SPECIES RICHNESS, ETHNOBOTANICAL SPECIES RICHNESS AND HUMAN SETTLEMENTS ALONG A HIMALAYAN ALTITUDINAL GRADIENT: PRIORITIZING PLANT CONSERVATION IN PALAS VALLEY, PAKISTAN

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Abstract

This study explores the distribution pattern of species richness and ethnobotanically important plant species richness along an altitudinal gradient in Palas valley, Pakistan. The data related to species' occurrences were derived from field GPS surveys from 2004 to 2007, while settlement data were obtained from Google Earth™. The altitudinal information, based on locational data of species and settlements, was extracted from a 30 m resolution digital elevation model (DEM) using a geographic information system (GIS). Species richness and number of houses were then determined for 100 m altitudinal intervals and tested as response variables against altitude (independent variable) to explore their possible relationships using scatter plots and quadratic regression. The species richness was found to follow a bell-shaped distribution (R^2=0.87) with a maximum near mid-altitudes. The greatest species richness was attained between 2400-3200 m a.s.l (above sea level) and ethnobotanically important species richness was highest between 2500-2800 m a.s.l. (R^2=0.93). There was a highly positive correlation (r=0.88) between species richness and ethnobotanically important species richness. The majority of settlements were distributed between 2000-2400 m a.s.l. (R^2=0.47). The highest overall plant species richness, as well as ethnobotanically important species, is thus attributed to altitudes adjacent to but higher than the permanent settlements (2400-3200 m a.s.l.). Considering the valley as an important species rich area within its neighborhood, the localities in mid-altitudes (2400-3200 m a.s.l.) should be considered as major sites to be managed for the sustainable harvest of local plant resources and for plant conservation in a regional context.

Introduction

The northern part of Pakistan is characterized by mountainous terrain with distinct altitudinal zonations of climate, vegetation types and land use systems. Since the population is largely rural, there is extra heavy reliance on wild plants and their products to meet daily food, shelter, medicinal and other requirements, and there is an ever-increasing demand for these species because they are freely available (Sundriyal & Sundriyal, 2004). The commercialization of certain plants and their exploitation to meet pecuniary needs have also threatened their survival in some parts, especially when the source is a nearby forest. Therefore it is important to know the patterns of richness and distribution of plants, particularly in relation to human settlement patterns for management and conservation. Hotspots of biological richness have been always looked upon as conservation priorities (Mittermeier *et al.*, 2005), and considerable attention has been paid to the factors determining species richness (Malik & Husain, 2006). Altitude is one of the important determinants of species richness, particularly in mountainous terrain, as it influences temperature and precipitation, thus directly affecting the distribution and abundance of plants (Austin, 2007). In general, plant species richness decreases with increasing elevation, but peaks at mid-altitudes (Wohlgemuth *et al.*, 2008). The relationship between altitude and species diversity has been investigated in many studies both worldwide and within the Himalayas (Vetaas & Grytnes, 2002), however, richness of ethnobotanically important species in relation to altitude has been rarely studied (Acharya *et al.*, 2009).

The hilly tracts of Hazara division, Pakistan, are part of the Himalayan mountain chain and have been identified as containing the richest flora in the country, with more than 1700 species of vascular plants (Stewart, 1957). The Palas Valley has more than 600 vascular plant species, with the majority having a distribution confined to the Northern Mountains of Pakistan, Kashmir and East Afghanistan. Only about one third of the flora has a wider distribution and importantly, the vegetation is still in relatively pristine condition (Rafiq, 1996). Just like other neighboring valleys, livestock keeping and herd raising are the backbone of the local economy in Palas. The people seasonally occupy high (sub-) alpine pastures (>3000 m a.s.l.) to graze their livestock during summers and return to their permanent residences (1800-2400 m a.s.l.) during winters. Since agriculture is not very prominent, the locals have to rely on wild vegetation to supplement their dietary, fiscal, medicinal, housing and other requirements (Saqib & Sultan, 2005).

Though many articles have been written on the human-vegetation connection, both in Pakistan and worldwide, their main focus has been only the systematic documentation of useful plants (Ali & Qaiser, 2009; Khan *et al.*, 2003; Qureshi & Bhatti, 2008). There is a serious deficiency of quantitative information on the distribution pattern of ethnobotanically important plants, especially with reference to human settlement patterns. Since the scant information on distribution patterns of the target species may lead to their ineffective management and conservation practices (Saqib *et al.*, 2006), the present study specifically focuses on the distribution patterns of useful plants along the altitudinal gradient in Palas Valley and its correlation to human settlement patterns.

Materials and Methods

The study area: The Palas Valley covers an area of about 1400 hectares (Fig. 1) and is located on the eastern bank

of the river Indus in District Kohistan (Khyber Pakhtoonkhwa), *c*. 170 km north of Islamabad, and extends between 34.73°N to 35.21°N latitude and 72.90°E to 73.58°E longitude (Google Earth™). Altitude varies from 500 m a.s.l. at Chakot (near the river Indus) to 5200 m a.s.l. at Mukchaki Peak at the northern boundary. The valley is bounded by Jalkot (Kohistan district) to the north, Naran (Mansehra district) to the east, Alai (Battagram district) to the south and Pattan (Kohistan district) to the west. The valley consists of a southwestern watershed Kuz-Palas, drained by Sharakot and Sharial Nalah (rivulets) and a larger northern watershed Bar Palas/Daro Palas that is drained by the Musha'Ga Nalah. The climate is influenced by both western disturbances and the edge of the monsoon, thus supporting luxurious forest growth. The mean annual precipitation in Palas ranges from 900 mm near Indus to 1350 mm at higher elevations (Sinnott *et al.*, 1995).
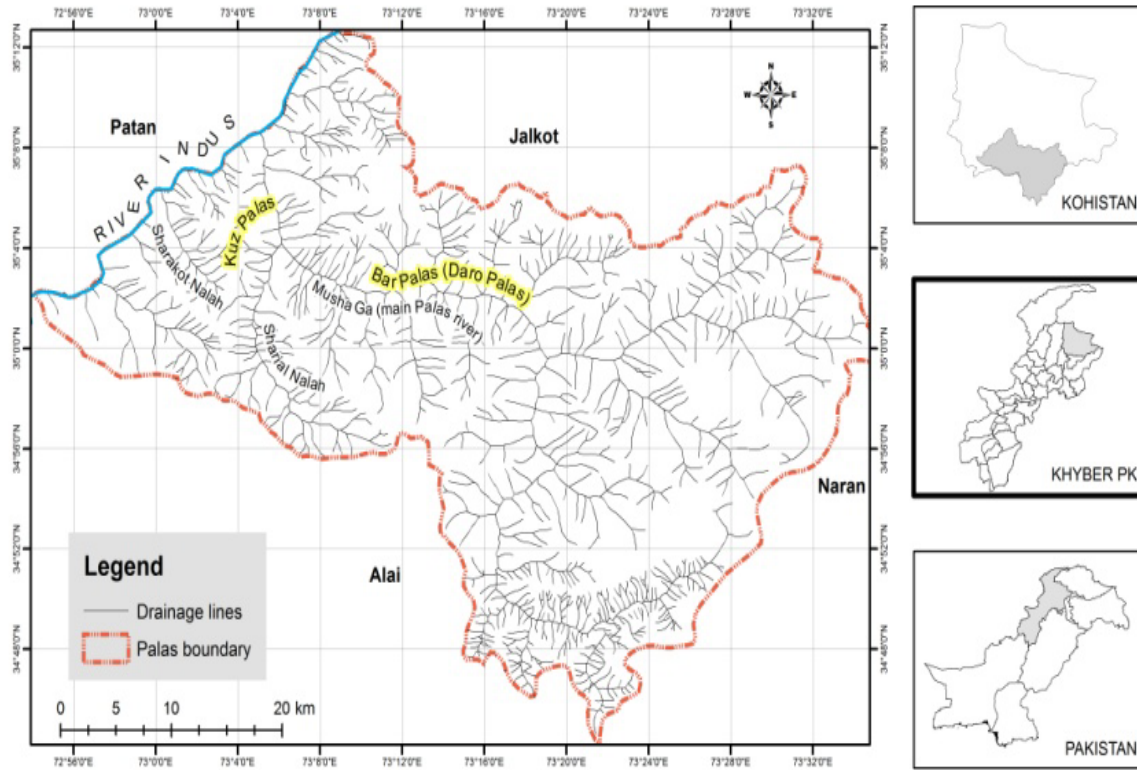

Fig. 1. Map of the study area showing its location, drainage patterns and main watersheds.

The social system is based upon egalitarian formations that lack status or rank distinctions and are free from outside coercive controls and feudal exploitation. The locals practice marginal/subsistence agriculture (mixed maize-vegetables cropping), but livestock rearing is the main source of income. The population of Palas, according to a 1998 population census, was more than 60,500 individuals and *c.* 70% of the population belonged to Kuz Palas (Anon., 1998).

Data collection: Data on altitudinal distributions of plant species were derived from ecological observations taken during transect walks and field surveys carried out from 2004-2007, during the whole length of the growing period. Data points for each plant species were collected with a handheld global positioning system (GPS) device (Garmin GPSMAP® 60). The locational data for all recognizable houses were derived from Google Earth™. The altitude for each species occurrence and house/settlement was extracted from a 30 m resolution digital elevation model (DEM) of the study area based on ASTER satellite data (www.gdem.aster.ersdac.or.jp). A species was considered to be "present" in the whole altitudinal range bounded by its observed upper and lower elevation limits. Species richness was determined as the number of species present within 100 m elevation intervals/bins (total of 46 intervals from 500-5100 m a.s.l.).

Ethnobotanical information was obtained from the locals during transect walks as well as during semi-structured interviews; see Saqib & Sultan, (2005) for methodology. Pearson correlations were determined between elevation, species richness, ethnobotanically important species richness and proportion of human settlements to explore their interrelationships. The trend in species richness and ethnobotanically important species richness along an altitudinal gradient was modeled using quadratic regression in R for Windows ver. 2.13.1 (Anon., 2011).

Results and Discussion

The altitudinal distribution data were synthesized for a total of 545 species, out of which 170 plants were found to be customarily used by locals. The highest proportion of plants was used for medicinal purposes (89 species), followed by food (32 regular diet species, total plants = 59) and fodder plants (22 species). There were 18 plants

with commercial value (mainly medicinal), and 10 species were used as preferred fuel wood. A total of 12 species were categorized in a miscellaneous use class, including those used for making agricultural implements, pottery tools and cleaning utensils, etc. (Saqib & Sultan, 2005)

A negative correlation was observed between altitude and all other variables. The highest negative correlations with elevation were observed for fodder species richness (r=-0.61) and regular diet food plants (r=-0.56), suggesting that fodder and chief food plants are mainly collected at altitudes near permanent settlements, i.e., 2000-2500 m a.s.l. (Fig. 2). With the exception of medicinal and commercially important plants, all other

categories of ethnobotanically important species had relatively stronger positive correlations with the number of houses (r>0.42). Out of 18 species commonly brought to the market, 10 are medicinal plants (*Angelica glauca*, *Geranium wallichianum*, *Paeonia emodi*, *Pistacia chinensis*, *Podophyllum hexandrum*, *Rheum webbianum*, *Saussurea costus, Thymus linearis, Valeriana jatamansii* and *Viola betonicifolia*) and mainly collected from the montane zone (2500-3100 m a.s.l.) under *Picea smithiana* and *Abies pindrow* forest; a few species are collected from (sub-)alpine areas. These are mid elevations where both species richness and ethnobotanically important species richness (especially medicinal plants) are highest.
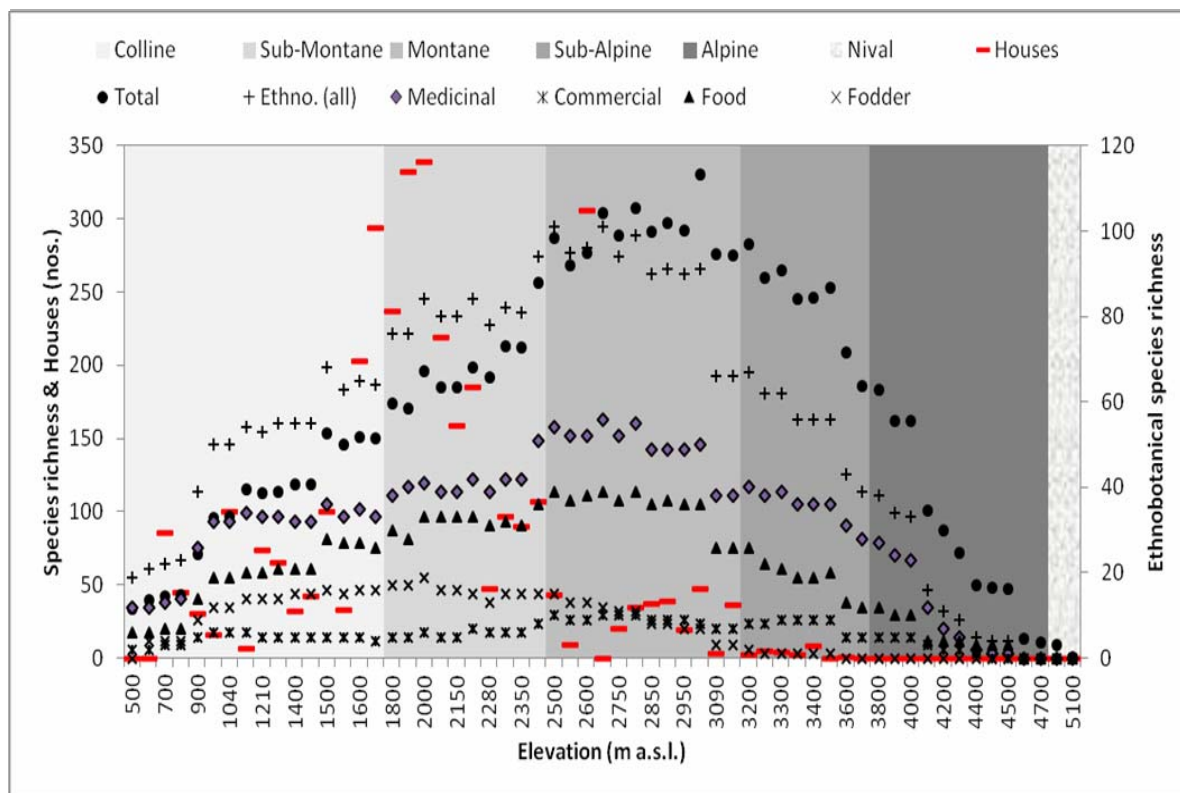

Fig. 2. The scatter plot of altitude against settlements and species richness showing an obvious increase in species richness at mid-altitudes. Settlements peak at elevations just below the mid-altitudes. The altitudinal zonation as shown in shaded background is modified after Dickoré & Nüsser (2000).

In summary, the high correlation between species richness and ethnobotically important species richness simply implies that the higher the species diversity, the greater the utilization potential or perceived usefulness.

Most important is that the species rich sites are well within reach of the locals (Table 1). The correlation between the usefulness of a plant and access/availability has been repeatedly demonstrated (Thomas *et al.*, 2009).

Table 1. The correlation matrix for the elevation, house density and species richness.

		1	2	3	4	5	6	7	8	9	10
1.	Elevation	1									
2.	Houses (number)	-0.36	1								
3.	Species richness (total)	-0.04	0.18	1							
4.	Ethnobotanical species richness	-0.37	0.45	0.88	1						
5.	Medicinal plant richness	-0.37	0.36	0.91	0.98	1					
6.	Commercial plant richness	-0.28	0.19	0.93	0.90	0.95	1				
7.	Food plant richness (all)	-0.35	0.47	0.86	0.99	0.96	0.86	1			
8.	Food plant richness (regular)	-0.56	0.50	0.75	0.95	0.93	0.83	0.96	1		
9.	Food plant richness (occasional)	-0.18	0.42	0.90	0.97	0.94	0.84	0.98	0.88	1	
10.	Fodder plant richness	-0.61	0.68	0.34	0.73	0.66	0.46	0.75	0.84	0.65	1

The scatter plot of species richness against altitudinal gradient revealed that the species do not follow a monotonic decrease, as could be inferred from the correlation analysis (Table 1 & Fig. 2), but rather a bell-shaped species richness pattern is seen that peaks around mid elevations in montane vegetation zone (Fig. 2). The determination coefficient of the regression model (Table 2, Equation 1) for number of houses vs altitude was 0.47, whereas its value for (ethnobotanically important) species richness against elevation was greater than 0.68 (Table 2, Equation 3), indicating a strong relationship with altitude. In the Himalayan region, such unimodal patterns of species richness with respect to altitude are common (Acharya, *et al*., 2009; Bhattarai & Vetaas, 2003; Hamilton & Radford, 2007). Similar richness patterns have been observed from other mountainous regions of the world as well (Levin *et al.*, 2007; Wang *et al.*, 2003; ZhenHua *et al.*, 2007).

Table 2. The regression equations quantifying the relationship of species richness and number of houses with elevation.

Equation No.	Term	Relationship with elevation	R^2
1	Houses (number)	$= -0.11 \times elevation^2 + 4.37 \times elevation + 59.24$	0.47
2	Species richness	$= -0.34 \times elevation^2 + 20.53 \times elevation - 44.07$	0.87
3	Ethnobotanically important species richness	$= -0.11 \times elevation^2 + 5.69 \times elevation + 10.28$	0.93
4	Medicinal species richness	$= -0.05 \times elevation^2 + 3.0 \times elevation + 7.20$	0.91
5	Commercial species richness	$= -0.01 \times elevation^2 + 0.53 \times elevation + 0.72$	0.73
6	Food species richness	$= -0.0422 \times elevation^2 + 2.2633 \times elevation + 3.3164$	0.90
7	Fodder species richness	$= -0.0114 \times elevation^2 + 0.4093 \times elevation + 9.01$	0.68

Since most of the settlements are located in the sub-montane and lower montane zones, these areas may be most affected by human activities. Human activities in montane zones can lead to a reduction in natural habitat, and reduced species richness at these altitudes has also been reported by Nogues-Bravo *et al.*, (2008). The correlation between altitude and climate can well explain the high species richness at mid-altitudes, because the maximum species richness is expected at locations with higher precipitation, which generally occurs at higher altitudes. Other authors have observed that moist conditions at upper montane vegetation zones are correlated with higher species richness (Schweinfurth, 1984; Vetaas & Grytnes, 2002; von Wehrden *et al.*, 2010). The mid-altitude species richness peak may also be attributed to the large-scale mass effect due to flow of individuals or source-sink dynamics (Shmida & Wilson, 1985), due to which these elevations get inputs from both upslope and low-lying areas.

Elevations ranging from 2500-3000 m a.s.l. showed maximum species richness and ethnobotanically important species richness; permanent settlements are located below this altitude, which might have resulted in a montane zone relatively protected from anthropogenic disturbance. However, this zone can be regarded as a zone of economic activity since the majority of the commercial plants are obtained from these elevations. Therefore, these elevations should be considered priorities for conservation, especially in regional context; they should also be considered for sustainable harvest of plant resources. In a regional context, comparable elevations in other valleys have already been exhausted. The only protected area in the region is Saiful Malook and Lulusar-Dodipat National Park, Naran, (east of the study area), which only covers the alpine region (>3200 m a.s.l.) and thus misses the altitudes with the greatest diversity and utility.

Conclusion

Plant species richness in the Palas Valley follows a bell-shaped curve along an altitudinal gradient that has been observed from other parts of the Himalayas as well. Ethnobotanically important species richness follows the same pattern and seems to be directly related to overall species richness. Since the mid-altitudes (2500-3000 m a.s.l.) are important areas with respect to overall and ethnobotanically important species richness, they should be the priority for plant conservation efforts.

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