**Altitudinal Variation in Floristic Composition and Phytosociology of Temperate Forests in Langate Forest Division of Kashmir Himalayas**

**Abstract**

The present study investigates the altitudinal variation in floristic composition and phytosociological attributes of temperate forests in the Langate Forest Division of the Kashmir Himalayas, with a particular focus on habitats of *Arnebia benthamii*, a critically rare and medicinally important alpine species. The study area, located between 1590 and 4308 m a.m.s.l., is characterized by a temperate continental climate and diverse vegetation types along its altitudinal gradient. Vegetation sampling was conducted across three distinct elevations—3000 m, 3300 m, and 3600 m—using the quadrat method for trees (10×10 m), shrubs (5×5 m), and herbs (1×1 m). Species frequency, density, and Importance Value Index (IVI) were calculated to assess community structure and species dominance. A cumulative total of 6 tree, 10 shrub, and 52 herbaceous species were recorded. Species composition and structure showed marked altitudinal variation. At 3000 m, *Acer caesium*, *Viburnum grandiflorum*, and *Sibbaldia cuneata* were dominant among trees, shrubs, and herbs respectively. At 3300 m, dominance shifted to *Betula utilis*, *Salix denticulata*, and again *Sibbaldia cuneata* among respective layers. At the highest altitude (3600 m), *Betula utilis*, *Berberis jaeschkeana*, and *Bergenia ciliata* showed maximum IVI among trees, shrubs, and herbs respectively. Notably, *Arnebia benthamii* was restricted solely to the 3600 m elevation, underscoring its narrow ecological amplitude and highlighting its vulnerability to climatic and ecological shifts. A gradual decline in species richness and density was observed with increasing altitude, likely due to lower temperatures, reduced soil fertility, and shorter growing seasons. High-altitude medicinal species like *Aconitum heterophyllum* and *Saussurea costus* exhibited low IVI values, raising serious conservation concerns under projected climate change scenarios.

**Keywords:** *Altitudinal Gradient, Phytosociology, Floristic Composition, Arnebia benthamii, Species Richness, Kashmir Himalayas*

**Introduction**

Phytosociological studies form the cornerstone of ecological research, particularly in forest ecosystems where understanding the structure, composition, and dynamics of vegetation is crucial for biodiversity conservation and sustainable management. These studies not only provide a snapshot of the existing plant communities but also help track ecological changes driven by both natural and anthropogenic factors. Phytosociology, as a discipline, seeks to describe and classify plant communities based on their floristic composition, abundance, dominance, and frequency, thereby providing insights into the organization and functioning of ecosystems. As such, phytosociological surveys are invaluable tools for ecologists aiming to monitor the health and trends of vegetation in a given ecosystem (Li et al., 2002).

In an era marked by rapid environmental change, phytosociological studies have gained significant importance in documenting the current status of biodiversity and forecasting future ecological scenarios. The continuous and detailed monitoring of plant communities’ aids in understanding how ecosystems respond to pressures such as deforestation, climate change, land-use transformations, and overexploitation of resources. This is especially relevant in fragile and biodiversity-rich regions like the Himalayas, where unique ecological niches harbor a vast array of endemic and threatened species. Detailed quantitative estimations of parameters such as cover, density, basal area, and Importance Value Index (IVI) not only enhance our understanding of species interactions but also enable the formulation of region-specific conservation strategies (Kharakwal et al., 2009).

The Himalayas, forming one of the most significant biodiversity hotspots of the world, present a complex mosaic of ecosystems governed by steep environmental gradients. Altitudinal variation is one of the most critical factors influencing the distribution and composition of plant species in these mountainous landscapes. Changes in altitude are often accompanied by shifts in temperature, soil moisture, radiation, and other microclimatic conditions, which in turn influence species richness and vegetation structure (Sharma et al., 2009; Brown, 2001). It has been well established that altitude, along with other physiographic and climatic variables, governs not only the diversity of plant species but also their abundance and spatial distribution.

Understanding the species composition and structural attributes of plant communities is vital for characterizing the functioning of ecosystems and the services they provide (Loreau et al., 2001). In the context of global biodiversity loss and ecological degradation, such information becomes even more pertinent. Human-induced disturbances such as logging, overgrazing, urban expansion, and agricultural encroachments continue to reshape natural habitats at an unprecedented rate, leading to the fragmentation and degradation of forests (Pala et al., 2015). These disturbances can have far-reaching consequences on the population dynamics, interspecific interactions, and regenerative capacities of forest ecosystems (Shaforth et al., 2002).

Moreover, phytosociological studies hold immense value in habitat classification and conservation planning. The pioneering work by Tansley (1920) laid the foundation for the systematic study of plant communities and their ecological relationships. The classification of plant associations and the identification of indicator species serve as essential tools in the management and restoration of degraded habitats. Quantitative inventories, as emphasized by Keel et al. (1993), help in generating comprehensive baseline data that can inform biodiversity conservation policies. The floristic composition, being a defining feature of any vegetation community (Dansereau, 1960), acts as a sensitive indicator of ecological stability or disturbance. Any loss in biodiversity is inherently linked to shifts in these community attributes, potentially resulting in reduced ecosystem resilience.

The present research has been undertaken to investigate the altitudinal variation in floristic composition and phytosociological attributes of temperate forests in the Langate Forest Division of the Kashmir Himalayas. The study aims to document species diversity across different altitudinal gradients in habitats of *Arnebia benthamii*—a critically endangered, high-altitude medicinal herb. Understanding the ecological preferences and community associations of this species is crucial for its conservation and the management of its fragile alpine habitat.

**Materials and Methods**

**Study area**

The Langate Forest Division falls in the North-Western part of the Kashmir valley at an altitudinal range of 1590-4308m a. m. s. l. The division is situated between the northern latitude at 34°13’ to 34°30’ and eastern longitude at 73°56’ to 74°26’. It extends over an area of 36,060.75 ha. And occupies North Eastern slopes of Kazi-Nag and Shamasbari ranges. The drainage of most of the area is Eastward with Nallah Pohru forming its eastern boundary and principal forest cover extends up to 3500 m asl only in the dominant eastern aspect. The climate of the study area is continental temperate type, with average precipitation about 1270 mm.

**Methodology**

For assessing the floristic diversity along Arnebia benthami habitat sites in Langate Forest division, three altitudes were selected viz., (3000m, 3300m & 3600m amsl) through random sampling using quadrat method. The size and number of quadrats were determined following (Kersaw, 1973; Misra, 1968). To study the various vegetation attributes, quadrates of 10 m × 10 m size for trees, 5 m x 5 m for shrubs and 1m x 1m for herbs, were laid down. The floristic data was computed for frequency, density and abundance (Curtis and McIntosh, 1950). The relative values of frequency, density and dominance were determined as per Philips (1959). These values were summed to represent IVI (Important Value Index) of individual species in order to express the dominance and ecological success of the species (Curtis, 1959). The important quantitative analysis such as density, frequency and abundance of tree species, shrubs and herbs were determined as per Curtis and McIntosh (1950).

**Results and Discussion**

The present study conducted across three altitudinal zones (3000 m, 3300 m, and 3600 m) in the Langate Forest Division revealed significant variation in phytosociological attributes of tree, shrub, and herbaceous species associated with *Arnebia benthamii*. A cumulative total of 6 tree species, 10 shrub species, and 52 herb species were recorded habitats (Fig 1 and Table 1). Notably, *Arnebia benthamii* was strictly confined to the 3600 m altitude, indicating its narrow ecological amplitude and altitudinal specificity, potentially governed by microclimatic thresholds and soil edaphic at higher elevation Altitude 3000m.

**Altitude 3000 m**

The data presented in the table 1, 2 and 3 revealed the presence of five tree species, four shrub species and thirty-seven herb species. Among tree species *Acer caesium* was dominant with IVI value 64.6 followed by *Pinus wallichiana* with IVI 64.0. In case of shrubs, *Viburnum grandiflorum* was the dominant species which was followed by followed by *Rosa macrophylla* with the IVI values of 83.50 and 77.46 respectively. The minimum IVI of 68.91 was exhibited by *Salix denticulata.* Among herbs maximum IVI of 17.43 was dominated by *Sibbaldia cuneata* followed by *Fragaria nubicola* i.e., 15.53. However, the minimum IVI value of 2.46 was recorded for *Aconitum heterophyllum.* The maximum density (133.43/m² ha-1), among trees was contributed by *Acer caesium* among shrubs by *Viburnum grandiflorum* (311.24/m² ha-1) and by *Sibbaldia cuneata* (3.06/m² ha-1) among herbs respectively.

**Altitude 3300m**

The data presented in table 1, 2 and 3 revealed the presence of five tree species, four shrub species and twenty-eight herb species**.** *Betula utilis* was the most dominating IVI value of 61.22 followed by *Pinus wallichiana* with IVI of 60.32. However, minimum IVI was recorded for *Abies pindrow* (58.7). Similarly, among shrub species present at the site, maximum IVI was dominated by *Salix denticulata* (81.89) followed by *Salix flabellaris* (80.13) however; minimum IVI was exhibited by *Juniperus communis* (61.83). Among herbs at maximum IVI was recorded for *Sibbaldia cuneata* (22.81) followed by *Fragaria nubicola* (17.91) however minimum IVI was dominated by *Sedum oreades* (5.76). In case of density, Maximum density (167.93/ m² ha-1) among trees was recorded for *Betula utilis*, among shrubs for *Salix denticulata* (299.97/ m² ha-1) and among herbs for *Sibbaldia cuneata* (4.4/ m² ha-1) respectively.

**Altitude 3600m**

 The data presented in table revealed the presence of four tree species, four shrub species, and twenty-eight herb species. Out of the total tree species present at the site maximum IVI (80.99) was dominated by *Betula utilis* followed by *Picea smithiana* with IVI value 78.7. In case of shrubs, *Berberis jaeschkeana* showed dominance with an IVI of 83.17 followed by *Vibernum grandiflorum* with IVI 80.79, however, the minimum IVI was exhibited by *Rhododendron campanulatum* (67.71). Among herbs maximum IVI (15.54) was recorded for *Bergenia ciliata* followed by *Poa aungustifolia* (15.01). The minimum IVI (4.75) was exhibited by *Saussurea costus.* Among trees, shrubs and herbs Maximum density (148.41/ m² ha-1) was shared by *Betula utilis*, *Vibernum grandiflorum* (298.43/ m² ha-1) and *Poa aungostifolia* (5.12/ m² ha-1) respectively.

The results exhibit a clear altitudinal stratification of species composition, with a noticeable decline in overall species richness from 3000 m to 3600 m. The absence of *Arnebia benthamii* at 3000 and 3300 m and its restriction to cold, alpine microhabitats at 3600 m underscores its ecological sensitivity and reinforces its conservation priority. The confinement of *Arnebia benthamii* to 3600 m and the limited IVI values of high-altitude medicinal herbs like *Saussurea costus* and *Aconitum heterophyllum* raise serious conservation concerns under climate change scenarios, where upward shifts in vegetation belts may expose these taxa to habitat fragmentation and extinction. Altitudinal gradient is an important factor affecting species composition and structure (Whittaker, 1972) and its gradual monotonic decrease in species richness with increasing altitude is a general pattern. Decrease in diversity and species richness at high elevation strata could be due to ecophysiological constraints such as reduced growing season and low temperature (Korner, 1998). Other factors such as soil fertility and topography may also affect the patterns of species richness along altitudinal gradient. Sharma *et al.* (2009) reported that the distribution and species richness pattern of different species are largely regulated by the altitude and climatic factors. Several researchers have reported that the regional patterns of species richness are consequences of many interacting factors, such as plant productivity, competition, geographical area, historical or evolutionary development, regional species dynamics, regional species pool, environmental variables and human activity (Ajaz *et al*., 2022; Adil *et al*., 2022; Criddle *et al.,* 2003). The altitude, environmental factors, habitat and soil characteristics may be the main factors which eventually lead to the variations in species diversity and density in the study area.

**Conclusion**

The present study highlights significant altitudinal variations in the floristic composition and phytosociological structure of the temperate forests in the Langate Forest Division of the Kashmir Himalayas. A total of 6 tree species, 10 shrub species, and 52 herbaceous species were recorded across three altitudinal gradients—3000 m, 3300 m, and 3600 m. Species richness showed a declining trend with increasing altitude, reflecting the influence of climatic and edaphic constraints. *Arnebia benthamii*, a critically important alpine medicinal herb, was confined exclusively to the 3600 m altitude, indicating its narrow ecological amplitude and vulnerability to environmental change. The dominance of species like *Betula utilis*, *Viburnum grandiflorum*, and *Sibbaldia cuneata* across higher elevations further underscores adaptive strategies of certain taxa. These findings emphasize the importance of conserving high-altitude habitats, particularly in the face of climate change. Targeted conservation strategies and monitoring programs are essential to preserve these fragile ecosystems and protect endemic and threatened species from ecological degradation and extinction.

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**Fig 1: Species Life forms**

**Table 1: Floristic composition and phytosociological attributes of tree species in *Arnebia benthami* dominated sites in Langate Forest Division**

|  |  |  |  |
| --- | --- | --- | --- |
| **Species** | **A** (**3000m)** | **A (3300 m)** | **A (3600 m)** |
| **D** | **F** | **IVI** | **D** | **F** | **IVI** | **D** | **F** | **IVI** |
| *Abies pindrow* Royle. | 129.91 | 66.66 | 59.33 | 144.31 | 77.77 | 58.70 | 127.93 | 55.55 | 73.58 |
| *Acer caesium* Wall. Ex Brandis | 133.43 | 88.88 | 64.60 | 149.92 | 88.88 | 59.70 | 123.43 | 66.66 | 66.73 |
| *Pinus wallichiana* | 118.94 | 77.77 | 64.31 | 136.71 | 77.77 | 60.32 | - | - | - |
| *Picea smithiana* (Wall.) Boiss. | 116.43 | 66.66 | 60.89 | 133.21 | 77.77 | 60.03 | 119.91 | 66.66 | 78.70 |
| *Prunus cornuta* | 98.94 | 55.55 | 50.82 | - | - | - | - | - | - |
| *Betula utilis* | - | - |  | 167.93 | 88.88 | 61.22 | 148.41 | 77.77 | 80.99 |

**A-altitude; D-Density (ha-1); F-Frequency (%); IVI-Importance value index**

**Table 2: Floristic composition and phytosociological attributes of shrub species in Arnebia benthami dominated sites in Langate Forest Division**

|  |  |  |  |
| --- | --- | --- | --- |
| **Species** | A (**3000m)** | **A (3300 m)** | **A (3600 m)** |
| **D** | **F** | **IVI** | **D** | **F** | **IVI** | **D** | **F** | **IVI** |
| *Berberis jaeschkeana* | 277.43 | 77.24 | 70.09 | - | - |  | 296.56 | 77.24 | 83.17 |
| *Rosa macrophylla* | 291.94 | 77.24 | 77.46 | - | - |  | - | - | - |
| *Salix denticulata* | 286.97 | 64.44 | 68.91 | 299.97 | 77.24 | 81.89 | - | - | - |
| *Viburnum grandiflorum* | 311.24 | 85.75 | 83.50 | - | - | - | - | - | - |
| *Juniperus communis* | - | - | - | 179.94 | 64.44 | 61.83 | - | - | - |
| *Salix flabellaris* | - | - | - | 289.46 | 85.75 | 80.13 | - | - | - |
| *Juniperus squamata* | - | - | - | 281.94 | 77.24 | 76.11 |  |  |  |
| *Juniperus squamata* | - | - | - | - | - | - | 211.24 | 64.44 | 88.27 |
| *Rhododendron campanulatum* | - | - | - | - | - | - | 231.97 | 64.44 | 67.71 |
| *Viburnum grandiflorum* | - | - | - | - | - | - | 298.43 | 77.24 | 80.89 |

**A-altitude; D-Density (ha-1); F-Frequency (%); IVI-Importance value index**

**Table 3: Floristic Composition and Phytosociological Attributes of Herb Species in Arnebia benthamii Dominated Sites in Langate Forest Division**

|  |  |  |  |
| --- | --- | --- | --- |
| **Species Name** | **A (3000m)** | **A (3300 m)** | **A (3600 m)** |
| **D** | **F** | **IVI** | **D** | **F** | **IVI** | **D** | **F** | **IVI** |
| *Aconitum heterophyllum* | 0.20 | 10.00 | 2.46 | — | — | — | — | — | — |
| *Anaphalis triplinervis* | 1.53 | 51.11 | 12.91 | 1.89 | 37.78 | 13.29 | 3.34 | 40.00 | 11.32 |
| *Anemone obtusiloba* | 1.69 | 42.22 | 10.34 | 1.95 | 48.89 | 12.93 | 2.21 | 51.11 | 10.54 |
| *Aquilegia nivalis* | 2.21 | 33.33 | 8.9 | — | — | — | 2.98 | 37.78 | 13.11 |
| *Artemisia absinthium* | 1.78 | 35.56 | 8.66 | 0.97 | 24.44 | 10.86 | 3.32 | 26.67 | 11.36 |
| *Arnebia benthamii* |  |  |  |  |  |  | 2.66 | 38.89 | 11.45 |
| *Aster spp.* | 1.11 | 22.22 | 8.03 | — | — | — | — | — | — |
| *Bromus spp.* | 1.87 | 31.11 | 9.04 | — | — | — | — | — | — |
| *Bupleurum longifolium* | 1.78 | 35.56 | 9.02 | — | — | — | — | — | — |
| *Clinopodium vulgare* | 1.06 | 26.67 | 6.94 | 0.60 | 20.00 | 6.37 | 1.98 | 22.22 | 10.52 |
| *Daucus carota* | 1.89 | 37.78 | 9.59 | — | — | — | — | — | — |
| *Euphorbia wallichii* | 0.73 | 24.44 | 5.38 | 1.73 | 46.67 | 11.05 | 2.22 | 46.67 | 11.59 |
| *Fragaria nubicola* | 2.72 | 51.11 | 15.53 | 3.46 | 57.78 | 17.91 | 2.46 | 62.22 | 13.03 |
| *Galium aparine* | 0.80 | 26.67 | 6.53 | — | — | — | — | — | — |
| *Heracleum candicans* | 0.96 | 31.11 | 6.21 | — | — | — | — | — | — |
| *Impatiens thomsonii* | 1.93 | 64.44 | 11.68 | 1.21 | 60.00 | 11.00 | 1.11 | 64.44 | 11.99 |
| *Malva neglecta* | 1.21 | 31.11 | 5.91 | — | — | — | — | — | — |
| *Nepeta laevigata* | 0.80 | 20.00 | 5.04 | — | — | — | — | — | — |
| *Poa annua* | 1.05 | 21.11 | 4.66 | 1.24 | 31.11 | 10.49 | — | — | — |
| *Poa angustifolia* | 1.24 | 31.11 | 9.62 | 1.31 | 35.56 | 9.25 | 5.12 | 32.22 | 15.01 |
| *Podophyllum hexandrum* | 0.83 | 27.78 | 5.36 | 0.80 | 26.67 | 5.96 | 1.12 | 28.89 | 7.00 |
| *Polemonium caeruleum* | 0.89 | 44.44 | 6.89 | 1.23 | 41.11 | 8.54 | 1.44 | 44.44 | 9.21 |
| *Polygonum plebeium* | 2.23 | 21.11 | 6.71 | — | — | — | — | — | — |
| *Ranunculus laetus* | 2.12 | 26.67 | 6.95 | — | — | — | — | — | — |
| *Rhodiola imbricata* | 0.96 | 32.22 | 8.76 | 1.24 | 31.11 | 10.29 | 1.54 | 28.89 | 12.21 |
| *Rumex nepalensis* | 1.23 | 26.67 | 6.68 | — | — | — | — | — | — |
| *Salvia spp.* | 1.33 | 31.11 | 6.88 | — | — | — | — | — | — |
| *Sibbaldia cuneata* | 3.06 | 76.67 | 17.43 | 4.40 | 73.33 | 22.81 | — | — | — |
| *Stipa spp.* | 0.99 | 22.22 | 5.29 | — | — | — | — | — | — |
| *Swertia petiolata* | 0.42 | 21.11 | 4.59 | 0.70 | 23.33 | 6.19 | — | — | — |
| *Tanacetum dolichophallus* | 1.21 | 26.67 | 7.15 | — | — | — | — | — | — |
| *Taraxacum officinale* | 3.02 | 37.78 | 15.31 | 2.64 | 37.78 | 16.88 | — | — | — |
| *Trifolium repens* | 1.36 | 31.11 | 10.16 | — | — | — | — | — | — |
| *Trillium govanianum* | 2.21 | 10.00 | 5.85 | — | — | — | — | — | — |
| *Veronica laxa* | 1.12 | 10.00 | 4.56 | — | — | — | — | — | — |
| *Viola biflora* | 2.72 | 38.89 | 10.95 | 1.13 | 37.78 | 8.96 | — | — | — |
| *Viola pilosa* | 1.24 | 31.11 | 7.41 | 0.86 | 28.89 | 7.26 | — | — | — |
| *Viola sylvestris* | 1.06 | 26.08 | 7.26 | 1.22 | 24.44 | 8.53 | — | — | — |
| *Anaphalis busua* | — | — | — | 1.42 | 35.56 | 10.10 | 2.23 | 38.89 | 8.99 |
| *Bergenia ciliata* | — | — | — | 2.86 | 47.78 | 15.48 | 2.21 | 51.11 | 15.54 |
| *Bistorta vaccinifolia* | — | — | — | 1.95 | 48.89 | 12.34 | 2.42 | 48.89 | 12.28 |
| *Cirsium falconeri* | — | — | — | 0.67 | 22.22 | 6.42 | 2.22 | 20.00 | 9.94 |
| *Epilobium laxum* | — | — | — | 1.86 | 46.67 | 11.27 | 1.97 | 48.89 | 11.87 |
| *Geum elatum* | — | — | — | 2.17 | 54.44 | 13.23 | 0.98 | 53.33 | 9.95 |
| *Gaultheria trichophylla* | — | — | — | 1.68 | 42.22 | 11.16 | 0.96 | 52.22 | 11.19 |
| *Poa alpine* | — | — | — | 0.94 | 18.89 | 9.33 | 2.21 | 20.00 | 7.50 |
| *Rhodiola imbricate* | — | — | — | — | — | — | 1.54 | 28.89 | 12.21 |
| *Rosularia alpestris* | — | — | — | 0.67 | 22.22 | 6.22 | 2.01 | 21.11 | 9.42 |
| *Sedum oreades* | — | — | — | 0.63 | 21.11 | 5.76 | 1.84 | 22.22 | 8.77 |
| *Saussurea costus* | — | — | — | — | — | — | 1.23 | 20.00 | 4.75 |
| *Geranium pretense* | — | — | — | — | — | — | 2.21 | 17.78 | 9.30 |
| *Phlomis bracteosa* | — | — | — | — | — | — | 0.55 | 31.11 | 8.28 |

**A-altitude; D-Density (ha-1); F-Frequency (%); IVI-Importance value index**