Understanding Social Behavior and Dynamics of Four-horned Antelope in Captivity

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Abstract:

The Four-horned Antelope, a typically shy, elusive, and solitary species, is found throughout India, excluding the coastal regions, and is housed in 26 zoos across the country. Despite this, there is a scarcity of studies on their social behavior, leading to a knowledge gap in conservation strategies and captive breeding program management. Our study, conducted at Sardar Patel Zoological Park, focused on the social behaviors and group composition of 14 Four-horned Antelopes (1 male, 7 females, 6 fawns) housed in a mixed-herbivore enclosure with Spotted Deer, Thamin Deer, Barking Deer, and Himalayan Goral. Contrary to their natural solitary behavior, our findings suggest that in captivity, Four horned Antelopes prefer to stay in groups and exhibit social behaviors.We observed daily activity patterns among the Four-horned Antelopes and found significant differences in the activities of males and females. Our study also revealed novel behaviors in Four-horned Antelopes, such as allonursing, allosuckling, head bunting, excitatory behaviors, and inter-specific grooming. These findings can contribute to the development of improved strategies for the conservation and management of Four-horned Antelopes in captivity.

Understanding Social Behavior and Dynamics of Four-horned antelope in captivity

A Dissertation thesis submitted

In Partial Fulfilment of the Requirement for the Degree of Master of Science

In

ZOOLOGY

BY

Mr. Rohan Kunchala

(PRN No. 8022013522)

To the

DEPARTMENT OF ZOOLOGY

Faculty of Science

THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA

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7. The thesis has been prepared without resorting to plagiarism.
8. All sources used have been cited appropriately.
9. The thesis has not been submitted elsewhere for a degree.

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CERTIFICATE

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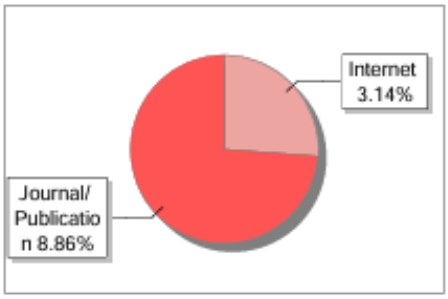

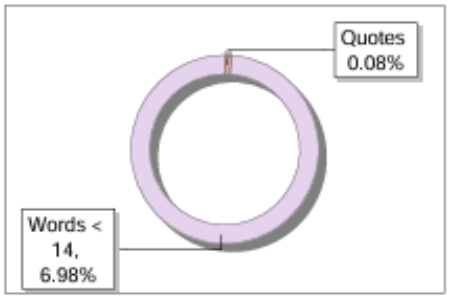

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LIST OF ABREVIATION

- IUCN SSC – International Union for Conservation of Nature Special Survival Commission.
- ZIMS – Zoological Information Management System.
- CZA – Central Zoo Authority.
- SPZP- Sardar Patel Zoological Park.

ABSTRACT

The Four-horned Antelope, a typically shy, elusive, and solitary species, is found throughout India, excluding the coastal regions, and is housed in 26 zoos across the country. Despite this, there is a scarcity of studies on their social behavior, leading to a knowledge gap in conservation strategies and captive breeding program management.

Our study, conducted at Sardar Patel Zoological Park, focused on the social behaviors and group composition of 14 Four-horned Antelopes (1 male, 7 females, 6 fawns) housed in a mixed-herbivore enclosure with Spotted Deer, Thamin Deer, Barking Deer, and Himalayan Goral.

Contrary to their natural solitary behavior, our findings suggest that in captivity, Four-horned Antelopes prefer to stay in groups and exhibit social behaviors. This group preference appears to be influenced by factors such as age, sex, and inter and intra-specific interactions between enclosure species.

We observed daily activity patterns among the Four-horned Antelopes and found significant differences in the activities of males and females. Males predominantly spent their time resting and engaging in reproductive activities, while females spent more time exploring and feeding.

Our study also revealed novel behaviors in Four-horned Antelopes, such as allonursing, allosuckling, head bunting, excitatory behaviors, and inter-specific grooming.

These findings can contribute to the development of improved strategies for the conservation and management of Four-horned Antelopes in captivity.

1. **Introduction**

Zoos and wildlife parks are home to a wide variety of animals that serve essential functions in the fields of education, research, and conservation. Various factors threaten the welfare of captive animals in artificial habitats, hence one of the crucial goals of zoos around the world is to improve the health and welfare of animals kept in non-native climates. In order to accomplish this objective, it is necessary to have a solid understanding of the social behavior of animals that are kept in captivity and the ways in which their environment affects that behavior. It is essential to have a comprehensive grasp of the social behavior and dynamics of these species, in addition to assuring the well-being of animals that are maintained in captivity and improving breeding programs that are effective. This research is to investigate the social behavior and dynamics of captive Four-horned Antelope, a species that is well-known for the complex social interactions it engages in.

The Four-horned Antelope, *or Tetracerus quadricornis*, is an endemic species of antelope found in Nepal and India (Meghwal et al., 2018). It is also referred as the Chousingha in local languages. In the past, four-horned antelope were inhabited all over India, with the exception of coastal areas. They were seen in the terai forests of Jammu in the north, the Nilgiri Hills of Tamil Nadu in the south, the Gir forests of Gujarat in the west, and the Bengal region in the east. The only antelope in the world with four horns one anterior pair and one posterior pair is the Four-horned Antelope, which is a member of the tribe Boselaphini of the subfamily Bovinae (Family Bovidae) (Meghwal, 2018; Kunwar et al. 2016).

The Four-horned Antelope eats fruits, shrubs, forbs, and various types of grass. It is known to stimulate the nitrogen cycle and help spread seeds from various plant species (Krishna et al., 2008). Over 90% of their global distribution is currently found in India, making their distribution irregular and highly fragmented (Meghwal et al., 2018). Very little research and conservation effort has been dedicated to the species (Meghwal et al., 2018). The Four-horned Antelope is listed as Vulnerable by the International Union for the Conservation of Nature (IUCN) under Red-list of Threatened Species (IUCN SSC Antelope Specialist Group 2017) and it is protected in India under Schedule I of the Wildlife (Protection) Act, 1972.

1.1.Species Description

Fig:1 Four-horned Antelope at Enclosure

The Four-horned Antelope is a light brown-colored, solitary animal but sometimes observed in groups of three to five. Its weight is approximately 20–25 kg, and its body length is approximately 80–100 cm (Meghwal, 2018; Sharma et al., 2009). Its four horns—one pair of front horns and one pair of back horns set it apart from other antelopes. The front horns are smaller than back horns (Meghwal et al., 2018). They can be distinguished from other antelopes like the Blackbuck (*Antilope cervicapra*) and Chinkara (*Gazella bennettii*) by their lack of horn rings. Another antelope without horn rings is the Nilgai (*Boselaphus tragocamelus*), both of which are native to the Indian subcontinent (Sharma et al., 2009). Despite being widely dispersed throughout the Indian subcontinent, their abundance rates are not very high (Baskaran et al., 2009). It is exceedingly difficult to notice them in the wild because of their modest body size and shy and elusive behavior (Meghwal et al., 2018; Baskaran et al., 2009; Swain et al., 2003). The four-horned antelope is often confused with similarly sized antelopes such as the Muntjac (*Muntiacus muntjac*) and Hog deer (*Axis porcinus*) (Sharma, 2009; Meghwal et al., 2018).

1.2. Sub-species and Distribution

Based on morphometric data, body size, coloration, and horn shape, there are three subspecies. *Tetracerus quadricornis sub-quadricornis* of southern India is distinguished by the absence of the anterior pair of horns (Meghwal et al., 2018). *Tetracerus quadricornis quadricornis* of central India is characterized by its large size and large horns. *Tetracerus quadricornis iodes* of northern India and Nepal are similar in size to *Tetracerus quadricornis quadricornis* but have smaller horns (Meghwal et al., 2018).

1.3. Habitat

The Four-horned Antelope avoids densely forested areas and is commonly found in dry deciduous forests, open grounds, hilly regions, and wooded areas (Meghwal et al., 2018; Sharma et al., 2009; Swain et al., 2003). Due to increased visibility, the Four-horned Antelope favours deciduous forests resembling wide savannas. (Swain, 2003; Meghwal et al., 2020). For the Four-horned Antelope (Swain et al., 2003), the zone between dense mixed and open savanna-type deciduous woodland is excellent. The Four-horned Antelope prefers regions with short grass that ranges from 25 to 70 cm in height, as well as an open canopy that conceals their presence. They feed their young and rest in areas with a closed canopy and dense undergrowth, while they forage in areas with an open canopy. In summertime, four-horned antelopes inhabit regions that are vulnerable to forest fires (Swain et al., 2003).

1.4.Behavior

The Four-horned Antelope is a shy and elusive species that usually stays away from humans. If they sensed danger, they would swiftly hide behind a dense canopy (Meghwal, 2018; Sharma et al., 2009). They are usually seen alone, though occasionally groups of three to five are observed (Meghwal et al., 2018 and 2020; Swain et al., 2003). The four-horned antelope is a non-migratory, likely sedentary, and territorial species that inhabits its small home ranges and typically stays there for the duration of its life (Swain, 2003; and Meghwal et al., 2020). The Four-horned Antelope has a distinctive antipredation strategy in that, instead of immediately running away from a threat, it prefers to hide and freeze (Swain, 2003; Pokharel et al., 2015). In the occurrence of a frontal confrontation with a threat, it immediately flees that way (Pokharel et al., 2015). They typically eat in the morning and evening, and in the middle of the day, they relax, drink water, and lick salt (Pokharel et al., 2015). They have two well-developed glands between their hind legs'

artificial hooves, although it's unclear what they're used for. In general, males and females live independently and only interact during the mating season (Krishna et al., 2009).

In most cases, breeding takes place between the months of June and August (Meghwal, 2018; Krishna et al., 2009). Fawning begins in February and continues through May. These animals have a preference for certain areas to defecate, and they will frequently return to these areas—also known as middens (Baskaran et al., 2009; Krishna et al., 2008 and 2009; Sharma et al., 2009; Swain et al., 2003).

1.5. Biological Role

The Four-horned Antelope contributes to the dispersal of indifferent species' seeds since it is a species that consumes indifferent grass, shrubs, forbs, and fruits. Less than 2 percent of large carnivores' diets are made up of Four-horned Antelope (Meghwal et al., 2018). The nitrogen cycle is stimulated in part by the Four-horned Antelope (Krishna et al., 2008). In-depth research is needed to close the existing gaps in our knowledge of ecology and its function, as there are still gaps in the data (Meghwal, 2018; Krishna et al., 2008).

1.6. Threats to the species

Habitat loss due to increasing human activity poses a significant threat to the four-horned antelope, potentially leading to local extinction (Meghwal, 2018; Sharma et al., 2009). They are occasionally killed for bush meat, but mostly for their skull, which is a sought-after trophy for trophy hunters (Krishna et al., 2008 and 2009). An additional danger to Four-horned Antelope is loping and cutting for fuel wood and fodder. The main danger to Four-horned Antelope is cattle grazing. Although antelopes and other ungulates should

naturally compete with cattle for food resources, cattle grazing causes the natural food sources to diminish, placing additional strain on antelopes and other ungulates (Meghwal et al., 2020). One of the main threats in the summer is fire (Baskaran et al., 2009). Invasive species, like lantana, are also a serious threat because they impede the passage of native vegetation and trees and prevent them from growing, which reduces the antelope's access to food sources (Meghwal et al., 2018).

1.7.Four-horned Antelope in Captivity

The Zoological Information Management System (ZIMS) database suggests that there are 143 (45 males, 50 females, and 58 unknowns) specimens in the population of this species, which is kept in 14 institutions across the Indian subcontinent (Wildlife Institute of India, 2018). Only one institution outside of India is listed in the database—the National Trust for Nature Conservation, Kathmandu—as possessing three (2 male and 1 female) specimens in Nepal (Wildlife Institute of India, 2018). According to the Central Zoo Authority (CZA) inventory, there are 261 (91 males, 120 females, and 50 unknowns) specimens at 23 Indian zoos, although the information provided by 15 holding zoos for the studbook's compilation has 153 (50 males, 73 females, and 30 unknowns) specimens (Wildlife Institute of India, 2018). The species was first known to be kept in captivity in 1979 at Sakkarbaug Zoological Garden in Junagadh, when the zoo bought a doe from the wild. The main cause of population growth has been captive births with specimens from the wild; these births account for just 24% of the captive population 84 (42 males and 42 females) (Wildlife Institute of India, 2018). There have been 266 births that have occur in captivity, with 115 males, 119 females, and 32 unknowns. This accounts for 76% of the total population of Four-horned Antelope (Wildlife Institute of India, 2018).

1.8.Need for the Study

Study has been done on the reproductive Behavior of Four-horned Antelopes in captivity (*Dubost* et al., *2019*), but not on their social Behavior or group dynamics. This species has not been studied extensively within wild, and zoos hardly ever keep it under observation (Wildlife Institute of India, 2018).

Studying the social Behavior of Four-horned Antelope in captivity may help in the captive management of the species and aid in the welfare of animals and help to create environments that promote the wellbeing of animals in the zoo, which is also crucial for their successful breeding program in the zoo. Understanding social Behavior also aids in the management of populations, which may help to prevent inbreeding and promote genetic diversity.

Through this study, we have investigated the Behavioral information, social structure, Group formation, and compatibility of Four-horned Antelope in captivity. The need for this research arises from the significance of providing appropriate social environments for captive animals. There are various factors that emphasize the importance of understanding social behavior and dynamics in captive Four-horned Antelope. Various factors threaten the welfare of captive animals in artificial habitats, and it is crucial to improve their health and welfare. The captive animals in zoos and wildlife parks, including Four-horned Antelope, play important roles in education, research, and genetic diversity conservation (Zhang et al., 2021). Secondly, successful breeding programs heavily rely on understanding and managing the social behavior of animals. Breeding success in captive four-horned antelope is influenced by social components such as colony age and number of breeding pairs.

Understanding the social influences on reproduction can contribute to improving breeding success and maintaining healthy populations of Four-horned Antelope in captivity. To effectively provide appropriate social environments for captive Four-horned Antelope, it is essential to consider their natural social behavior. Furthermore, social habitations of incompatible animals can induce chronic stress, injury, and even death. Not all members of a social species are socially compatible, and in some cases, social incompatibility may be sex biased. Therefore, understanding the social dynamics and compatibility of Four-horned Antelope in captivity is crucial for their well-being and preventing harmful consequences. The sources provided underscore the importance of understanding social behavior and dynamics in captive animals. By considering the animals' natural social behavior, we can ensure that suitable social environments are given, whether they are naturally territorial or communal. In conclusion, the study on understanding social Behavior and dynamics in captive four-horned antelope is important for various reasons. It contributes to the welfare of captive animals, improves breeding success, and ensures appropriate social environments are provided.

1.9. Review of literature

1.9.1. International Review

Living in dry deciduous forests, the Four-horned Antelope is more closely related to African forest species globally than it is to those found in open habitats in Africa. In terms of ecology, it is also more similar to them, much like Barking Deer (*Muntiacus muntjak),* another Asian forest species. The primary distinguishing characteristic between the Four-horned Antelope and many other species is their reproductive system. (Dubost et al., 2019).

This is the first study demonstrating the use of deciduous hill forest and Sal forest in lowland Nepal by Four-horned Antelopes. Additionally, the dung pile sample demonstrated a distinct niche divergence between Barking Deer and Four-horned Antelope along the altitudinal gradients, allowing these similarly sized solitary ungulates to coexist in lowland Nepal (Krishna et al., 2015).

Whether the latrines placed in the habitat might accurately reflect the research animal's preference for different habitat and/or habitat characteristics is one specific issue of paramount significance (Krishna et al., 2015).

One of the least researched ungulate species in Nepal, the Four-horned Antelope is the subject of this study's diet composition analysis in Banke National Park. Between December 2015 and January 2016, 53 fresh pellet groups were gathered, and the micro-histological faecal analysis technique was used to analyse the samples (Oli et al., 2018).

They prepared 133 micro-histological images of various sections of 64 reference plant species. Next, in order to determine the percentage of various plant species present in the

diet of Four-horned Antelope that had been raised in captivity, They compared 1,590 fragments of 53 faecal samples with images of reference plants. Faecal samples revealed the presence of thirty distinct plant species from eighteen different families. Chi-square goodness of fit analyses revealed that it didn't seem like Four-horned Antelope fed every plant equally (Oli et al., 2018).

Among the 1,520 fragments found in faecal samples, 1,300 belonged to browse species and 220 to grass species. 85.5% of the identified plant fragments were browsers, indicating that FHA may be using a browser strategy, at least in the winter, when grasses are scarce and of low nutritional quality (Oli et al., 2018). The largest percentage of the diet was made up of tree species (46.55%), with shrubs coming in second (24.52%). The family *Euphorbiaceae* (11.95%) was consumed in the second-highest percentage, behind the *Gramineae* (27.68%). Overall, the findings suggest that Four-horned Antelope has the feeding flexibility to adjust to changes in resource availability (Oli et al., 2018).

Natural resources, including food, water, and cover, are not dispersed equally across Chitwan National Park. In addition, animals like chital, sambar, and muntjak have a comparatively higher degree of inter-specific competition in the lower zone. Additionally, the bottom level flat space serves as the tiger's habitat. These could be the primary causes of the clumped and unequal distribution of Four-horned Antelope. Furthermore, there exist multiple enduring water sources, albeit restricted to gorges (Krishna et al., 2009).

The majority of Four-horned Antelope signs (77% of all signs) in Chitwan National Park were found in areas prone to forest fires during the dry season. This result is comparable to that of Krishna et al. (2008) in Bandipur National Park, India, and Pokharel (2010) in Bardia National Park, Nepal. The more severe, drier areas of Bardia National Park are prone to frequent forest fires throughout the dry season (Krishna et al., 2009).

Given that most plant species present in the hilly terrain are fire tolerant and that fire may have restricted their growth to a low breast height diameter and a stunted height, it appears that fire manages the features of the vegetation association in the area that is more frequently used by Four-horned Antelope (Krishna et al., 2009).

1.9.2. National Review

The smallest solitary Asian herbivorous bovid, the Four-horned Antelope (*Tetracerus quadricornis*), is native to peninsular India and Nepal (Leslie & Sharma, 2009). It weighs 17–22 kg as an adult and measures 55–64 cm at the shoulder. It inhabits hilly and undulating terrain (Prater, 1980; Baskaran et al., 2011). It uses tropical dry deciduous forest habitats at the landscape level, but they are distributed unevenly (Krishna et al., 2009; Sharma et al., 2013; Pokharel et al., 2016). It is a cautious, cryptic, and elusive species that is quite challenging to see up close throughout its range. When a male reaches maturity, their four horns differentiate the sexes (Leslie & Sharma, 2009).

According to predictions made by Sharma et al. (2013) and Pokharel et al. (2016), a number of ecological factors, including water availability, slope, temperature, seasonality, tree species richness, precipitation, elevation, and anthropogenic disturbance, will influence its spatial distribution in tropical dry deciduous forests. Research has shown that the presence of the alien weed *Lantana camara* is negatively associated with the spread of the Four-horned Antelope (Krishna et al., 2008).

Four-horned Antelope consumes fruits, flowers, grasses, and climbers, according to direct field observation and laboratory studies (Sharma et al., 2009; Kunwar et al., 2016). The IUCN (Mallon, 2008) has classified Four-horned Antelope as vulnerable because of its small population, declining population trend, and habitat degradation brought on mostly

by habitat removal for agriculture. Additionally, it is covered under the Indian Wildlife (Protection) Act 1972 (amended 2006), Schedule I, which offers complete protection.

Four-horned Antelope was generally observed alone and in groups of no more than four individuals, as reported in the literature (Leslie & Sharma, 2009; Baskaran et al., 2011). In the Indian Nagarhole National Park, Karanth & Sunquist (1992) recorded the largest group size of two individuals, although Berwick (1974) reported the maximum group size of four individuals in the Gir National Park (India). According to Sharma et al. (2005), in Panna National Park, 24% of sightings involved groups of two individuals, and 69% were solitary individuals.

Observations of solitary individuals in Mudumalai Tiger Reserve accounted for 58%, two individuals for 28%, three individuals for 6%, and four individuals for 2%, with a mean of ≤ 1.50 (Baskaran et al., 2009; 2011).

According to studies by Baskaran et al. (2011) and Sharma et al. (2009), feeding and walking were most common in the tropical deciduous forests of Panna National Park and Mudumalai Wildlife Sanctuary. On the other hand, Pokharel (2015) found that in the climax Sal *Shorea robusta* and mixed deciduous forests of lowland Nepal, Four-horned Antelope exhibited higher levels of alertness (40%) and licking (26%), with walking (21%), staring at the subject (8%), drinking (2%), and browsing (1%).

Dalke et al. (1965) say that changes in the animals' geographic environment, tasty food, the taste of salt licking, which is usually done to make up for sodium deficiencies; the presence of other elements like calcium, magnesium, and potassium in the licked soil or rocks; and the pressure from predators at the licking sites are likely what causes the differences in licking and alertness.

In terms of preference, the species most commonly observed with the Four-horned Antelope were Nilgai (*Boselaphus tragocamelus*) at 34.86%, Sambar (*Rusa unicolor*) at 27.26%, and Southern Plains Gray Langur (*Semnopithecus dussumieri*) at 54.56%. Numerous studies (Stensland et al., 2003; Desbiez et al., 2010) have shown the benefits of foraging, predator avoidance, and predator detection that ungulates receive from their relationship with primates. These benefits eventually allow the individual to spend less time being watchful.

Four-horned Antelope is a shy animal that avoids being noticed. When a predator approaches it from a distance, it typically hides, freezes, and lays down instead of taking off immediately. However, if the predator approaches it up close, it will normally run away from the predator. During the investigation, we discovered that threat reactions in Four-horned Antelope vary depending on their social composition.

According to research conducted on both free-ranging animals (Prater, 1971; Sharma et al., 2005) and captive animals (Shull, 1958; Acharyo, 1975), reproductive activity is seasonal, with mating occurring in the early monsoon (May–July) and fawning in the spring (February–April). The reproductive Behavior of Nilgai is comparable to that reported by Sharma et al. (2005). Males mate with females for the purpose of copulation; the females are responsible for the remainder of the parental role, including gestation and childrearing.

According to Acharjyo and Misra (1975), who reported the age at first birth to be 21 months for two captive females based on an eight-month gestation period recorded by Shull (1958), females are sexually ready by the time they are one year old.

A higher percentage of the fawns were twins at birth (Mauget et al., 2000). Inter-birth intervals of 285 and 327 days were reported by Acharjyo and Misra (1975) from

observations based on a single female; however, comparable data from free-ranging animals is not accessible in the literature.

Since there are still risks to the long-term survival of four-horned antelopes in their native habitats throughout their range, they are classified as vulnerable in both Schedule I of the Wildlife Protection Act of India and the IUCN Red List of Threatened Species. The risks to the species are still present, and numbers all over their range are trending downward. Thus, maintaining genetically and demographically viable ex-situ populations is essential to guaranteeing the species' continued survival (Wildlife Institute of India, 2018).

2. Hypothesis

In captivity, Four-horned Antelope may display behaviors that are not typical for them and may communicate with other members of their species as well as other species of enclosure. This may lead to the formation of new social structures and groupings, particularly among individuals who are living alone.

3. Objectives

1. To methodically monitor and assess the behavioral activity patterns exhibited by four-horned antelopes that are kept in captivity.
2. Understanding the social structure and groups within captive population of Four-horned Antelope.
3. Investigate the interspecies and intra-species communication and relation between Four-horned Antelope and other enclosure species.

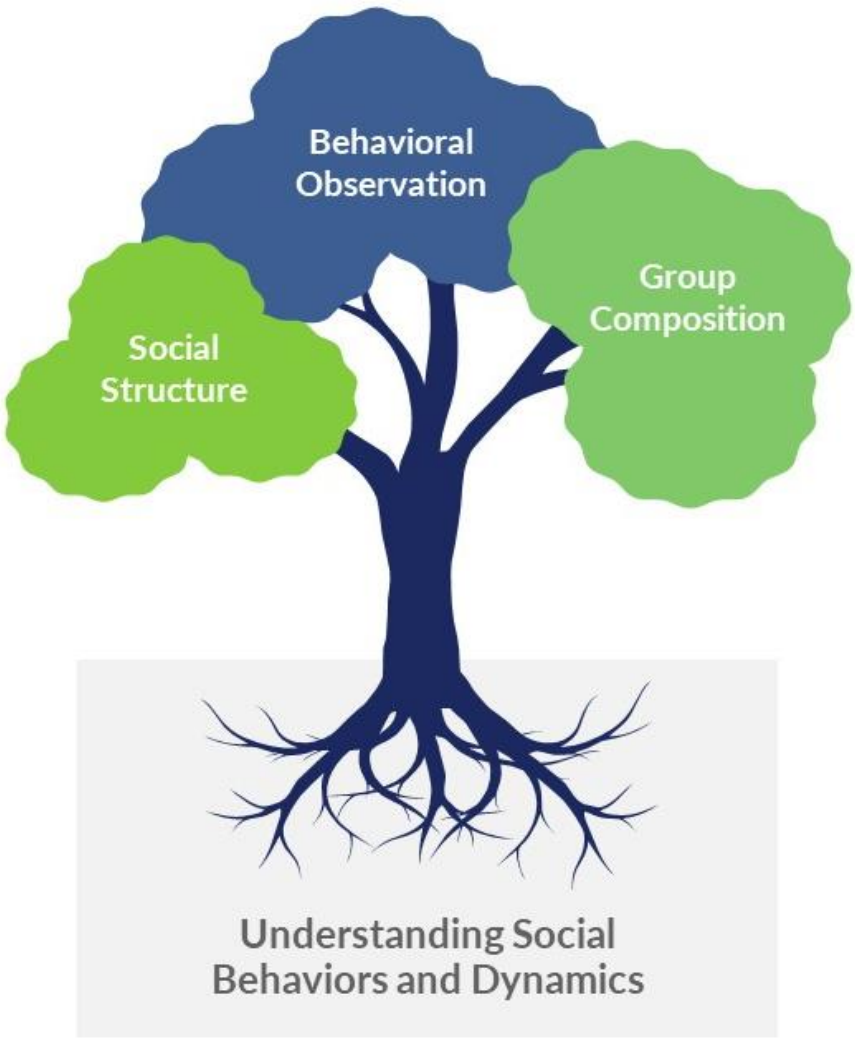

Fig:2 Objectives of the Research

4. Materials and Methods

4.1.Study Area

The Sardar Patel Zoological Park is one of the many attractions that can be found in Ekta Nagar, which is surrounded by the picturesque Satpura and Vindhyanchal Mountain ranges. The park is spread across 43.7 hectares and located on the banks of the Narmada River. It is home to more than 105 species of native and exotic animals. Animals like Asiatic Lion (*Panthera leo persica*), Jaguar (*Panthera onca*), Greater One-horned Rhinoceros (*Rhinoceros unicornis*), Gaur (*Bos gauras*), Bornean Orangutan (*Pongo pygmaeus*), etc are some of highlights of the park.

Fig:3 Map of Sardar Patel Zoological Park (SPZP**)**

The zoo also houses a variety of herbivorous animals in a dedicated zone. The Herbivore zone is a captivating enclave that houses a diverse and extraordinary collection of hoofed animals. These fascinating creatures come from different parts of India, making the section a vibrant and educational experience for visitors of all ages. One of the key enclosures among these exhibits is the Mixed Herbivore enclosure. The Mixed Herbivore enclosure houses five herbivore species: Four-horned Antelope, Barking Deer or Indian Muntjac, Spotted Deer, Thamin Deer, and Himalayan Goral. The Mixed Herbivore enclosure covers an area of 2300 square meters.

Fig:4 Mix-herbivore Enclosure

The enclosure includes a small natural mountainous area that is nearly twenty feet high and serves as the physical barrier between two enclosures. The enclosure is home to trees like Neem (*Azadirachta indica*), Banyan *(Ficus benghalensis*), Champak (*Magnolia*

champaca), and Palash (*Butea monosperma*), all native to this habitat. Within the enclosure, there are two shaded areas and a central pond that provide shelter and drinking water for the animals.

4.2. Methods

For this particular study, we employed two distinct approaches: the focal sampling method and the scan sampling method.

4.2.1. Focal Animal Sampling

Focal sampling is used for prolonged, continuous observation of a single animal or subgroup for a specific amount of time. All instances of the designated behavior are noted throughout this time. This method provides unbiased data on the social behavior of the group. However, it does not capture the synchronized behaviors of group members (Gopal, 2012).

This approach enables data collection based on the age and gender of the animals. By choosing animals with specific tags for the study, it also simplifies collecting data on unique characteristics (Gopal, 2012).

Data from specific events and social interactions during targeted sampling can be analyzed based on the hourly frequency of initiated events. As a result, the frequency of a certain Behavioral event was determined by using the below mentioned formula. (Gopal, 2012). For the purpose of collecting data on the behaviors of individual animals, we utilized focal animal sampling.

Focal Sampling = n_i / N_i

(Here, “n” is the number of times, individual “i” displayed Behavior “j” and “N”, is the total duration of time (in hours) of observing the individual “i”.)

4.2.2. Scan Sampling

Scan sampling is generally used to observe multiple animals. The data is collected at regular intervals while scanning a large group of animals. The behavior of specific individuals may be included in the recording. But typically, the process doesn't require identifying each individual (Gopal, 2012). As a result, the frequency of a certain group dynamics event was determined by using the below mentioned formula. (Gopal, 2012).

Scan Sampling = S_{ij} / T_i

(Here, “S” is the number of scans in which Behavior “j” is displayed by individual and “T”, is the total number of scans conducted on individual “i”.)

In this kind of sampling, bias is influenced by the intervals between scans. Less observation of rare or unusual behaviors could result in a lower frequency being recorded (Harcourt and Stewart, 1984). We used this method for observing and recording data on social behavior and group dynamics.

4.3 Data Collection

Data collection was conducted for a total of sixty days from 1st February to 31st March 2024. Observations were made from 09:00 hrs to 18:00 hrs every day at an interval of 10 minutes. During data collection, information such as individual behavior, group composition, social structure, etc., were recorded. We classified 31 behaviors into 6 major categories: Feeding and Foraging, Exploration, Reproductive behavior, Resting behavior,

Social Interactions, and Solitary behaviors. All inter-specific and intra-specific behavior were also recorded from the Mixed herbivore enclosure.

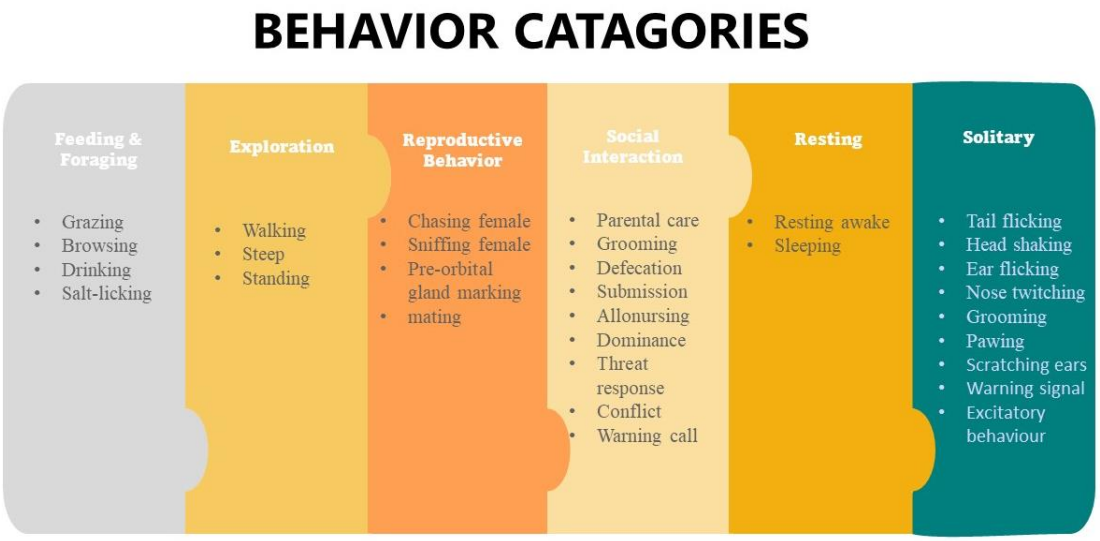

Fig:5 Behavior categories defined for data collection

Fig:6 Observation and data collection at Enclosure

The Four-horned Antelope (*Tetracerus quadricornis*) is listed as 'Vulnerable' on the IUCN Red List and is protected under Schedule I of the Wildlife Protection Act 1972. In response to this classification, a non-invasive marking method was used for individual identification and data collection.

We used individual's unique biometric traits, such as the ear, face, nose, scar and footprint print for individual identification. Most individuals have been identified based on natural scar markings on specific body parts like forelegs, hindlegs, or rump.

Individual Name	**Traits / Markings**
Male	Have two pairs of horns
Female A	Have broad scar marking underside of right front leg.
Female B	Have slender scar marking underside of right front leg.
Female C	Have multiple scar markings on lower neck region at both sides.
Female D	Have scar marking on neck and upper left side of front leg.
Female E	Have scar marking on rump or hip region.
Female F	Have scar marking on upper muzzle region and scar marking on lower abdomen.
Female G	Have no significant scar marking on body but smallest female of the enclosure.
Fawns	Fawns are identified based on their activity with respective females like following female and protective Behavior shown by female towards particular fawns.

Table:1 Individual identification table of Four-horned Antelope

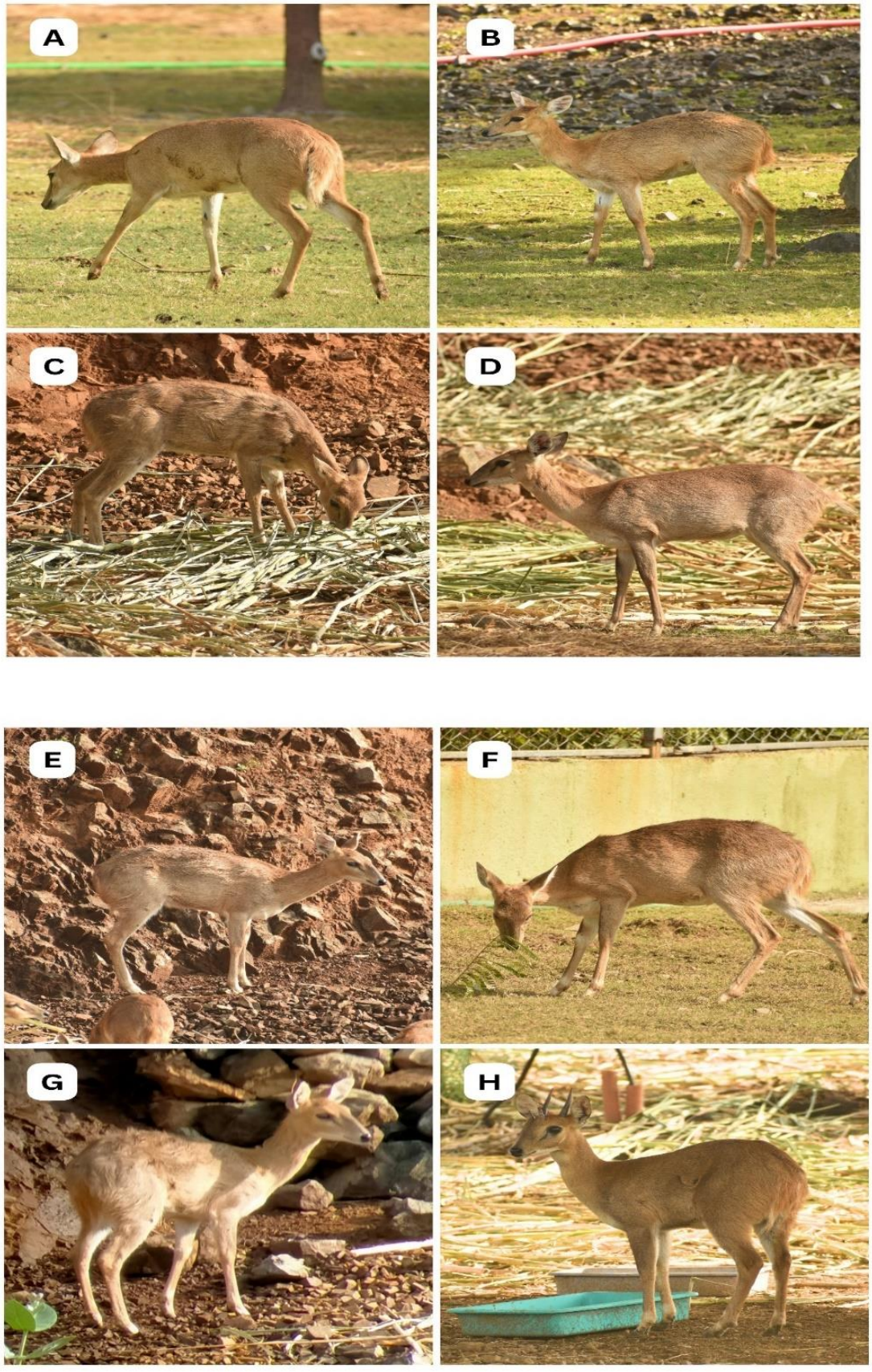

Fig:7 Profile photos for Individual Identification

A special data sheet was created specifically to collect the required data for the study. Later, Epicollect5, an android mobile application, was used for data collection. The application streamlines the data collection process and enhances the efficiency of study. To commence the data collection, a private project was meticulously set up on the Epicollect5 portal. A private project was customized on the portal to include a data sheet that precisely met the content requirements for the study. The flexibility of the application allowed for a diverse range of data types to be captured, counting but not limited to geographical coordinates, images, temperature, notes, which were pivotal for comprehensive field research.

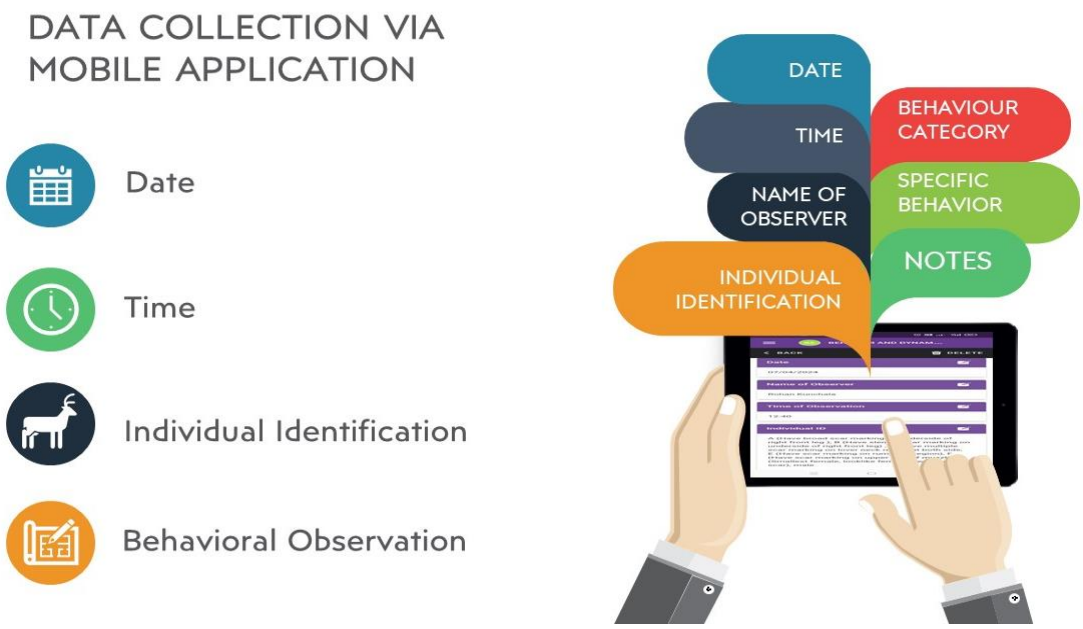

Fig:8 Data collection by Epicollect5 Mobile Application

The synchronization feature of Epicollect5 ensured that all collected data was combined and stored on a central server. The collected data underwent daily verification by a Zoo Biologist, who meticulously checked for the accuracy and integrity of the gathered

information. This rigorous validation process is essential for maintaining the high standards of data quality necessary for scientific research.

When the time for data analysis arrived, this format is universally recognized and compatible with an abundance of data analysis software, thereby facilitating a smooth move from data collection to analysis. Exporting data in CSV format was crucial for aiding the statistical analysis phase, allowing for a comprehensive exploration of the data to reveal patterns and gain valuable insights.

5. Result

The Four-horned Antelope, typically a solitary creature in the wild, exhibits a change in behavior when in captivity at the Sardar Patel Zoological Park (SPZP). Despite their solitary nature, these antelopes have been observed to form groups for specific activities such as feeding, resting, and social interaction. In the mixed-herbivore enclosure at SPZP, there are 14 Four-horned Antelopes: 1 male, 7 females, and 6 fawns.

5.1. Group Formation Frequency

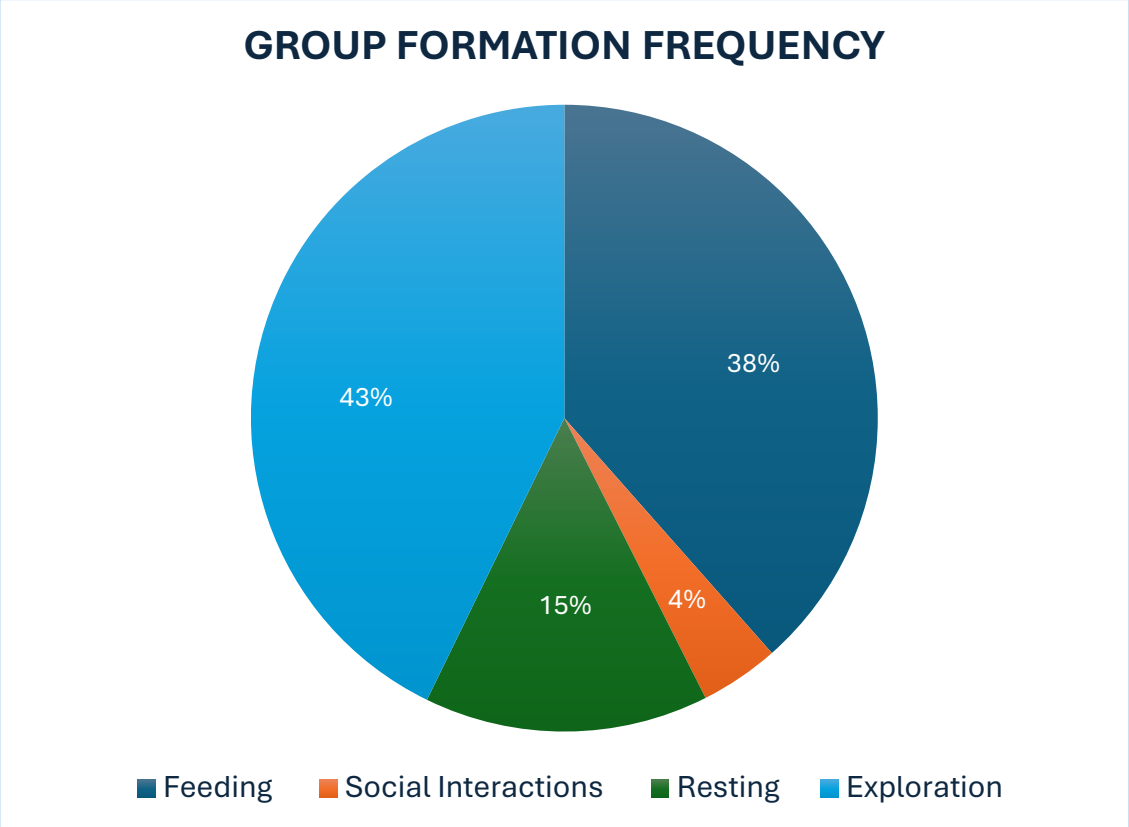

Fig:9 Group formation frequency during various activities

Our study focused on the group formation frequency of Four-horned Antelopes in captivity during various activities. The activities were selected based on their frequency of occurrence and included feeding, exploration, social behaviors, and resting.

5.1.1. Feeding

During feeding, which involves grazing, browsing, salt licking, and drinking, the four-horned antelopes tend to form groups more frequently. Specifically, some females showed a preference for particular individuals when forming groups. For instance, female ‘B’ showed a strong preference for group size and individual, often forming a group with female ‘G’ (frequency of 24). Other notable pairs included ‘AD’ (20), ‘AF’ (18), and ‘EF’ (18). Groups such as ‘ACDF’, ‘ACEG’, ‘ADEG’, and ‘BEG’ showed lower frequencies of group formation, suggesting a preference for smaller group sizes (2–3 individuals) during feeding. Age also appeared to influence group formation, with younger females ‘B’ and ‘G’ (approximately 2 years old) preferring to feed together.

5.1.2. Exploration

Exploration activities, which encompass walking, steep walking, and standing, also revealed preferences in group formation. Female ‘B’ frequently formed a group with female ‘G’ (frequency of 27), indicating a preference for a particular group size and individual. Female ‘A’ preferred to explore with females ‘D’ and ‘F’, forming groups ‘AD’, ‘ADF’, and ‘AF’ with frequencies of 18, 18, and 16, respectively. Female ‘E’ preferred to explore with female ‘F’ (EF, 20) and a male (EM, 18).

5.1.3. Social Behaviors

Social behaviors, categorized into inter-species and intra-species interactions, included dominance, conflict, grooming, defecation, submission, threat response, and warning calls. In these activities, female ‘A’ preferred to form a group with ‘D’ and ‘F’ (‘ACD’, ‘ACDE’, ‘ADEG’, frequency of 12). However, the Four-horned Antelopes showed less group formation frequency in social activities compared to other activities.

5.1.4. Resting Behavior

Resting behavior, categorized into sleeping and resting awake, also demonstrated preferences in group formation. During resting, female ‘A’ preferred to form a group with females ‘C’ (‘AC’ = 10), ‘D’ (‘AD’ = 8), and ‘F’ (‘ADF’ = 8). Female ‘B’ preferred to form a group with female ‘G’ (BG = 11), and female ‘C’ preferred to form a group with female ‘D’ (‘CD’ = 10).

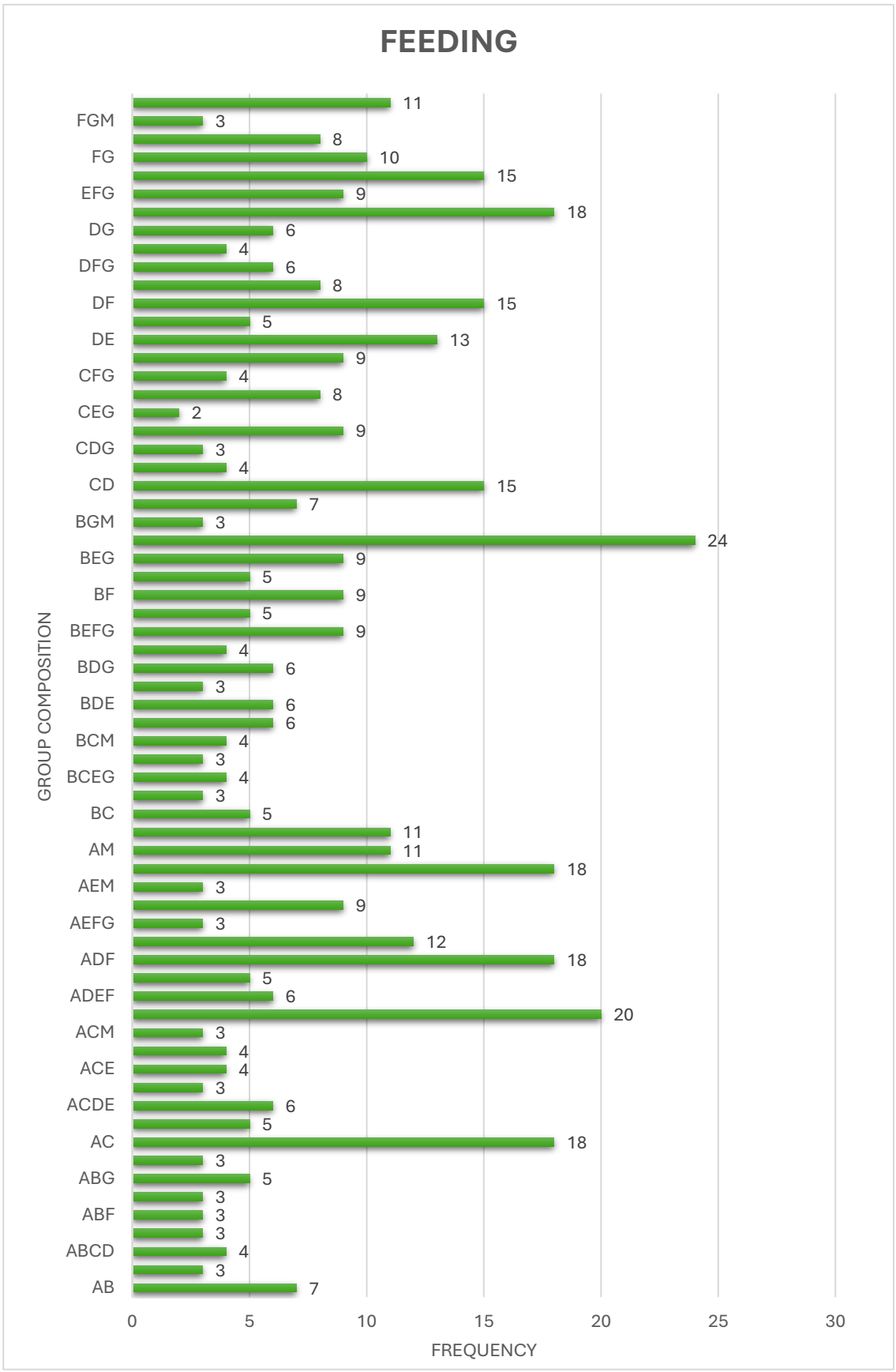

Fig:10 Group formation frequency during feeding

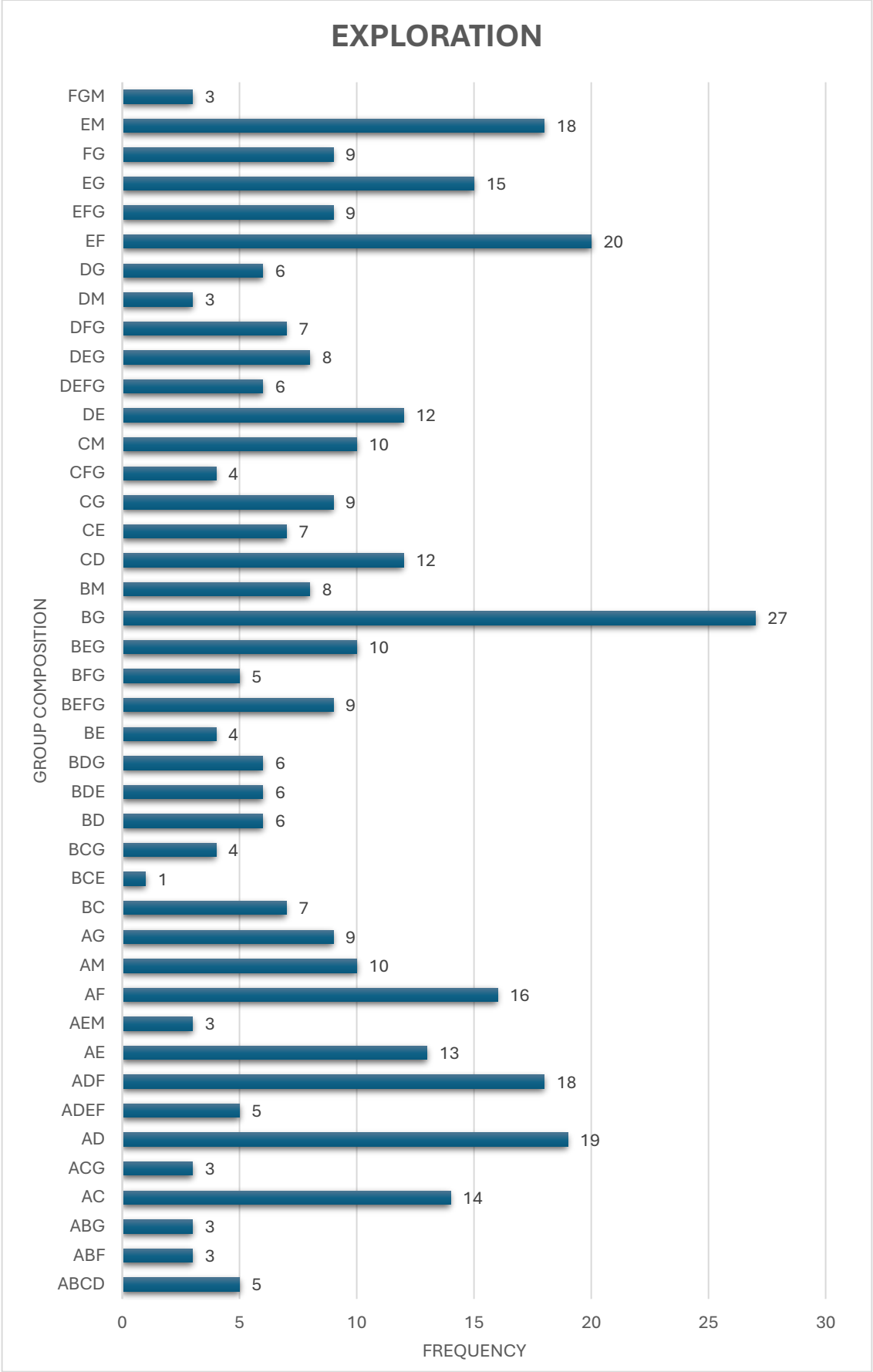

Fig:11 Group formation frequency during exploration

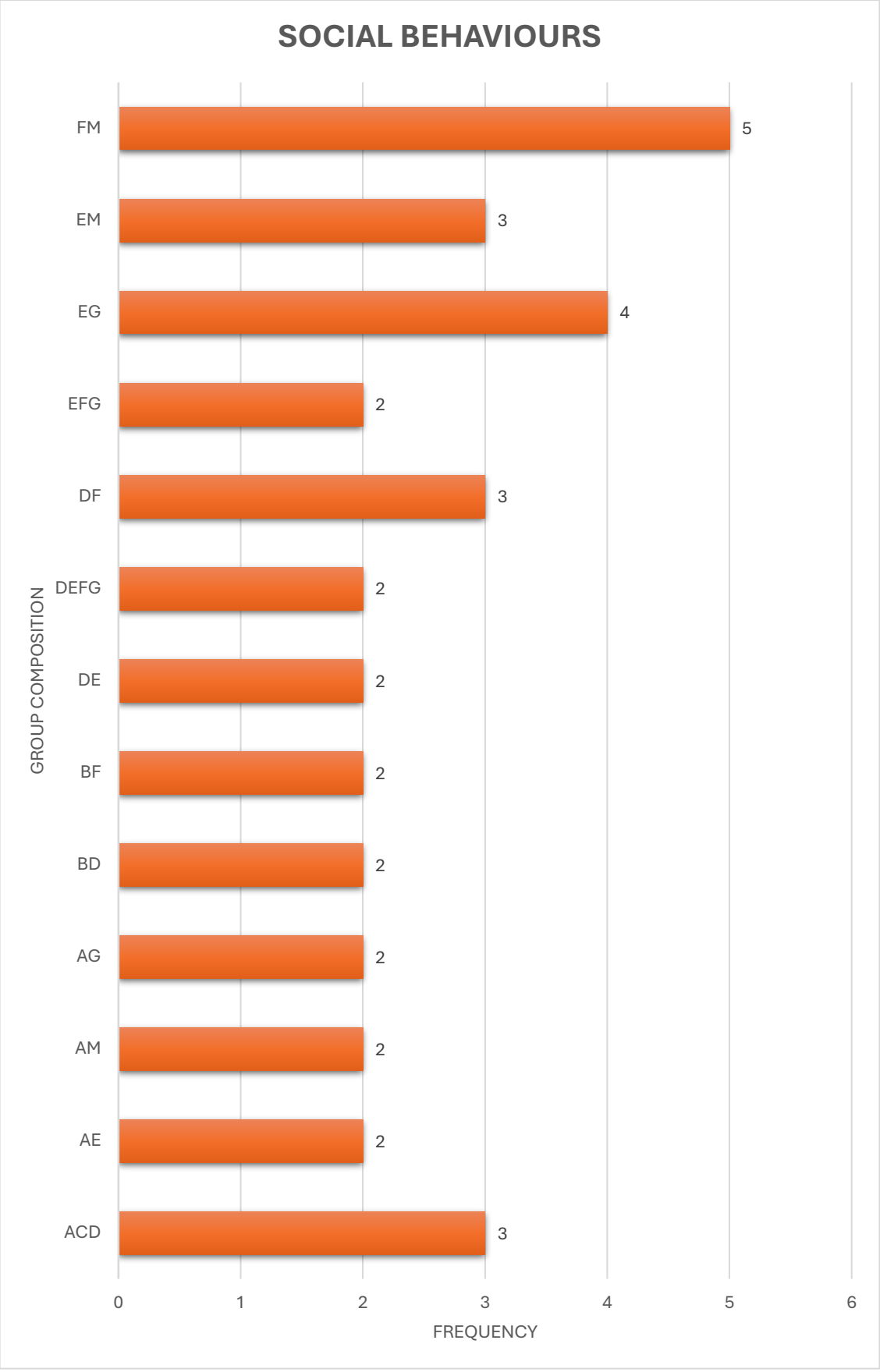

Fig:12 Group formation frequency during social behaviors

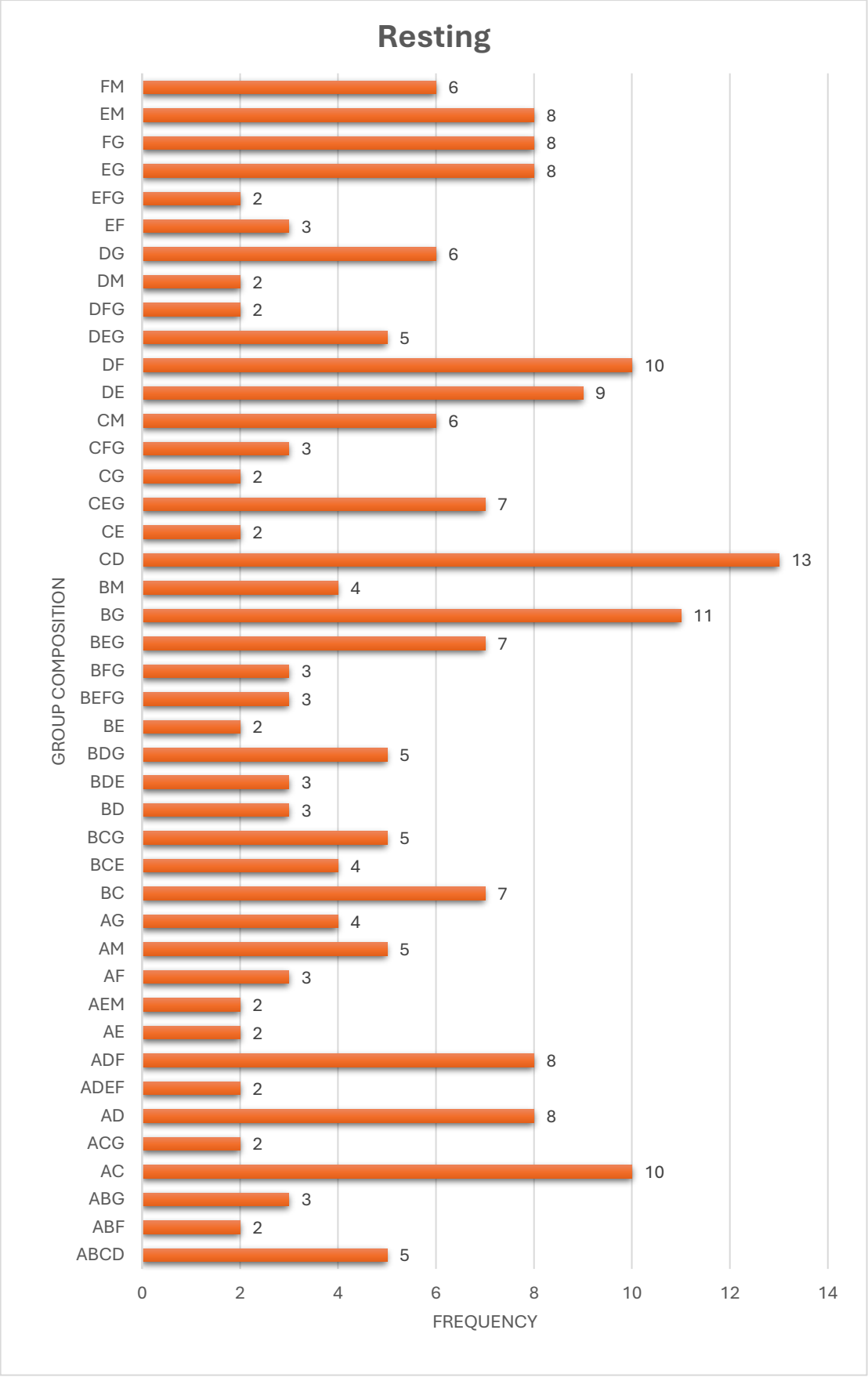

Fig:13 Group formation frequency during resting

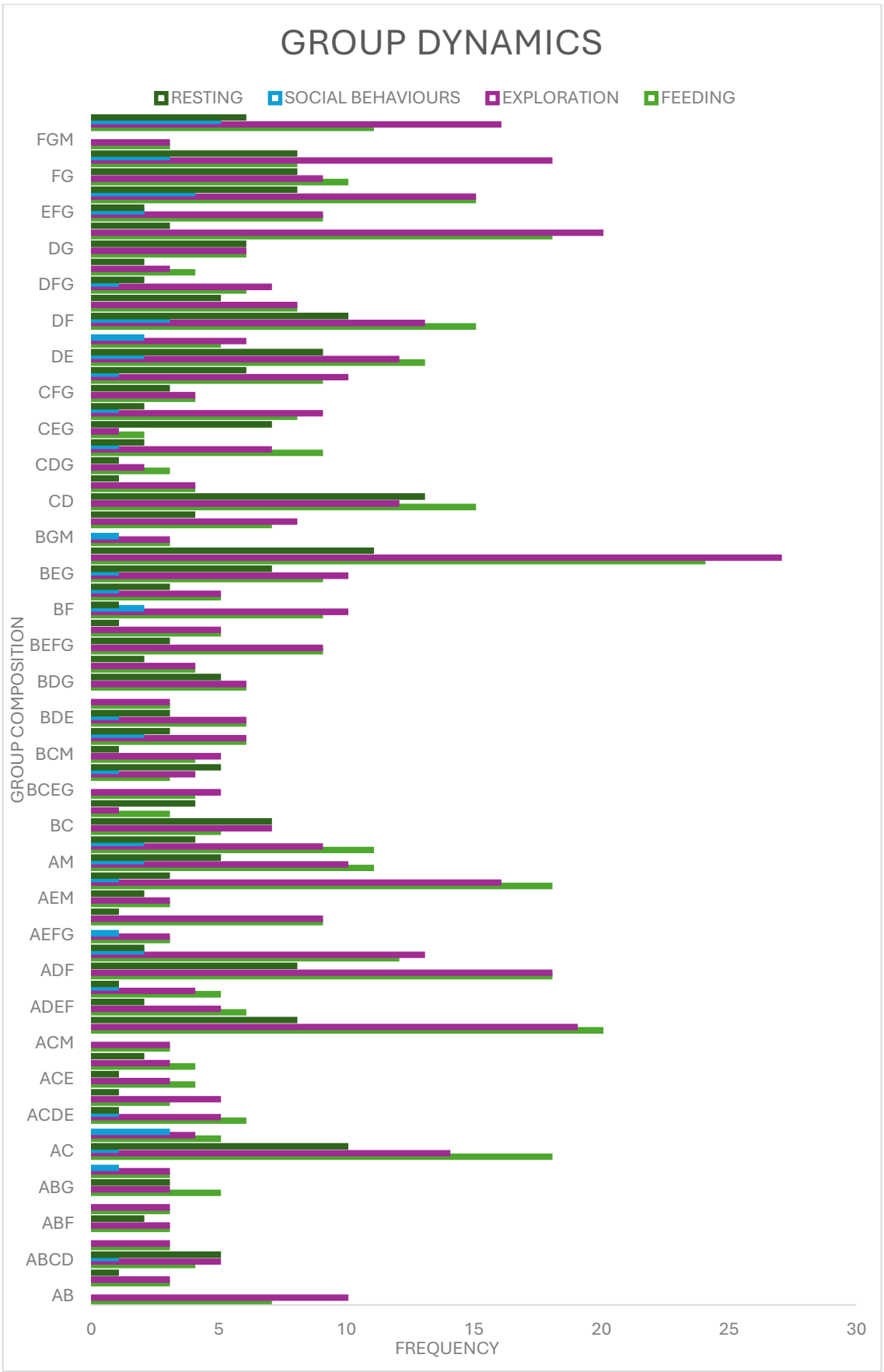

Fig:14 Group Composition during feeding, exploration, social interaction and resting behavior.

The limited space and lack of species diversity in the enclosure appear to influence the formation of groups. Certain individuals show a preference for staying in a group or forming one during activities. The frequency of group formation varies with the type of activity. Following feeding, social interaction, and resting, exploration activities show the highest frequency of group formation.

In above figures we have categorised group formation frequency on the basis of activities like feeding, exploration etc. We observed a preference for group size and specific individuals within the group.

5.1.5. Group of Female ‘B’ and ‘G’

Female ‘B’ and ‘G’, both nearly 2 years of age, spent most of their time together. Female ‘B’ and ‘G’ showed the highest feeding activity with a total frequency of 24. Female ‘B’ and ‘G’ also demonstrated a high frequency of group formation during exploration (27) and resting (11). However, Female ‘B’ and ‘G’ did not form any ‘BG’ group during social activities. This recommend that they prefer to feed, explore, and rest in a group.

5.1.6. Group of Female ‘A’, ‘D’, and ‘F’

Females ‘A’, ‘D’, and ‘F’, who have 2, 1, and 2 fawns respectively, aged 10 to 11 months, also showed group preferences. Observations revealed that female ‘F’ exhibited allosuckling towards the fawns of females ‘A’, ‘D’, and ‘E’. One of the primary reasons for females staying in a group with other females was their similarity in routine activity and age. There were also observations of grooming between female ‘A’ and females ‘D’ and ‘F’. During feeding, female ‘A’ grouped with female ‘D’ and ‘F’ 20 times each, forming groups of 2 individuals (‘AD’, ‘AF’). During exploration, female ‘A’ formed groups with ‘D’ (‘AD’) and ‘F’ (‘AF’) 19 times. They did not make any groups during

social activities but were seen in a group with a frequency of 8 during resting behavior, which also consisted of 2 individuals (‘AD’, ‘DF’).

5.1.7. Group of Female ‘A’ and ‘C’

Female ‘C’ also showed group formation with female ‘A’ during various activities. There was an observation of allonursing by female ‘C’, who did not possess any fawns. Her fawns had died soon after birth due to unknown reason, but female ‘C’ was still lactating, which benefited the fawns of other females. During feeding, female ‘C’ showed a higher frequency in feeding activity by making a group with female ‘A’, which was 18 (‘AC’). During exploration, they explored together with a frequency of 14 (‘AC’), and during resting, they also showed group formation with a frequency of 10 (‘AC’).

Our analysis of the data reveals that certain groups of Four-horned Antelopes in captivity are more active across all activities and exhibit higher frequencies of group formation. Conversely, some groups display lower frequencies of activity and group formation.

The data suggests that groups of two individuals are more active and show a higher frequency of group formation. In contrast, groups comprising greater than two individuals show less activity and a lower frequency of group formation.

The study indicates that captivity and limited space can significantly influence the behavior of Four-horned Antelopes, leading them to exhibit social behaviors that are uncommon in the wild.

In conclusion, our observations promote that group formation in Four-horned Antelopes in captivity is influenced by the type of activity, individual preferences, and certain survival strategies such as allonursing. The type of activity and individual preferences significantly affect group formation in Four-horned Antelopes kept in captivity.

These findings underscore the need for further research to understand the underlying factors driving these behaviors. Such insights could have significant implications for the conservation and management strategies for this species.

5.2. Social Dynamics of Four-horned Antelope

Our research on the social dynamics of Four-horned Antelopes in captivity revealed several key behaviors:

5.2.1. Aggression

5.2.1.1. Dominance Aggression

Dominance aggression, which does not involve driving out the other animal, was observed. The dominant animal keeps a larger share of a particular welfare factor, which may be in short supply in the habitat. In the Mix-herbivore Enclosure, Thamin Deer particularly showed aggression towards Four-horned Antelope and Himalayan Goral during feeding times. Spotted Deer also displayed Dominance Aggression towards Four-horned Antelope and Barking Deer.

5.2.1.2. Sexual Aggression

Male Four-horned Antelopes exhibited Sexual Aggression towards females during walking, grazing, browsing, resting, and mating. This behavior ensures mating by preventing females from straying away.

5.2.2. Inter-Specific Grooming

Inter-specific grooming, not yet discovered in the wild or in captivity, was observed in the mix herbivore enclosure of the Sardar Patel Zoological Park (SPZP). The female Barking Deer showed grooming behavior towards female ‘C’, licking her inner and outer ear portions.

Fig:15 Inter-specific Grooming between Female ‘C’ and Female Barking Deer

5.2.3. Head Bunting Behavior

On the 10th February 2024, the 2-year-old female ‘G’ exhibited excitement, jumping and sprinting in the enclosure. Other fawns joined her in sprinting. After half a minute, female ‘G’ bent her fore-limbs and pushed it towards the fawns’ head, initiating a playful competition.

Fig:16 Head Bunting between Female ‘G’ and Fawn

5.2.4. Allosuckling

Fig:17 Allosuckling on Female ‘F’ by Fawn of Female ‘D’

Allosuckling was observed among the 7 fawns of Four-horned Antelope present in the Mix-herbivore enclosure. Fawns get stimulated and try to join milking when they observe other fawns suckling or milking from the female. After nearly 7 or 8 bouts, the female steps forward and shows negative action towards all fawns.

5.2.5. Allonursing

Fig:18 Allonursing by Female ‘C’

Allonursing was observed in a female that did not have any fawns due to health problems. Female ‘C’ was observed milking other female’s fawns most of the time without showing any negative signs. However, during feeding, she was observed to show aggression towards fawns and rejection towards milking or suckling.

5.2.6.Middens

Fig:19 Midden of adult individuals (A) and midden of fawns (B)

Four-horned Antelopes in the enclosure create middens, which are specific to particular times and individuals. Elder fawns (2 years old) create their middens differently from the females, while other fawns share the defecation space with their respective mothers. Males defecate on each midden present in the enclosure, with observations of males specifically defecating on a specific female's defecation nearly 1 to 2 minutes after the female defecates.

5.2.7. Courtship Behavior and Mating

Four-horned Antelopes display a unique courtship Behavior where the male follows the female after giving a small call. The female then shows submissive behavior towards the male, and the male sniffs the female's aboral region. If the female is not ready to mate, it runs away from the male. This process happens several times and can take some days before the male and female mate for nearly 10 to 15 seconds. There are also observations of males falsely mounting on the females. If the female is interested in mating, it grooms

the male's hump and mouth region. If the male is not ready for mating, it attacks the female by horns at the head region or ribs and flank region.

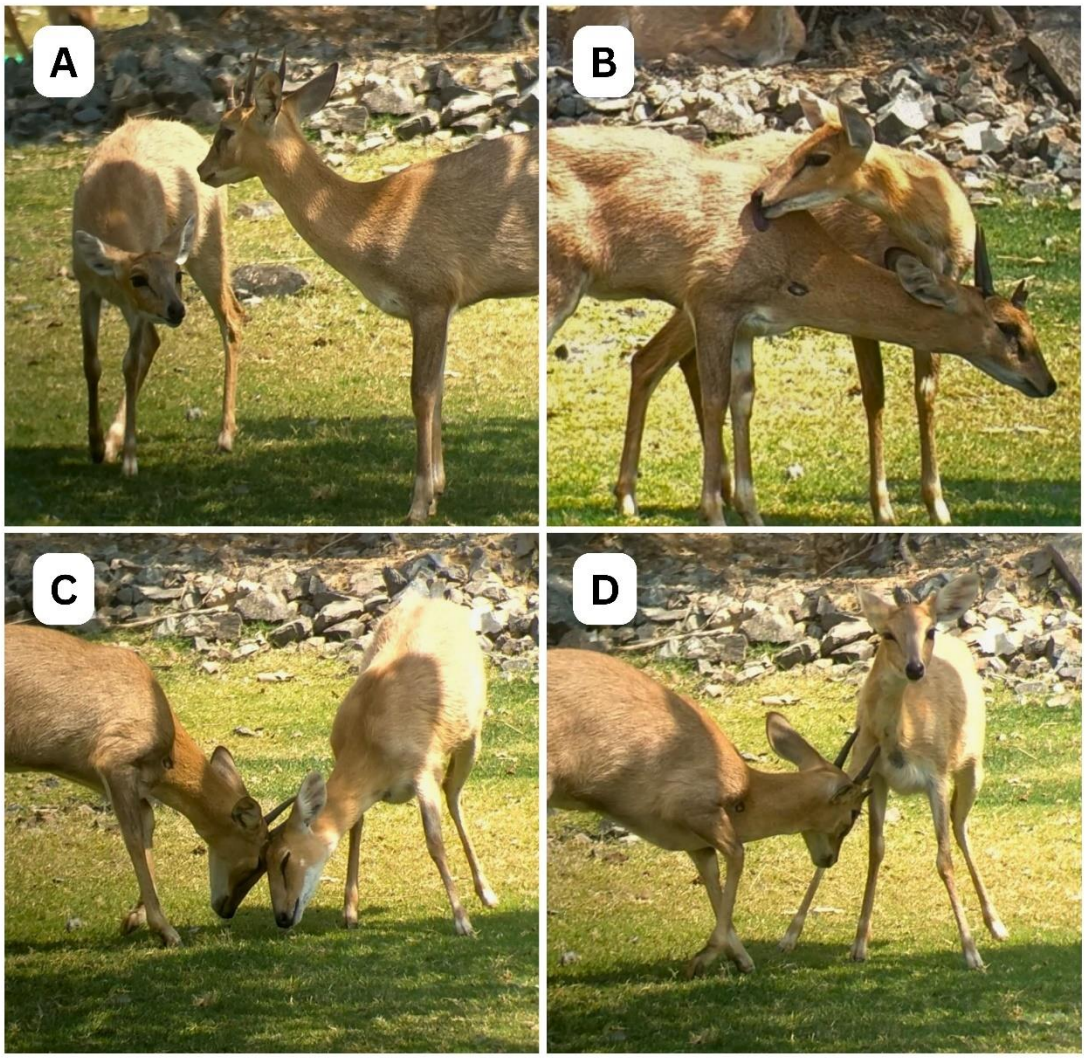

Fig:20 Submissive Behavior of female (A), Male groomed by Female (B), Head bunting between male and female (C), Male shows Sexual Aggression towards Female (D)

5.2.8. Female and Fawns Interaction

Females are followed by their respective fawns during feeding, exploring, and resting. Females have been seen grooming their fawns several times during the day. There are

observations of females showing anti-predatory aggressiveness towards other individuals or unknown objects or persons.

Fig:21 Fawn following female ‘F’

5.2.9. Excitatory Behavior

This unusual Behavior, seen only three times during the study, involves female ‘A’ and female ‘B’ starting to run in the enclosure during the evening time. This stimulates other females and fawns to run with them, lasting for nearly 5 to 6 minutes. During this time, they jump, run in a circular motion, and repeatedly cross each other.

5.3.Individual Activity Budget

The study of individual activity budgets revealed distinct patterns of behavior among the observed subjects.

Female ‘A’ was found to be more active in exploration and performed fewer reproductive activities. This suggests a higher interest in environmental interaction and a lower focus on reproduction. Female ‘D’ and the Male subject showed a higher level of participation in social activities compared to other females. This indicates a strong social inclination in their behavior.

Interestingly, Female ‘D’ was also more active in feeding but showed no participation in reproductive activities. This could suggest a prioritization of sustenance over reproduction. The Male subject, on the other hand, showed a higher tendency towards resting and spent very little time feeding. This could indicate a different energy conservation strategy compared to the females.

Female ‘C’ spent more time resting than other females, suggesting a possible need for higher energy conservation or recovery periods. Female B and Female G, who are both nearly 2 years of age and without any fawns, spent more time in solitary activities compared to other females with fawns. This could be attributed to the absence of parental responsibilities.

There was a significant change in male and female activities. The male was more active in reproductive activities like chasing and sniffing females and less active in exploratory behaviors like walking and standing. This is likely due to most of the females (4 out of 6) having 10 to 12 months old fawns, therefore they actively participate in parental care and

show less reproductive activity. They also more actively participate in feeding and exploration.

These findings provide valuable insights into the behavioral patterns and activity budgets of the subjects, contributing to our understanding of their daily lives and interactions. Further research could explore the underlying factors influencing these behaviors and their implications for the subjects' overall well-being.

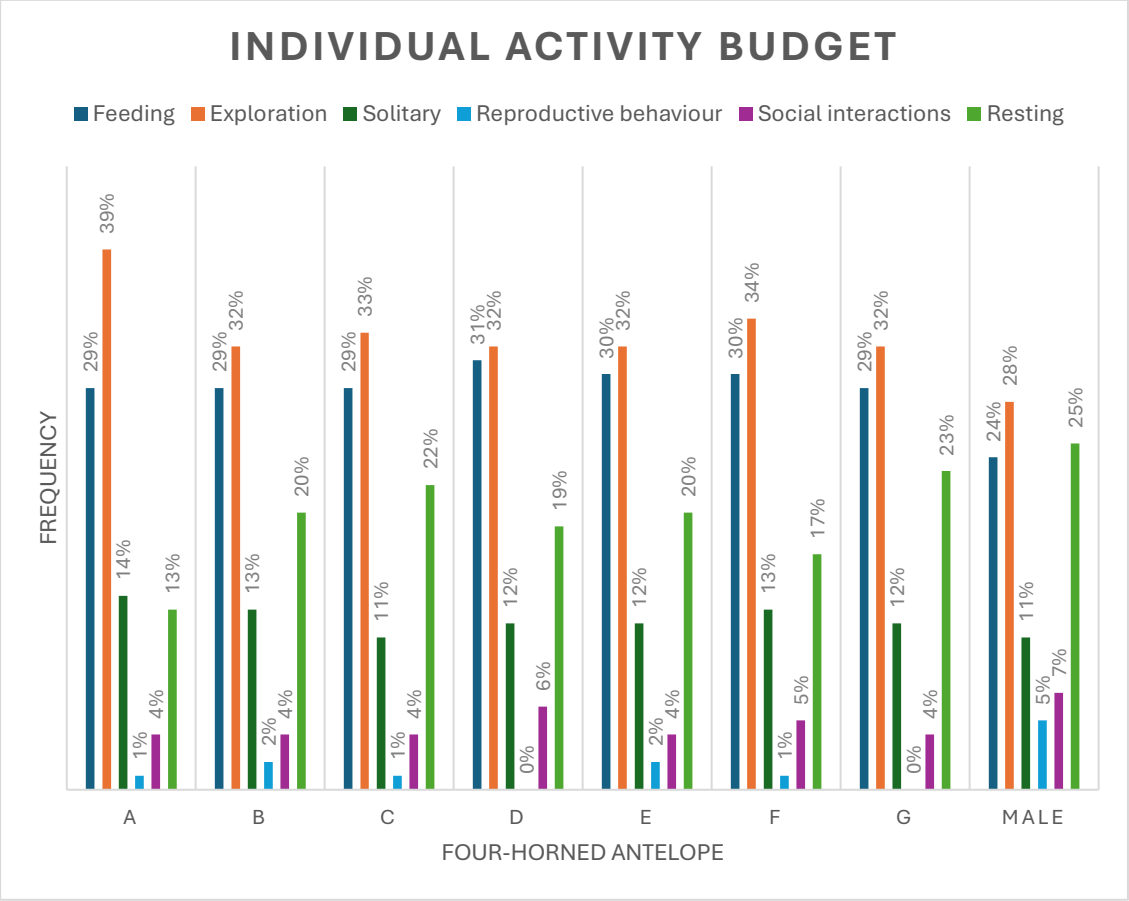

Fig:22 Individual activity of Four-horned Antelope

6. Discussion

The Four-horned Antelope, a solitary species in the wild, exhibits intriguing behavioral adaptations in captivity (Sharma et al., 2005). In the wild, the maximum group size seen was four individuals, with an average of 1.5 to 1.6 individuals (Berwick, 1974). However, in captivity, group formations of 2 to 5 individuals were observed 888 times during a 2-month observation period. These group formations were found to be beneficial for various activities like exploration, feeding, resting, and other social activities. Interestingly, while the antelope is sighted alone 62% of the time in the wild, in captivity, they prefer to stay in groups of 2 rather than 3 to 5 individuals (Baskaran et al., 2011).

During feeding, which involves grazing, browsing, salt licking, and drinking, the Four-horned Antelopes tend to form groups more frequently. Specifically, some females showed a preference for particular individuals when forming groups. For instance, female B showed a strong preference for group size and individual, often forming a group with female ‘G’. Other notable pairs included ‘AD’, ‘AF’, and ‘EF’. Groups such as ‘ACDF’, ‘ACEG’, ‘ADEG’, and ‘BEG’ showed lower frequencies of group formation, suggesting a preference for little group sizes (2–3 individuals) during feeding. Age also appeared to influence group formation, with younger females ‘B’ and ‘G’ (approximately 2 years old) preferring to feed together.

Exploration activities, which encompass walking, steep walking, and standing, also revealed preferences in group formation. Female ‘B’ frequently formed a group with female ‘G’, indicating a preference for a particular group size and individual. Female ‘A’ preferred to explore with females ‘D’ and ‘F’, forming groups ‘AD’, ‘ADF’, and ‘AF’

with frequencies of 18, 18, and 16, respectively. Female ‘E’ preferred to explore with female ‘F’ and a male.

Social behaviors, categorized into inter-species and intra-species interactions, included dominance, conflict, grooming, defecation, submission, threat response, and warning calls. In these activities, female A preferred to form a group with ‘D’ and ‘F’. However, the Four-horned Antelopes showed less group formation frequency in social activities compared to other activities.

Resting behavior, categorized into sleeping and resting awake, also demonstrated preferences in group formation. During resting, female ‘A’ preferred to form a group with females ‘C’, ‘D’, and ‘F’. Female ‘B’ preferred to form a group with female ‘G’, and female ‘C’ preferred to form a group with female ‘D’.

In terms of activity patterns, Four-horned Antelopes in the wild spend more time feeding (56%), followed by exploration (28%), resting (15%), and drinking (1%) (Baskaran et al., 2011). However, in captivity, there is a change in these patterns, with most of the time spent in exploration (32.75%), followed by feeding (28.88%), resting (19.88%), solitary (12.25%), social interactions (4.75%), and reproductive behaviors (1.50%).

The study also revealed intriguing examples of alloparental care in the form of allosuckling and allonursing. Allosuckling, or non-offspring nursing, was observed when one or more fawns saw another fawn nursing on its mother (Riedman 1982; Packer et al. 1992; Dittrich,1968; Birgersson et al. 1991). Allonursing, was observed where a female nurses another’s offspring, was observed in a female Four-horned Antelope that had lost her fawns due to malnutrition after birth. Both behaviors are reported for the first time in this species.

The Four-horned Antelope naturally shares habitat with the Spotted Deer and Barking Deer, and there is spatial niche partition between Four-horned Antelope and Barking Deer (Pokharel et al., 2015). However, in captivity, conflicts between Four-horned Antelope, Thamin Deer, and Himalayan Goral have been observed, affecting the daily behavioral patterns of these animals. They spend the majority of their time exploring rather than feeding, a behavior that contradicts their natural tendencies. Among other factors, anthropogenic pressure from continuous visitor gatherings influences the natural behavioral patterns of the Four-horned Antelopes. The study highlighted conflicts during feeding in the mixed-herbivore enclosure, where dominating species like Thamin Deer and Himalayan Goral dominated the feed, leading to significant changes in the feeding activity of the Four-horned Antelope from the wild.

The existence and abundance of an animal in a region can be demonstrated using faecal pellets (Neff, 1968; Marques et al., 2001) and faecal pellets of Four-horned Antelope is known as Middens.

The site for the middens changes approximately every 2 weeks in captivity and is used by specific individuals who share the same age group. During defecation every individual first take olfaction of midden and then particularly female bend their back portion of body and take it close to the ground (Dubost, 2023). Middens play a vital role in conspecific communication (Sharma et al., 2009). For example, fawns use the defecation site of their mother, and males defecate on specific females' defecation sites for communication purposes.

Observations also include head bunting, excitatory behavior, and inter-species grooming, behaviors that have not yet been observed in the Four-horned Antelope.

These findings collectively suggest that while Four-horned Antelopes exhibit a general behavioral pattern, individual variations exist, possibly reflecting distinct behavioral adaptations to their captive environment. Further research is necessary to investigate the implications of these findings on the management and conservation strategies for Four-horned Antelopes in captivity. Understanding the behaviors and needs of Four-horned Antelopes in captivity can enhance their welfare and breeding success. By studying these individual variations, conservationists can tailor management strategies to better support the species' long-term survival. Moreover, by identifying and addressing specific behavioral adaptations, zoos and wildlife parks can enhance the environments for Four-horned Antelopes. This approach can ultimately enhance the success of breeding programs and contribute to the overall conservation efforts for this species.

7. Conclusion

The Four-horned Antelope, a solitary, non-migratory, and elusive species, presents unique challenges for behavioral study in the wild due to its anti-predatory behavior. However, continuous observation in captivity allows for a detailed analysis of their social behavior and reveals other behavioral changes.

In the mixed-herbivore enclosure at SPZP, there are 14 four-horned antelopes: 1 male, 7 females, and 6 fawns. Our study focused on the group formation frequency of four-horned antelopes in captivity during various activities.

Contrary to their solitary nature, Four-horned Antelopes in captivity actively participate in social groupings. They form groups of up to 5 individuals and show preference for group composition and individuals within the group during various activities such as feeding, exploration, resting, and reproductive activities. The group composition is based on their age and sex of individuals.

There is a slight change in the activity budget of Four-horned Antelopes in captivity from their wild relatives. They spend more time in exploration and feeding due to captive conditions.

The study also discovered novel behaviors like allosuckling, allonursing behaviors in Four-horned Antelopes which have not been seen before. Uncommon behaviors like head bunting between female and fawn and excitatory behavior, where female sprinting stimulates fawns to run and sprint, were also observed.

Females with similar age or siblings spend time together during activities and even prefer to defecate on the same sites or middens. Despite reproductive behavior, males spend

more time in resting and solitary and are also observed to be more active in reproductive activities such as chasing or sniffing females, preorbital gland markings, and mating.

Four-horned Antelopes are housed in 26 zoos in India according to the Central Zoo Authority, but there are very little studies done on Four-horned Antelope and there are gaps in conservation strategies due to less information about Four-horned Antelope's social behavior. Therefore, further studies with a greater sample size can explore more about their behavioral dynamics in captivity and can aid in their conservation strategies. This study contributes to the understanding of the social and behavioral dynamics of Four-horned Antelopes in captivity, providing important insights for future research and conservation efforts.

8. References

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9. Appendix

Initial Data Sheet Design Sample

This data sheet was used to conduct pilot observations and later on mobile application data collection form was designed based on this.

Data Sheet

Name of Observer: _____ Date: _____ Start Time: _____ End Time: _____

Time	Individual ID	Behavior Category Code	Specific Behavior Code	Group Composition	Notes