Studies on the habitat ecology of gaur *Bos gaurus* (H. Smith) at Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park of the Western Ghats, Goa.

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In Zoology

By

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CERTIFICATE

This is to certify that I, the undersigned have incorporated all the improvements/modifications suggested by the examiners in the thesis entitled "Studies on the habitat ecology of gaur *Bos gaurus* (H. Smith) at Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park of the Western Ghats, Goa" before resubmitting the same.

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This is to certify that the thesis entitled "**Studies on the habitat ecology of gaur *Bos gaurus* (H. Smith) at Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park of the Western Ghats, Goa**" is an authentic work carried out by Suman D. Gad at Department of Zoology, Goa University, Goa under my supervision and guidance, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Zoology of Goa University and no part thereof has been presented before for any other degree in any University.

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DECLARATION

I hereby declare that the work incorporated in this thesis is original and is carried out in Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park and Department of Zoology, Goa University, Goa and it has not been submitted in part or in full for any degree of any other university.

Place:

Date:

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LIST OF ABBREVIATIONS

1. BMWLS and MNP - Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park
2. IUCN - International Union for Conservation of Nature and Natural Resources
3. CITES - Convention on the International Trade in Endangered Species of Wild Flora and Fauna
4. NTFP - Non Timber Forest Product
5. ADL - Acid Detergent Lignin
6. NDF - Neutral Detergent Fiber
7. ADF - Acid Detergent Fiber
8. CP - Crude Protein
9. ANOVA - Analysis of Variance
10. CV - Coefficient of Variation
11. CI - Confidence Interval
12. SE - Standard Error
13. SD - Standard Deviation
14. df- Degree of freedom
15. Rf - Relative frequency
16. ER - Encounter Rate
17. MDF- Moist Deciduous Forests
18. SEF - Semi-evergreen Forests
19. GRS - Grassland
20. EF - Evergreen Forests
21. MSL - Mean Sea Level.

INTRODUCTION

Ungulates, the hoofed mammals comprise one of the most successful and diverse group of large mammals alive today. The artiodactyls or even-toed ungulates, though can be traced as a distinct line back to the Eocene, may be considered as the latest mammalian herbivores, having radiated out chiefly in the Miocene and attained then, a dominance that has persisted to the present day (Ellerman and Morrison-Scot, 1951).

The artiodactyls are currently the most successful groups of large herbivores. An incredible diversity is seen in the approximately 220 members of these orders, which include swine, hippopotami, chevrotains, camels, musk deer, giraffes, deers, pronghorns and bovids. Humans have relied heavily upon this order, which has provided them with many domesticated species including cattle, pigs, goats and sheep. Many species have been introduced into areas outside of their natural range, including New Guinea, Australia and the islands of Oceania (Grizmek, 1990).

Gaur

Gaur (*Bos gaurus*), the state animal of Goa (locally called *Govo Redo),* is the tallest and most splendid specimens of wild oxen in the world. Belonging to the order Artiodactyla of family Bovidae, gaur is the largest living bovine confined to the oriental

biogeographic realm of the world. The ancestors of gaur are known to have evolved in Asia around 20 million years ago (Grizmek, 1990).

Gaur is one of the most impressive of wild cattle with its muscular built and striking light eyes. It is known to inhabit tropical woodlands, tropical monsoon and dry forests, lowlands and tropical rainforests. Their habitat is characterized by large, relatively undisturbed forest tracts, hilly terrain, availability of water, abundance of bamboo, grasses, shrubs and trees (Prater, 1971).

One of gaurs distinguishing features is the saddle like hump on their back. Adult males are shiny black with cream-colored leggings and rump patch whereas the young males and females are of medium to dark brown colour with the same markings. The body of the gaur is massive with a large hump at the shoulders, sturdy legs and a narrow dewlap under the chin and between the front legs. Gaurs have huge heads with a bulging forehead ridge between the horns, which are approximately 30 inches in length in the males.

Gaur feeds on dry grass, young shoots, ground herbs, small shrubs, bamboo and foliage (Prater, 1971). These ungulates share the ancestry of domestic cattle directly (Buchholtz, 1990) and are considered as important genetic reservoirs for maintaining or improving the quality of their domestic descendents in the tropics (National Research Council, 1983).

Gaurs are gregarious and known to move over wide ranges within forested tract (Schaller, 1967; Krishnan, 1972; Conry, 1989). Being the most massive of true cattle, with large biomass they are certain to play important roles in the dynamics of the forest ecosystems. With its majestic appearances, gaur is a charismatic wildlife, which used to be a prized trophy for hunters in the past and have enough appeals even today to the popular mind. Thus, its presence can add to the potentials of a forest patch for ecotourism significantly. All these information define gaur as one of the most important wild life resource that deserves the best conservation efforts.

Systematic position of *Bos gaurus*

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Artiodactyla
Family	Bovidae
Genus	*Bos*
Species	*gaurus*

International Commission on Zoological Nomenclature (2003) ruled that the name for this wild species is not valid by virtue of being antedated by the name based on the domestic form. Therefore, IUCN (2002) considers the wild species of gaur under *Bos gaurus*, while referring to the domestic form (Mithun, Mithan or Gayal) as *Bos frontalis*

Lambert, 1804. Traditionally, three subspecies of gaur have been recognized *Bos gaurus gaurus* in India, Nepal and Bhutan; *B. g. readei* in Myanmar (Burma), Southern China, Lao, Viet Nam, Cambodia and Thailand North of the Isthmus of Kra (Lydekker, 1903) and *B. g. hubbacki* in Thailand South of the Isthmus of Kra and in West Malaysia (Lydekker, 1907).

Groves and Grubb (National Research Council, 1983) concluded that there were only two subspecies viz. *Bos gaurus gaurus* in India and Nepal and *Bos gaurus laosiensis* in Myanmar (Burma), Lao, Vietnam, Cambodia, Thailand and West Malaysia. Later works by Groves (2003) also supports this division into two subspecies. Analysis of skull and horn measurements revealed little multivariate overlap between Indian and South-east Asian specimens. South-east Asian specimens are much bigger, with relatively shorter nasal bones, a less wide horn span and a narrower occiput. In South-east Asian specimens the ascending branch of the premaxilla generally does not reach the nasal whereas in Indian specimens it usually does.

Specimens from Bhutan, Chittagong (Bangladesh), Upper Chindwin (North Myanmar) and Mogok (North Myanmar) were intermediate, but tended more towards the South-east Asian type. The locations of these specimens suggest that the gaur in North-east India is also likely to be intermediate but more similar to South-east Asian animals than to the gaur in the rest of India. The extinct subspecies *B. g. sinhaleyus* survived in Sri Lanka into historic times (Grubb, 2005).

Threats to gaur

a) Habitat destruction

Habitat destruction by humans has threatened the survival of gaur throughout its range. Frequent clearance of the vegetation result in the fragmentation, isolated or pocketed populations. The main reasons for forest destruction are logging, expansion of agriculture, jhum or slash and burn shifting cultivation by the hill tribes, clearance for human settlements, large scale bamboo harvesting for large paper mills and mining (Choudhury, 2002).

b) Poaching

Poaching of gaur in the Indian subcontinent takes place for meat, mostly for local consumption. Although no official record is available, every year an unspecified number are shot outside protected areas, mostly in Central India and North-east India.

c) Diseases

Diseases such as foot and mouth (FMD), rinderpest and anthrax are regarded to be the greatest threat to gaur population (Areendran, 2000). Although FMD is the most frequent, rinderpest has taken the heaviest toll. Usually communicated by the domestic stock that grazes inside the forests, such outbreaks have taken a heavy toll from time to time. Several sub-populations of gaur in Bandipur-Mudumalai were nearly destroyed as a result of rinderpest in 1968 (Choudhury, 2002).

d) Insurgency

This problem affects the survival of gaur and other wildlife in different parts of India. Since the 1960's, insurgency by underground Guerrillas has been a feature of Nagaland and Mizoram until late 1980's. In the 1990's it spread to almost all the North-east, affecting many of the well known protected areas such as Manas, Balpakram, Gumti, Intanki and Sonai-Rupai. The naxalite movement has severely affected much of the gaur habitat in Central India. While the extremists themselves do not usually harm wildlife, others take advantage of the situation. The poorly equipped forest staff is no match for the heavily armed extremists with modern firearms (Choudhury, 2002).

e) Other problems

Straying into human habitations including farms and tea estates cause death of few animals every year. This is an important issue for gaur conservation because a major part of its habitat in South and North-eastern India has common borders with tea, coffee and rubber plantations (Choudhury, 2002). Accidental poisoning from pesticides used on tea estate is also a danger to the gaur.

Distribution and Population Estimates

a) Global distribution

The distribution of gaur includes the countries of Bangladesh, Bhutan, Cambodia, China, India, Lao People's Democratic Republic, Peninsular Malaysia, Myanmar, Nepal,

Thailand and Vietnam. The geographical distribution of the present-day gaurs approximately corresponds to the remaining large forested areas and the majority of the population is in India. The global population of gaur is estimated to be 13000-30000, with a population of mature individuals of 5200-18000 (Choudhury, 2002).

b) Distribution in India

The gaur (*Bos gaurus*) is found in three regions, South-western India, Central India and North-eastern India including Nepal, Bhutan, Bangladesh, Myanmar, Thailand, China, Laos, Cambodia, Vietnam and Malaysia (Ellerman and Morrison-Scot, 1951, Corbet and Hill, 1992 and Choudhury, 2002).

In South-west India, gaur occurs in Western Ghats including the Southern ranges of Nilgiris, Annamalais, the Cardamom hills and the adjacent plateau. It ranges from South-western Maharashtra through Goa, Karnataka, Tamil Nadu and Kerala (Prater, 1971, Choudhury, 2002). The approximate population of gaur is 9000-12000, about two-thirds of which is in protected areas. Karnataka has the largest population of gaur in India including some of the best gaur habitats such as Bandipur, Nagarhole and Bhadra. Other major areas are Periyar and Parambikulam in Kerala, Mudumalai and Annamalai in Tamil Nadu, Bhagvan Mahaveer Wildlife Sanctuary with Mollem National Park in Sanguem taluka of Goa and Radhanagri in Maharashtra (Choudhury, 2002).

In Central India gaur extends from Central parts of the Satpura range to the Chotanagpur plateau and to the Northern ranges of the Eastern Ghats. State-wise, it is

found in Maharashtra (Northern and Eastern areas), Andhra Pradesh (Northern areas), Madhya Pradesh (mainly Eastern and Southern areas), Chattisgarh, Jharkhand, Bihar (South-western corner) and Orissa. The approximate population of the gaur is 9000-14000, more than half of which is in the protected areas (Choudhury, 2002). Some important gaur habitats in this region are Melghat in Maharashtra, Kanha and Pench in Madhya Pradesh, Indravati in Chattisgarh, Palamau in Jharkhand and Simlipal in Orissa.

In the North-east the gaur is found in the Himalayan foothills from the Narayani river through North Bengal to the Siang river, in the Mishmi hills, Dapha Bum range, Patkai range, Naga hills, Barail range, Mizo hills, hill tracts of Chittagong, Tripura, Manipur and the Meghalaya plateau. The gaur is extinct in the plains of the Barak valley however it is still found in the parts of the Terai, *Duars* and Bramhaputra valley. The habitat in the North-east is contiguous with that in Bhutan, Bangladesh, Myanmar and to some extent Nepal. State-wise, the gaur is found in West Bengal in the Himalayan foothills and adjacent *bhabar* tract of the Darjeeling and Jalpaiguri districts (Choudhury, 2002).

The gaurs regularly move down to the plains, especially to the Jaldapara and Chapmari Sanctuaries and Gorumara National Park. In Assam, the gaur is found in the Himalayan foothills and adjacent *bhabar-terai* (locally called *Duars*) tract on the North bank of Bramhaputra river. Two isolated populations inhabit the Chakrashila Sanctuary of Dhubri-Kokrajhar districts and in Bhairab Pahar of Bongaingaon district. The

distribution of gaur in Nagaland is thin and scattered except for the Intanki Sanctuary and adjacent areas of Dimapur and Kohima districts and in the Saramati (Choudhury, 2002).

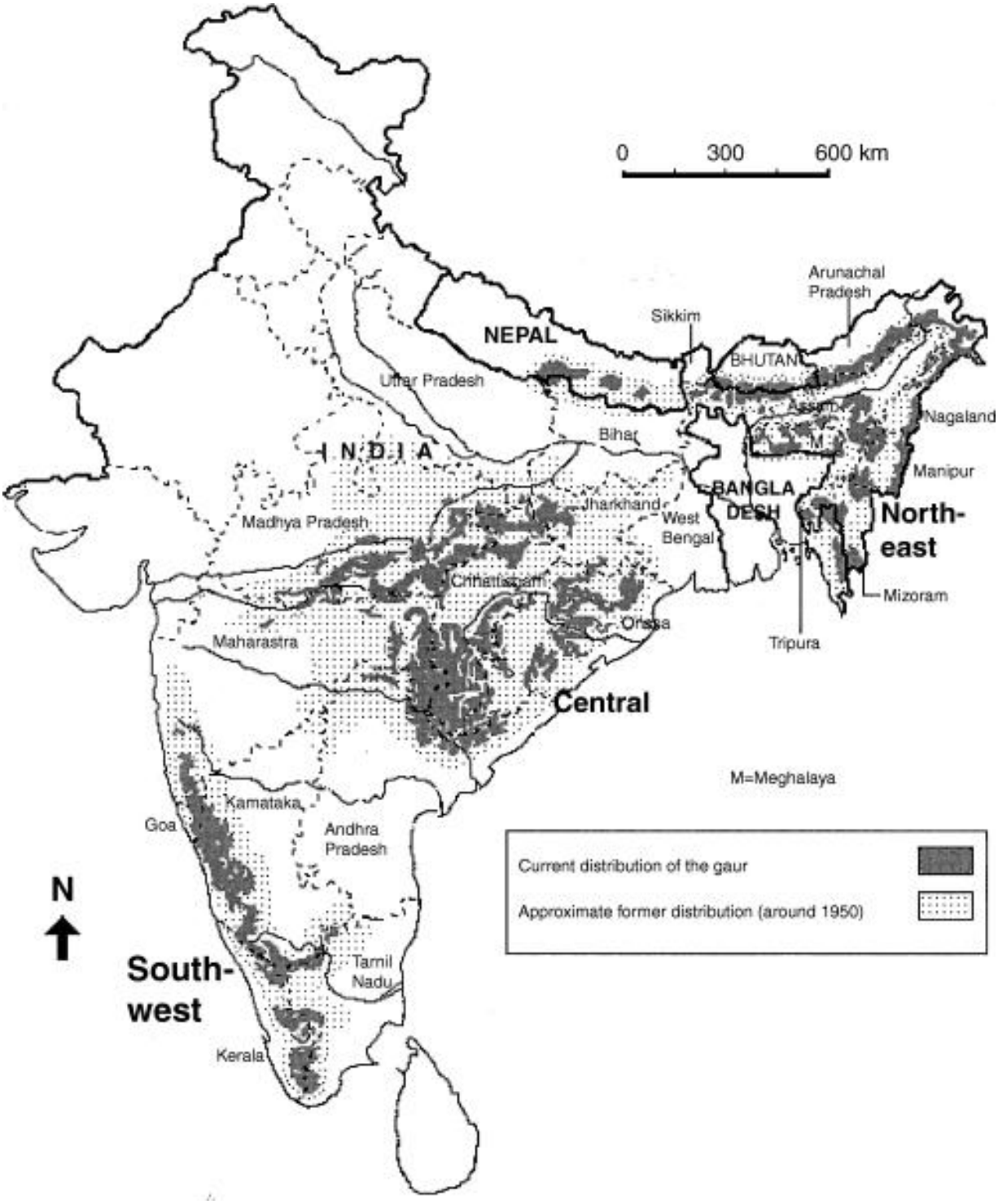
In Manipur the species is also very thinly distributed in the five hill districts. In Meghalaya, the gaur is mostly found in the South Garo hills and West Khasi hill districts. In Mizoram, the gaur is now mostly confined to the Dampha sanctuary, Mamit district, in the West and the Ngengpui Sanctuary, Lawngtlai district in the far South. There is a small pocket in the North-western tip of Bihar, now a protected area (Valmiki National Park/Tiger reserve) where a few gaurs occasionally come from the Royal Chitwan Park of Nepal (Choudhury, 2002).

The gaur was exterminated from Thattakad Wildlife Sanctuary in Kerala, Bandavgarh Tiger Reserve in Madhya Pradesh and Kanger Valley National Park in Chattisgarh in the last two decades (Sankar *et.al*, 2002).

Conservation Status

Gaur is listed as 'Vulnerable' according to the 2000 IUCN Red Data List (Hilton-Taylor, 2000). The IUCN rating is based on its overall decline of at least 20% population over the last three generations. It is listed as 'Endangered' by the U.S. Endangered Species Act and is listed in Appendix I by CITES (2003) which bans all international trade of gaur and gaur products.

Distribution of gaur population in India (Source:Choudhury,2002)



Habitat use and Habitat selection

Selection and use of a particular area by an animal are the result of proximate and ultimate factors. Proximate factors are those features used as cues when an animal evaluates a site. They may include structural features such as under story cover, canopy height or slope. The presence or absence of other animals that may act as competitors or predators also may influence habitat use (Morrison *et.al*, 1992).

Ultimate factors are those parameters that determine how successful an animal is within a particular habitat. An individual's ability to reproduce, obtain food and avoid predators is examples of ultimate factors that influence habitat selection.

Population Estimation

Estimating the population size or density of an animal species in an area is fundamental to understanding its status and demography and to plan for its management and conservation. Although knowledge of the population size of a species is critical to the development of a sound wildlife management programme, this data is extremely difficult to obtain.

For most methods, data are collected by walking a randomly located transect line and recording the distance from the transect line to the point where each individual was first observed. Individuals must be counted in their initial position i.e. there should be no movement of animals before they are observed.

Food

The abundance and distribution of food resources are among the major environmental features that influence habitat selection. As a result, food acquisition or foraging can be considered as a demonstration of how an animal actively uses its habitat**.** Studies of food habits have intrinsic value because they are important components of an animal's life history (Morrison *et.al,* 1992).

Animals are able to differentiate between species of plants and even between individual plants of the same species. They prefer plants that are palatable to them and most often these plants have high nutritive contents than those plants, which are avoided. They are free of toxic contents. Individual plants of the same species seem to be singled out by herbivores on the basis of nutritive contents as well as amount of volatile oils and terpenes in their tissues.

Animals need water for their metabolic processes. It is used in transport of metabolic products, in secretion and excretion, in regulation of body temperature, digestion etc. as might be expected animals of different environments are adapted through physiological, behavioural and ecological methods to conserve or obtain water. Some being able to manufacture their own water through metabolic processes need never drink. Others have behavioural patterns and morphological adaptations design to conserve the little water available to them (Berwick and Saharia, 1995).

The water requirements of the animals must be known before management decisions about its provision can be made. Ordinarily, on livestock ranges sufficient water is available through natural and artificial means to provide for most species of wildlife.

Behavior

Behavior is the means by which animals interact with the environment. Behavior reveals to us what resources in the environment are important to a species and how important they are, how animals organize themselves in space and time to exploit these resources and the amount of space a species requires fulfilling its resource requirements.

Through behavioral studies we can assess the degree of competition within and between species for the same resources and the importance of predation in a species life. Behavioral mechanisms in many species directly control the population growth rate in relation to the availability of food and other vital resources.

In any behavioral study the observer must be fully cognizant of the behavioral repertoire of the species under study. This may require that the observer spends an extensive periods familiarizing himself with the often subtle acts and relationships (Berwick and Saharia, 1995).

To study behavior in a scientifically acceptable manner, the units of behavior must be both objective and measurable. For these reasons behavioral scientists describe

behavior in terms of simple actions that are discrete, easy to recognize and about which there can be little or no room for subjective interpretation.

The conservation of species involves safeguarding those resources that are necessary for survivorship and reproduction of species. These resources are food, water and safe refuge from predators and environmental extremes. It also includes providing a social environment in which a species can engage in the normal reproductive activities of courtship, mating and rearing of young. Since behavior is the means by which an organism obtains resources and interacts with its environment and conspecifics, the study of behavior is central to management and conservation issues (Berwick and Saharia, 1995).

Feeding and drinking

A convenient way to learn animal's food requirements is to observe its feeding behavior and to record the food that it eats. As the availability of food plants or prey usually changes with seasons, competitors and geography, a complete record of food eaten must take these differences into account.

Similarly observation of drinking behaviour reveals the kind of water resources, if any, that can be exploited by the species in question. Behavioural observation remains the most direct tool for assessing resource requirements.

Refuging

Animals tend to seek to refuge on regular or recurrent daily schedule whenever they are resting or sleeping. In addition they seek refuge whenever it is necessary to escape from an external threat such as a predator. The types of refugees that are used in relation to the external environmental situation such as sun, rain or predators and parasites, can reveal a great deal about the environmental requirements of a population (Berwick and Saharia, 1995).

Behaviour towards conspecifics or social behaviour

Behavior towards other members of the same species is known as social behavior. Behavior is social when it influences the behavior of conspecifics. An understanding of a species social behavior is important for management because it is by means of social behavior that animals partition essential environmental resources, amongst themselves in space and time.

In particular, such partitioning determines the spatial requirements of a population and may have profound influence on population growth. Also, social behavior is a requisite for reproduction. The study of social behavior can be approached conveniently according to a species social structure, its use of space and its social order. A species can be described as being either solitary or social. Individuals of solitary species usually live alone, out of direct contact with conspecifics for most of their lives (Berwick and Saharia, 1995).

Social species are those whose individuals live in the company of one or more conspecifics for most of their lives that is they live in groups. Several grades of social living are recognized according to how individuals organize themselves in space and time, in relation to other conspecifics – aggregations, open social group and close social group.

Home range

The importance of home range of an animal lies in the fact that it constitutes the environmental base for all its essential resources of food, water, refuges and breeding places (Berwick and Saharia, 1995).

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India harbors a great diversity of its natural ecosystems ranging from evergreen tropical rain forests in the Andaman and Nicobar Islands, the Western Ghats and the North-eastern states to dry alpine scrub high in the Himalayas to the North. Between these two extremes, the country has semi-evergreen rain forests, deciduous monsoon forests, thorn forests, subtropical pine forests in the lower montane zone and temperate montane forests.

The rainforests of the Western Ghats like the Eastern Himalayas consist of very dense and lofty trees with a multitude of species occurring in the same area. Hundreds of species of trees can be identified in a hectare of land, including the mosses, ferns, epiphytes, orchids, lianas, vines, herbs, scrubs and fungi that make this region the most diverse habitat. Giant trees more than 30 m in height form the canopy.

Many National Parks, Wildlife Sanctuaries and Reserves are demarcated along the Ghats including the Nagarhole National Park, Bandipur National Park, Mudumalai Wildlife Sanctuary, Periyar Tiger Reserve, Kudremukh National Park, Bhadra Tiger Reserve, Dajipur Wildlife Sanctuary, Cotigao Wildlife Sanctuary and Mollem National Park.

The Western Ghats is under severe threat of habitat destruction. Various anthropogenic activities such as plantation of cash crops (coffee, cashew and tea), mining, roads, massive irrigation, hydroelectric projects and poaching have left the Western Ghats in a vulnerable state.

OBJECTIVES

Long term conservation of viable population of wild ungulates and their habitat is essential because the future of all our large carnivores depend on survival of these ungulates.

Although, gaur has been important ecologically, little is known about its habitat ecology especially with respect to its habitat requirements and behaviour. Hence it is most essential to know more about the ecological needs of the gaur in relation to the characteristics of the forest so that proper conservation strategies can be implemented to prevent the extinction of this animal in India. The key to successful application of any management policy is collection of adequate basic information on which decisions can be made. Thus there is an urgent need for a comprehensive study on habitat and distribution of gaur. Hence the present study was planned to fulfill following objectives:

- ⇒ To study the habitat (use/selection) of gaur
- ⇒ To study the density and distribution of gaur
- ⇒ To study the human-animal conflicts, if any
- ⇒ To study behavioural patterns
- ⇒ To study the food and feeding habits of gaur
- ⇒ To provide information that could help for better management of the sanctuary in general and conservation of the gaur population in particular

REVIEW OF LITERATURE

Ample amount of research is carried out on mammals, especially the herbivores. But research on ungulates, particularly in Southern India is limited. A brief review of the research findings on gaur is outlined below:

Brander (1923) and Finn (1929) have cited gaur in their reports on wild mammals of India. Further general information on the distribution of the gaur can be found in Gee (1964), Schaller (1967) and Prater (1971).

Data on gaurs in North-eastern India are found in Choudhury (1987, 1992, 1993, 1994a-b, 1995, 1996a-c, 1997a-b, 1998a-d, 1999, 2000a-b); Wegge (1976) and Gupta and Mukherjee (1994). Studies in Central and Southern India are discussed in Krishnan (1972); Basappanavar (1985); Imam (1985); Balakrishnan and Easa (1986); Davidar (1986); Karanth (1986), Dwivedi (1987), Samant (1990), Rao (1991) and Karanth and Sunquist (1992, 1995).

Information on gaur in Malaysia is given in Conry (1989), Srikosamatara and Suteethorn (1995), Duckworth and Hedges (1998), and Johnsingh (1998). The status survey of *Bos gaurus* was undertaken in North Bengal (Bhattacharya *et. al*, 1997).

Reynolds *et. al* (1982) studied the habitat of wild mammals including bison (*Bison bison*) in North America. Habitat preference of gaur in summer was studied by Goswami (2007). Ahrestani (2010) studied the life-history traits of gaur under captivity in Mysore zoo. Ranging patterns and habitat use by gaur (*Bos gaurus*) in Pench Tiger Reserve was studied by Pasha (1998). He reported that males and females showed significant differences in habitat use in different season. Andheria *et. al*, (2007) from his studies in Bandipur Tiger Reserve reported that gaur is the most important prey species of tiger and leopard. He further observed gaur remains in 24% tiger faeces and 9% leopard faeces.

The role of bison in maintaining the short grass plains was studied by Larson (1940). Krishnan (1972) reported general activity pattern of gaur and carried out ecological survey of lager mammals of Peninsular India. The trophic ecology of *Bison bison* on short grass plains was studied by Peden *et. al* (1974).

Sathyanarayana and Murthy (1995) studied the activity patterns and feeding habits of gaur (*Bos gaurus*) in Berijam Reserve forest in Tamil Nadu. Microhistological studies on the food habits of sambar, gaur and cattle in Periyar Tiger Reserve in winter was undertaken by Srivastava *et. al* (1996). Shukla and Khare (1998) studied food habits of wild ungulates including gaur and their competition with livestock in Pench Wildlife Reserve, Central India. They reported that the overlap in two classes of ungulates in food habits may lead to degradation of wildlife habitat. Pasha *et. al* (2002) studied debarking of teak (*Tectona grandis*) by gaur *Bos gaurus* during summer in a tropical dry deciduous

habitat of Central India. Diet of gaur by microhistological analysis of fecal samples in Parsa Wildlife Reserve, Nepal was studied by Chetri (2006). He reported that diet of gaur consisted of diverse species of plants with grasses forming the major proportion of diet.

Belsare *et.al* (1984) studied composition and behavior of gaur herd in Kanha National Park. They reported that gaur herd consists of mature bulls, cows, sub-adult, yearlings and calves. They also reported the herd size of gaur to be 6-7 individuals and ratio of bulls to cows to be 1:2. Group size and age-sex composition of Asian elephant and gaur in Mudumalai Tiger Reserve was studied by Ashokkumar *et.al* (2010). They concluded that gaurs have larger group sizes than elephants. Ahrestani and Prins (2011) gave methods to determine age and sex of gaur. They opined that sexes can be distinguished based on horn shape and size difference.

Reynolds and Hawley (1987) studied bison ecology in relation to agricultural development in the Slave River tow lands. Sivaganesan and Desai (1995) studied conservation perspectives of the threatened wildlife habitats and selected endangered mammals of Nilgiri Biosphere Reserve. Choudhury (1999) studied *Bos gaurus* in Dibang valley district of Arunachal Pradesh. He also studied distribution and conservation of gaur in Indian subcontinent (Choudhury, 2002) and reported that population of gaur is declining alarmingly and may not last long especially outside the protected areas. Further, he proposed an action plan for its conservation. Nameer *et. al.* (2001) presented a thorough checklist of mammals of Western Ghats including gaur with the status of the taxa in Western Ghats. He also summarized the impact of human activities within the

hotspot as indicated by the level of threat faced by endemic mammalian taxa. Sahoo and Das (2010) studied anthropogenic threats to gaur in Baisipalli Wildlife Sanctuary. They reported livestock grazing, poaching and contagious diseases to be the main threats to gaur.

However, studies on gaur in Goa are very limited. Naik (unpublished) studied the behavior of gaur and its habitat at Bhagvan Mahaveer Wildlife Sanctuary. Kittur (unpublished) carried out habitat analysis of gaur using remote sensing and GIS. But a detailed study on habitat ecology and behavioral patterns was required for proper management and conservation of the habitat of this magnificent animal in the wild. Hence, the present study was planned and carried out to fulfill these objectives.

Study area

Goa, the smallest state of India is situated on the West Coast fringed on the North and North-east by Maharashtra, on the West by Arabian Sea and on the South and South-east by Karnataka (Fig.1). As per the State of forest report 2001 published by the Forest Survey of India, the forest cover in Goa is 2095 sq. km consisting of 1785 sq. km dense forest and 310 sq. km open forest (Source: Forest Department website, Government of Goa; www.goaforest.com).

Most of Goa is a part of the coastal country known as the Konkan, which an escarpment is raising up to the Western Ghats range of mountains that separates it from the Deccan plateau. The monsoons are the main feature of the climate of Goa.

Around 755 sq. km i.e. 20 percent of the total geographical area of 3702 sq. km of the state has been constituted into wildlife protected areas to afford complete protection to the natural fauna/flora and thereby to conserve the unique biological diversity of this region. Gaur (*Bos gaurus*), sambar (*Cervus duavaceli*), cheetal (*Axis axis*), barking deer (*Muntiacus muntjak*), hog deer (*Hyelaphus porcinus*), mouse deer (*Tragulus meminna*), jungle cat (*Felis chaus*), sloth bear (*Melursus ursinus*), wild boar (*Sus scrofa*), giant squirrel (*Ratufa indica*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), civets (*Viverra civettina*) and jackal (*Canis aureus*) are the common

fauna found in these sanctuaries. The reptilian fauna is also very rich and a wide variety of snakes including the king cobra (*Ophiophagus hannah*), monitor lizards (*Varanus sp*) and crocodiles (*Crocodylus palustris*) are seen.

Bhagvan Mahaveer Wildlife Sanctuary & Mollem National Park

Bhagvan Mahaveer Wildlife Sanctuary (BMWLS) and Mollem National Park (MNP) situated at Mollem in Sanguem taluka in South Goa represent the study area of the present investigation (Fig.2). Together they encompasses an area of 240 sq. km (BMWLS-133 sq. km and MNP-107 sq. km) ascending to an altitude of about 800 m and lies between 15^0 14' 09.82"- 15^0 22' 51.57 N latitude and 74^0 09' 47.79" - 74^0 20' 02.92" E longitude in the Western Ghats, India (Fig.3) (Source: Forest Department, Government of Goa).

The forest cover of this area has been classified as tropical evergreen, semi-evergreen, moist deciduous and South Indian subtropical hill savannah woodlands (Champion and Seth, 1968). Wet and moist bamboo brakes are found throughout the semi-evergreen and moist deciduous forests. The main rivers that flow through this region are Dudhsagar, Caranzol, Boma, Calem, Ragada and Jambauli River. The National highway NH4A makes its way through this sanctuary. South-central railway also has its broad gauge route through this sanctuary.

Climatically, the area witnesses four seasons viz. Summer (March-May), Monsoon (June-August), Post-monsoon (September-November) and Winter (December-February). The average annual rainfall is 2400 mm. BMWLS and MNP is

a highly undulating terrain. The altitude varies from 100m to 800m MSL. The slope varies extensively often going up to 90^0.

Vegetation of this area is broadly categorized into moist deciduous, grassland and semi-evergreen type dominated by species such as *Terminalia crenulata, T. belerica, T. paniculata, Lagerstroemia parviflora, Adina cordifolia, Albizia lebbeck, A. procera* and *Dillenia pentagyna.* Apart from this, sub-tropical hill forests represent trees like *Syzygium cuminii* and *Cinnamomum verum.*

In the second storey, *Strobilanthes callosus* and *Capparis sp* are found (Champion and Seth, 1968). Semi-evergreen forests occur intermingling between tropical evergreen and moist deciduous forest mostly above 500 MSL and comprise of *Artocarpus hirsutus, Calophyllum sp, Sterculia guttata, Lagerstroemia microcarpa, Pterospermum diversifolium, Garcinia indica, Diospyros montana* and *Macranga peltata.*

In addition to this, the lateritic semi-evergreen vegetation is found on shallow dry lateritic soils. *Xylia xylocarpa* is the prominent tree species with other associates like *Pterocarpus marsupium, Grewia tiliaefolia, Terminalia paniculata, Schleichera oleosa, Careya arborea, Bridelia retusa* and *Strychnos nux vomica.* Some climbers and grasses are also found.

Methodology

Primary information and data about the Sanctuary and National park were procured from the Forest Department, Government of Goa, India. Maps and toposheets of the Sanctuary were also collected. Further a formal permission was obtained from them so as to carry out these studies. Field visits were carried out to get a general idea of the vegetation, potential habitat of gaur and other supplementary details. Geographically the sanctuary was marked into different beats as followed during census operations carried out by the Forest Department. The study was carried out from August 2004 to July 2008.

Encounter Rate (ER) for gaur

This protocol outlines a simple method for quantifying ungulate abundance in an area based on visual encounters while walking along fixed line transects. Data collection was done employing the following procedure:

a) The shape, size, vegetation and terrain type of each beat were analyzed and accordingly specific transect lines of a minimum of 2 km and not exceeding 4 km were marked for sampling.

b) The transect lines traversed similar habitat types as far as possible. For beats comprising two or three distinct vegetation types, two separate line transects were marked for sampling. Care was taken that no line transects were located near the highway or parallel to a river (to avoid biased sightings).

c) The broad forest type/s that each transects traverses was recorded.

d) Each transect was walked at dawn (6 am to 9 am), afternoon (1pm to 3 pm) and at dusk (5 pm to 7 pm) on a monthly basis.

e) 28 hours per month were spent observing the animals on field totaling to 1345 hours during the entire study period.

f) 6 hours per week were spent in direct contact observing the animals.

g) Gaurs sighted were recorded in a specific format (Appendix Ia) with necessary details.

h) Animals were considered to belong to two different groups if the closest animals were seen at a distance of over 20 m.

i) Each line transect was walked at least two different mornings, afternoons and evenings and the encounter rates (ER) of gaur were estimated as follows:

ER=No.of animals sighted/100km.

Habitat study

Direct sightings of gaurs along the foot transect and indirect evidences as indicated by their dung were used to indicate the habitat occupance of gaur and were correlated to the various habitat parameters such as topography, tree, shrub cover and water availability. A one way analysis of variance (ANOVA) was used to test the significance of habitat parameters.

Habitat preference of gaur was calculated using Ivlev's selectivity index (IV), the values of which range from -1.0 to+1.0. Positive values indicate habitat

preference, negative values avoidance and 0 indicates random use (Ivlev, 1961). Friedman (1937) test was used here to test for difference in the percentage of availability and the percentage of utilization of each habitat to determine selection.

Estimation of animal density

Based on the vegetation types, the study area was stratified into different habitat zones such as moist deciduous forests (MDF) admeasuring 85 sq. km, evergreen forests (EF) of 40 sq. km, semi-evergreen forests (SEF) of 45 sq. km and grassland (GRS) of 2 sq. km. Transect lines were placed in these zones in a fashion that they sampled each zone in rough proportion to their areas.

A total of fifteen transects (n=15) were laid in moist deciduous forests, eight (n=8) in semi-evergreen forests, five (n=5) in evergreen forests and one (n=1) in grassland totaling to 29 transects throughout the study area. Each transect was walked at dawn (6-9 am), afternoon (1-3 pm) and at dusk (5-7 pm) on four different days per month. This gave a total sampling effort of 726 km. The transects were covered from opposite ends in order to minimize any bias arising from variation in animal activity with time. For each sighting the central location of the animal group was noted and the perpendicular distance from this location to the transect line was recorded at 10m class interval in addition to details of group composition.

A general form of density estimator is given by:

$$D=\frac{nf(0)}{2L}$$

Where,

D= Density

n= Number of objects sighted

f(0)= Estimate of the probability density function of distance values at zero distance.

L= Transect length

The data was analyzed using software DISTANCE 6.0 (Thomas *et.al*, 2010). The density was estimated by multiplying the density of groups by mean group size. Data was recorded in data sheet in specific format (Appendix Ib).

For the purpose of analysis; animal sightings were categorized into 20m distance class intervals (from 0-200m). The standard error (SE) of the mean was estimated following Goodman (1960) and 1.96 SE was taken as 95% confidence interval.

$\{SE(D)^2\}=\{Y^2x(SE(Z)^2\}+\{Z^2x(SE(Y)^2\}$

Where,

Z=Density of groups/sq. km

Y= Mean group size

D= Density of individuals /sq. km

Vegetation sampling

1) A beat was considered as a unit for sampling.
2) The same principle of laying line transects as explained previously was applied here.
3) Broad vegetation types and associated types of terrain encountered in these transects were recorded.

4) Vegetation sampling and their dominance, as well as, human disturbances were recorded in 15m radius circular plots earmarked in each transect at an interval of 400 meters along the transect.

5) In each season, data on 14 habitat variables were collected from every sampling station. These variables were related to vegetation structure, composition, phenology (leaf stage and greenness) and ground cover. These parameters were subjected to one way ANOVA test to test for significance in use of different parameters.

6) Leaf stage of trees and shrubs were scored on a five point scale (0-4) of proportion of young to mature leaves. Greenness was scored on a five point scale (0=full dry; 1=brown; 2=average green; 3=moderate green; 4= fully green). Data was recorded in data sheet in prescribed format (Appendix Ic).

Human disturbance assessment

The number of signs of lopping, woodcutting, presence/absence of human foot trail and livestock were also recorded in the above mentioned 15m circular plots. Data was recorded in data sheets in a prescribed format (Appendix Id).

Procedure for estimating ground cover

Plots were laid 5m away from the centre of the 15m circular plot. Imaginary circle of 2 meter diameter was defined by employing a 2 meter long thick stick. Within this circular plot (2m diameter) the percent ground cover was quantified i.e.

the proportion of the ground covered by herbs, grasses, shrubs and litter. Data was recorded in data sheets in a prescribed format (Appendix Ie).

Behavioral studies

The behavior of gaur was familiarized first with captive gaur population at Bondla zoo. Various information including daily activity patterns of gaurs, their behavior and feeding were procured from zoo authorities. Scan sampling and focal animal sampling technique of Altman (1974) was employed to study the behavior of gaurs.

Under field conditions, the dominant activity or behavioral state of the herd was recorded at predetermined time interval at once every minute. Various behavioral states such as feeding, drinking, movement, resting, fighting and 'others' (including behaviors like vocalization, self grooming, ruminating and alertness) were recorded in data sheets in prescribed format (Appendix If). The proportion of time spent on each behavior was calculated for each observation session. Behavioral data were analyzed using the observation session as the experimental unit and was subjected to ANOVA with season as factor.

Determining food habits

Two methods were adopted for studying food habits viz. direct observation and fecal analysis:

a. *Direct observation*: Feeding activity of gaurs were observed through binoculars (10 x 50), followed by onsite inspection of food plants. A

herbarium of unidentified plant species was prepared for later identification by taxonomists. Time of feeding and the prevalent atmospheric temperature at this moment were recorded.

b. *Fecal analysis*: This was carried out by adopting procedure outlined by Satakopan (1972) as follows-

Dung samples of animals were hand-picked from different sampling sites in different season in plastic bags and labeled accordingly. As there are no other large ungulate species in the study area, the gaur dung could easily be identified as a large black pile of fecal matter. Altogether 70 dung samples (summer-30, monsoon-6, post-monsoon-9 and winter-25) were collected from different habitats. These samples were sun dried or oven dried to prevent fungal infestation on storing.

The above sample was boiled in about 2-3 ml of chloral hydrate solution directly for few minutes. If the chloral hydrate was too dark, the powder was allowed to settle, supernatant poured off and fresh quantity of chloral hydrate added and boiling repeated. After cooling distilled water was added and the material was boiled again. It was cooled, allowed to settle and the supernatant was poured off. This washing was repeated until the solution became clear.

A dehydration process with alcohol was followed by washing two or three times. The plant fragments were passed through grades of alcohol; xylol mixtures (alcohol:xylol- 3:1, 1:1, 1:3) and finally in pure xylol. Mounting was done in DPX on a glass slide.

Screening and Identification

The above preparations were screened under a light compound binocular microscope under a magnification of 400X and their size was recorded using micrometers. Distinguishing histological features (e.g. cell wall structure, shape and size of cells, hairs and trichomes, shape and size of stomata and inter-stomatal cells, fibre structure and arrangement of veins) were sketched to match with the faecal plant fragments.

Five horizontal transect lines were drawn randomly on each slide and the first 12 non-overlapping fragments which intercepted the fields per scale line were recorded and identified under compound microscope at 400X magnification with an ocular measuring unit. Further replica of their images was recorded in the paper using camera lucida.

Simultaneously reference slides of fresh plants were prepared by taking thin sections of leaves involving upper and lower epidermis. A key was thus prepared for all possible food plants of the study area. Identification of plant fragments was based on Williams (1969), Satakopan (1972), Johnson *et.al* (1983), Ghosh (1994) and Sharma (1996). The results were compared with field observations.

The size/area of plant epidermal fragments, as well as their frequency of occurrence was considered in order to account for differential fragmentation of plant material (Stewart, 1967; Hanson, 1970). The relative percentage frequency of each species in the fecal sample was estimated using the formula:

$$Rf\ \% = \frac{n1+n2\ldots\ldots\ldots}{N} \times 100$$

Where,

Rf % = Relative frequency

n = total no of fragments identified for a given food species or category

N= grand total no of fragment counts made in the sample

Availability and selection of food

Food selection studies were carried out based on seasonal comparison between the composition of the faeces and that of available vegetation, using Ivlev's (1961) index of selectivity as follows:

Selectivity =U-A /U+A; Where U= percent use and A= percent availability.

A positive index indicates selection for a particular food item, whereas a negative value indicates that it is avoided. The standing crop of all vegetation within the reach of gaur was used as a crude measure of forage availability.

Twenty-two sampling points were selected along a single transect which passed through all vegetation zones in the study area. The vegetation was sampled in summer, monsoon, post-monsoon and winter. These were classified into the following categories viz. leaves of woody plants (i.e trees and shrubs), grasses and bark. A distinction was also made between ground vegetation such as grasses and aerial vegetation such as woody plant leaves.

Plant samples were dried in an oven for 24 hrs and subsequently weighed. The association between type of food preference and season was analyzed statistically using chi-square test.

Quality of the diet

Dung samples were collected from August 2004 to June 2008 and pooled into monthly composite samples as in the micro histological procedure for the analysis of crude protein (Mason, 1969; Van Soest, 1980). Duplicate samples were analyzed subsequently.

Crude protein measured as nitrogen 6.25, was determined by Kjeldahl procedure (AOAC, 1990) in which organic nitrogen is converted to ammonium ions by digestion with sulphuric acid. The ammonium ions were estimated by distillation of ammonia against standard acid. Cellulose and lignin contents were analyzed using Van Soest (1982) detergent procedure for NDF, ADF and ADL.

Estimation of crop loss

The probable extent of damage and loss of various agricultural crops in the periphery of the sanctuary was estimated employing a questionnaire survey of the farmers at the village and household level. Forest guards, locals and farmers in the study area were also interviewed and the extent of perceived damage, patterns of crop depredation, time of raiding, composition of the herd and protection measures adopted by farmers were noted down. Indirect evidences like dung, hoof marks and damage signs were also recorded from these areas. The distance of the village (in km) from

sanctuary boundary was also taken into consideration. Data was collected during August 2004 to July 2008.

Herd size and composition

Gaurs sighted during study period were categorized into the following four groups based on classification of Schaller (1976) with minor modifications:

a) Adult solitary black bulls (large, dark black bulls with the characteristic hump).

b) Adult bulls (light black bulls, slightly smaller in size).

c) Adult females (fully-grown females, with characteristic stockings and horns).

d) Younger animals [i.e. i. young (less than 1 yr)] ii. yearlings (between 1 and 2 yrs).

A collection of 2 or more than two individuals of any age-sex within 20m of each other was considered as a group or herd. All the animals in a herd or group were counted and this was considered the herd size. Based on the number of animals sighted together, 4 categories were recognized:

a) Single individual which consisted of single large, solitary adult black bull.

b) Small herd which consisted of 2-10 individuals.

c) Medium herd which consisted of 11-20 individuals.

d) Big herd which consisted of >20 individuals.

Data was recorded in data sheets in a prescribed format (Appendix Ig).

RESULTS

Present study focuses on the habitat ecology of gaur *(Bos gaurus)* in Bhagavan Mahaveer Wildlife Sanctuary and Mollem National Park, Goa. The detailed results of the study are as follows:

Identification of the vegetation/habitat types

Based on the characteristic tree species predominant within the study area, following four broad habitat types were recognized in BMWLS and MNP:

1. Moist Deciduous forest (MDF)
2. Semi-evergreen forests (SEF)
3. Evergreen forests (EF)
4. Grassland (GRS)

Gaurs used moist deciduous forests as compared to other three types of forests although available in the study area. Friedman test confirms that use of different habitats is significant (Chi-Sq.=8.086, df=3, p=0.0345).

Density Estimation

Significant differences in the gaur density in the above four habitats analyzed by one-way analysis of variance (ANOVA) is represented in table 1. One way ANOVA test shows that there is significant difference in density of gaurs between various habitats ($F=12$, $p=0.05$). The results are also supported by its wide distribution in moist deciduous habitat as compared to semi-evergreen forests, evergreen forests and grassland (Fig. 4).

The results suggest that BMWLS and MNP supported a large population of gaur (335±28 individuals). Gaur showed a high overall individual density of 33.28±6.53 individuals/ sq. km (Data at 95% Confidence interval) in MDF as compared to GRS (20.6±6.3), SEF (16.4±2.53) and EF (5.66±1.6) (Table 1, Fig. 5). Density estimates, percentage coefficient of variation and χ^2 values of different habitats grouped into distance classes and class intervals are represented in table 2.

Encounter rate

Encounter rate (ER) of gaur in different habitats are represented in table 3. It was found to be highest in moist deciduous forests (125±6 individuals/100 sq. km) and lowest in evergreen forests (23±7 individulas/100 sq. km).

Vegetation sampling to determine habitat preference

Month-wise temperature and rainfall data of study area are represented in fig. 6. Description of season-wise habitat variables is depicted in table 4. Ground cover data showed maximum green grass cover (55%) in monsoon. The herb cover

remained nearly constant throughout the year except a minimum 4% in summer (Fig.7). Gaurs preferred 50-80 % of green grass cover (IV=0.5) and avoid 0-25 % grass cover (IV=-0.71). There was significant difference in the use of different ground covers in proportion to their availability ($F=2.62$, $p<0.05$). Gaurs preferred open forest (IV=0.12) and avoided rocky plateaus and denser forest (IV=-0.43). There was significant difference in the use of different ground features in proportion to their availability ($F=4.68$, $p<0.05$). Gaurs mostly preferred the altitudinal range of 200-300 m (IV=0.2) and avoided areas above 600 m (IV=-0.2). There was significant difference in the use of different altitudes in proportion to their availability ($F=6.23$, $p<0.05$).

Human disturbance

The result of human disturbance assessment in the study area is given in table 5. Out of the 14 plots studied, two plots were found to be highly disturbed (Fig.8). Cattle grazing were observed in seven out of 14 plots surveyed. Livestock and people were seen in majority of the plots studied. *Eupatorium odorarum* (locally called '*Ranmari*') infestation was observed though not much in the interior of forest. Certain grasslands were also seen with *Eupatorium*. This was reported to cause a lot of damage as it was known to inhibit other plants from growing.

Behaviour studies

Behavioural records from scan and focal animal sampling of gaurs are depicted in table 6. Altogether 10,714 scan records were made. The results showed

that gaurs spend most of their daily time feeding (63%) (Table 7, Fig. 9) with peak feeding hours from 0630 hrs to 0830 hrs in the morning and then in the evening hours between 1730 to 1845 hrs. No significant differences between seasons were observed. During summer the animals concentrate at waterholes where most of the sightings were made. Most gaur population was observed at an altitude of 200-300 m MSL.

During hot hours of the day (mean temperature-30^0C) i.e. between 1330 to 1500 hrs gaurs were found resting under the shade of big trees. Gaurs were found to drink at least once during the day either early morning or late evenings except during monsoons. In the present study gaurs were found to visit natural as well as artificial salt licks periodically for minerals.

Female herds were often observed with their calves. This kind of herd showed aggressive behavior when tried to approach from a distance. Maximum numbers of juveniles were observed in February, June and September (Table 8, Fig. 10). No juveniles were observed in December and January.

Diet of gaur

The varieties of plant species consumed by gaur in the study area are listed in table 9. It comprises of thirty-two species of plants (seven grass species, five herb species, eight shrub species and twelve species of trees (Fig. 11) belonging to seventeen families. Family Graminaceae was represented by maximum i.e. six species (Fig.12). Based on direct observation, *Strobilanthes ixiocephalus* and *Strobilanthes callosus* were the most consumed food plants of gaur.

More varieties of grass and herbs were consumed in monsoon in comparison to the trees, whereas in winter all the food classes are proportionately consumed by gaur. However in summer maximum tree species were represented as compared to grasses and shrubs. Statistical analysis of this data by chi-square test indicates that food preference is directly associated with season (Chi-sq=12.94; df=1; p=0.001).

Parts of each species of diverse plants fed by gaurs are represented in table 10. Among them, leaves (87%) were consumed the most. Gaurs consumed fruits of *Dillenia pentagyna* and Cashew *Anacardium occidentale* (thrown by the locals after extracting juice) as well as barks of teak (*Tectona grandis)* and cashew (*Anacardium occidentale)* in summer. They were seen feeding on young bamboo shoots when bamboo shoots were abundant in the study area, especially during monsoon to winter. The difference in consumption of plant parts is significant (Chi sq=0.209; df=1; p=0.647).

Botanical composition of the faeces

Seasonal variation in plant epidermal fragments observed in the fecal matter of gaur is represented in table 11. Woody plants formed the bulk of epidermal fragments from January to June with maximum in summer season, whereas graminoids were found to be maximum in monsoon and post-monsoon (Fig.13).

Bamboo like *Dendrocalamus strictus* and *Bambusa arundanacea* were present in the fecal samples almost throughout the year. Short grasses like *Cynodon dactylon*, *Digitaria sp.* and *Cyperus rotundus* were predominantly eaten in monsoon,

post-monsoon and winter but tall grasses like *Bambusa arundinacea* and *Dendrocalamus strictus* were eaten throughout the year.

Spermacoce sp. and *Vetiveria zizanoides* contents fluctuated similarly with high levels in faeces in winter. Herbs and shrubs were eaten year round, even in summer when only few plants were available. The relative frequency of different plant species recorded in the diet of gaur on the basis of frequency distribution of number of intercepted fragments from microhistological analysis is represented in table 12. The proportion of herbs in faeces progressively increased from a minimum level of about 15 % to 50 % in winter.

Graminoids usually accounted for >60 % of epidermal fragments. Levels of grasses and sedges tended to be highest in monsoon and post-monsoon whereas those of bamboo were normally highest throughout the year. The compositions of woody plant leaves never exceeded 15% in monsoon and post-monsoon, but were found to be highest (40%) in summer.

Availability and selection of food

Seasonal availability of various categories of plants and their presence in faeces of gaurs are compared in table 13. When the Ivlev's Index for different categories of plants were compared, significant difference was seen between their Ivlev's Indexes ($Z= 0.336$, $p=0.737$). Abundant green vegetation were available in monsoon, post-monsoon and winter whereas in summer they almost dry up. Ground vegetation constituted between 75% to 100 % of the standing crop within reach of

gaur in monsoon and post-monsoon. The most abundant sources of potential forage in winter were bamboo and *Strobilanthes* leaves. The availability of fresh green grass was limited in this period.

The selectivity index for bamboo was positive throughout the year, whereas those of herbs and woody plants showed seasonal variation. A negative index was observed for graminoids in summer. Leaves of woody trees were avoided for most part of the year except in summer when green vegetation (mostly grasses) was scarce.

Three species of *Strobilanthes* were available in the study area which comprised of more than 60 % of ground vegetation in winter and summer. *Strobilanthes* species were the most preferred among the ground vegetation. *Dendrocalamus strictus* and *Bambusa arundinacea* were also available in abundance throughout the sampled plots.

Quality of the diet

The chemical composition of fecal matter of samples of gaur is represented in table 14. The crude protein content of the faeces was high during the monsoon and post-monsoon and low in summer. Conversely, faecal cellulose was low in monsoon and post-monsoon but high in summer. The lignin content (determined as ADL) was lowest in summer but remained nearly constant in monsoon, post-monsoon and winter.

Crop depredation

Data on crop depredation by gaur in the study area is represented in table 15. Altogether 128 crop-raiding cases were reported from the study area over a period of two years. Maximum cases were reported in summer (57%) and minimum in post-monsoon (7%) with highest number (32 cases) in the month of April (Fig. 14). Gaurs raided the sugarcane crops several times in Caranzol village in the core area of the National park. The field composed of about 80 hectares of sugarcane under cultivation throughout the year.

The total population of the villages in the fringe area of the sanctuary is approximately 3920 with livestock population of 150 animals including cattle and goats. Crop damage by gaurs occurs in big herds of 15-20 individuals and gaurs exhibit aggressive behavior when tried to drive away. Maximum damage was caused by a medium sized herd (mean herd size-12.83) and none by a solitary bull (Table 16). But there seems to be no correlation between mean herd size and the number of incidences (t-test: 0.278) (Fig.15). We observed that gaurs damage more crops by stamping or through their movement across the fields, than they actually eat.

In our present study maximum damage was caused at Caranzol, Collem, Surla and Karemol that are the villages located inside the core area away from the sanctuary boundary.

Different crop protection measures adopted by farmers in the study area are represented in table 17 and fig.16. The most commonly used crop protection strategy (by 64 % farmers) is guarding their fields by constant vigilance during night hours. 15

% of farmers protect the field by pipe or stone fencing. Few farmers (~9%) use dogs whereas 6 % of farmers even use fatal methods like high voltage electric fencing in which gaurs are usually killed or seriously injured. Cases of death by electrocution have been reported in the past. While the remaining 6% used miscellaneous methods including stoning and driving away.

Herd size and composition

Composition of gaur herd is represented in table 18 and fig.17. Of the 95 observations made, total 90 herds were observed consisting of 361 individuals. This included 30 solitary bulls, 45 small herds and 13 medium sized herds. Each herd consisted of bulls, cows, yearlings and sub-adult gaurs. Big herds consisting of more than 20 individuals were observed only twice. Altogether 117 bulls and 111 females were observed. The adult black bulls were always found to be solitary. The most frequent herd size was that of small sized herd with mean herd size 5.73±1.23.

Table 1: Habitat-wise comparison of the density of gaur using ANOVA

Habitat type	**Group density (Sq. km) ±SE**	**Density of individuals (Sq. km) ±SE**	**p>0.05**
MDF	12.21±1.89	33.28±6.53	0.924
SEF	5.2±0.30	16.4±2.53	0.305
EF	2.09±0.97	5.66±1.6	0.429
GRS	9.3±1.8	20.6±6.3	*

*Low sample size for valid statistical analysis

Table 3: Encounter rate of gaur in different habitats

Vegetation /Habitat type	ER/100 km
MDF	125±6.7
SEF	44±2.4
EF	23±1.8
GRS	59±2.8

Table 4: Season-wise habitat variables encountered in BMWLS and MNP

Variables	Summer **Mean** ±SD	Monsoon **Mean** ±SD	Post-monsoon **Mean** ±SD	Winter **Mean** ±SD
Tree Variables				
No.of trees	12.56±3.4	28.3±4.6	27.6±3.5	27.2±5.1
Height of canopy (m)	7.21±2.33	6.66±1.34	8.32±6.23	8.13±2.33
Leaf stage of trees	0.97±0.17	2.9±1.1	4.0±1	2.62±1.3
Greeness of trees	1.04 ±0.3	2.65±1.2	3.63±1.3	2.32±1.6
Canopy cover (%)	45±3.8	60.1±3.6	65.3±4.1	65.6±2.5
Shrub variables				
No. of shrubs	8.47±7.3	9.35±1.2	9.6±1.1	11.6±2.33
Shrub height (m)	47.2±8.6	50.4±4.2	51.3±3.8	52.1±5.3
Leaf stage of shrub	0.89±0.4	1.23±0.6	3.8±1.8	3.7±1.6
Greenness of shrub	1.35±0.6	2.56±1.1	4.4±1.6	3.8±0.3
Ground cover				
% Dry grass cover	38.3±3.5	5±4.66	9.7±8.2	8±2.1
% Green grass cover	1.3±0.9	55.3±12.1	39.4±12.3	28±2.1
% Herb	4±3.2	18±4.2	20.3±6.8	18.7±11.4
% Weeds	14.3±3.5	12±9.7	14.7±4.7	20.7±5.8
% Bare soil	13.8±7.3	8.3±7.6	15.7±3.6	23.7±6.8

Table 6: Behavioural records of gaur

Month	Total records	Feeding	Movement	Resting	Drinking	Fighting	Others
January	**1216**	756	196	218	21	-	25
February	**1142**	734	265	77	45	-	21
March	**1440**	823	364	214	39	-	-
April	**1398**	789	456	98	55	-	-
May	**1273**	856	357	13	39	08	-
June	**311**	112	129	34	26	05	05
July	**768**	452	258	42	-	-	16
August	**569**	356	123	72	-	-	18
September	**464**	311	103	26	-	-	24
October	**895**	489	201	193	12	-	-
November	**813**	637	124	41	11	-	-
December	**625**	521	35	60	09	-	-
TOTAL RECORDS	**10,714**	**6836**	**2611**	**1088**	**257**	**13**	**109**

.

Table 7: Activity budgets expressed by gaur in different season (Mean ±SE)*

(Total hours spent-1345 hours)

Activity	**Summer**	**Monsoon**	**Post-monsoon**	**Winter**	***p>0.05***
Feeding	60±4.55	55.8±4.1	66.1±5.3	67.4±4.9	0.009
Moving	28.6±4.2	30.9±5.2	19.7±2.9	6.6±2.8	0.21
Resting	7.8±1.4	8.9±1.7	11.9±2.3	11.9±2.3	0.003
Drinking	3.2±0.33	1.6±0.27	1.05±0.28	2.51±1.2	0.423
Fighting	0.19±0.05	0.3±0.07	0	0	0.346
Others	0	2.36±1.3	1.1±0.21	1.54±0.45	0.321

*****Data expressed as percent of time

Table 8: Record of juveniles of gaur sighted in the study area (n=58)

Month	Total no. of Juveniles observed	No. of times Juveniles observed
January	-	-
February	12	6
March	1	1
April	8	4
May	6	3
June	12	7
July	1	1
August	1	1
September	11	4
October	1	1
November	5	3
December	-	-

Table 9: Food plants consumed by gaur in the study area

Sr. No.	Species	Family	Local Name	Part eaten
Grasses				
1.	*Arundinella leptochloa*	Graminaceae	*Benel/Kotir*	Leaves
2.	*Bambusa arundinacea*	-do-	*Bans*	YS*/Leaves
3.	*Cynodon dactylon*	-do-	*Durva*	Leaves
4.	*Cyperus rotundus*	Cyperaceae	*Nagar-motha*	Leaves
5.	*Dendrocalamus strictus*	Graminaceae	*Kania Bans*	Leaves
6.	*Digitaria sp.*	-do-	*Dinohi*	Leaves
7.	*Vetiveria zizanoides*	-do-	*Valerum*	Leaves
Herbs				
8.	*Spermacoce sp.*	Rubiaceae	*Dhoti*	Leaves
9.	*Cordia myxa*	Boraginaceae	*Bhokar*	Leaves
10.	*Desmodium triflorum*	Leguminosae-Papilionoideae	*Janglimethi*	Leaves
11.	*Stylosanthes sp.*	-do-	-	Leaves
12.	*Urena lobata*	Malvaceae	*Rantupkada*	Leaves
Shrubs				
13.	*Strobilanthes callosus*	Acanthaceae	*Karvi*	Leaves
14.	*Strobilanthes ixiocephalus*	-do-	*Karvi*	Leaves
15.	*Strobilanthes sp.*	-do-	*Karvi*	Leaves
16.	*Gardenia latifolia*	Rubiaceae	*Kaul*	Leaves
17.	*Grewia abutifolia*	Tiliaceae	*Khar-phulsa*	Leaves

18.	*Helicteres isora*	Sterculiaceae	*Kevani*	Leaves
19.	*Symplocos racemosa*	Symplocaceae	*Kawla*	Leaves
20.	*Vitex negundo*	Verbenaceae	*Nimgud*	Leaves
Trees				
21.	*Anacardium occidentale*	Anacardiaceae	*Kaju*	Fruits/Bark
22.	*Bauhinia racemosa*	Leguminosae-Caesalpiniodae	*Apto*	Leaves
23.	*Butea monosperma*	Leguminosae-Papilionoideae	*Palas*	Leaves
24.	*Cassia fistula*	-do-	*Balo*	Fruits
25.	*Dillenia pentagyna*	Dilleniaceae	*Karmal*	Fruits
26.	*Phyllanthes emblica*	Euphorbiaceae	*Avale*	Leaves
27.	*Gmelina arborea*	Verbenaceae	*Gomari*	Leaves
28.	*Grewia tiliaefolia*	Tiliaceae	*Damani*	Leaves
29.	*Tamilnadia uliginosa*	Rubiaceae	*Cindra*	Leaves
30.	*Syzygium cumini*	Myrtaceae	*Jambhul*	Leaves/Flowers
31.	*Tectona grandis*	Verbenaceae	*Saylo/Sag*	Bark
32.	*Terminalia paniculata*	Combretaceae	*Kinal*	Leaves

***YS=Young shoots**

Table 10: Various plant parts consumed by gaur in different seasons

Season	Plant part eaten by Gaur				
	Fruits	**Leaves**	**Young shoots**	**Bark**	**Flowers**
Summer	3	20	-	2	1
Monsoon	-	25	1	-	-
Post-monsoon	-	24	1	-	-
Winter	2	21	1	-	2

Table 11: Seasonal variation in plant epidermal fragments in faeces of gaur

Season	Month	Herbs and shrubs	Woody plants (Browse)	Graminoids (Grasses) including bamboo	χ^2 $p>0.05$
Summer	March	5	20	2	7.55
	April	6	20	3	26.8
	May	5	21	2	7.64
Monsoon	June	4	17	5	2.53
	July	6	1	16	27.78
	August	9	3	22	32.95
Post-monsoon	September	11	3	19	25.9
	October	13	2	16	24.07
	November	8	4	15	16.54
Winter	December	8	5	11	8.9
	January	6	11	2	2.15
	February	5	18	2	5.54

Table 12: Frequency of different plant species recorded in the faeces of gaur

Species	**Relative frequency %**					
Grasses	**Summer**	**Monsoon**	**Post-monsoon**	**Winter**	χ^2	**±SE**
Arundinella leptochloa	-	4.33	6.33	2.67	0.44	0.27
Bambusa arundinacea	2.33	5.67	3.67	6.00	0.17	0.17
Cynodon dactylon	-	9.33	11.62	4.23	3.78	0.79
Cyperus rotundus	-	0.33	1.33	1.33	0.39	0.25
Dendrocalamus strictus	0.33	2.67	2.0	0.33	1	0.41
Digitaria sp.	-	3.67	9.67	3.33	2.89	0.69
Vetiveria zizanoides	0.67	6.33	12.33	6.33	0.56	0.3
Herbs & shrubs						
Spermacoce sp.	-	3.33	6.28	12.33	3.68	0.19
Cordia myxa	-	2.98	3.65	9.33	1.28	0.56
Desmodium triflorum	-	1.33	2.98	12.33	0.56	0.41
Stylosanthes sp.	-	2.33	6.55	18.9	0.38	0.16
Urena lobata	0.12	5.29	2.33	6.68	3.46	0.41
Strobilanthes callosus	0.33	2.33	5.69	9.0	2.89	0.25
Strobilanthes ixiocephalus	0.33	2.33	6.56	12.33	0.56	0.30
Strobilanthes sp.	0.33	1.98	3.33	9.56	0.28	0.30
Gardenia	-	2.66	3.33	9.56	2.28	0.15

latifolia						
Grewia abutifolia	0.16	0.67	2.33	2.0	0.28	0.22
Helicteres isora	1.25	3.0	2.33	2.0	0.22	0.19
Symplocos racemosa	2.33	0.33	1.0	3.0	1.78	0.54
Vitex negundo	3.33	1.0	1.0	2.33	0.22	0.19
Trees/forbs						
Anacardium occidentale	12.33	-	-	-	0.22	0.19
Bauhinia racemosa	7.33	0.67	-	1.33	0.28	0.22
Butea monosperma	4.67	1.67	5.0	1.33	0.56	0.30
Cassia fistula	7.67	-	-	1.33	2.33	0.41
Dillenia pentagyna	12.33	-	-	-	1.0	0.33
Phyllanthes emblica	6.33	-	7.33	4.33	0.67	0.47
Gmelina arborea	4.0	-	6.33	0.67	1.33	0.17
Grewia tiliaefolia	7.0	-	5.0	1.33	0.17	0.41
Tamilnadia uliginosa	7.67	-	1.67	5.0	1.0	0.30
Syzygium cumini	0.33	-	4.33	0.33	0.56	0.22
*Tectona grandis**	-	-	-	-	-	-
Terminalia paniculata	6.67	0.67	0.67	0.67	0.22	0.19
Unidentified	-	0.33	0.33	0.67	-	-

*Bark of *Tectona grandis* not identified in faeces

Table 13: Season-wise availability (%) of various categories of plants and the composition (%) of gaur faeces using Ivlev's (1961) index of selectivity

Season	Plant category	Composition (U)	Availability (A)	Selectivity U-A/U+A
Summer	Graminoids (Grasses)	2	30	-0.9
	Herbs and shrubs	15	13	0.07
	Woody plants (Browse)	30	20	0.2
	Bamboo	4	2	0.33
Monsoon	Graminoids (Grasses)	23	5	0.64
	Herbs and shrubs	25	30	-0.09
	Woody plants (Browse)	3	23	-0.76
	Bamboo	4	2	0.33
Post-monsoon	Graminoids (Grasses)	35	5	0.75
	Herbs and shrubs	18	7	0.44
	Woody plants (Browse)	3	23	-0.76
	Bamboo	4	2	0.33
Winter	Graminoids (Grasses)	7	5	0.17
	Herbs and shrubs	16	10	0.23
	Woody plants (Browse)	6	5	0.09
	Bamboo	4	2	0.33

Table 14: Chemical composition (% dry matter) of seasonal composite samples of gaur faecal matter**.**

Season	CP*	ADL#	Cellulose
Summer	10.56±1.56	15.67±2.4	40.34±5.66
Monsoon	25.23±2.5	35.2±5.3	25.5±6.3
Post-monsoon	30.4±3.1	42.8±4.56	32.6±5.3
Winter	20.45±1.89	30.6±4.67	20.56±1.87

***CP=Crude protein; #ADL=Acid digestible lignin**

Table 15: Data on crop damage by gaur (n=128)

Season	Month	No. of incidences	%
Summer	March	14	11
	April	32	25
	May	25	19.5
Monsoon	June	6	4.7
	July	5	4
	August	1	0.78
Post-monsoon	September	1	0.78
	October	2	1.56
	November	6	4.7
Winter	December	12	9.3
	January	11	8.6
	February	13	10.1

Table 16: Population characteristics of crop raiding by gaur (n=128)

Month	Mean Herd Size	No. of incidences
January	7	11
February	4.92	13
March	10.68	14
April	13.96	32
May	14.36	25
June	18	6
July	10.4	5
August	4	1
September	8	1
October	14.5	2
November	12.83	6
December	12	12

t-test value: 0.278 ; Co-relation coefficient: 0.278

Coefficient of determination: 7.75

Table 17: Various crop protection measures used by farmers (n=34)

Measures	**% people adopted**
Manual guarding	64
Using Dogs	9
Electric fencing	6
Pipe or stone fencing	15
Others	6

Table 18: Composition of gaur herd (n=95)

Herd Size	Mean herd size	No. of times observed
Single Individual (1)	1	30
Small Herd (2-10)	5.73±2.1	45
Medium Herd (11-20)	12.8±2.1	13
Big Herd (>20)	21.3±3.8	02

DISCUSSION

Present research work involves an attempt to study the habitat ecology of gaur (*Bos gaurus*) in Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park in Goa. Results of this study are analyzed with reference to relevant studies/reports elsewhere, discussed and the significant inferences are outlined:

Habitat studies

Our investigations indicate the predominance of gaurs in moist deciduous forest against others including evergreen forest which is least preferred by them. Although gaurs have been reported as essentially a hill animal (Prater, 1971) during the present study we could find them often in plains. This observation of ours is in agreement with the reports of Choudhury (2002) that low-lying areas seem to comprise the optimal habitat for gaur. Further, as winter advances and the green grasses turn coarse with the advancing summer they were mostly found inhabiting semi-evergreen/evergreen forests and fed on the predominant species of that region. Often during summer gaurs were seen to visit sugarcane plantations may be because of the availability of both water and food in abundant quantity. The semi-evergreen and evergreen patches seem to be less preferred or never used in these seasons. Moist deciduous and grasslands were the most used habitats in monsoon and winter may be because of the abundance of grass species in this season. Schaller (1967) opined that

gaurs occur in forests with abundance of water and forage availability (in form of grasses, shrubs and trees).

Wharton (1968) reported that gaurs avoid evergreen rainforest, preferring foothill tracts of deciduous forests. In the present study, we could find gaurs in grasslands also apart from moist deciduous, semi-evergreen and evergreen forest as per the predominant vegetation of this study area.

In the present observation gaurs were found to occur at 100m MSL to 800m MSL. Earlier studies also reported them to occur within this range (Wood 1937, Wharton 1968, Choudhury 2002).

Duckworth *et.al* (2008) reported that gaurs can better tolerate rugged terrain and denser forest with adequate water sources. However in our present study we observed that gaurs avoid denser forests and prefer grasslands/open forests. The preference for grasslands may be due to the availability of grasses as food.

Animal population and density

Balkrishnan and Easa (1986) based on their studies on mammals of Parambikulam Wildlife Sanctuary in Kerala, reported that density of gaur population was higher in grassland than in moist deciduous forests. However, we could find maximum density of gaurs in moist deciduous forests followed by grasslands. This may be due to the domination of moist deciduous forests in our study area.

Human disturbance

Goa being a major tourist destination, thousands of tourists across the world visit the Sanctuary. Dudhsagar waterfalls and Devils Canyon being the major tourist destinations in the sanctuary were identified as highly disturbed regions.

Lopping and wood cutting activities were observed to be minimum in the study area may be because of the good management practices of the Forest Department in the Sanctuary. Although grazing by cattle was observed intermittently within some study sites, it was not as high enough to put pressure on the food resources of gaur. Madhusudan (2004) reported that interaction with domestic stock is probably the main factor which limits large herbivore populations in South and Central India. He further reported that gaur densities in shared grazing areas declined sharply with increasing livestock densities. However our observations do not match with his findings. This may be due to the low density of livestock in the study area.

Human-wildlife conflict

Human conflict with wildlife is a significant and growing conservation problem around the world. Conservationists have long been concerned about the effects of human disturbance on wildlife (Carney and Sydeman, 1999).

Bhattacharya *et.al* (1997) reported several straying cases of gaur in human habitations in North Bengal. Our present observation that gaurs account for the maximum damage to the sugarcane plantations in BMWLS and MNP in summer may be due to the scarcity of green vegetation and water in their natural habitat. Minimum

damage recorded in August to September may be due to the fact that food and water availability was in sufficient quantities in the sanctuary area in this season due to monsoon. Although sugarcane was cultivated in BMWLS and MNP throughout the year, crop raiding by gaur followed a seasonal pattern.

Veeramani and Jayson (1995) reported that gaur can also damage mulberry, paddy and other cash crops. In spite of the ready availability of paddy in addition to sugarcane in large quantities in our study area, gaurs raided only sugarcane plantations and fed on it. This may indicate that gaurs prefer sugarcane over paddy.

Crop damage in Caranzol village by gaurs observed in the present study may be because of its location in the core area and the surrounding hills on all the sides. Our present observation is in par with the studies of Studsrod and Wegge (1995) who reported that the seriousness of crop losses varied considerably with the distance from the parks border and specific location of households.

Crop protection strategies

In the present study, guarding was the most effective measure according to farmer's opinion, although it involved hardship and time. This observation of ours is in accord with several related reports (Studsrod and Wegge, 1995; Bhattacharya *et.al,* 1997; Sekhar, 1998; Chhangani and Mohnot, 2004). Fencing was not successful in the present study area and this is in par with the observation of Sekhar (1998) who also reported that fencing was not a successful crop protection strategy in Sariska Tiger Reserve.

Herd behavior

Our present findings that gaurs spent most of their daily time feeding with peak feeding hours in the early morning hours and in the evening hours is in agreement with Linnane *et.al* (2001). They observed that the total daily grazing time tends to be relatively stable in order to meet animals' nutritional requirements at the circadian level. In the present study on average gaurs fed for 15-18 hours a day. This is in agreement with the reports of Chetri (2006) who reported that 'because of their large size and energy demand gaurs have to consume large quantities of food'.

Other dominant activity recorded was movement (24 %) followed by resting (10 %). During hot hours of the day i.e. between 1330 hrs to 1530 hrs gaurs were found resting under the shade of tall trees. This is in agreement with the observation of Schaller (1967) who also reported gaur resting during noon hours in Central India.

Reproductive behavior

Juveniles were observed by us during February to November with no records in December and January. This may indicate that gaurs avoid mating during summer months of March and April. This observation of ours is in conformity with the findings of Stebbing (1911) and Brander (1923) that most gaurs mate in December to January in Central India. Schaller (1967) recorded rutting bulls in Kanha National Park during December to June, with an apparent peak of sexual behavior in March and April. In Southern India the majority of mating reportedly takes place between November to March (Morris 1937). However, in the present study the gaurs seem to avoid summer months may be due to shortage of food in the form of green vegetation.

Diet of gaur

On the basis of present study of gaur feeding habits it may be generalized that gaur is an intermediate or adaptable mixed feeder with an ability to adapt to poorer diets when high quality food is in short supply, such as in summer.

The statistically significant seasonal variation in food plants of gaur indicated that gaurs mostly consumed grasses and shrubs in monsoon, whereas in summer fed mostly on trees. Similar observations were made by Schaller (1967) in Central India where gaurs fed on various herbs, large quantities of leaves, shoots of bamboo, various grasses and leaves of various tree species. Further a higher preference for grass during June due to the abundant growth of new grass stimulated by monsoon was observed by Chetri (2006).

In the present study we could observe that finer and fresh grasses were preferred by gaurs as compared to coarse grasses. Our results are supported by studies of Shukla and Khare (1998) who reported that gaur grazed and browsed on varieties of green grasses, young leaves and soft shoots. But Sathyanarayana and Murthy (1995) as well as Srivastava *et.al* (1996) reported that gaurs prefer both finer and coarse grasses.

Shukla and Khare (1998) reported that gaurs did not differentiate between varieties of grasses. However in spite of the availability of few more tall grass species, gaurs fed on only two tall grass species viz. *Dendrocalamus strictus* and *Bambusa arundinacea.* The selectivity index for these two species was positive throughout the year whereas the selectivity index for other graminoids, herbs and woody plants

showed seasonal variation. Pasha *et.al* (2002) reported that browse formed a major proportion of the diet of gaur during summer. This may be due to unavailability of grasses and shrubs in enough quantities during this part of the year.

Although three species of *Strobilanthes* were available in study area comprising of more than 60% of ground vegetation in winter and summer, gaurs preferred only two species *viz*. *Strobilanthes ixiocephalus* and *Strobilanthes callosus*.

Fruits of *Dillenia pentagyna* and *Anacardium occidentale* (discarded by the locals after extracting juice for Cashew feni) were recorded in the diet of gaur in the months of April to May (summer). Similar frugivorous habit of gaurs was reported earlier by several authors. Gaurs feeding on fruits of *Phyllanthus emblica* and *Terminalia chebula* were observed by Chetri (2006). Krishnan (1972) also observed gaurs feeding on fruits of *Cassia fistula*, *Gmelina arborea*, *Aegle marmelos*, *Phyllanthus sp* and *Terminalia bellerica*. These varieties of fruits although available in abundance in the study area were not consumed by gaurs. This may be because of the availability of sufficient forage in form of trees. Fruits of *Dillenia pentagyna* and *Anacardium occidentale* were preferred by gaurs in Goa over others.

Our observation that gaur fed on bark of young *Tectona grandis* trees is in agreement with similar findings of Ranjitsingh (1997), Shukla and Khare (1998) and Pasha *et.al* (2002). Gaur is also known to feed on bark of *Adina cordifolia* (Brander, 1923; Schaller, 1967; Shukla and Khare 1998), *Holarrhena antidysentrica* (Ogilive, 1954) and *Wendlandia natoniana* (Ogilive, 1954). However in spite of the abundance

of these trees in our study area gaurs were not observed debarking them. This may indicate the preference of gaurs on *Tectona grandis* over other species.

Feeding on bark in summer may be due to scarcity of green vegetation. Several authors have put forth their views to explain the probable cause for the debarking behavior of different species of mammals. The mammals may debark in response to shortage of food resource in an area (Mac Kinnon, 1976) or shortage of minerals and trace elements required to meet their nutritional demands (Allen, 1989; Bax and Sheldrik, 1963; Croze, 1974 and Vancuylenberg, 1977) or for maintaining an optimum fibre: protein ratio for proper digestion of food and better assimilation of nutrients (Spinage, 1974). In dry season, high fibre diet increases the retention time of food in the gut (Owen-Smith, 1988) and also decreases the turnover rate of the rumen contents (Bell, 1971). Tewari (1992) reported high concentration of calcium (22400 ppm) and phosphorus (400 ppm) in the teak bark. Thus the consumption of teak bark may help the gaurs to satisfy their mineral needs and meet the food shortage to fulfill their physiological and nutritional requirements.

In the present study gaurs were found to drink at least once during day either early morning or late evening. Our present observation is in agreement with Schaller (1967) who reported that gaur in Kanha National Park drunk at least once per day during the hot season. Sahai (1972) stated that gaur drank at least twice in a 24-hour period but there appears to be no fixed time for drinking. Vairavel (1998) reported that gaurs in Parambikulam Wildlife Sanctaury were seen drinking water only during noon hours.

Our present observation that gaurs visit natural as well as artificial salt licks periodically for minerals is supported by similar reports of Schaller (1967) and Krishnan (1972).

Quality of the diet

The relative frequency of different plant species recorded in the diet of gaur showed seasonal variation with the frequency of grasses in the fecal matter progressively decreasing from monsoon to winter. The frequency of tree species or forbs in the fecal matter increased from post-monsoon to summer and showed highest frequency in summer. This may be due to unavailability of green grasses in summer. This observation of ours is in agreement with Chetri (2006) who opined that seasonal availability of plant species could be a major factor governing food consumption.

Herd size and composition

In the present study, the most frequent herd size was that of 2-10 individuals (n=45). Big herds consisting of more than 20 individuals were observed rarely. The mean herd size reported was 5.73±2.1 and this observation is in agreement with Brander (1923), Hubback (1937), Hislop (1961), Schaller (1967), Sahai (1972), Belsare *et.al* (1984) and Vairavel (1998) who reported herd size to be in the range of 5–12 animals.

In the present study, the ratio of bulls to cows was 0.98. Ahrestani *et.al* (2010) reported this ratio to be 0.86 at birth in captive population at Mysore zoo. Schaller, (1967) also reported that bulls and cows are equal in proportion.

We could observe that the fully-grown adult black bulls were always solitary and were never seen joining a herd. Such observations were also reported by Schaller (1967), Belsare *et.al* (1984) and Forsyth (1989). According to Brander (1923) the old bulls lead a solitary life and seem to have lost sexual instinct at a comparatively early age. In the present observation in a single occasion, adult black bull was seen on the same place for two consecutive days. This is in agreement with the report of Schaller (1967) that solitary bulls might take up residence along a particular area for several days.

Major findings:

1. This is the first such scientific study on gaur in Goa.

2. Moist deciduous forest is the most preferred habitat of gaur over grassland, evergreen and semi-evergreen forests.

3. Gaur is an intermediate or adaptable mixed feeder, consuming varieties of grasses, herbs and forbs.

4. Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park may form a ideal habitat for gaur if problems of crop raiding are reduced.

Table 2: Density of gaur using DISTANCE analysis in four habitats based on different class intervals

	Class intervals											
	30m X 4 classes			**20m X 6 classes**			**20m X 7 classes**			**10m X 12 classes**		
Habitat type	**Group density**	**CV (%)**	**χ 2 (df)**	**Group density**	**CV (%)**	**χ 2 (df)**	**Group density**	**CV (%)**	**χ 2 (df)**	**Group density**	**CV (%)**	**χ 2 (df)**
MDF	**3.28**	**12.2**	**4.72 (2)**	**3.47**	**14.1**	**10.7 (4)**	**3.32**	**10.4**	**9.42 (5)**	**5.28**	**12.1**	**31.7 (10)**
EF	**1.08**	**18.8**	**0.52 (1)**	**1.70**	**25.2**	**23.7 (3)**	**0.66**	**16.4**	**18.8 (5)**	**0.67**	**20.4**	**29.8 (10)**
SEF	**2.33**	**12.2**	**4.72 (2)**	**2.16**	**12.1**	**11.4 (4)**	**3.63**	**14.0**	**18.7 (5)**	**2.11**	**12.0**	**31.8 (10)**
GRS	**0.71**	**62.2**	**10.89 (1)**	**0.68**	**82.9**	**17.7 (3)**	**1.33**	**32.0**	**15.3 (4)**	**1.16**	**23.7**	**24.5 (10)**

Table 5: Human disturbance assessment (Study sites surveyed n=14)

STUDY SITES SURVEYED	Human disturbances					
	0-4 Rating*					
	Wood cutting ±SE	**Lopping ±SE**	**Grass /Bamboo cutting ±SE**	**Presence of human/livestock trail ±SE**	**People seen Yes (Y) or No (N)**	**Livestock seen Yes (Y) or No (N)**
Nandran village	0	0	0	3.67**±1.2**	Y	Y
Nandran Mol	0.33**±0.1**	0	0	2.33**±1.1**	Y	Y
Grass plot	0	0	0	1.33**±0.5**	N	Y
Vasant Bandhara	0	0	0	0.33**±0.1**	N	N
Ring Road	0	0	0	0.33**±0.1**	N	N
Dudhsagar 1	0.33**±0.1**	0	0	2.33**±1.1**	Y	Y
Dudhsagar 2	0	0	0	2**±1**	N	Y
Devils canyon	0	0	0	4**±2**	Y	N
Caranzol 1	0	2.33**±1.2**	0	3.33**±0.5**	Y	Y
Caranzol 2	0	0	1.33**±0.5**	1.33**±0.5**	Y	Y
Collem	0	0	0	4**±2**	Y	N
Surla 1	1.67**±0.9**	0	0	3.67**±1.2**	Y	Y
Surla 2 (Bolkornem)	0	0	0	3**±1**	Y	Y
Sigao	0	0	0	1**±0.5**	Y	N

*0=No; 1=Very low; 2=Low; 3=High; and 4=Very high

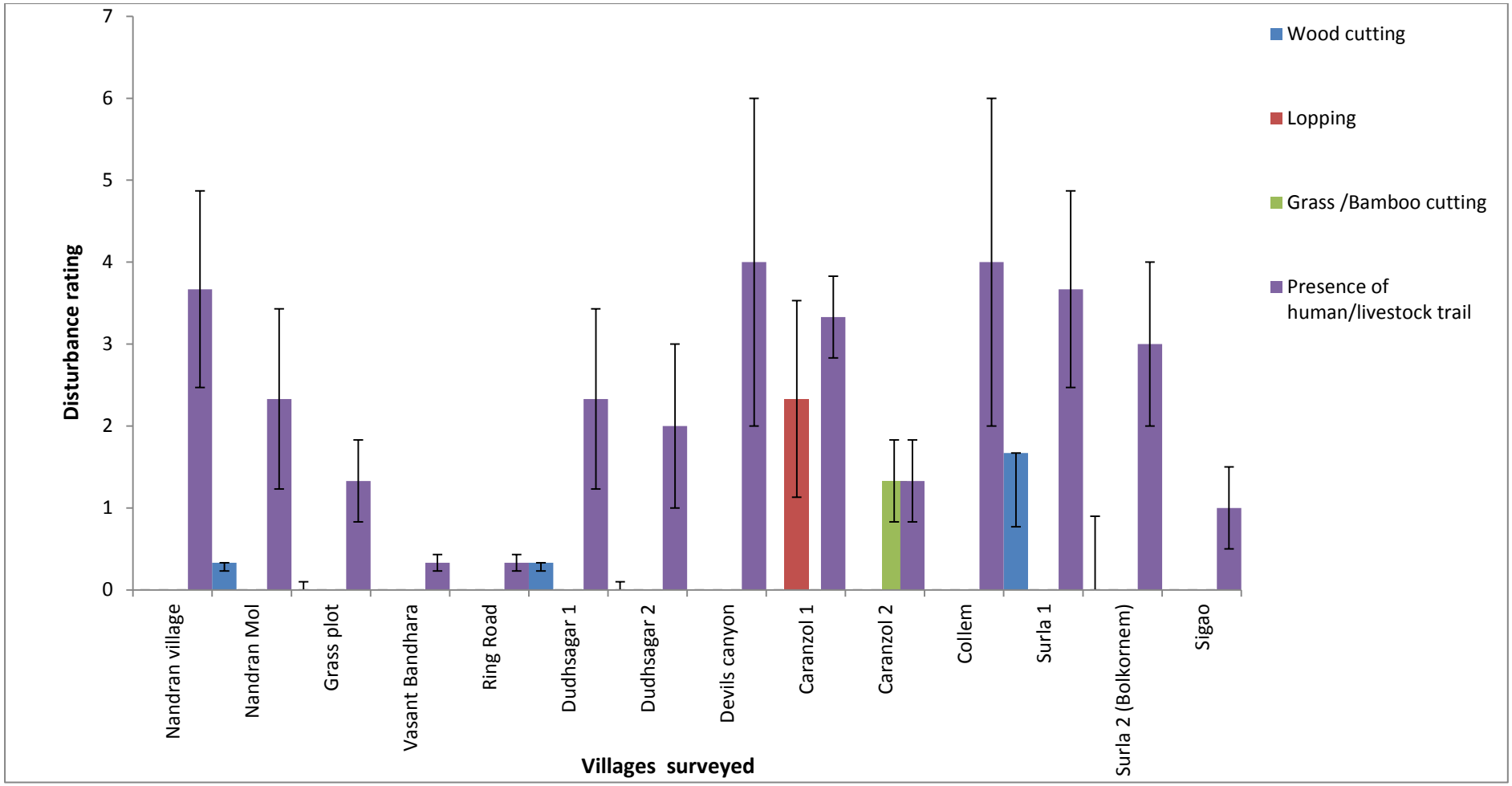

Fig. 8: Human disturbance assessment in study area

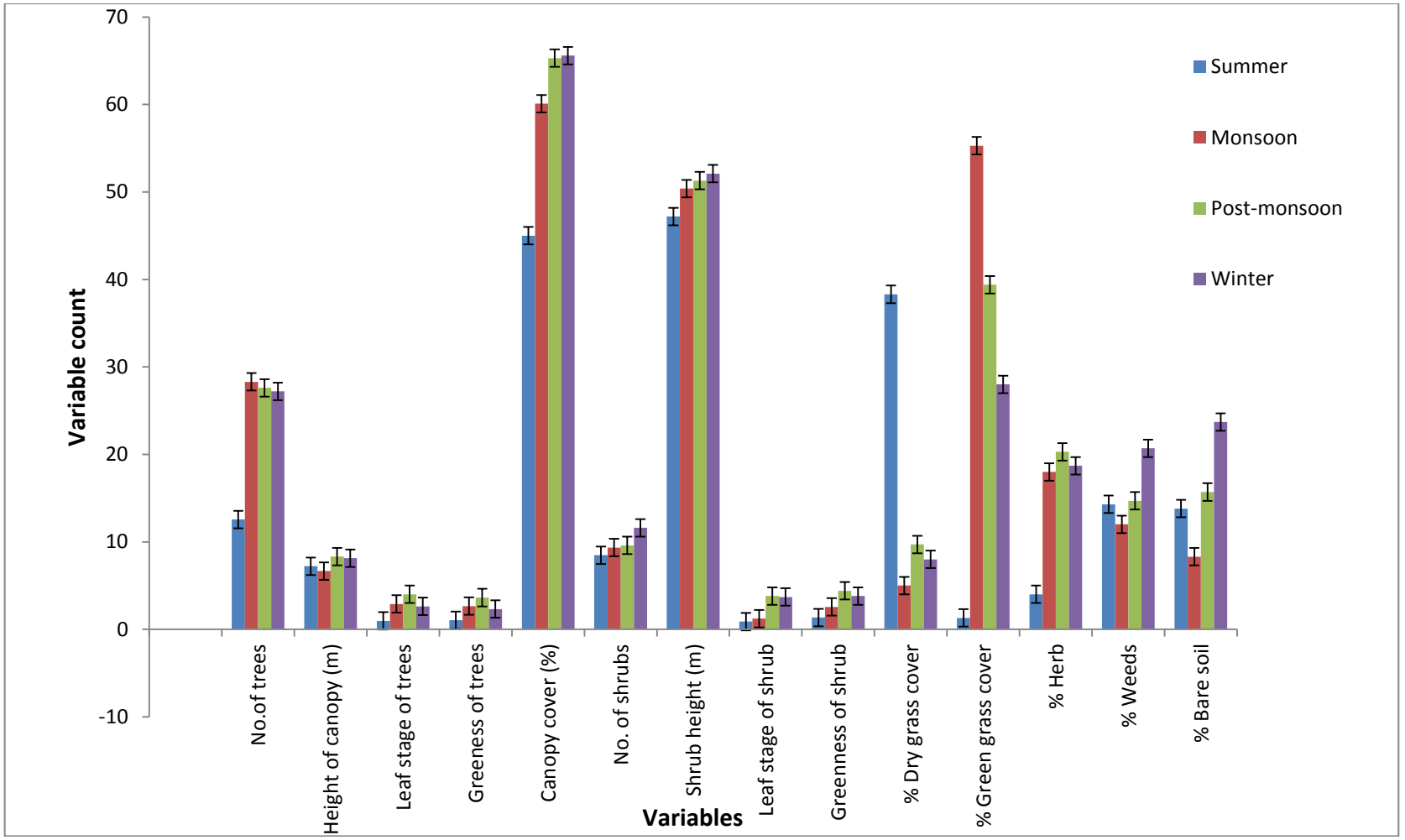

Fig. 7: Habitat variables encountered in study area

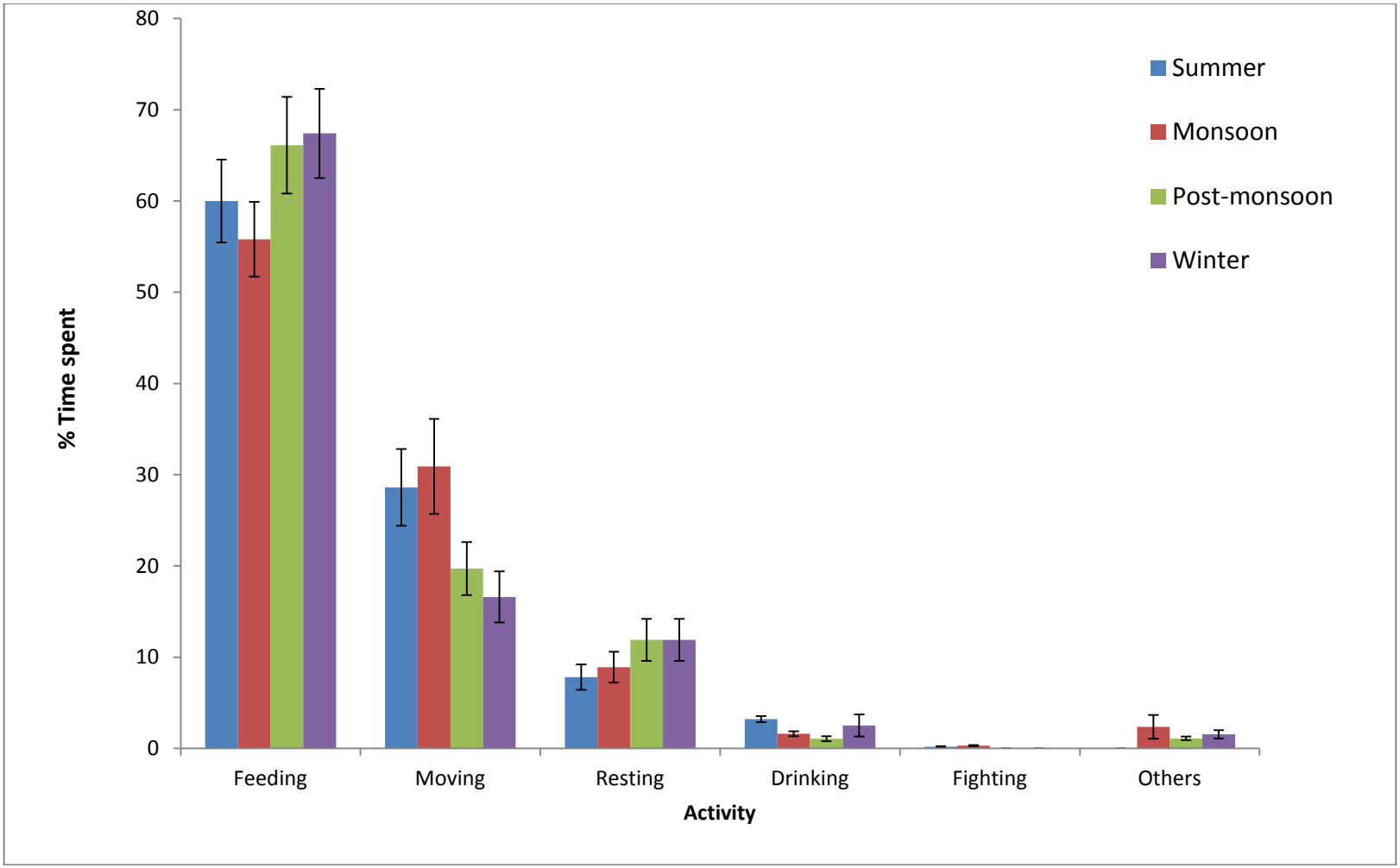

Fig. 9: Activity budgets expressed by gaur in different seasons

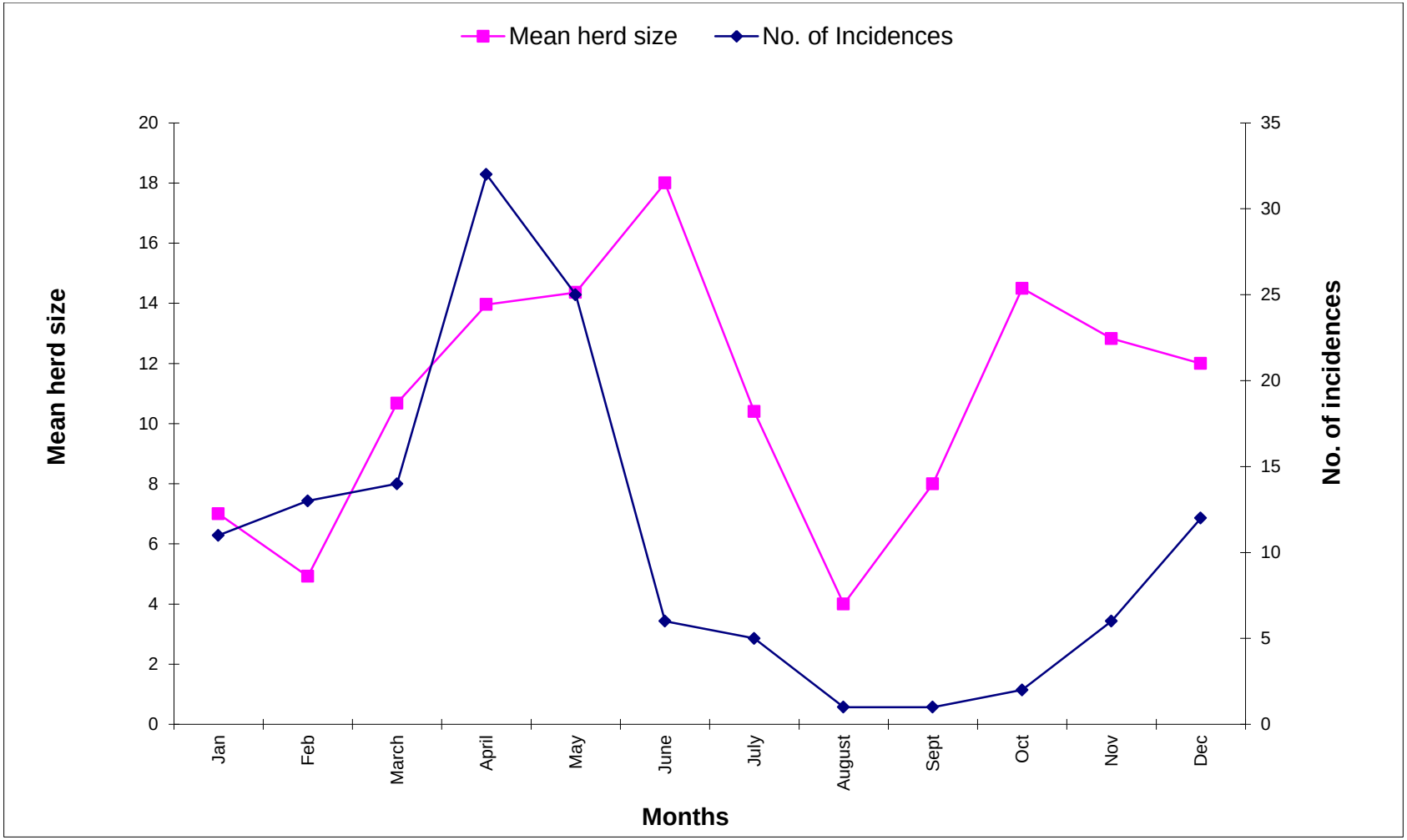

Fig. 15: Corelation of mean herd size and number of incidences of crop damage by gaur

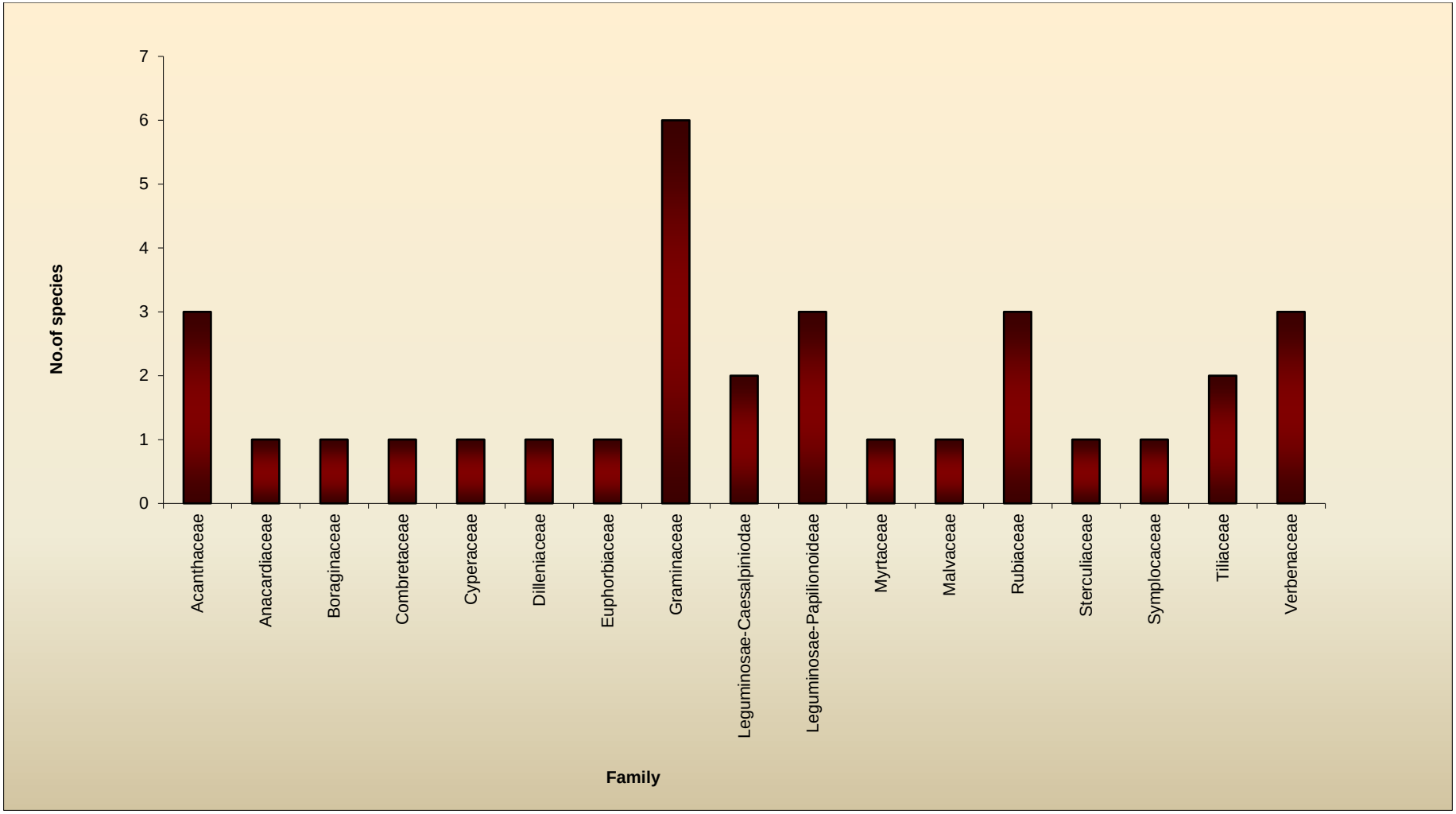

Fig. 12: Familywise representation of food species of gaur

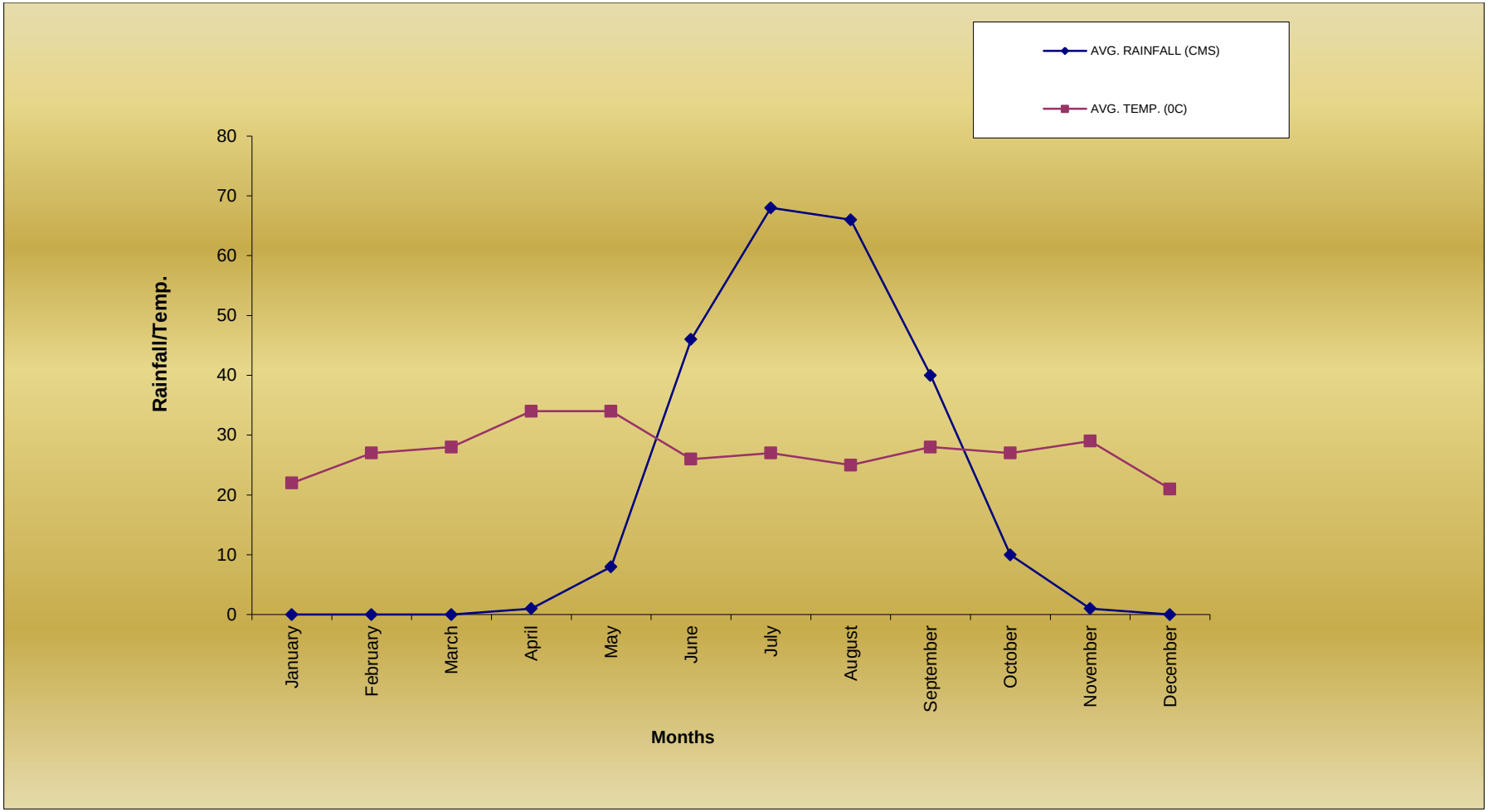

Fig. 6: Monthwise rainfall and temperature of the study area

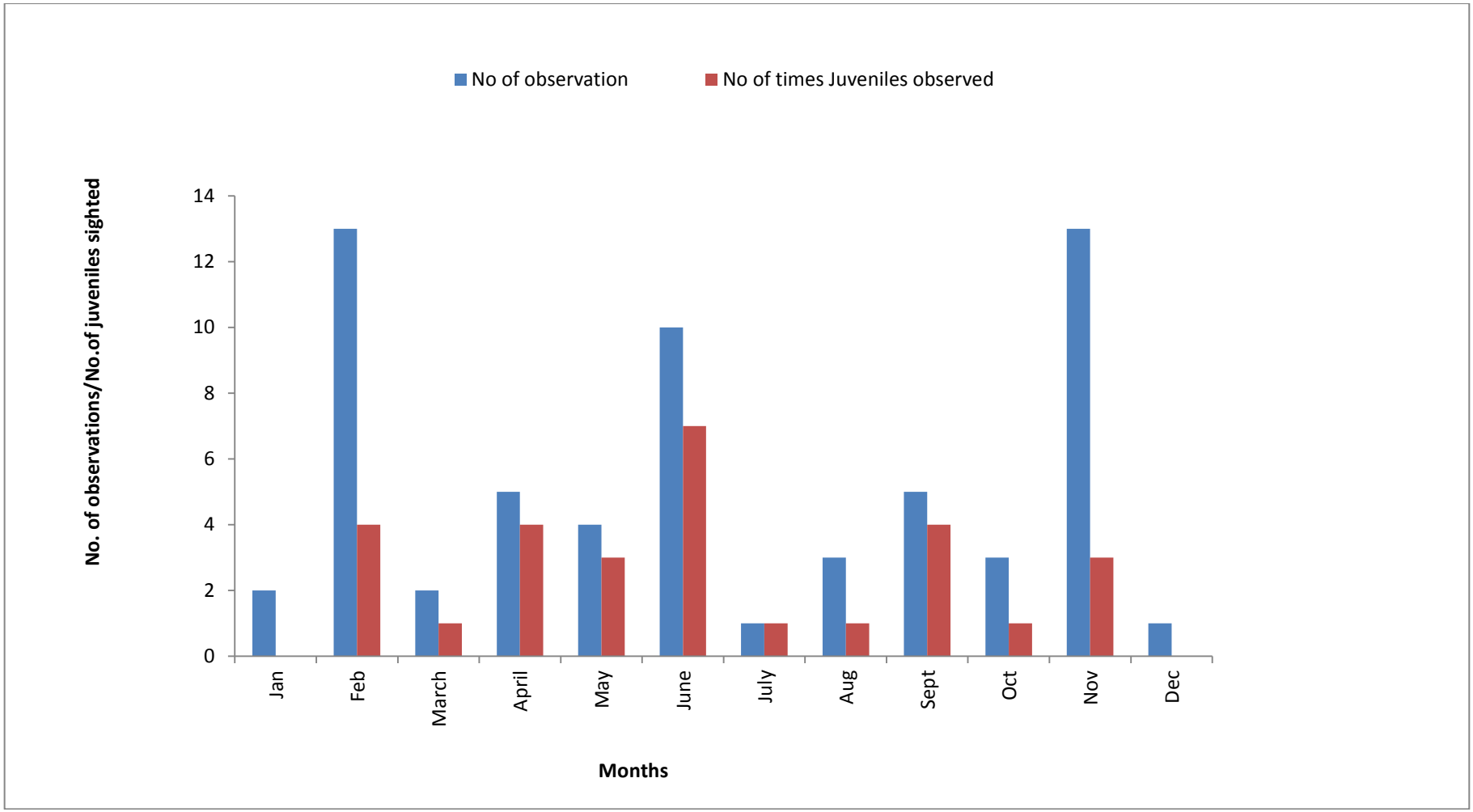

Fig.10: Record of juveniles sighted in the study area

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Ia) DATA SHEET FOR GAUR (*Bos gaurus*) ENCOUNTER RATE (ER) ON LINE TRANSECTS

Observer Name:…….. Start time:……

Date:…… End time:……..

ID No of line transect:…… Total length: _____Km

Beat:…… Range:……..

Whether condition: Cloudy/Clear sky/Rainy:…….

Sl. No	Time	Total Nos.	Young	Forest type	Terrain type	Remarks
1						
2						
3						

Ib) DATA SHEET FOR LINE TRANSECT SAMPLING TO ESTIMATE ANIMAL DENSITY

Observer Name:…….. Start time:……

Date:…… End time:……..

ID No of line transect:…… Total length: _____Km

Beat:…… Range:……..

Whether condition: Cloudy/Clear sky/Rainy:…….

Strata*	Strata area	Transect ID	Transect length	Angular distance	Angle	Group size	Perpendicular distance

*Strata-Type of forest (1-MDF; 2-EF; 3-SEF; 4-GRS)

Ic) DATA SHEET FOR SAMPLING VEGETATION (15 m Plot)

Name of the observer:…….. Date…….

Range……. Beat……

ID of line transect……..

Distance of the plot from start of transect in meters	**Canopy cover (%)**	**Tree species (All veg > 6ft) Descending order of abundance**					**Shrub species (veg. >20cm & < 6ft tall) Descending order of abundance**					**Weed/Invasive species (Descending order of abundance)**	**Remarks**
		1	2	3	4	5	1	2	3	4	5		

Id) DATA SHEET FOR RECORDING HUMAN DISTURBANCE

Name of the observer:…….. Date…….

Range……. Beat…… ID of line transect……..

Distance of the plot from start of transect in meters	**Human disturbances** **0-4 Rating, 0-No; 4-Very high**					
	Wood cutting	**Lopping**	**Grass /Bamboo cutting**	**Presence of human/livestock trail**	**People seen Y/N**	**Livestock seen Y/N**

Are there any permanent human settlements in the beat? (Y/N). If yes, how many?……..

If there is any NTFP collection in the beat? If Yes, what NTFP?……..(0-4 scale)

Ie) DATA SHEET FOR RECORDING GOUND COVER (1m radius or 2m diameter plot)

Name of the observer:…….. Date…….

Range……. Beat…… ID of line transect……..

Distance of the plot from start of transect in meters	**Dry leaf litter %**	**Ground cover (The following 5 columns should total 100 %)**					**Grass species (Descending order of numbers)**			**Herb species (Descending order of numbers)**			**Remarks**
		Dry grass %	Green grass %	Herb %	Weeds %	Bare soil %	1	2	3	1	2	3	

If) DATA SHEET FOR RECORDING BEHAVIOUR OF GAUR

Date:…… Time:…….

Observer:……. Area:……

Time (hrs.)	Activity					
	Feeding	**Movement**	**Resting**	**Drinking**	**Fighting**	**Others**
Total records						

Ig) DATA SHEET FOR RECORDING COMPOSITION OF GAUR HERD

Month	Herd size	Time	Activity	Herd composition					
				Old Bull	Adult male	Adult female	Juvenile	Sub adult	Unsexed

SUMMARY

The present research work was planned to study habitat ecology of gaur *Bos gaurus* at Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park of the Western Ghats of Goa. The objectives of the present study were to study distribution, density, food and feeding habits, behaviour and conflicts of gaur with humans.

The animal selected for study, Indian Bison or gaur (*Bos gaurus*) is a vulnerable species and is also the state animal of Goa.

The study area Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park is part of the South-western ghats with tropical evergreen, semi-evergreen, moist deciduous and sub-tropical hill savannah woodlands type of forest. Climatically the area has four seasons, viz. summer, monsoon, post-monsoon and winter.

The density of gaur population was estimated by line transect method (Thomas *et.al*, 2010). Vegetation sampling was undertaken for all habitat types and ground cover was estimated. Behavioural patterns were studied by scan and focal animal sampling methods given by Altman (1974).

Diet composition was studied by two methods viz. direct observation and faecal analysis (Satakopan (1972). The study of food selection was based on seasonal

comparison between the composition of the faeces and that of available vegetation, using Ivlev's (1961) index of selectivity as Selectivity =U-A /U+A.

Crude protein measured as nitrogen 6.25 was determined by Kjeldahl procedure (AOAC, 1990). Cellulose and lignin contents were analyzed using Van Soest (1982) detergent procedure analyzing NDF, ADF and ADL.

Data on crop depredation was obtained by questionnaire survey at village and household level. The farmers, forest guards and locals were interviewed to ascertain the extent of perceived damage, patterns of crop depredation, time of raiding and other details. Herds of gaur were categorized into age sex classes to determine herd size and composition.

The results suggest that BMWLS and MNP supported a large population of gaur (335±28 individuals). Gaur showed a high overall individual density of 33.28±6.53 animals/ sq. km (Data at 95% Confidence interval) in MDF as compared to GRS (20.6±6.3), SEF (16.4±2.53) and EF (5.66±1.6). Encounter rate was found to be highest in moist deciduous forests (125±6 individuals/100 sq. km) and lowest in evergreen forests (23±7 individuals/100 sq. km).

Gaurs were found to be primarily intermediate or adaptable mixed feeders with grasses, shrubs and forbs constituting the bulk of diet. Thirty-two species of plants belonging to seventeen families were identified as food plants of gaur. These included seven species of grasses, five species of herbs, eight species of shrubs and twelve species of trees.

Significant variations were noticed in the quantity of various chemical constituents in the monthly faecal samples and are comparable with changes in forage quality. Crude protein contents of faeces were high during monsoon and post-monsoon and low in summer. Conversely faecal cellulose was low in monsoon and post-monsoon and high in summer.

The selectivity index for bamboo was positive throughout the year, whereas those of herbs and woody plants showed seasonal variation. A negative index observed for graminoids in summer indicated that green grasses were not consumed due to its unavailability. Leaves of woody trees were avoided for most part of the year except in summer when green vegetation (mostly grasses) was scarce. Ground vegetation constituted between 75-100% of standing crop within reach of gaur. Leaves were consumed the most as compared to other plant parts.

Out of the 14 plots studied, two plots were found to be highly disturbed. Cattle grazing were observed in seven out of 14 plots surveyed. Other livestock and people were seen in majority of the plots studied.

Altogether 10,714 scan records were made. The results showed that gaurs spend most of their daily time feeding (63%). No significant differences between seasons were observed.

Altogether 128 crop-raiding cases were reported from the study area over a period of two years. Maximum cases were reported in summer (57%) and minimum in post-monsoon (7%) with highest number in the month of April. The most

commonly used crop protection strategy (by 64% farmers) is guarding their fields by constant vigilance during night hours. 15% of farmers protect the field by pipe or stone fencing. Few farmers (~9%) use dogs whereas 6% of farmers even use fatal methods like high voltage electric fencing in which gaurs are usually killed or seriously injured.

95 observations on gaur herd were made and total 90 herds were observed consisting of 361 individuals. This included 30 solitary bulls, 45 small herds and 13 medium sized herds. Each herd consisted of bulls, cows, yearlings and sub-adult gaurs. Big herds consisting of more than 20 individuals were observed only twice. Altogether 117 bulls and 111 females were observed. The adult black bulls were always found to be solitary. The most frequent herd size was that of small sized herd (mean herd size-5.73±1.23).

The present results are discussed objective-wise and compared with studies in other parts of the subcontinent.