***Review Article***

**Vegetation as a Key Determinant in Sloth Bear Habitat Preference: A Systematic Review**

**ABSTRACT**

Sloth bears (Melursus ursinus), native to the Indian subcontinent, exhibit unique ecological behaviours and habitat preferences intricately tied to vegetation structure and diversity. This review summarizes current literature on the role of vegetation in shaping the habitat selection, dietary ecology, and spatial distribution of sloth bears. These predominantly myrmecophagous mammals depend on forest ecosystems rich in termite mounds, ant colonies, and seasonal fruiting trees. Vegetation characteristics such as canopy cover, species diversity, and ground structure influence their foraging patterns, denning sites, and movement behaviours. Habitat suitability studies across India and Nepal highlight sloth bears’ preference for dry and moist deciduous forests, sal-dominated landscapes, and scrub habitats, each offering distinct foraging and shelter opportunities. The seasonal availability of native fruiting species like Ziziphus mauritiana, Ficus spp., and Madhuca indica further governs bear movement and home range configurations. Utilizing remote sensing (RS) and species distribution models (SDMs), especially MaxEnt, researchers have identified vegetation indices such as NDVI as strong predictors of habitat suitability. However, inclusion of floristic composition enhances the ecological resolution of these models. Despite the sloth bear’s adaptability, habitat fragmentation and human disturbance pose significant threats, underscoring the need for vegetation-based conservation planning. This review bridges ecological findings with conservation applications, advocating for habitat restoration strategies that prioritize native fruit species and minimize forest degradation to ensure sustainable sloth bear populations across their fragmented range.

*Keywords: Myrmecophagy, Habitat selection, Fruiting phenology, Vegetation*

# **INTRODUCTION**

Sloth bears (Melursus ursinus) are unique members of the bear family, found primarily across the Indian subcontinent. Their ecological profile is shaped by a variety of environmental and biological factors, including habitat preference, feeding behaviour, and social structure. Ecologically, sloth bears inhabit a diverse range of environments, from dry deciduous forests to moist broadleaf forests, often choosing areas with rocky outcrops and caves for denning and shelter (Yoganand & Rice, 2005). Their home range and movement patterns are influenced by food availability and human disturbance (Baskaran et al., 2015). They consume a variety of fruits and occasionally small vertebrates. This dietary flexibility is essential for survival in habitats with fluctuating food resources (Dharaiya & Rabari, 2022). Behaviourally, sloth bears are mostly nocturnal and solitary, with unique adaptations such as a gap in their upper incisors to suck up insects effectively. Vocalizations and scent markings play a critical role in communication and territory establishment (Laurie & Seidensticker, 1977).

Vegetation plays a fundamental role in the habitat selection of sloth bears, influencing not only their distribution and movement but also their foraging behaviours, denning, and overall ecological fitness. As primarily insectivorous and frugivorous mammals, sloth bears rely on forested landscapes rich in termite mounds, ant colonies, and seasonal fruits, which are largely dictated by the type and structure of vegetation present. Studies across various Indian landscapes have shown that sloth bears favour forest habitats with dense undergrowth and a high diversity of fruiting plant species. In particular, deciduous and mixed forests provide critical food resources and shelter from predators and human disturbances (Ramesh et al., 2012). Habitat suitability models confirm that areas with substantial vegetative cover and minimal fragmentation are more likely to support stable sloth bear populations (Rather et al., 2021). In regions such as Chitwan National Park, Nepal, habitat preference studies revealed that sloth bears selectively use areas with high canopy cover and undergrowth, where food availability and cover coincide (Ghimire & Thapa, 2014). Similarly, in Panna National Park, India, radio telemetry studies found that bears showed a clear preference for areas rich in fruiting trees, which were closely tied to specific vegetative patterns (Yoganand & Rice, 2005). Beyond food, vegetation structure provides essential cover for resting and denning. Forest heterogeneity, including the presence of bamboo, fruiting shrubs, and tree cavities, enhances habitat suitability and influences home range configurations (Akhtar et al., 2004).

The primary objective of this review is to synthesize existing research on the ecological requirements and habitat selection behaviour of the sloth bear, with a specific focus on the role of vegetation. Vegetation characteristics such as canopy density, species diversity, and ground cover are vital determinants in shaping the spatial distribution and habitat preferences of sloth bears. As these animals depend heavily on natural food sources like fruits, termites, and ants, their habitat use is closely tied to the presence and abundance of such resources, which in turn are governed by vegetation type and structure. This review also aims to explore how sloth bears interact with their environment across different landscapes, including protected forests and anthropogenic altered zones, and how vegetation influences their foraging behaviours, denning sites, and movement patterns. Further, it seeks to identify gaps in current ecological knowledge that hinder effective conservation planning, particularly in the context of increasing habitat fragmentation and human-wildlife conflicts. The findings from various ecological studies, this review provides a comprehensive understanding of the role vegetation plays in the life history of sloth bears, serving as a critical reference for conservation biologists, wildlife managers, and policymakers involved in habitat management and species preservation.

# **METHODOLOGY**

We adopted a systematic approach to identify, screen, and synthesize existing review literature focusing on sloth bear habitat selection, with an emphasis on vegetation characteristics. The goal was to consolidate findings from peer-reviewed articles and ecological assessments that employed empirical methods or analytical models.

## **Literature Search Strategy**

Relevant studies were retrieved from scientific databases including Google Scholar, PubMed, SpringerLink, ResearchGate, etc. Keywords used for search included: “sloth bear,” “habitat selection,” “vegetation,” “habitat suitability,” and “ecological review.”

## **Inclusion Criteria**

Studies were included based on the following criteria:

1. Focused on habitat selection or suitability modelling of sloth bears.
2. Highlighted vegetation characteristics or landscape features.
3. Published in English in peer-reviewed journals or recognized reports between 2000-2024.
4. Provided sufficient methodological detail for review extraction.

## **Data Extraction and Synthesis**

Key themes extracted from each study included vegetation types (canopy cover, species richness), feeding ecology, scale of habitat analysis (landscape vs microhabitat), data collection methods (e.g., remote sensing, telemetry), and main ecological findings.

# **RESULTS AND DISCUSSIONS**

## **Sloth Bear Ecology**

### **Distribution and Major Habitat Types**

Sloth bears are primarily distributed across the Indian subcontinent, with over 90% of the population residing in India. Their range is constrained by geographic barriers such as the Himalayas to the north, deserts to the northwest, and the ocean to the south. Historically widespread across the Indian Peninsula, their distribution is now highly fragmented due to habitat degradation and human conflict, and is limited to five major regions: northern, north-eastern, central, south-eastern, and south western India (Garshelis et al., 1999a; Yoganand et al., 2006). In India, the northern region includes Uttarakhand, western Uttar Pradesh, and parts of Bihar. The north-eastern distribution, though poorly documented, spans Assam, Manipur, Meghalaya, and Arunachal Pradesh. The central zone, the largest, includes Madhya Pradesh, Chhattisgarh, Odisha, Andhra Pradesh, and Jharkhand. The south-eastern and south western regions correspond to the Eastern and Western Ghats, respectively, with populations in Karnataka, Kerala, Tamil Nadu, and extending into Gujarat and Rajasthan (Johnsingh, 2003; Bargali, 2012).

In Nepal, sloth bears are primarily found in the lowland Terai grassland–forest mosaics and lower Siwalik hills, with recent recolonization evidence in Suklaphanta Wildlife Reserve from adjacent Indian populations (Lamichane, 2015; Sathyakumar et al., 2012).

Bangladesh has seen local extinction of sloth bears due to massive habitat loss, with the last verified sightings in the mid-1990s (Sarker, 2006).

In Bhutan, their presence remains highly doubtful. While early maps suggested a wider range, recent evidence confirms only one verified photo near the Indian border, likely of a transient bear (Garshelis et al., 2015).

The Sri Lankan subspecies occupies the northern and eastern dry forests of the island, covering about 17% of the land. Although connectivity among populations is relatively intact, civil conflict in these regions has left conservation impacts largely undocumented (Ratnayeke et al., 2007).



**Fig. 1. Distribution Map of Sloth Bear (Source- (IUCN Sloth Bear Expert Team, 2016)**

### **Dietary Behaviour and Dependence on Vegetation**

Sloth bears are predominantly myrmecophagous, feeding heavily on termites and ants, which form the protein base of their diet. However, they also consume a variety of fruits, making them facultative frugivorous. Seasonal changes in fruit availability significantly influence their foraging behaviour and habitat use (Dharaiya & Rabari, 2022). The species shows dietary plasticity, adjusting its consumption based on local vegetation composition and availability of wild or cultivated fruit species (Palei et al., 2020). In disturbed areas, sloth bears often depend on agroforestry crops and non-timber forest products (NTFPs), which may increase human-wildlife conflict (Bargali et al., 2004).

### **Role of Forest Types**

Sloth bears exhibit varying ecological dependencies based on forest types. Dry deciduous forests, characterized by open canopies and abundant termite mounds, provide year-round insect prey and are often utilized during the dry season (Bargali et al., 2012). Moist deciduous and sal-dominated forests, on the other hand, provide dense cover and a rich diversity of fruiting trees, supporting denning and foraging activities during monsoonal peaks (Seidensticker & Yoganand, 2011). Scrub and degraded forests serve as secondary habitats and corridors, particularly in fragmented landscapes. These habitats often support lower food diversity but are crucial for maintaining population connectivity and facilitating movement between core forest areas (Sukhadiya et al., 2013).

## **Vegetation Structure and Composition in Sloth Bear Habitats**

### **Dominant Vegetation in Sloth Bear Habitats across Regions**

Sloth bears occupy a variety of forested ecosystems across their range, which includes dry deciduous, moist deciduous, tropical thorn, sal-dominated, and scrub forests. In central India, dry and mixed deciduous forests are the most common habitats, while in the Western Ghats and northeastern states, sloth bears are associated with moist broadleaf forests. These forests often include an understorey of shrubs and grasses, interspersed with rocky outcrops and termite mounds, which are critical for foraging and denning (Seidensticker & Yoganand, 2011).

### **Key Plant Species Used for Food**

Sloth bears are myrmecophagous and frugivorous, relying primarily on termites, ants, and seasonally available fruits. In multiple studies across India and Nepal, species such as *Zizyphus mauritiana (ber), Diospyros melanoxylon (tendu), Ficus spp., and Aegle marmelos (bael)* have been recorded as important dietary components (Bargali et al., 2004; Joshi et al., 1997). These fruiting trees are found abundantly in dry deciduous and moist forest types, and their phenology dictates seasonal foraging shifts.

### **Seasonal Availability of Resources (Fruiting Phenology)**

Seasonal changes strongly influence the diet of sloth bears. During summer and early monsoon months, fruiting peaks in key species like *Zizyphus, Diospyros, and Ficus*, providing critical energy sources (Dharaiya & Rabari, 2022). During the cooler dry season, when fruit availability declines, sloth bears rely more heavily on termites and ants, which remain accessible under soil and decaying wood layers (Mewada, 2015). This seasonal dietary flexibility helps buffer nutritional stress and supports survival in variable environments.

**Table 1. Forest Types and Sloth Bear Habitat Use**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Forest Type** | **State/Region** | **Dominant Trees** | **Fruiting Species** | **Importance for Sloth Bears** | **References** |
| Dry Deciduous | Madhya Pradesh, Chhattisgarh | *Tectona grandis, Anogeissus spp.* | *Zizyphus, Madhuca, Diospyros, Aegle, Ficus, Boswellia etc.* | High insect prey and seasonal fruits | Bargali et al. 2004; Seidensticker & Yoganand 2011 |
| Moist Deciduous | Western Ghats (Karnataka, Kerala) | *Terminalia spp., Lagerstroemia spp.* | *Ficus spp., Syzygium spp., Ziziphus, Madhuca* | Dense cover and diverse fruit supply | Baskaran et al. 2015; Dharaiya & Rabari 2022 |
| Sal-Dominated | Chhattisgarh, Madhya Pradesh, Uttarakhand, Nepal | *Shorea robusta* | *Diospyros, Aegle, Terminalia etc* | Preferred in monsoon due to fruiting trees | Joshi et al. 1997; Seidensticker & Yoganand 2011 |
| Scrub | Rajasthan, Gujarat | *Acacia spp., Zizyphus spp.* | *Zizyphus, Prosopis, Acacia* | Used as corridors, low fruit density | Sukhadiya et al. 2013 |
| Agroforestry | Odisha, Eastern India | *Mango, Cashew, Mahua* | *Madhuca indica, Semecarpus etc* | Supplement diet, high conflict risk | Palei et al. 2020; Mewada 2015 |

Here is Table-1 presenting the vegetation characteristics of different forest types and their significance for sloth bear ecology across regions.

## **Food Plants and Phenology in Sloth Bear Ecology**

### **List of Major Food Plants**

Sloth bears exhibit a diverse diet dominated by insects such as termites and ants, but they also heavily rely on plant-based foods, particularly seasonal fruits, roots, and tubers. Common fruiting species *include Zizyphus mauritiana (ber), Diospyros melanoxylon (tendu), Ficus racemosa, Aegle marmelos (bael), Syzygium cumini (jamun), and Madhuca indica (mahua)*. Roots and tubers of various forest plants, such as Curcuma spp. and wild yams, are also consumed, especially during periods when fruit is scarce (Sajeer, 2013; Joshi et al., 1997).

The availability of these food resources is highly seasonal. Fruiting peaks generally occur during the summer and monsoon months (April–August), when trees like *Zizyphus, Ficus*, and *Syzygium* produce abundant fruits. Mahua flowers bloom in early summer and are a critical resource at the end of the dry season. During winter and dry months (November–March), when fruit availability declines, sloth bears shift their diet towards insect prey and underground parts of plants like tubers and roots (Rathore, 2008).

### **Alignment of Food Peaks with Seasonality and Availability**

A wide variety of native tree species play a crucial role in supporting the frugivorous dietary needs of the sloth bear, with fruit availability often guiding seasonal habitat preference. Key species such as *Aegle marmelos, Buchanania lanzan, Mangifera indica, Syzygium cumini, and Ziziphus mauritiana* exhibit high palatability and are strongly preferred by sloth bears, particularly during the post-monsoon and early winter months (Bargali et al., 2004; Laurie & Seidensticker, 1977; Kumara et al., 2023). These trees offer soft pulpy fruits, which are rich in sugars and nutrients, making them critical food resources during periods of high energy demand.

Several fig species (*Ficus benghalensis, F. racemosa, F. religiosa, F. virens*) also contribute significantly to sloth bear diets due to their extended fruiting windows and wide distribution, particularly in Central India (Kumara et al., 2023; Paul & Kumar, 2021). Similarly, other moderately preferred species like *Annona squamosa, Cordia dichotoma, and Cassia fistula* serve as supplementary food sources, especially when primary fruits are scarce. Interestingly, certain floral or young shoot resources such as *Bombax ceiba* (flowers), *Bambusa vulgaris*, and *Dendrocalamus strictus* (shoots) are consumed occasionally, although with lower preference, likely due to their seasonal or regional availability (Philip et al., 2022; Mewata et al., 2019).

The flowering and fruiting periods of these species vary widely from the summer fruiting of *Madhuca indica* and *Ziziphus rugosa*, to the monsoon and winter peaks of *Diospyros melanoxylon, Emblica officinalis, and Ziziphus mauritiana* offering sloth bears a diverse and temporally distributed food calendar (Bhaskaran & Desai, 2015; Suklhadiya & Dharaiya, 2013). This phenological spread is ecologically significant, ensuring year-round food availability across varied forest types such as dry deciduous, sal-dominated, mixed moist, and scrub forests. In southern and northeastern landscapes, lesser-known species like *Baccaurea courtallensis, Flacourtia sepiaria, and Elaeocarpus tuberculatus* contribute locally to the bear diet, albeit with lower preference ratings.

The dietary preferences recorded also highlight spatial variation. For instance, species like *Artocarpus heterophyllus, Prunus persica, and Pithecellobium dulce* have high preference in the Western Ghats and Eastern Himalayan regions, whereas *Boswellia serrata, Anogeissus latifolia, and Canthium parviflorum* are more relevant in the central and arid zones (Kumara et al., 2023; Khanal & Thapa, 2014). This ecological flexibility enables sloth bears to occupy a broad geographic range, from tropical forests to degraded and semi-urban forest edges.

**Table 2. Key Food Plants Used by Sloth Bears**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tree Species** | **Flowering/Fruiting Period** | **Type (Fruit/Root/Flower)** | **Bear Preferences** | **Source** |
| *Acacia leucophloea* | April-June | Fruit | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Aegle marmelos* | Sept-Dec | Pulp | High | Bargali et al., 2004; Laurie & Seidensticker, 1977; Kumara et al., 2023; Mewata T et al., 2019; Khanal & Thapa, 2014; Philip et al., 2022; Paul & Kumar, 2021 |
| *Alangium salvifolium* | April-June | Fruit | Low | Mewata T et al., 2019 |
| *Annona squamosa* | August-Jan | Fruit | High | Kumara et al., 2023; Philip et al., 2022; Mewata T et al., 2019 |
| *Anogeissus latifolia* | Dec-March | Fruit | Moderate | Kumara et al., 2023; Philip et al., 2022; Paul & Kumar, 2021 |
| *Artocarpus heterophyllus* | June-August | Fruit | High | Kumara et al., 2023 |
| *Artocarpus hirusta* | May-June | Fruit | High | Kumara et al., 2023 |
| *Baccaurea courtallensis* | June-Sept | Fruit | Low | Kumara et al., 2023 |
| *Bambusa vulgaris* | - | Young Shoots | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Bauhinia racemosa* | Nov-Dec | Fruit | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Bombax ceiba* | March-May | Flower | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Boswellia serrata* | March-May | Fruit | High | Philip et al., 2022; Kumara et al., 2023 |
| *Bridelia retusa* | August-Dec | Fruit | Moderate | Kumara et al., 2023; Khanal & Thapa, 2014; Paul & Kumar, 2021 |
| *Buchanania lanzan* | Apri-May | Fruit | High | Bargali et al., 2004; Kumara et al., 2023; Paul & Kumar, 2021 |
| *Butea monosperma* | April-June | Fruit/Flower | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Callicarpa macrophylla* | Sept-Feb | Fruit | Low | Laurie & Seidensticker, 1977 |
| *Canthium parviflorum* | July-August | Fruit | Low | Kumara et al., 2023; Paul & Kumar, 2021 |
| *Careya arborea* | June-July | Fruit | Moderate | Laurie & Seidensticker, 1977 |
| *Carissa carandas* | May-Oct | Fruit | Moderate | Kumara et al., 2023 |
| *Carissa congesta* | July-Sept | Fruit | Moderate | Kumara et al., 2023 |
| *Carissa spinarum* | Jan-Dec | Fruit | Moderate | Kumara et al., 2023; Philip et al., 2022 |
| *Cassia fistula* | Dec-April | Fruit | Moderate | Bargali et al., 2004; Kumara et al., 2023; Kumara et al., 2023; Bhaskaran & Desai, 2015; Mewata T et al., 2019; Suklhadiya & Dharaiya, 2013; Khanal & Thapa, 2014; Philip et al., 2022; Paul & Kumar, 2021 |
| *Cassia tora* | Dec-March | Fruit | Moderate | Suklhadiya & Dharaiya, 2013 |
| *Cordia dicotoma* | May-August | Fruit | Moderate | Mewata T et al., 2019 |
| *Cordia domestica* | July-August | Fruit | Moderate | Bhaskaran & Desai, 2015 |
| *Cordia gharaf* | January-March | Fruit | Moderate | Philip et al., 2022 |
| *Cordia myxa* | July-August | Fruit | Moderate | Kumara et al., 2023; Philip et al., 2022 |
| *Cordia oblica* | July-August | Fruit | Moderate | Bhaskaran & Desai, 2015 |
| *Cordia sinensis* | June-Dec | Fruit | Moderate | Kumara et al., 2023; Philip et al., 2022 |
| *Dendrocalamus strictus* | - | Young Shoots | Low | Kumara et al., 2023; Paul & Kumar, 2021 |
| *Dichrostachys cinerea* | Jan-Dec | Fruit | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Dillenia indica* | Sept-Feb | Fruit | Low | Laurie & Seidensticker, 1977 |
| *Diospyros melanoxylon* | May-August | Fruit | High | Bargali et al., 2004; Kumara et al., 2023; Bhaskaran & Desai, 2015; Mewata T et al., 2019; Philip et al., 2022; Paul & Kumar, 2021 |
| *Diospyros montana* | Dec-March | Fruit | High | Bhaskaran & Desai, 2015 |
| *Ehretia aspera* | Jan-April | Fruit | Moderate | Kumara et al., 2023; Philip et al., 2022 |
| *Ehretia laevis* | Jan-April | Fruit | Moderate | Laurie & Seidensticker, 1977 |
| *Elaeocarpus tuberculatus* | July-Sept | Fruit | Low | Kumara et al., 2023 |
| *Emblica officinalis* | Nov-Feb | Fruit | High | Mewata T et al., 2019 |
| *Eugenia spp.* | April-June | Fruit | Low | Laurie & Seidensticker, 1977 |
| *Feronia limonia* | Oct-March | Fruit | Moderate | Mewata T et al., 2019 |
| *Ficus arnottiana* | Dec-April | Fruit | Moderate | Kumara et al., 2023; Philip et al., 2022 |
| *Ficus benghalensis* | April-Nov | Fruit | Moderate | Bhaskaran & Desai, 2015; Paul & Kumar, 2021; Bargali et al., 2004; Kumara et al., 2023; Mewata T et al., 2019; Suklhadiya & Dharaiya, 2013; Khanal & Thapa, 2014; Philip et al., 2022 |
| *Ficus glomerata* | March-July | Fruit | Moderate | Paul & Kumar, 2021 |
| *Ficus racemosa* | March-July | Fruit | Moderate | Bargali et al., 2004; Kumara et al., 2023;Philip et al., 2022 |
| *Ficus religiosa* | April-May | Fruit | Moderate | Bargali et al., 2004; Kumara et al., 2023; Bhaskaran & Desai, 2015; Philip et al., 2022; Paul & Kumar, 2021 |
| *Ficus rumphii* | Nov-April | Fruit | Moderate | Kumara et al., 2023; Philip et al., 2022 |
| *Ficus semicordata* | May-June | Fruit | Moderate | Kumara et al., 2023; Khanal & Thapa, 2014 |
| *Ficus virens* | Dec-Feb | Fruit | Moderate | Bargali et al., 2004; Kumara et al., 2023; Philip et al., 2022; Kumara et al., 2023 |
| *Flacourtia cataphracta* | May-August | Fruit | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Flacourtia indica* | May-August | Fruit | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Flacourtia sepiaria* | May-August | Fruit | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Gmelina arborea* | May-June | Fruit | Moderate | Kumara et al., 2023; Philip et al., 2022 |
| *Grewia asiatica* | April-June | Fruit | Low | Laurie & Seidensticker, 1977; Kumara et al., 2023; Philip et al., 2022 |
| *Grewia damine* | July-Nov | Fruit | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Grewia flavescens* | Dec-March | Fruit | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Grewia sclerophylla* | June-Jan | Fruit | Low | Laurie & Seidensticker, 1977 |
| *Grewia tiliifolia* | Jan-Dec | Fruit | Moderate | Kumara et al., 2023; Bhaskaran & Desai, 2015; Philip et al., 2022 |
| *Ixora coccinea* | May-June | Fruit | Moderate | Kumara et al., 2023 |
| *Lantana camara* | June-Dec | Fruit | Low | Kumara et al., 2023; Philip et al., 2022 |
| *Madhuca indica* | May-July | Fruit/Flower | High | Kumara et al., 2023; Mewata T et al., 2019; Suklhadiya & Dharaiya, 2013; Paul & Kumar, 2021; Bargali et al., 2004 |
| *Mangifera indica* | March-June | Fruit | High | Bargali et al., 2004; Kumara et al., 2023; Philip et al., 2022; Paul & Kumar, 2021; Mewata T et al., 2019 |
| *Melothria maderaspatana* | June-Dec | Fruit | Low | Kumara et al., 2023 |
| *Miliusa tomentosa* | May-July | Fruit | Low | Kumara et al., 2023; Mewata T et al., 2019 |
| *Murraya koenigii* | July-August | Fruit | Low | Kumara et al., 2023 |
| *Olea dioeca* | March-April | Fruit | Low | Bhaskaran & Desai, 2015 |
| *Phoenix acaulis* | April-June | Fruit | Moderate | Laurie & Seidensticker, 1977; Paul & Kumar, 2021 |
| *Phoenix dactylifera* | Feb-July | Fruit | Moderate | Kumara et al., 2023 |
| *Phoenix humilis* | March-May | Fruit | Low | Kumara et al., 2023 |
| *Phoenix sylvestris* | Sept-Oct | Fruit | Moderate | Mewata T et al., 2019 |
| *Pithecellobium dulce* | June-July | Fruit | High | Kumara et al., 2023; Paul & Kumar, 2021 |
| *Pongamia pinnata* | April-Oct | Fruit | Moderate | Mewata T et al., 2019 |
| *Prunus persica* | June-Oct | Fruit | High | Kumara et al., 2023 |
| *Psidium guajava* | April-Nov | Fruit | High | Bargali et al., 2004; Kumara et al., 2023 |
| *Pueraria tuberosa* | Sept-Oct | Fruit | Low | Kumara et al., 2023 |
| *Rhus semialata* | Dec-April | Fruit | Low | Laurie & Seidensticker, 1977 |
| *Saraca indica* | May-June | Fruit | Low | Kumara et al., 2023 |
| *Schleichera oleosa* | June-July | Fruit | Low | Bargali et al., 2004; Kumara et al., 2023 |
| *Schleichera trijuga (Nepal)* | March-July | Fruit | Moderate | Laurie & Seidensticker, 1977 |
| *Semecarpus anacardium* | Dec-March | Fruit | High | Kumara et al., 2023; Paul & Kumar, 2021 |
| *Solanum indicum* | Oct-Nov | Fruit | High | Laurie & Seidensticker, 1977 |
| *Syzygium cumini* | June-Aug | Fruit | High | Bargali et al., 2004; Kumara et al., 2023; Paul & Kumar, 2021; Bhaskaran & Desai, 2015; Mewata T et al., 2019 |
| *Syzygium heyneanum* | March-April | Fruit | High | Mewata T et al., 2019 |
| *Terminalia belerica* | Nov-March | Fruit | Moderate | Mewata T et al., 2019 |
| *Ziziphus jujuba* | Dec-March | Fruit | High | Laurie & Seidensticker, 1977; Suklhadiya & Dharaiya, 2013; Paul & Kumar, 2021 |
| *Ziziphus mauritiana* | Dec-March | Fruit | High | Bargali et al., 2004; Kumara et al., 2023; Mewata T et al., 2019 |
| *Ziziphus nummularia* | Aug-Sept | Fruit | High | Bargali et al., 2004; Kumara et al., 2023 |
| *Ziziphus oenopolia* | Oct-Jan | Fruit | High | Kumara et al., 2023; Bargali et al., 2004; Paul & Kumar, 2021; Bhaskaran & Desai, 2015; Bhaskaran & Desai, 2015 |
| *Ziziphus rugosa* | April-June | Fruit | High | Kumara et al., 2023 |
| *Ziziphus xylopyrus* | June-Dec | Fruit | High | Mewata T et al., 2019 |

## **Habitat Suitability and Vegetation Mapping**

Habitat suitability modelling has become an indispensable tool in wildlife conservation and management, offering spatially explicit insights into species distributions under current and projected conditions (Guisan & Zimmermann, 2000; Elith & Leathwick, 2009; Franklin, 2010). For the sloth bear whose habitat preferences are closely tied to seasonal food resources and forest cover, remote sensing (RS) and geographic information system (GIS)-based habitat models particularly using Maximum Entropy (MaxEnt) and other species distribution modelling (SDM) techniques have proven especially useful (Yoganand et al., 2006; Ratnayeke et al., 2007; Paul & Kumar, 2021).

### **Review of Habitat Modeling Studies (MaxEnt, RS-GIS Based)**

Several studies have utilized MaxEnt to map sloth bear habitat suitability across varied ecological regions in India. For example, Srivathsa et al. (2018) used presence-only data to model sloth bear distribution in the Western Ghats and found that forest cover, distance from roads, and terrain ruggedness significantly predicted bear occurrence. Similarly, Rajwar & Uniyal (2020) applied MaxEnt to model bear habitats in Uttarakhand and emphasized the importance of natural vegetation and proximity to water bodies. In Central India, Rather et al., (2021), incorporated vegetation type, elevation, and anthropogenic pressures into a MaxEnt framework and successfully identified habitat patches with high conservation priority. These models consistently highlight vegetation both in terms of cover and composition as a primary determinant of sloth bear presence. For instance, models based on land use/land cover (LULC) classifications show that sloth bears prefer dense and moderately dense forests over degraded or open forest classes (Khanal & Thapa, 2014). Moreover, forest fragmentation and canopy breaks due to mining, logging, and agriculture are often associated with decreased habitat suitability and increased human-bear conflict (Suklhadiya & Dharaiya, 2013).

### **Vegetation Indices Used (NDVI, Canopy Density, etc.)**

To quantify vegetation quality and productivity, most habitat models incorporate vegetation indices derived from satellite imagery. The Normalized Difference Vegetation Index (NDVI) is the most commonly used metric, as it provides an indirect measure of primary productivity, vegetation greenness, and forest health. Studies have shown that areas with moderate to high NDVI values indicative of productive and stable forests are more frequently used by sloth bears. In Eastern India’s Nilgiri Wildlife Range, Mardaraj et al. (2023) used MaxEnt modeling and highlighted NDVI and Digital Elevation Model as key predictors for sloth bear distribution. Apart from NDVI, other indices such as Enhanced Vegetation Index (EVI) and Leaf Area Index (LAI) have been applied in fine-scale analyses, although less commonly. Canopy cover or density maps (derived from high-resolution imagery or FSI datasets) also serve as useful proxies for cover availability, denning suitability, and thermal refuge, especially in dry deciduous landscapes. For example, bears are known to avoid open canopy or grassland areas during dry seasons due to exposure and lack of fruiting vegetation (Bargali et al., 2004).

### **Integration of Vegetation Composition into Modelling**

While LULC and NDVI provide general indicators of vegetation presence, they often fail to capture floristic richness and species-specific food resource distribution, which are crucial to sloth bear ecology. Recent studies have addressed this limitation by integrating floristic (vegetation) survey data such as the presence of *Ziziphus mauritiana*, *Ficus spp., Madhuca indica, and Diospyros melanoxylon* as habitat predictors. For example, Bargali et al. (2004) emphasized that the seasonal availability of native fruiting species was a strong determinant of bear foraging patterns in Central Indian forests. In modelling sloth bear presence, Areas rich in key food plants (such as *Buchanania lanzan or Mangifera indica*) were shown to have significantly higher habitat suitability scores, especially during monsoon and post-monsoon periods. Some studies have even overlaid fruiting calendars and species presence grids with NDVI layers to distinguish between green biomass and actual food availability. This integration allows a more nuanced understanding of seasonal habitat use and can inform temporal conservation strategies like fruit-tree restoration or corridor planting (Dharaiya et al., 2020).

# **CONSERVATION IMPLICATIONS**

## **Habitat Restoration Needs**

Given the sloth bear's strong dependence on specific fruiting and tuber-bearing plants, habitat restoration efforts must prioritize floristically diverse and seasonally productive native species. Field studies across Central and Eastern India highlight several tree species crucial to sloth bear foraging ecology, including *Ziziphus mauritiana, Madhuca indica, Diospyros melanoxylon, Buchanania lanzan, Ficus racemosa, and Syzygium cumini* (Bargali et al., 2004; Mewata et al., 2019; Paul & Kumar, 2021). These species provide critical food during pre-monsoon and post-monsoon months, which are often periods of natural scarcity. Restoration interventions should focus not only on planting these keystone fruiting species but also on ensuring spatial continuity and phonological complementarity i.e., mixing species that fruit at different times to provide year-round food availability. Additionally, in areas degraded by mining or monoculture plantations, rewilding efforts must incorporate multi-layered vegetation, including shrubs and tubers such as *Pueraria tuberosa* and *Curcuma spp.* that are also consumed by bears.

## **Mitigating Seasonal Food Shortages**

Sloth bears experience natural bottlenecks in food availability, particularly during the dry season when insect prey is reduced, and fruits are less abundant. This shortage often pushes bears into human-dominated landscapes, where they raid crops and come into conflict with local communities (Dharaiya et al., 2020; Suklhadiya & Dharaiya, 2013). To mitigate this, conservation programs should promote the protection and augmentation of seasonal food trees inside core forest areas. Establishing seasonal resource buffers small patches of fruiting and flowering species near critical bear habitats can reduce foraging pressure on fringe areas. In some landscapes, solar-powered electric fencing combined with fruit tree enrichment within forest interiors has helped reduce crop raiding incidents (Bhaskaran & Desai, 2015).

## **Recommendations for Forest Management**

Effective forest management for sloth bear conservation requires a shift from generic green cover targets to qualitative vegetation assessments. Forest working plans and afforestation schemes should integrate sloth bear–centric habitat parameters, including:

1. Retention and regeneration of key fruiting trees
2. Mapping and protection of denning and resting sites (rocky outcrops, dense shrub areas)
3. Control of invasive species like Lantana camara, which suppress native understory flora
4. Avoidance of monoculture plantations (e.g., teak, eucalyptus) in sloth bear corridors

Also community involvement is vital. Many forest fringe communities rely on the same fruit species (Mahua, Tendu, Chironji) for subsistence. Promoting community-led forest stewardship and NTFP-based livelihoods can foster coexistence while preserving critical bear food resources (Khanal & Thapa, 2014). Integrating sloth bear habitat priorities into Joint Forest Management (JFM) programs, eco-development committees, and state-level conservation action plans will strengthen the ecological integrity of forested landscapes where sloth bears reside.

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