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Altitudinal distribution and spatial pattern of species richness of the high mountain flora: A case study on Ladakh (Himalaya)

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Abstract: Species diversity is a well-documented resource in biodiversity, but its spatial pattern for remote areas like Ladakh is lacking. We estimated species profiles for all growth forms applying published data on the floristic and elevational distribution of vascular plants in Ladakh and converted them to the spatial distribution of species richness. The spatial distribution of species richness has been quantified according to 100 m a.s.l. and visualised by the SAGA software. We found the highest species diversity and the peak of all growth forms at around 3000 m a.s.l. The heights of species richness curves shift upward along the elevational gradient in the order of epiphytes/lianas – trees – graminoids – shrubs – herbs. The humped patterns of species richness found in Ladakh are consistent with findings from previous Himalayan mountain studies. Further research and fine-scale local data can facilitate the evolutionary issues and conservation purposes of flora in Ladakh.

Introduction

A primary current focus in species richness is how to ensure the sustainability of biodiversity. It is generally accepted that high mountains are the most suitable habitat for species richness. Ladakh is a land of unearthly beauty in the Transhimalaya of Northwest India, containing around 1250 species of vascular plants, including cultivated ones (Dvorský et al., 2018). The plants and wildlife of this high altitude cold desert are adapted to the harsh circumstances, with a small population, and get very little precipitation (< 100 $mm.yr^{-1}$) (Kala & Mathur, 2002; Singh and Gupta, 1990). Over half of the plants in the region have been identified as having therapeutic use (Kala and Mathur, 2002; Kumar et al., 2011; Singh and Chaurasia, 2000), which is very important for the economic growth of the inhabitants of Ladakh in the emerging world market.

There is extensive literature on the identification and exploration of species in Ladakh (Blatter, 1984; Dickoré and Nüsser, 2000; Khuroo et al., 2011, 2010; Klimeš and Dickoré, 2005; Sharma and Jamwal, 1988; Shukla and Srivastava, 2020; Singh and Kachroo, 1987; FRLHT, 2010) and since the early nineteenth century, the association between vegetation and altitude has been established (Bunzhuo et al., 1997; Kala and Mathur, 2002; Mani, 1978). However, although the species distribution individually was demonstrated by Dvorský et al. (2018), the regional distribution of total species richness in Ladakh has received little consideration.

There is a growing demand for biodiversity conservation in high mountains in the national and international context. The present paper presents the altitudinal and spatial distribution of species richness, including information about dominant families and genera of flora in Ladakh. This research will help to develop a strategy for the conservation of biodiversity in this area.

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Methods

Study area

Ladakh has been a part of the Jammu and Kashmir state since 1947 and has been explored by scientists from several disciplines, including botany, ecology, geography, etc. Ladakh covers about 87,000 km^2 or, including disputed territories, 117,000 km^2, of high mountain terrain bordering Pakistan lies to the western part, and China is to the northern and eastern part (Fig. 1). This region ranges from approximately 2550 m in the Indus Valley along the Pakistani border to 7672 m on the Saser Kangri Peak in the Eastern Karakorum (Dvorský et al., 2018).

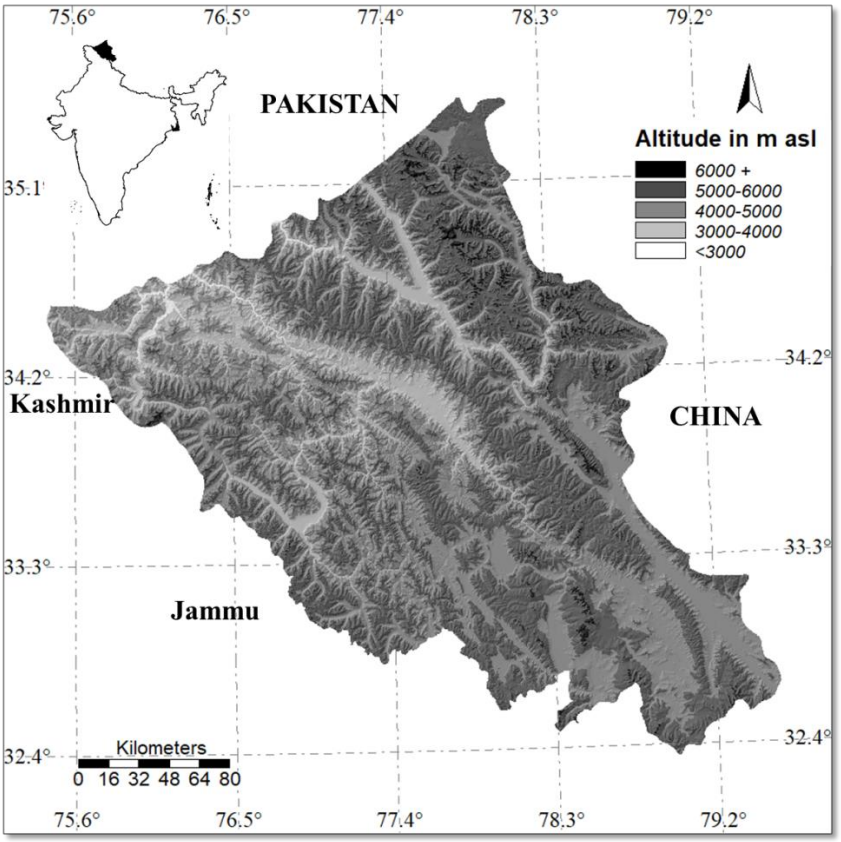

Figure 1: Physical map of Ladakh.

Methods

The current investigation involved gathering and analyzing data on the flora of Ladakh. The information on flora was collected from numerous published sources on Ladakh and Jammu & Kashmir (Blatter, 1984; Dickoré and Nüsser, 2000; Khuroo et al., 2011, 2010; Klimeš and Dickoré, 2005; Sharma and Jamwal, 1988; Shukla and Srivastava, 2020; Singh and Kachroo, 1987; FRLHT, 2010). A total of 1379 species was recorded with elevation information and then analyzed for the elevational distribution. The abundance of species for dominant families and genera were calculated, and the total number of species for 100 m interval was quantified. The species data subsequently converted as the

richness of species or spatial distribution of species by the tool 'Change grid value' in SAGA 7.9.0 (System for Automated Geoscientific Analyses) GIS software (Conrad et al., 2015).

Results

It was apparent beforehand that species richness pattern would be a desirable outcome of elevational zonation of vegetation. The vegetation of Ladakh displays striking vertical zoning, which is diversified by aspect, exposer, and substrate (Dvorský et al., 2018). As can be seen in figure 2 (upper), the elevational zones of different vegetation belts are subsequently distributed. The submontane belt (up to 2900 m a.s.l.) is the lowest altitudinal vegetation zone, comprising only a small part (less than 1%) of the arid gorge section in the lower Indus valley (Dvorský et al., 2018). The montane belt extends between about 2900 and 3700 m a.s.l. and hosts a semi-desert vegetation (7% of total area), characterized by scattered coarse subshrubs, sturdy herbs, including several halophytes (Dvorský et al., 2018). This belt supports the most considerable oasis cultivation because of high summer temperatures and large tracts of relatively level ground. The subalpine vegetation belt stretches from around 3700 m up to 4200 m in the west and more than 4400 m in the east of Ladakh (Dvorský et al., 2018). The alpine belt is composed of herbs and dwarf shrubs and altitudinally extends from 4,200 to 4,900 m a.s.l. (occasionally 5,500 m a.s.l. on the Tibetan border) (Dvorský et al., 2018). The subnival vegetation belt is located above 5200 m a.s.l. to 5600 m a.s.l. and a very sparse vegetation can be seen there (Dvorský et al., 2018).

Figure 2 (lower) shows the elevational zones of vegetation in which half of the total area is the alpine belt and the subnival vegetation belt covers 33% of the entire region. That represents the dominance of the higher portion (more than 80%) of the study area falls in the high altitude of the cold desert.

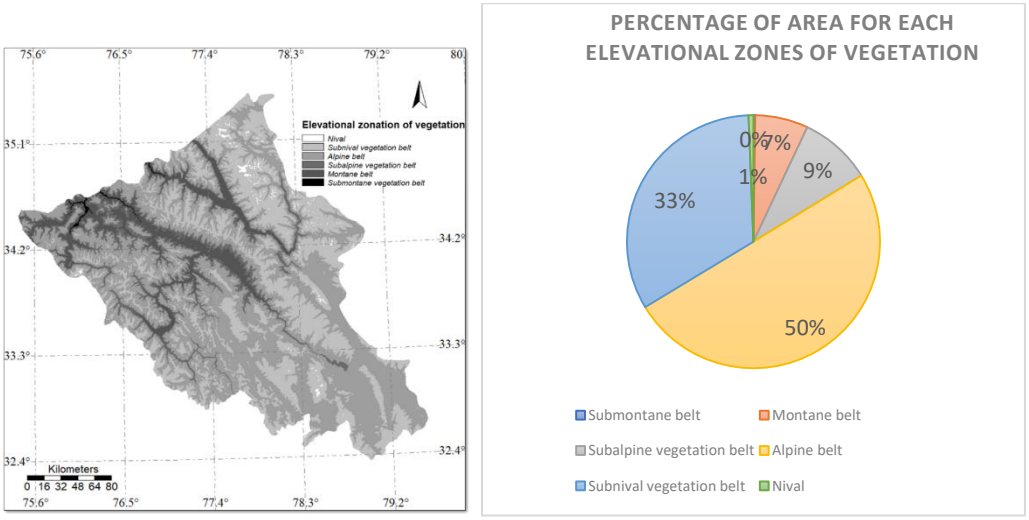

Figure 2: Elevational zonation of vegetation in Ladakh (upper figure) and the percentage of land covered by each vegetation zone at different elevations (lower figure) (according to Dvorský et al., 2018)

The current analysis found a total of 1379 species spread throughout 461 genera in 95 families. The leading families are Poaceae (with 194 species), followed by Asteraceae (162), Fabaceae (91), Cruciferae (88), Cyperaceae (58), Scrophulariaceae (51), Ranunculaceae (48), etc. and the dominant genera are Astragalus (39), followed by Carex (32), Corydalis (26), Nepeta (24), Artemisia (24), Polygonum (21), Potentilla (19), Stipa (17), etc. (Fig. 3 and 4). These analyses of family and genera show a considerably higher number of species than the recent study by Shukla and Srivastava (2020).

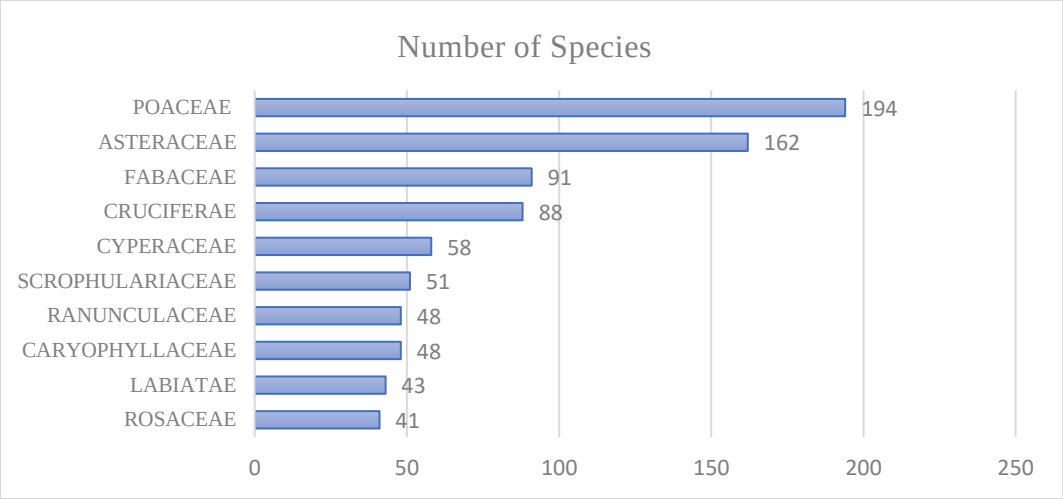

Figure 3: The ten most species-rich families of the Ladakh flora (vascular plant species).

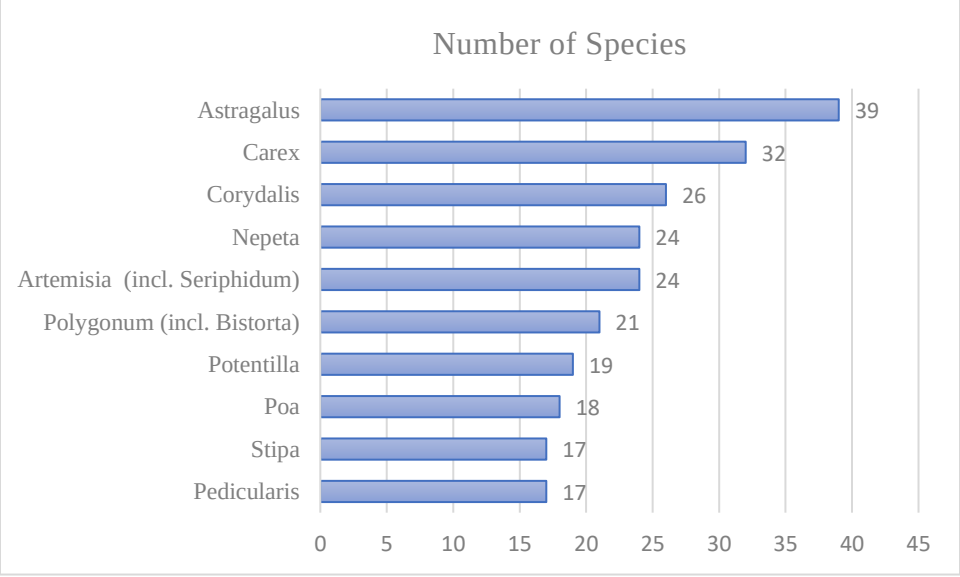

Figure 4: The ten most species-rich genera of the Ladakh flora (vascular plant species).

There were 1140 species with information about altitude in Ladakh and used to generate the species richness distribution pattern along gradients. Between 3000 and 3500 m a.s.l., most plant species (667) were discovered, with the number of species decreasing as elevation ascended. Figure 5 depicts the elevational distribution of plant species in Ladakh graphically. This distribution pattern has been converted to a spatial extent (Fig 6), and the highest species richness (more than 600 species) was observed in the montane and submontane vegetation zone. Alpine vegetation belt has moderate species richness (around 300 to 400 species), and the higher altitude region has very poor species richness.

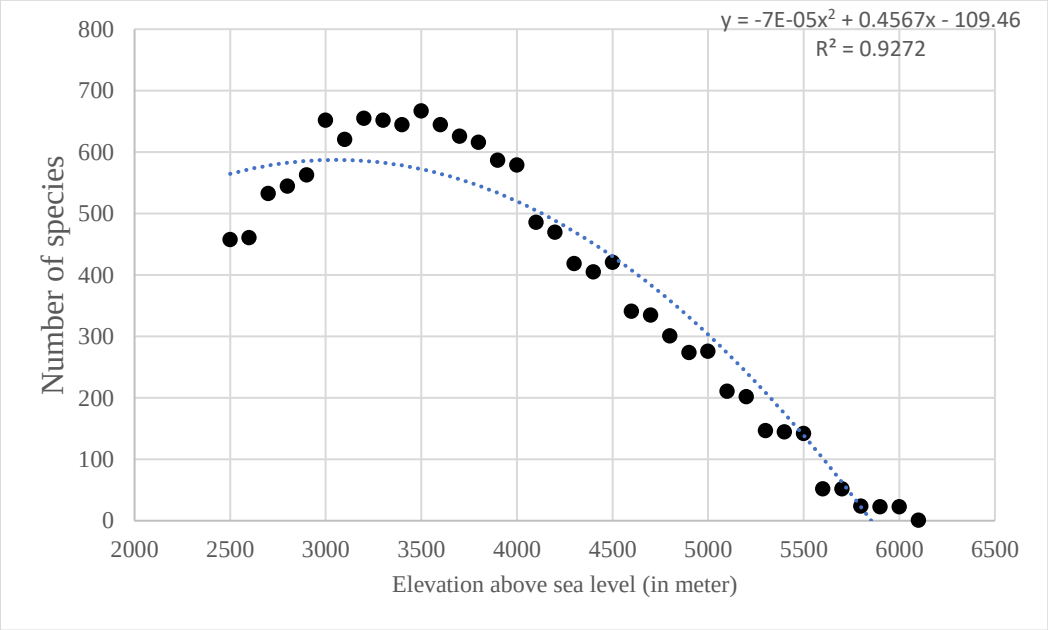

Figure 5: Species richness according to different altitudes in Ladakh.

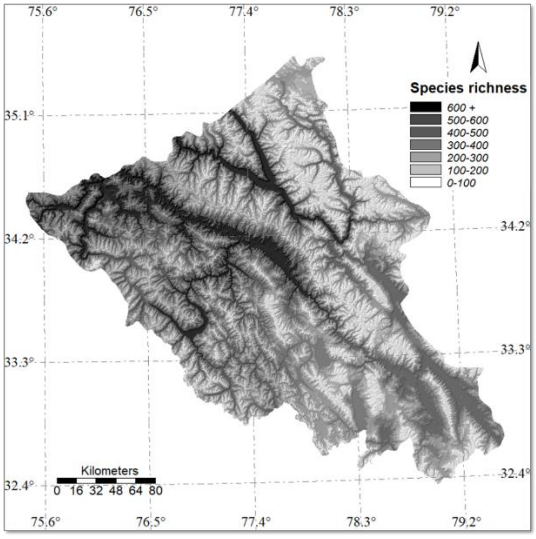

Figure 6: Spatial distribution of species richness in Ladakh.

As shown in figure 7, the richness distribution of each growth form of the species also differs, and the herbaceous species show the highest richness along the whole study area (Fig 7, right). The peak of this unimodal distribution consists of around 550 species and is distributed from 3,000 to 4,000 m a.s.l. which is notably higher than other growth forms of that region. To compare, the second dominating growth form of plant in Ladakh is a shrub, and the highest number of shrubs is also found in the elevation range between 2,800 to 3,500 m a.s.l. followed by graminoids and tree species (Fig. 7, left). Only two epiphytes and lianas can be seen in these montane areas.

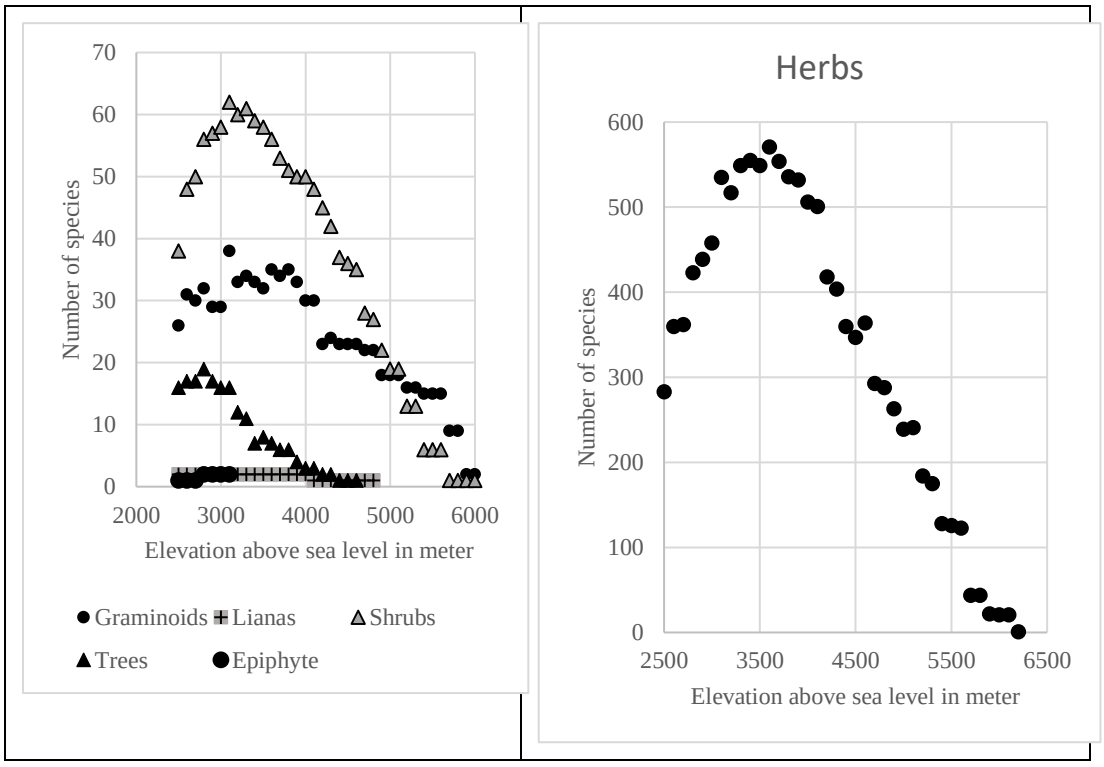

Figure 7: Elevational species richness of different life forms in Ladakh.

Discussion

Prior work has documented the occurrences of species in different parts of the Himalaya, and the spatial distribution, including elevation records, has been documented precisely (Dvorský et al., 2018). However, these studies have either explored floral records or have not focused on the spatial distribution of those flora and species richness. In this study, we analyzed species data for 100 m elevation and plotted the distribution of species richness over space in Ladakh. We found that the elevational distribution of vegetation revealed a humped shape and a unimodal pattern in virtually all cases.

The results suggest that we have unique peaks in species richness, distributed along the gradient of elevation from the montane belt to subalpine vegetation. These findings extended to draw spatial information for the species-rich areas in the study area. In addition, the added spatial information of the species richness in our study was related to

elevational zonation of vegetation or vertical differences of species distribution. Therefore, this study indicates that the updated vegetation distribution can be used for analyzing further spatial factors or variables that have relative importance for species richness. There is a decline in richness at high elevations due to less precipitation in the mountainous area (Bhattarai et al., 2004; McCain, 2007; McCain and Grytnes, 2010; Vetaas et al., 2019). In temperate to cold climates, thermal energy could be a critical variable (Hawkins et al., 2003; Vetaas et al., 2019; Whittaker et al., 2006).

Conclusion

Plant growth forms influence elevational richness gradients in our study area. Like other studies (Manish et al., 2017; Kluge et al., 2017), varied growth forms have different elevational richness patterns, but the dominant growth form with the highest number determines the overall shape. Montane belt has the highest species richness, consisting of only 7% area of the entire region. For the conservation approach, analyzing the richness patterns of each growth form is essential, especially for medicinal plants. It is crucial to have assessments for small plots and conservation of remote areas like Ladakh for nature conservation and study of mountain biogeography. Spatial distribution of species richness is also applicable to a correlation between geodiversity and species richness, while mountains represent varied diversity of all variables. This research will also bring light to the botanical studies of Bangladesh's conservation areas and hill tracts to manage biodiversity.

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