3 D) show that this habitat has one of the lowest deposition rates whereas the less disturbed plateau transects bordering Hinota village are all associated with high deposition rates.

An important result of the potential for crop depredation by animals in the agricultural areas adjoining the park is that it attracts animals to the fringes of the forest. And it is reasonable to speculate that move away from the fringes, back into the park, as the day begins and people and livestock start coming out into these parts of the forest. Such a movement pattern could explain the difference in our observations between different habitats and methods, as we would be less likely to encounter nilgai through the direct sampling in the fringe areas. Thus, this is a case where the use of indirect sampling methods like pellet group counts can reveal useful information.

Gogate and Chundawat (1997) report that in Panna, nilgai and sambar are found in equal proportion in the tiger's diet (24.4% in terms of number). Nilgai however is found to be less preferred in relation to availability as compared to chital and sambar, both of which are reported to be preferred. Therefore although nilgai contributes substantially to the tiger's prey base in Panna, it may not be an ideal situation. Nilgai are found in open areas or areas associated with high levels of disturbance. Such open/disturbed areas even if used by tigers may not be suitable habitat for breeding (Schaller 1967) because the hunting success of large felids is intricately connected with the amount of hunting cover available (Krukk, 1986; Stander and Albon 1993). For a mother nursing cubs, habitats conducive to hunt successfully enough to feed herself as well as her growing cubs is of prime importance. Therefore, cervids having evolved in closed forested habitats that offer sufficient cover to hunt by ambush, are preferred as prey by tigers.

In Panna however nilgai are distributed over wide range of habitats (Fig. 4.2) that are open and appears to be catering to a substantial proportion (0.35 in terms of number) of the tiger's diet Gogate and Chundawat (1997). In the absence of a wide distribution of sambar and chital (as compared to nilgai) the Nilgai's wide distribution across the entire gradient of disturbance regimes is probably of great importance for dispersing tigers or transient individuals restricted to these poor quality habitats. This situation while no doubt beneficial is only likely to serve as a foothold for tigers but not provide suitable conditions for them to thrive.

Wild Pig

Wild pig (*Sus scrofa*) is a generalist species and is adapted to a range of habitats, such as forests, secondary thickets, woodlands and grasslands. Its feeding habits are omnivorous, adjusting to the seasonal variation in the availability of various food resources.

This study found that wild pig, like nilgai, have a wide range of habitat occupancy (Fig. 4.2, and Fig. 4.3 E). The dung deposition rate reveals a peak on 2 of the disturbed plateau transects T3.1 and T6. From the map of the study area (Fig. 2.1), we see T 3.1 runs parallel to the village and T6 radiates from the immediate vicinity of a village. The parts of Hinota and Talgaon village bordering these transects are agricultural fields. Therefore, an explanation for the observed peaks in dung deposition rate on these two transects is the proximity to agriculture fields and the attraction of crop raiding (Schultz 1986). This might explain the otherwise largely similar level of dung deposition rate across the other habitats.

Rao (1991) reported density estimates from Sariska Tiger Reserve, Rajasthan in the range of 18.7 ± 12.3 for winter and 26 ± 15.9 (± SE) for summer. Both these estimates are much higher than what is found in our study along the undisturbed plateau transects 9.74 / Km^2.

Studies at Panna show that though wild pig is selected more (prop. available. .03, prop. utilised = 0.06; in terms of numbers) in proportion to availability Gogate and Chundawat (1996), it does not constitute a substantial portion of the prey of the tiger. This is largely because of its low overall densities. But the fact that it is preferred, inspite of its low densities across all habitats is important, because if the densities observed are an effect of the inherent quality feature of the habitat, one cannot do much, however if these densities are an effect of the factors under human influence, then management actions can be targeted at mitigating these effects.

Chinkara

Chinkara (*Gazella gazella benneti*) are known to use wastelands crisscrossed by dry streambeds, scattered bush and woodland (Roberts 1977). The results of this study show that chinkara occupy a wide range of habitats (Fig. 4.2). In this study the results from both pellet deposition rates and density estimates from line transects corroborate each other. This is quite intuitive for a species, which because of its preference for extremely open habitats has got accustomed to human and livestock. Random observations of chinkara in the undisturbed plateau transect show that they are extremely shy, when compared with those found around habitation.

The highest densities and pellet deposition rates for chinkara are found on the disturbed plateau transect bordering Hinota village (T 3.1). This transect stands out the most on the disturbance axis (Fig. 4.4 A). Proximity to agricultural fields is a possible factor that is responsible for high densities (Schultz 1986). Comparing this with the disturbed plateau transect radiating from Talgaon village (T6), another transect that is similar in its proximity to agriculture, shows a different pattern in chinkara abundance. Both these transects are similar on the disturbance axis. But they vary slightly in relation to structure (Fig. 4.4A) due to the extensive spread of lantana bushes along the initial sections of this transect which also results in lower visibility on T6. But comparisons of pellet deposition rate data, appears to corroborate the low densities observed. Therefore the low densities of chinkara are not necessarily an effect of lower detectability or visibility in this habitat. Also species detectability of chinkara did not vary between transects (Section 4.1.1). The observation that Chinkara prefer open areas as an anti-predatory strategy probably explains the use of such habitats.

Langur

Hanuman langur (*Presbytis entellus*) shows a wide distribution across the Indian sub-continent being reported from an altitude in the range of 3600 m in the Himalayas and south into peninsular India and Srilanka. But unlike its congeners Langur, does not usually inhabit evergreen forests (Newton 1984).

The highest abundance of Langur in the present study was reported form the hill transects. Disturbance does not appear to have a significant effect on langur habitat occupancy. With the disturbed hill (T2) transect showing higher abundance of langur as compared to the control hill transect (T8). Being folivores who spend much time on tree tops they are not affected drastically by disturbances on the ground like grazing, but are probably more dependent on the tree species diversity and density of trees. Of course at high lopping intensities this might result in a significant difference in abundance between habitats. But at present lopping levels, although the habitats ordination differentiates between the two hill transects, habitat occupancy by langur does not seem to reflect this distinction. Further, langur is quite evenly distributed across all the other disturbance regimes (Fig. 4.3 H). The influence of water also appears to be important in influencing the distribution of langurs. The ordination diagram of transects shows that both the disturbed and undisturbed hill transect are associated strongly with reducing 'distance to water' with the disturbed hill transect having more number of water sources. Food habit studies of tigers reveals that langur are used less than available (prop. available =0.11, prop. used = 0.05 in terms of numbers).

Overlap of ungulate species in relation to the habitat quality

The overlap of species in terms of their association with habitat quality, structure and disturbance is depicted in Fig. 4.2. Chital shows a very localised distribution and a strong tendency to avoid disturbance. Sambar is slightly more wide-ranging and relatively more tolerant to disturbance than chital. This is because being a browser it does not have to compete directly with livestock, which are primarily grazers. Sambar also shows the strongest relationship with habitat quality and structure. The area of overlap between sambar and chital is the relocated village site at Badgadi. In sharp contrast to the cervids the antelopes, nilgai and chinkara, show a wide range of distribution that is strongly skewed towards open habitats and higher disturbance variables. Similar patter was observed for wild pig, which is an omnivore utilising wide range of food resources.

Significance for tiger conservation

As has already been discussed in the introduction a viable and abundant large mammalian prey population (particularly cervids) is a prerequisite for a viable population of tigers. In Panna the cumulative pressure on biomass resources of the park from numerous villages leaves little habitat left to sustain a large viable population of cervids and other ungulates.

The highest abundance of all the ungulate prey species during the study was recorded in the undisturbed relocated village site a habitat, which provides an ecotone of grassland and woodland apparently preferred by these cervids. Given the wide availability of prey in this area it tigers in Panna are reported to be prefer this area. The only successful cubbing of tiger in the last 3 years has taken place in this area (R. S. Chundawat pers. comm.).

Thus, if areas like Badgadi are maintained at the particular seral stage so as to sustain such high abundances of large to medium-bodied ungulate prey they can serve as small core areas within the park and act as source areas that facilitate the breeding and dispersal of tigers.

This study found disturbance to be an important factor contributing to low densities. The variables on the disturbance axis are grazing and browsing by livestock and cutting or lopping of wood. The proximate reasons often mentioned to explain such activities include 'lack of awareness' amongst the local population or the absence of 'social development' in the form of literacy, health or alternate livelihood opportunities. The perpetuation of these conditions no doubt heightens the dependence of a large number of people on the biomass resources of the forest.

However, the larger picture of conflict between livelihood activities, habitat loss and conservation objectives is a significantly more complex social phenomenon that is beyond the scope of this dissertation. I only wish to offer that this is a problem that requires serious consideration by ecologists, planners and social scientists to probe the larger questions of development and social change in India. To terminate the analysis of conservation at proximate causative factors is inadequate.

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APPENDIX

Density of all species pooled (i.e. total prey density) on individual transects

Habitat	Model	AIC	DI/ Km^2	LCL	UCL	%CV	GOF-p	DF
TN1 Disturbed plateau	Uniform	170.99	15.556	4.22	57.25	30.99	0.49	2
TN2 *** Disturbed Hill	Negative Exponential	48.01	18.62	5.92	58.60	49.50	---	6
TN3.1 Disturbed Plateau	Negative Exponential	189.16	14.833	5.4451	40.40	40.51	0.83	5
TN3.2 Disturbed Plateau	Negative Exponential	107.06	41.859	14.965	117.08	47.92	0.67	9
TN4.1 Less Disturbed Plateau	Uniform	119.76	19.694	7.0552	54.97	38.27	0.43	4
TN4.2 Less Disturbed Plateau	Uniform	40.597	2.8757	0.1021	80.94	26.73	0.65	1
TN5 Disturbed Plateau	Uniform	117.43	11.201	4.6329	27.08	32.62	0.47	4
TN6 Disturbed Plateau	Uniform	43.064	3.193	1.094	9.319	40.06	0.17	4
TN 7 UndisturbedPlateau	Hazard Rate.	523.56	191.22	75.711	482.9	40.74	0.02	7
TN8 Undisturbed Hill	Negative Exponential.	199.16	39.791	15.255	103.7	38.63	0.17	5

***- Program Warning: "Do not expect reasonable results with such sample sizes".