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Research Article

Interspecific Association of Pangolin Ecosystem in Deng-Deng National Park, Eastern Region, Cameroon

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ABSTRACT

Understanding the heterospecific associations within the pangolin ecosystem is important for developing effective conservation strategies. These associations not only contribute to the ecological resilience of the national park but also shed light on the intricate ecological relationships in this unique habitat. This research aimed to examine the heterospecific association of pangolins within deng-deng national park, focusing on their interactions with other species and the ecological implications of these associations. Field surveys and observational techniques were employed to gather data on pangolin associations with other wildlife species. Camera traps were used to record direct observations of pangolins and their interactions with co-occurring species. The study revealed a significant association of wildlife species on human activity X^2=28.489, df=12, P=0.005, forest vegetation type X^2=10.002, df=12, P<0.05, and forest vegetation canopy X^2=28.655, df=8, P=0.001 respectively. Also, the most frequently observed wildlife species in the pangolin environment were gorillas (*Gorilla gorilla*) 12% and chimpanzees (*Pan troglodytes*) 11% respectively, while the least were tortoise (*Centrochelys sulcata*) 5% and red-river hog (*Potamochoesrus porcus*) 5% respectively. A significant association was found between forest undergrowth and wildlife species in pangolin environment X^2=5.567, df=8, P<0.05. Furthermore, the study has shown a significance between forest visibility and wildlife species, X^2=6.175, df=8, P<0.05. There is a significant relationship between forest landscape and wildlife species, X^2=16.699, df=8, P<0.05. Forest landscape and the vegetation canopy showed a significant association as well X^2=5.434, df=4, P<0.05. The study on the heterospecific association of pangolin ecosystem in deng-deng national park provides valuable insights into the interactions between pangolins and other wildlife species. These findings contribute to our understanding of the complex ecological dynamics within the park and provide a basis for informed conservation decision-making to ensure the sustainability of pangolin ecosystem in deng-deng national park.

Keywords: Pangolin ecosystem; Transect surveys; Camera trapping; Vegetation canopy; Human activity

INTRODUCTION

The ecological dynamics of an ecosystem are often shaped by the interactions between different species. Interspecific associations, which refer to the relationships between different species, play an important role in maintaining the balance and functioning of ecosystems. Animal communities consist of multiple species that interact directly and indirectly, both within and across trophic levels. These interaction networks are continuously changing with the changing environment and have ecological consequences on species abundances, distributions and community composition [1-7]. Understanding these associations is essential for comprehending the ecological roles of specific species and their contributions to overall ecosystem health. Pangolins, as unique and endangered mammals, have gained considerable attention in recent years due to their ecological importance and the threats they face. Despite their ecological significance, the knowledge regarding their interspecific associations and interactions with other species remains limited. Investigating these associations is important for gaining insights into the broader ecological context in which pangolins exist.

Additionally, interactions between species may result in long lasting evolutionary consequences *via* coevolution [8,9]. Consequently, species interactions are one of the forces altering diversity within

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a community, and the importance of species interactions in community ecology has recently gained increased attention [10-15]. However, the potential that understanding the ecological and evolutionary consequences of species interactions may provide for estimating species abundances in communities and changes in community dynamics has not yet been fully exploited. For example, species may aggregate or segregate as a result of their positive or negative interactions with other species, respectively, or dynamic species interactions may facilitate or diminish the potential for species to adapt to the changing environment leading to significant impact on species abundances [16-22].

Environmental changes alter the diversity within communities, which in turn will have a direct and indirect effect on which species may interact (e.g., the potential to encounter an individual of the other species) and how much (e.g., the frequency and intensity of interactions) depending on, for example the presence, density, range shift or specialization of species [5,7,12,14,23,24]. Additionally, the social structure of a community and the social behaviour of an individual affect which species and how they may interact [8,25]. Thus, the complex eco-evolutionary loop including species interactions and environmental change may have cascading effects over long time scales. With respect to the current declines of species abundances and biodiversity, there is a high demand for large-scale methods of collecting community data. Understanding the above-mentioned biotic mechanisms could offer novel insights into developing more accurate and effective methods for estimating species abundances or predicting species' responses to environmental changes. For example, the potential to utilize species aggregations for identifying novel ecological indicators, where a specific species or a species group is used to gain information on other species within the same area has not been fully explored. This may allow a cost-efficient avenue for large-scale data collection by exploiting citizen science [26,27].

Deng-deng national park, located in the Eastern Region of Cameroon, provides an ideal setting for studying wildlife interspecific associations within the pangolin ecosystem. The park is known for its rich biodiversity, including a diverse range of species coexisting with pangolins. Examining the associations between pangolins and other species in this unique ecosystem provides valuable insights into their ecological role and conservation implications. Investigating the heterospecific association of the pangolin ecosystem in deng-deng national park holds significant importance for understanding the ecological context in which pangolins exist. By examining these associations, the study contributes to the broader understanding of the intricate relationships within the park's ecosystem and provides a foundation for informed conservation decision-making to ensure the long-term sustainability of the pangolin ecosystem in Deng-Deng National Park.

MATERIAL AND METHODS

Description of study area

Deng deng national park is located in the East Region of Cameroon, precisely in the Lom-et-Djerem division (Figure 1). The park covers an area of about 523 km and lies between latitude 13° 23 to 13° 34 East and longitude 05° 5 to 05° 25 North, in the North-Eastern part of the lower Guinean forest [28]. The biophysical environment of deng-deng national park is described by its characteristics climate, relief, vegetation types and hydrology. Annual rainfall in the park ranged from 1500 mm to 1600 mm [29,30]. The park area features a typical equatorial and humid climate defined by the rainfall regime in this area [31]. Seasonal pattern in the park area is characterized by distinct but unequal dry and wet season periods. Heavy wet season starts from August to November, a light wet season from April to June, a long dry season from December to March and a short dry season from July to mid-August. With a mean annual temperature of 23°C, annual minimum and maximum temperatures within the park area ranged from 15°C and 31°C [29,30]. The park consists largely of flat and gently undulating terrain. Elevation within the park varies from 100 m in the south to 920 m above sea level in the north. So, the park is characterized by its location in the dense tropical rainforest of Central Africa. It is known for its rich biodiversity and serves as an important habitat for numerous plant and animal species. The park is part of the Congo Basin forest ecosystem, which is recognized as one of the world's most significant biodiversity hotspots. It is home to a diverse range of flora and fauna, including many endemic and endangered species. The forest canopy is often thick, allowing limited sunlight to penetrate the forest floor. The vegetation includes towering hardwood trees, lianas, epiphytes, and various understory plants. The national park provides habitat for a number of mammal species, including elephants, chimpanzees, gorillas, monkeys (such as colobus monkeys and guenons), duikers, forest buffalo, pangolin, and various small mammals. The park is also home to a wide range of bird species, reptiles, amphibians, and insects (Figure 1).

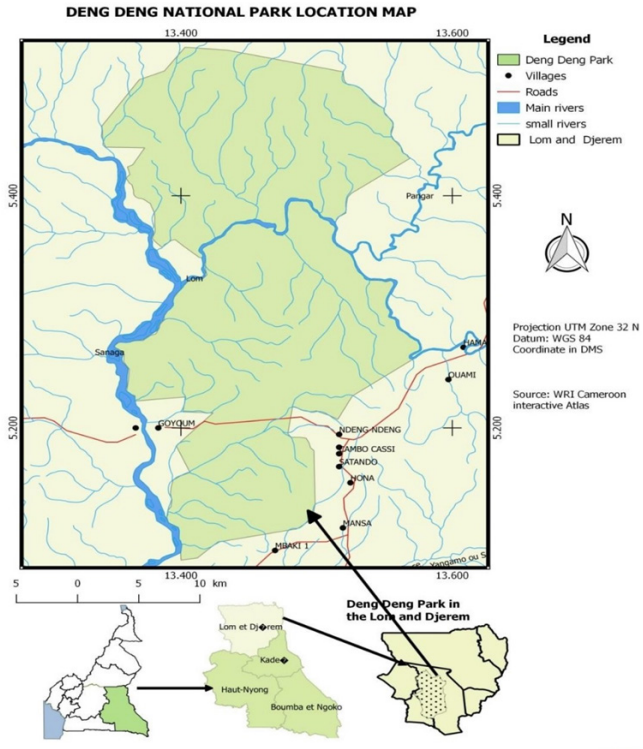

Figure 1: Map of Deng-deng national park [28]. **Note:** (▭): Deng deng park; (•): Villages; (—): Roads; (▭): Main rivers; (—): Small rivers; (▭): Lom and djerem.

Method of data collection and analysis

Exploring the association of pangolins with other wildlife species inDeng-Deng National Park, Eastern Region, Cameroon, a combination of field surveys and camera trapping was used as research method for data collection. Camera trapping involved the

use of motion-activated cameras placed strategically throughout the park. These cameras captured images or videos of wildlife passing by, offering valuable data on species presence, behaviour, and associations. After identification of key areas within the park, such as known pangolin habitats, feeding sites, or trails, camera traps were mounted in those locations. Regular checks were made on the cameras in these locations, including battery replacement, memory card retrieval, and camera repositioning if needed. This ensured uninterrupted data collection and maximized the chances of capturing pangolin and other wildlife activity. Combining field surveys and camera trapping, the research team gathered complementary data on the association of pangolins with other wildlife species in deng-deng national park. Field surveys provided more qualitative and direct observations, while camera trapping offered a broader coverage and the potential to capture elusive or nocturnal species. The data collected through these methods was then analysed to understand the patterns of co-occurrence and potential interactions between pangolins and other wildlife species in the national park.

RESULTS AND DISCUSSION

The study revealed a significant association of wildlife species on human activity X^2=28.489, df=12, P=0.005, (Figure 2), forest vegetation type X^2=10.002, df=12, P<0.05 (Figure 3), and forest vegetation canopy X^2=28.655, df=8, P=0.001 (Figure 4) respectively. The presence of other wildlife species play important roles in the pangolin environment, contributing to the ecological dynamics and overall well-being of pangolin populations. Maintaining a balanced and healthy ecosystem that supports a diverse array of wildlife species is essential for the well-being and conservation of pangolins. Protection of biodiversity, habitat preservation, and promoting ecological connectivity are key strategies to ensure the long-term survival of pangolin populations and their interactions with other wildlife species in deng-deng national park. However, pangolins interact with other wildlife species in various ways, creating ecological relationships that influence their environment. For example, pangolins may compete with other insectivorous mammals or birds that rely on similar prey resources. Competition for food shapes the distribution and behavior of pangolins and other wildlife species within their shared habitats. Additionally, pangolins may have mutualistic relationships with certain species, such as birds or primates, which benefits both parties through symbiotic interactions, such as seed dispersal or pest control. The most frequently observed wildlife species in the pangolin environment were gorillas 12% and chimpanzees 11%, while the least were tortoise 5% and red-river hog 5% respectively. Nonetheless, human activities such as deforestation, urbanization, and infrastructure development leads to habitat alteration and loss, which is one of the most significant threats to wildlife species (Figure 2).

As natural habitats are converted for agriculture, settlements, or industrial purposes, wildlife species lose their homes and essential resources. This habitat loss disrupt ecological processes, fragment populations, and lead to declines in wildlife abundance and diversity. So, understanding the role of human presence on wildlife species is crucial for implementing effective conservation strategies. Balancing human needs and development with the conservation of wildlife habitats and species is a complex challenge (Figure 3).

Different wildlife species have specific habitat requirements and preferences. Forest type, which is determined by factors such as dominant tree species, vegetation structure, and environmental conditions, can determine the suitability of an area as habitat for particular species. For example, some species may prefer dense, closed-canopy forests with a thick understory, while others may thrive in more open, savanna-like forests. The availability of suitable forest types directly influences the presence, abundance, and diversity of wildlife species in a given area (Figure 4).

The forest canopy provides shelter and protection for a wide range of wildlife species. The dense foliage and interlocking branches create a canopy cover that shields animals from direct sunlight, rain, and wind. Many species, including birds, arboreal mammals, and reptiles, utilize the forest canopy as a safe haven for resting, nesting, and avoiding predators. The presence of a healthy and intact canopy structure is essential for providing adequate shelter for wildlife (Figures 5 and 6).

There is an association between forest vegetation undergrowth and wildlife species in pangolin environment, X^2 =5.567, df=8, P<0.05 (Figure 6). The forest undergrowth offers shelter and protection for wildlife species, including pangolins, from predators, extreme weather conditions, and disturbances. The dense vegetation, fallen logs, and leaf litter in the undergrowth provide hiding places and refuge for animals. Pangolins, in particular, may use the undergrowth as a protective cover during periods of rest, nesting, or when avoiding threats. The structure and density of the undergrowth influence the availability and quality of shelter and protection for wildlife species. The forest undergrowth can serve as a vital habitat for nesting and reproduction for various wildlife species, including pangolins. Some pangolin species construct burrows or nests in the undergrowth for raising their young or for protection during breeding seasons. The presence of suitable undergrowth vegetation, such as dense shrubs or fallen logs, provides the necessary conditions for creating nesting sites and ensuring the survival of pangolin offspring. The forest undergrowth facilitates interactions between different wildlife species. It acts as a meeting point or corridor for species movement, allowing for encounters, mating opportunities, or territorial disputes. The undergrowth vegetation may also provide visual barriers or obstacles that influence the visibility and behavior of interacting species. These interactions shape the ecological dynamics, community structure, and associations among wildlife species, including pangolins, within the forest environment (Figure 7).

The study has shown a significance between forest vegetation visibility and wildlife species, X^2=6.175, df=8, P<0.05 (Figure 7). Forest vegetation visibility impacts the foraging efficiency of wildlife species. Some animals rely on visual cues to locate and capture their prey or to find suitable food sources. If the forest visibility is high, allowing for greater visibility between individuals and the surrounding environment, it may enhance the ability of visually-oriented predators to detect and capture prey. Conversely, if visibility is low due to dense vegetation, it may pose challenges for visually-dependent species, potentially impacting their foraging success. Forest vegetation visibility also influences interactions between wildlife and humans. High visibility in forests makes wildlife more easily detectable by humans, which may have both positive and negative consequences. On one hand, it may facilitate wildlife observation and ecotourism activities. On the other hand, increased visibility may make wildlife more vulnerable to poaching, disturbance, or habitat fragmentation caused by human activities (Figure 8).

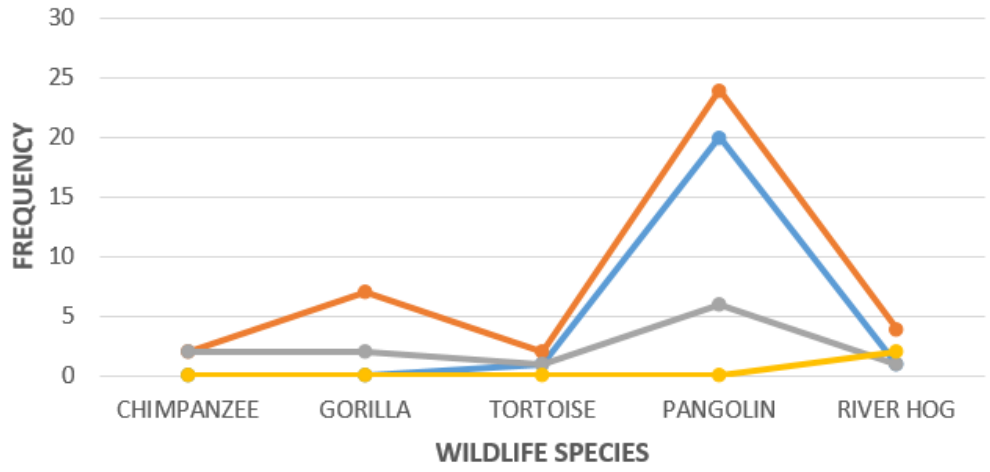

Figure 2: Wildlife species and human activity. **Note:** (—●—): Human sign snare; (—●—): Human sign bullet shell; (—●—): Human sign hunters hut; (—●—): Human sign human trail.

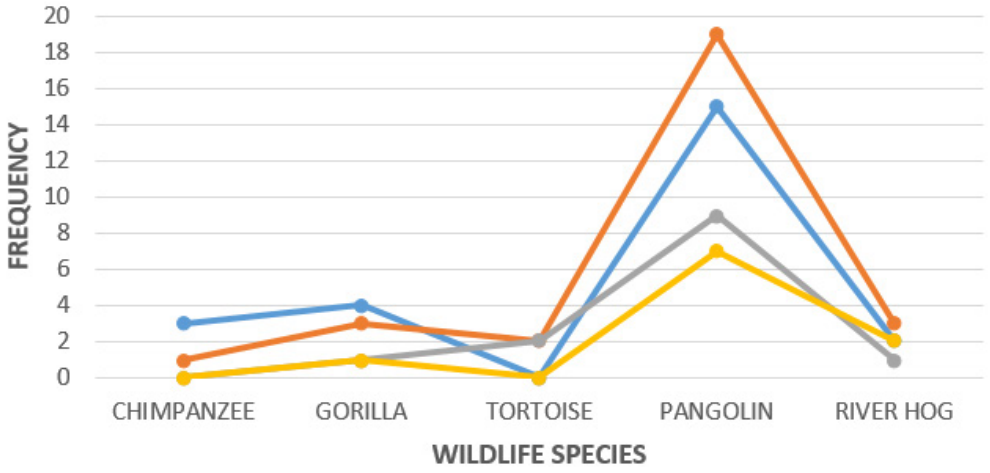

Figure 3: Wildlife species and forest vegetation type. **Note:** (—●—): Dense forest; (—●—): Liana-Ric forest; (—●—): Marshy forest; (—●—): Open forest.

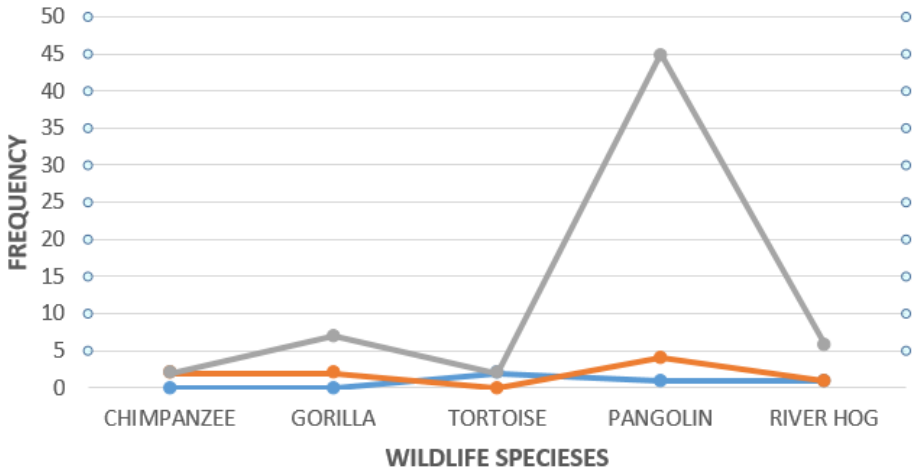

Figure 4: Wildlife species and forest vegetation canopy. **Note:** (—●—): Open canopy; (—●—): Closed canopy; (—●—): Thick canopy.

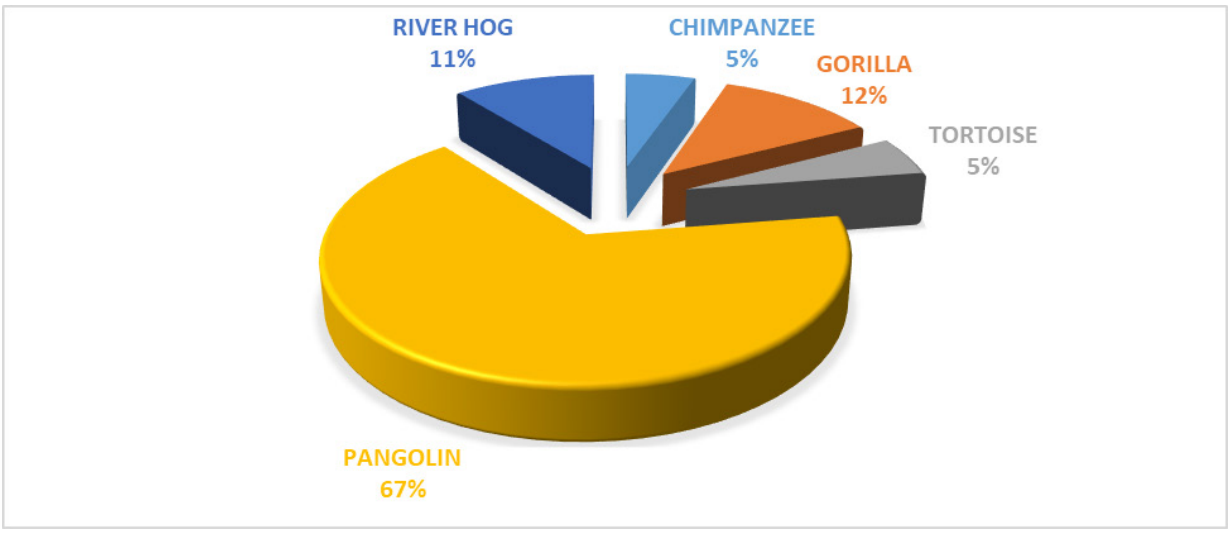

Figure 5: Dominant wildlife species in pangolin ecosystem. **Note:** (■): River hog 11%; (■): Chimpanzee 5%; (■): Gorilla 12%; (■): Tortoise 5%.

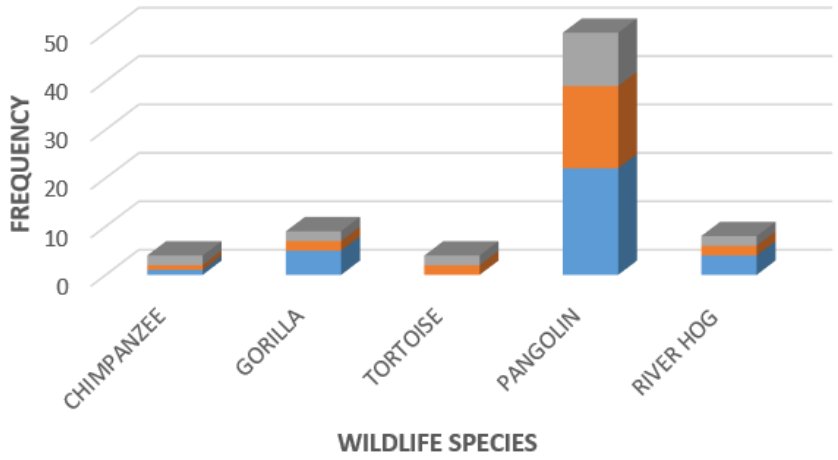

Figure 6: Dominant wildlife species in pangolin ecosystem. **Note:** (■): Open undergrowth; (■): Closed undergrowth; (■); Very closed undergrowth.

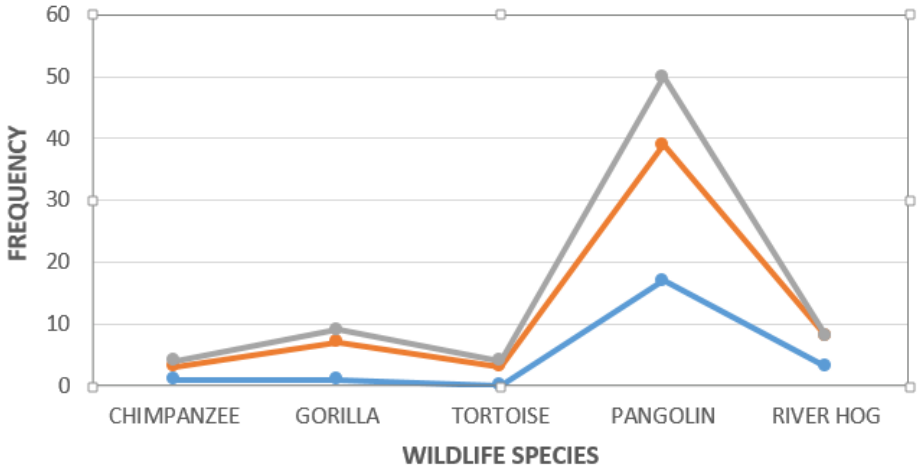

Figure 7: Dominant wildlife species in pangolin ecosystem. **Note:** (—●—): Low; (—●—); Moderate; (—●—): High.

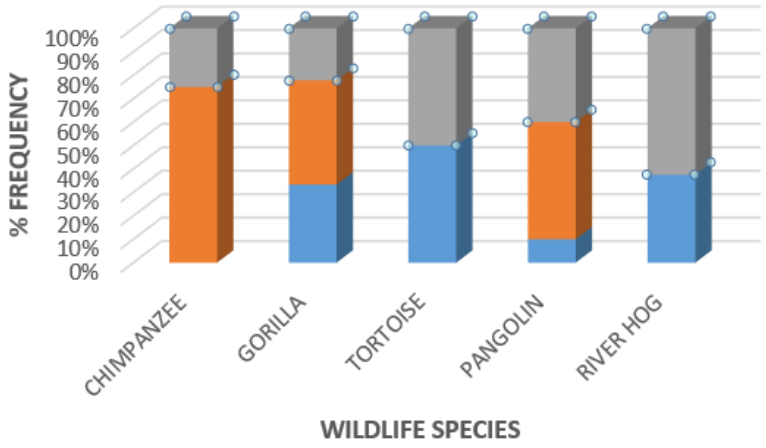

Figure 8: Forest landscape and wildlife species. **Note:** (■): Flat; (■): Slope; (■): Escapement.

There is a significant relationship between forest landscape and wildlife species, X^2=16.699, df=8, P<0.05 (Figure 8). The forest landscapes of deng-deng national park support complex ecological interactions among wildlife species. Pangolins interact with other animals, such as insects, mammals, and birds, within the forest ecosystem. For example, pangolins prey on ants and termites, which contributes to the regulation of insect populations. At the same time, pangolins can be preyed upon by larger predators. The forest landscape influences the availability of species that interact with pangolins and shapes the ecological relationships within the community. Forest landscapes provide a variety of resources that support the survival and reproduction of wildlife species. These resources include food sources such as specific plant species, fruits, insects, or small vertebrates. The availability of these resources is influenced by the composition and structure of the forest landscape. Changes in forest landscapes, such as deforestation or habitat degradation, can directly impact resource availability, affecting the population dynamics and distribution of wildlife species, including pangolins (Figure 9).

Forest landscape and the vegetation canopy showed a significant association, X^2=5.434, df=4, P<0.05 (Figure 9). The heterogeneity of the forest vegetation landscape, which refers to the variety and spatial arrangement of different habitat types, influences the diversity and structure of the forest vegetation canopy. Forest landscapes with a mix of different forest types, such as deciduous and coniferous forests, or a variety of tree species, support a more diverse canopy structure and composition. Landscape heterogeneity provides a range of environmental conditions and resources, promoting species richness and enhancing the complexity of the forest vegetation canopy. So, the connectivity of forest patches within a landscape has implications for the forest vegetation canopy. Connected forest patches allow for the movement of seeds, pollen, and wildlife species between different areas, promoting genetic diversity and maintaining ecological processes. Connectivity also facilitates the decolonization of disturbed or fragmented areas, which contributes to the restoration and regeneration of the forest vegetation canopy. Corridors, which are linear strips of forest vegetation connecting larger patches, play a crucial role in maintaining connectivity and facilitating species movement.

Species interactions have a profound effect in shaping biodiversity patterns, such as species richness, species diversity and species range shifts [6,13,15]. Yet, biotic interactions are still poorly integrated in current methods of measuring species abundances and estimating how different factors affect community composition and community dynamics. Thus, understanding species interactions is critical for developing practical and efficient methods to evaluate species abundances in a community and to predict species' responses to environmental changes. The research revealed that pangolins within deng-deng national park exhibit commensal relationships with certain wildlife species. Pangolins were observed utilizing rodent burrows or tree cavities as shelter. This association benefits both pangolins and rodents, as pangolins find secure resting places while rodents benefit from the maintenance and potential expansion of their burrow systems. The commensal relationship between pangolins and birds highlights the interconnectedness and interdependence of species within the national park.

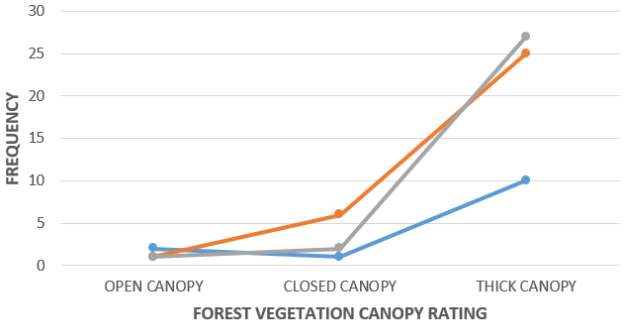

Figure 9: Forest vegetation canopy and land scape. **Note:** (■): Flat; (■): Slope; (■): Escapement.

The interactions among populations of different species play a major role in regulating population growth and abundance. A species interaction is the effect that a pair of organisms living together in a community have on each other. Interactions range from mutualism, which benefits both species involved, to competition, which harms both species involved [32]. Interactions can be indirect, through intermediaries such as shared resources or common enemies. All of these interactions can be organized by the effects the species have on each other. Species interactions may be short-term, like pollination and predation, or long-term; both often strongly influence the evolution of the species involved. Short-term interactions are short-lived in terms of the duration of a single

interaction: A predator kills and eats a prey; a pollinator transfers pollen from one flower to another; but they are extremely durable in terms of their influence on the evolution of both partners. As a result, the partners coevolve Bengtson, et al. [33,34].

However, understanding the interspecific associations of pangolins provides insights into their habitat requirements and the potential impacts of habitat degradation and fragmentation on these associations. Conservation efforts should prioritize the preservation of suitable habitats and the establishment of corridors that facilitate the movement and interactions of pangolins with other species. Protecting the pangolin ecosystem and its associated species will contribute to the overall biodiversity conservation and ecological integrity of the park. Competition is often for a resource such as food, water, or territory in limited supply, or for access to females for reproduction [35]. Pangolins were observed consuming ants as a significant part of their diet, and in return, pangolins benefited from the protective behavior of ants. Ants, known for their aggressive and swarming nature, offer protection to pangolins by deterring potential predators. Competition among members of the same species is known as intraspecific competition, while competition between individuals of different species is known as interspecific competition.

According to the competitive exclusion principle, no two species with the same ecological niche can coexist, and the species less suited to compete for resources should either adapt or die out [36,37]. Competition within and between species for resources plays a critical role in natural selection [38]. However, this mutualistic association underscores the importance of pangolins and ants in maintaining a balance within the ecosystem, as pangolins contribute to controlling ant populations while benefiting from their defensive capabilities. As pangolins and other mammals share a similar dietary preference for insects, competition arises, particularly in areas where food resources are limited. This competition highlights potential ecological trade-offs, as the presence of pangolins may impact the foraging opportunities and resource availability for co-occurring insectivorous mammals. Understanding these competition dynamics is crucial for assessing the carrying capacity of the ecosystem and its potential impacts on species survival.

The findings emphasized the ecological importance of pangolins within the ecosystem of deng-deng national park. Pangolins, as insectivores, play a vital role in controlling insect populations, which helps maintain the balance of the ecosystem. Their interactions with birds, ants, and other wildlife species further contribute to the ecological dynamics and functioning of the pangolin ecosystem. The research underscores the need for preserving suitable habitats that support the ecological role of pangolins and their associated species. The concept of wildlife distribution and abundance is very important in biodiversity conservation [39]. The distribution and abundance are dependent on many abiotic factors of continuous interaction of vegetation, and also includes the effects of continuous interaction of different species of wildlife [38]. Populations of all species are naturally dynamic and fluctuate over time. The degree to which they change depends on a complex interaction between the biology of the species and the ecosystem in which they live. Some changes in environmental conditions can be beneficial and lead to an increase in population size [40].

CONCLUSION

The research on the heterospecific association of pangolin ecosystem inDeng-Deng National Park provides valuable insights into the ecological dynamics, contributions, and conservation implications of pangolins and their interactions with other wildlife species. So, the study revealed significant findings regarding commensal relationships, mutualistic interactions, competition for resources, and the ecological role of pangolins within the park. These findings have important implications for the conservation and management of the pangolin ecosystem in deng-deng national park. Additionally, the study highlighted the commensal relationships between pangolins and certain wildlife species, where pangolins utilize rodent burrows or tree cavities for shelter, benefiting both pangolins and rodents. Understanding the heterospecific associations of pangolins provides insights into their habitat requirements and the potential impacts of habitat degradation and fragmentation on these associations. Conservation efforts should prioritize the preservation of suitable habitats and the establishment of corridors to facilitate pangolin movements and interactions with other species. Protecting the pangolin ecosystem and its associated species is crucial for biodiversity conservation and maintaining the ecological integrity of deng-deng national park. Nonetheless, the study on the heterospecific association of pangolin ecosystem in deng-deng national park contributes to our understanding of the intricate relationships between pangolins and other wildlife species. The findings underscore the ecological importance of pangolins, emphasize the need for conservation measures to protect their habitat and associated species, and provide a foundation for informed decision-making in the management of deng-deng national park. Preserving the pangolin ecosystem is not only crucial for the survival of these unique and endangered mammals but also for maintaining the overall health and biodiversity of the national park.

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