



## **Spatial distribution, habitat use, and conservation implications of Himalayan brown bears in Deosai National Park, Pakistan**

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### **Introduction**

The Himalayan brown bear (*Ursus arctos isabellinus*) is a critically endangered species, with its primary habitat in the Deosai National Park of Pakistan as their last stronghold for survival. This high-altitude plateau, situated between 4,000 and 6,000 meters above sea level, is crucial for the persistence of the species. The park lies within the Himalayan, Karakoram, and Hindu Kush ranges, bordering Afghanistan, China, and India, where political and environmental challenges complicate conservation efforts. The harsh conditions in Deosai, such as extreme cold temperatures reaching -20°C, thick snow and reduced oxygen levels (30% less than sea level), make it a challenging environment for both the bears and the researchers observing them. GPS collaring is an effective method to track these bears' movements and provide valuable data on their behavior and habitat use. The grazing impact and pressure is predominantly from livestock that should not be there. This study aims to understand the movement patterns of the Himalayan brown bear in the face of mounting threats, including habitat degradation, climate change, and human-wildlife conflict.

### **Methods**

#### **Study Area**

Deosai National Park, located at the heart of the Deosai Plateau, is the last stronghold of the Himalayan brown bear. The park spans over 3,000 square kilometres (Chaudhary et al. 2019). The habitat is rich with key species such as the Machor (*Capra falconeri*), Himalayan ibex (*Capra ibex*), snow leopard (*Panthera uncia*), and Tibetan wolf (*Canis lupus chanco*). Rangers and veterinarians face considerable challenges due to the terrain, altitude, and climate.

#### **Darting and Collar Fitting**

The process of darting (theoretically using a Pseudart dartgun with a 3cc dart, loaded with Fentanyl (10-20 µg/kg) and Medetomidine, aiming for the shoulder for immobilization) involves immobilizing the bear using a tranquilizer dart fired from a distance (no more than 30m) to minimize human-wildlife conflict risks. The tranquilizer is specifically tailored to the bear's body size and weight. Once the bear is sedated, a Africa-Wildlife Tracking device and GPS collar is fitted around the neck, ensuring that it does not interfere with the bear's movements. The collar is designed to remain on the bear throughout the study period, transmitting location data whenever the animal moves and varies between 10min intervals or usually set at 1 hour intervals (Bauer et al. 2020).

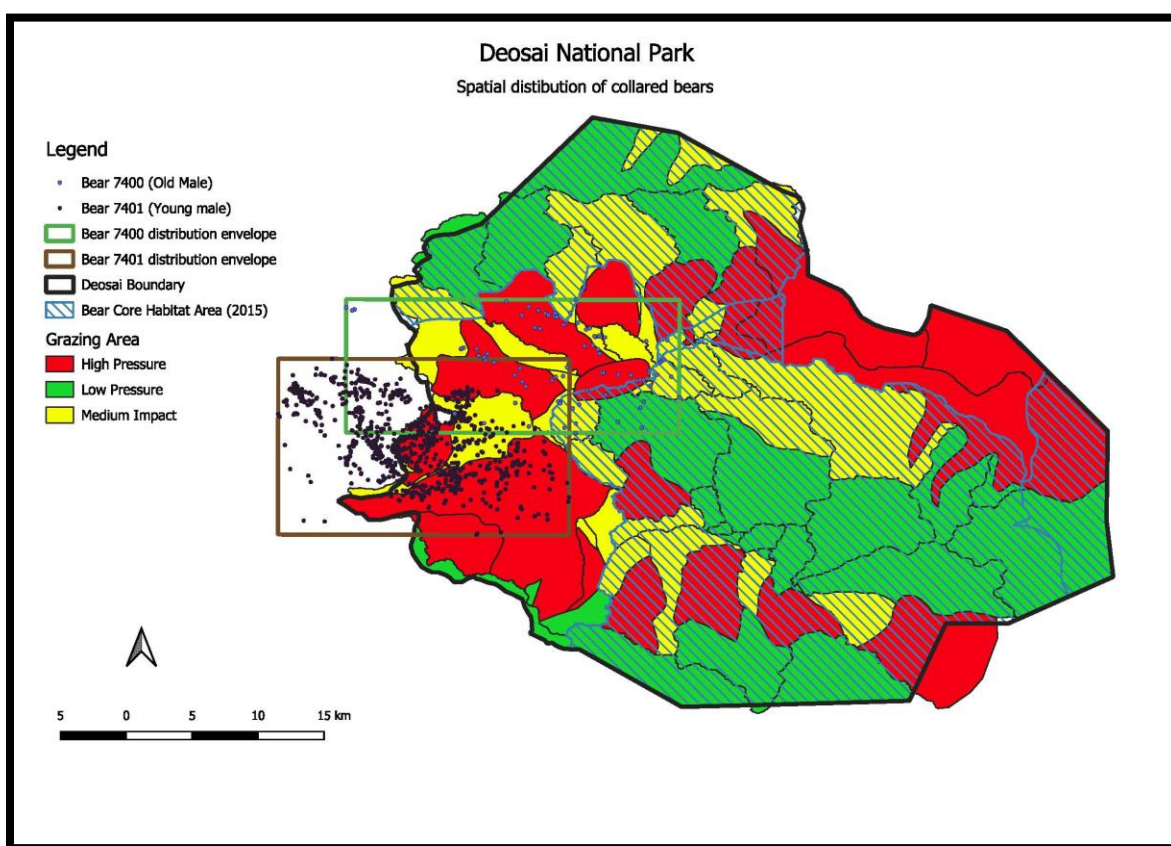
### Data Collection

Location data was obtained using GPS collars, and additional environmental data such as altitude, aspect, and slope were derived from Sentinel 2 imagery and Shuttle Radar Topography Mission (SRTM) data. These data were used to calculate NDVI (Normalized Difference Vegetation Index) and NDMI (Normalized Difference Moisture Index), both of which provide insights into vegetation density and moisture content, respectively.

### Results

#### Spatial Distribution of Collared Bears

The map in Figure 1 presents the spatial distribution of collared bears in Deosai National Park, with the locations of Bears 7400 and 7401 (male and young male) indicated in the field. The distribution of these bears is shown in relation to various grazing pressure zones: high pressure (red), medium pressure (yellow), and low pressure (green).



**Fig 1** Illustration of the spatial distribution of the collared bears in Deosai National Park

- Bear 7400 (Old Male): The older male bear’s distribution envelope overlaps significantly with areas of low to medium grazing pressure. This suggests a preference for less disturbed areas with abundant vegetation and fewer human-induced threats.
- Bear 7401 (Young Male): The young male bear also favours areas with low grazing pressure but appears to have a broader range, possibly indicative of its exploratory behaviour as it establishes its own home range.

This map also highlights the Bear Core Habitat Area and shows that the bears' preferred locations are predominantly within this core area, which is critical for their survival.

### ***Correlation between NDVI and NDMI***

Preliminary analysis of NDVI and NDMI values from Sentinel 2 data revealed a strong positive correlation, indicating that areas with higher vegetation density also exhibited higher moisture content. This correlation is critical in understanding the bears' habitat preferences for forage and shelter.

### ***Impact of Environmental Factors***

Aspect was found to have a significant effect on both NDVI and NDMI, with north-facing slopes showing greater vegetation and moisture content. However, temperature was not found to be significantly sensitive to aspect, suggesting that other factors such as solar exposure and wind play a role in vegetation growth. No significant correlation was found between altitude and temperature, further suggesting that climate factors are less influential in the selection of habitat.

### **Discussion**

The results indicate that Himalayan brown bears use specific areas within Deosai National Park based on vegetation density and moisture levels, both of which are influenced by the park's aspect. These findings are consistent with studies on other bear species, such as the Grizzly bear (*Ursus arctos horribilis*) in North America, where aspect also influences habitat selection (Miller et al. 2017). The fact that temperature did not significantly affect vegetation or bear movements may suggest that, in Deosai, other environmental variables such as altitude, vegetation, and moisture are more important factors in the bears' habitat use. This is crucial for management, as it highlights the need to protect the most critical vegetation-rich areas, regardless of temperature fluctuations.

Additionally, with the help of the GPS location data, it was surprising to find that the bears do not descend to lower altitudes during hibernation, as was previously expected. Instead, they remain on the plateau, utilizing marmot burrows for shelter under deep snow (confirmed by the park manager and ranger team on site), which could have implications for their survival in the face of warming temperatures and loss of snow cover (Johnson et al. 2016). The results also highlight significant correlations between the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI), both of which are indicators of vegetation health and moisture content. Our data shows a strong correlation between these indices, particularly in areas with high vegetation coverage, where the bears tend to spend the majority of their time. This suggests that vegetation health is a primary factor influencing bear movement patterns, as also observed in studies on other bear species (Sawyer et al., 2017; Derocher et al., 2018). Moreover, aspect—the direction of slope—was found to influence both NDVI and NDMI, with north-facing slopes showing higher vegetation productivity compared to south-facing slopes. This is likely due to differences in sunlight exposure, which affects the growing conditions for vegetation. Interestingly, temperature showed little sensitivity to aspect, with minimal differences in temperature across the landscape, but the overall temperature range was not a strong determinant of bear movement. It is apparent that both bears tend to utilize areas with relatively low grazing pressure, which is likely indicative of their preference for undisturbed habitats where vegetation can thrive.

Other important findings include Aspect vs. Altitude: A significant correlation was observed, with altitude generally increasing in areas with a particular aspect (i.e., north-facing slopes at higher altitudes). Aspect vs. Slope: No significant correlation was found, suggesting that slope direction did not greatly impact the bears' movements or habitat selection. Temperature and Vegetation Indices (NDVI/NDMI): No significant correlation was found between temperature and the vegetation indices, indicating that the bears do not rely on temperature fluctuations to dictate their habitat use.

The presence of collared bears in areas of low grazing pressure indicates that these zones provide a more favourable environment for the bears, with better access to vegetation and fewer disturbances from livestock. In contrast, high pressure grazing zones are typically avoided, as these areas likely suffer from overgrazing and a reduction in natural vegetation, leading to lower food availability for the bears. Understanding these distribution patterns is critical for management efforts, as it can guide the identification of areas that need to be protected or restored to support the bears' long-term survival.

Additionally, the Bear Core Habitat Area in the map is a zone that should be prioritized for conservation, as it provides the most consistent resources for the bears, and further encroachment or disturbances in this area should be minimized.

### **Conclusions & Implications**

The use of GPS collars to track the Himalayan brown bear provides critical insights into their spatial ecology. These collars have revealed new information about their habitat preferences, hibernation behavior, and the challenges they face due to habitat degradation and human activity. The data supports the need for improved conservation strategies that include better management of high-pressure grazing areas and protection of the bears' core habitat on the plateau. The new understanding of the bears' hibernation patterns, staying on the plateau and utilizing marmot burrows, challenges previous assumptions about their seasonal behavior and suggests a more adaptable strategy for winter survival. This information will guide future management decisions, ensuring that both the bears and their habitat are adequately protected. As the species is critically endangered, continued monitoring through GPS collaring will be essential for understanding their movements, estimating population densities, and making informed management decisions to ensure their survival.

### **Acknowledgments**

Include funding source and animal ethics approvals here.

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