PATTERNS OF DISTRIBUTION AMONG EPIPHYTIC ORCHIDS AND ENVIRONMENTAL FACTORS IN GORI VALLEY, WESTERN HIMALAYAS

Gurmehr Marwah, Soni Bisht, and G S Rawat

Wildlife Institute of India, Dehradun- 248 001, Uttarakhand, India

Abstract

Globally, orchids, especially epiphytic species, are increasingly threatened with extinction due to natural and anthropogenic influences. In order to conserve these species, it is crucial to gain insights into their distribution and the factors influencing it. Presently, patterns of distribution among epiphytic orchids and associated environmental factors were studied in lower Gori Valley, one of the orchid rich localities in the Western Himalayas. Epiphytic orchids and the host trees were quantified within 160 circular plots, along eight transects. Multivariate analyses were carried out to establish relationships with various environmental parameters. In total, 42 orchid species were recorded growing on 30 host species. Species richness, abundance, and composition of orchids varied across transects, forest communities, and host species. Species richness increased significantly with increasing tree height and moss cover, whereas it declined with increasing anthropogenic pressures. The study area exhibits high diversity of epiphytic orchids manifested by rich assemblages of host species and sub-tropical environment. Future investigations are required to study these at a larger spatial scale, to determine the generality of the patterns obtained.

Introduction

ORCHIDS ARE amongst the most diverse and widespread families of flowering plants exhibiting a wide range of habits *i.e.* terrestrial, epiphytic, lithophytic, and saprophytic. Of these, nearly 70% species are epiphytic in nature (Fischer *et al.,* 2011). However, many species are severely threatened due to alteration of habitat over exploitation and climate change (Timsina *et al*., 2016). Several factors are known to determine the distribution pattern of epiphytic orchids including altitude, diversity of host species, anthropogenic pressures in the form of timber extraction, fire, lopping, and degree of isolation of forest patches (Adhikari *et al.,* 2012a). Epiphytic orchids are closely linked with their hosts and therefore abundance of host species, host characteristics, forest type, and micro-climate are key determinants of their composition and diversity (Adhikari *et al.,* 2012a). Several authors have documented diversity of orchids and their habitats (Acharya *et al.,* 2011; Fischer *et al.,* 2011; Timsina *et al.,* 2016). However, patterns of distribution and host specificity amongst epiphytic orchids have largely been neglected. Information on these parameters is crucial for future conservation planning. Keeping this in view, a study was conducted in lower Gori Valley, Eastern Kumaun which is regarded as one of the orchid hotspots in Western Himalaya (Jalal *et al.,* 2008). Major objectives of the study were to: i) Assess and compare species richness, abundances, and composition of the different epiphytic orchids across different forest types, ii) Study associations between orchid species composition and host species, and iii) Establish relationships between orchid species richness, and environmental parameters (aspect, average tree height, altitude, moss cover, fern cover, human impact, and distance from the river).

Material and Methods

Study Area

The Gori Valley is located in the eastern margin of Kumaon in the state of Uttarakhand, between 29°5'-30°10'N latitudes and 79°45'-81°5'E longitudes. The valley exhibits a wide altitudinal range from 600-5,000 m amsl. It is known to have supported about 121 species of orchids out of 255 species reported from Western Himalayas and is regarded as an orchid hotspot in the Western Himalayas (Jalal *et al.,* 2008). The study area lies in the western fringe of Askot Wildlife Sanctuary. Much of the study area is hilly with moderate to steep slopes. A few flat areas along the river valley and at middle elevation have been taken over for agriculture and human habitation. More than 60% of the area is occupied by the forests which are controlled by the Uttarakhand Forest Department (UKFD) and classified as Reserved Forests. Local inhabitants, largely agro-pastoral communities have rights to collect fuel wood, fodder, and limited amount of timber from these forests. The forests of the study area are divisible into following categories: i) Riverine (dominated by species of *Toona* and *Engelhardtia*), ii) Pine forests dominated by chir pine (*Pinus roxburghii),* iii) mixed Banj

Received: December 5, 2021; Accepted: December 23, 2021

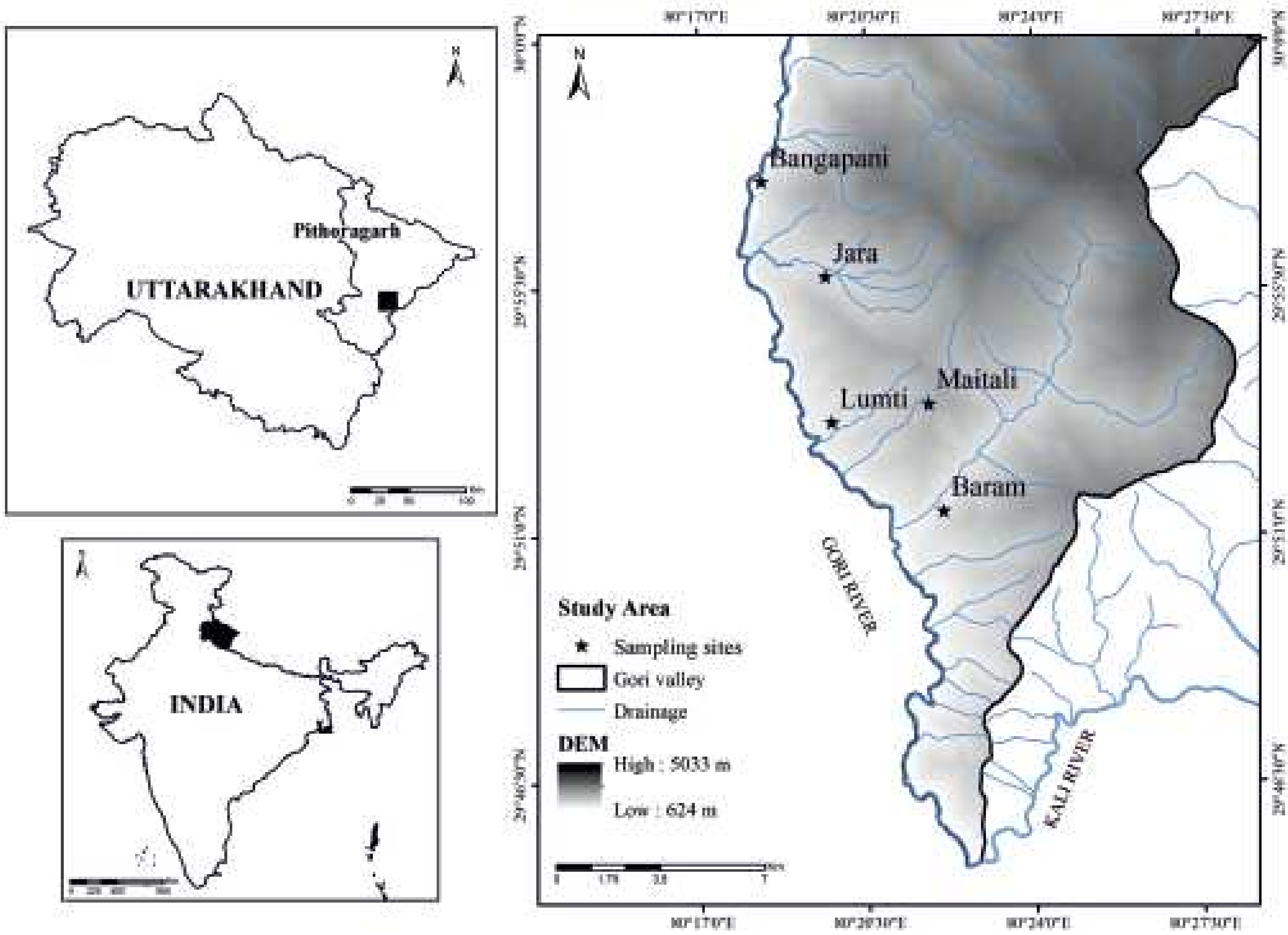

Fig. 1. Map showing the study area in the lower Gori Valley, with the transects highlighted in yellow.

oak (*Quercus leucotrichophora*), and iv) Rianj oak (*Quercus lanuginosa*) forests as described by Samant *et al.* (1995). The study was carried out in five villages in the lower Gori Valley: Lumti, Bangapani, Jarajibli, Maitli, and Baram (Fig. 1).

Data Collection

Epiphytic orchids and their hosts were recorded along 8 transects (160 plots) representing various strata *i.e.* four forest types described above, and different anthropogenic pressure gradients. The study was conducted during the months of May-June, 2019 when most of the species are easy to identify. These forests are interspersed with Lumti, Bangapani, Jarajibli, Maitli, and Baram villages which were at least 200 m apart, with greater distances between transects in larger areas. Each transect was 1 km long and 20 circular plots of 10 m diameter were laid, each at a distance of roughly 50 m, to record host tree species. Within the plots, all host species with height over 5 m and girth above 30 cm were considered for sampling the epiphytic orchids. As it is difficult to distinguish individual orchids of each species on a host tree, the number of host trees a particular orchid species was found on was utilised for calculating frequency and density of orchids. The host species and associated epiphytic orchids were identified using local floras (Pangtey *et al.,* 1991) and state flora. On each host tree the number and cover (%) of epiphytic orchid species was estimated. The moss and fern cover, tree height, altitude, and distance from the river were also recorded. Human impact was determined based on different types of activities, *e.g.* construction, agriculture, pollution, road, according to Adhikari *et al.* (2012a) (very low 1, low 2, intermediate 3, strong 4, very strong 5).

Data Analysis

A total of 21 plots with zero orchid species were identified. Subsequently, these plots were excluded from data analyses to prevent skewness. Orchid species richness (S) and Importance Value Index (IVI) (Ajayi and Obi, 2015) were calculated to determine the overall number and importance of each species in the community structure using the following equation:

Table 1. Importance Value Index values for orchid species in the different forest types and over the entire study area.

Species	Riverine forest	Chir pine forest	Banj oak forest	Rianj oak forest	Overall study area
Eria lasiopetala	55.69	4.27	11.70	9.66	45.70
Gastrochilus inconspicuus	26.49	6.26	5.54	-	21.65
Coelogyne ovalis	22.78	4.85	3.90	-	18.54
Smitinandia micrantha	23.05	-	-	-	18.06
Aerides multiflora	21.91	2.28	-	-	17.40
Oberonia pachyrachis	1.49	54.15	73.08	77.91	15.22
Vanda cristata	2.56	26.86	89.92	70.64	13.31
Thunia alba	16.24	1.70	-	-	12.89
Eria globulifera	16.05	-	-	-	12.62
Pholidota imbricata	15.78	-	4.72	-	12.58
Bulbophyllum careyanum	12.41	5.39	15.81	3.53	11.27
Pholidota articulata	5.77	45.12	4.72	11.06	10.20
Dendrobium heterocarpum	6.20	12.01	11.70	33.86	8.81
Oberonia ensiformis	9.50	4.85	8.62	-	8.35
Liparis cespitosa	9.21	4.56	3.90	-	7.86
Bulbophyllum affine	5.48	29.45	-	-	7.53
Luisia zeylanica	8.88	1.70	-	-	7.12
Dendrobium hesperis	7.47	-	-	-	5.86
Rhynchostylis retusa	4.78	2.57	31.19	-	5.54
Dendronium longicornu	-	-	-	83.46	5.10
D. fimbratum	4.39	-	-	-	3.43
Liparis viridiflora	1.95	15.43	-	-	3.17
Bulbophyllum reptans	2.24	9.37	-	6.34	3.15
Acampe papillosa	3.70	-	-	-	2.88
Eria alba	-	26.83	-	-	2.86
Bulbophyllum cariniflorum	2.94	-	-	-	2.31
Cymbidium aloifolium	2.9	-	-	-	2.27
Dendrobium spp.	1.74	6.74	-	-	2.11
Eria amica	-	15.43	-	-	1.64
Dendrobium chrysanthum	1.56	3.69	-	-	1.63
Eria spicata	1.94	-	-	-	1.52
Gastrochilus calceolaris	0.28	5.10	9.44	3.53	1.43
Dendrobium amoenum	0.24	11.40	-	-	1.41
Aerides odorata	1.5	-	-	-	1.18
Dendrobium denudans	1.05		-	-	0.82
Oberonia acaulis	0.31	-	13.56	-	0.82
O. prainiana	0.28	-	4.39	-	0.42
Coelogyne stricta	0.52	-	-	-	0.40
Pteroceras teres	0.48	-	-	-	0.38
Eria stricta	0.24	-	-	-	0.19
Phalaenopsis taenialis	-	-	3.90	-	0.19
Cymbidium iridioides	-	-	3.90	-	0.19

$$IVI = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100 + \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100 + \frac{\text{Cover of a species}}{\text{Total cover of all species}}$$

Canonical correspondence analysis (CCA) and detrended correspondence analysis (DCA) were executed in Canoco 5.10 to determine the orchid species distribution in relation to the forest types and host species. Parametric and non-parametric tests were used to determine important differences in environmental variables between the different forests. Multivariate tests were carried out using Canoco 5.10 to determine the factors associated with species composition of orchids. The significance of these environmental predictors for orchid species richness was tested using a step-wise Multiple Linear Regression (MLR) in IBM SPSS 25.

Results

Orchid Species Richness and Distribution

Species Richness

A total of 42 species of epiphytic orchids belonging to 19 genera were identified from the study area. This diversity represents over one-third (34.6%) of the orchid species reported in the Gori Valley and 16.5% in

Fig. 2. CCA results (Axis 1, 9.65% explained variance; Axis 2, 4.65% explained variance) showing the association between orchid species composition and forest type.

Uttarakhand. The dominant genera were *Dendrobium* (7 species), *Eria* (6 species), *Bulbophyllum* and *Oberonia* (4 species each). Based on forest type, the highest number of epiphytic orchid species was recorded in Riverine forests (37 species), followed by Chir Pine-mixed (23 species), Banj oak (17 species), and Rianj oak (9 species). Orchid species richness was highest in Riverine forest type (7.88), followed by Chir pine-mixed (5.1), and Banj and Rianj oak (both with 2.58). Based on altitude, the highest number of epiphytic orchid species was recorded in <1000 m (37 species), followed by 1000-2000 m (28 species) and >2000 m (4 species). In the altitudinal range, the below 1000 m range (8.13) had nearly double the species richness of the next closest range, 1000-2000 m (3.69). Thus, a decline in orchid species richness was observed with increasing altitude.

Relative Abundance

The leading species in terms of overall IVI value, were *Eria lasiopetala*, indicating that it was the predominant orchid species in the study area (Table 1). Species such as *Vanda cristata* and *Oberonia pachyrachis* were highly abundant in all forest types, except riverine, while *Dendrobium longicornu* was highly abundant in only Rianj oak forest. The species *Eria stricta, Cymbidium iridoides*, and *Phalaenopsis taenialis* possessed the lowest IVI values, *i.e.* they were quite rare in the study area.

Species Composition

Riverine forest supported high density and diversity of epiphytic orchids, with 13 species recorded only in this type of forest (Fig. 2). Chir pine-mixed forest was observed to share a number of species in common with riverine forest. Rianj oak forest displayed the most unique species composition of all the forest types. *Vanda cristata* was observed in significantly higher numbers in high altitude Banj oak and Rianj oak forests in comparison to riverine forest. The total variation explained by the forest type was 16.68%.

Associations with Host Species

A total of 30 host tree species belonging to 19 families were identified in the study area. Several tree species were found to have highly similar orchid species composition. *Pinus roxburghii* presented a unique orchid species composition compared to the other hosts. The total variation explained by the host species was 48.76%. Maximum number of host trees were of species *Engelhardtia spicata*, following by *Pinus roxburghii,* and *Toona ciliata*. High altitude forests were seen to consist of different host tree species (*Cedrus deodara, Quercus lanuginosa, Q. leucotrichophora,*

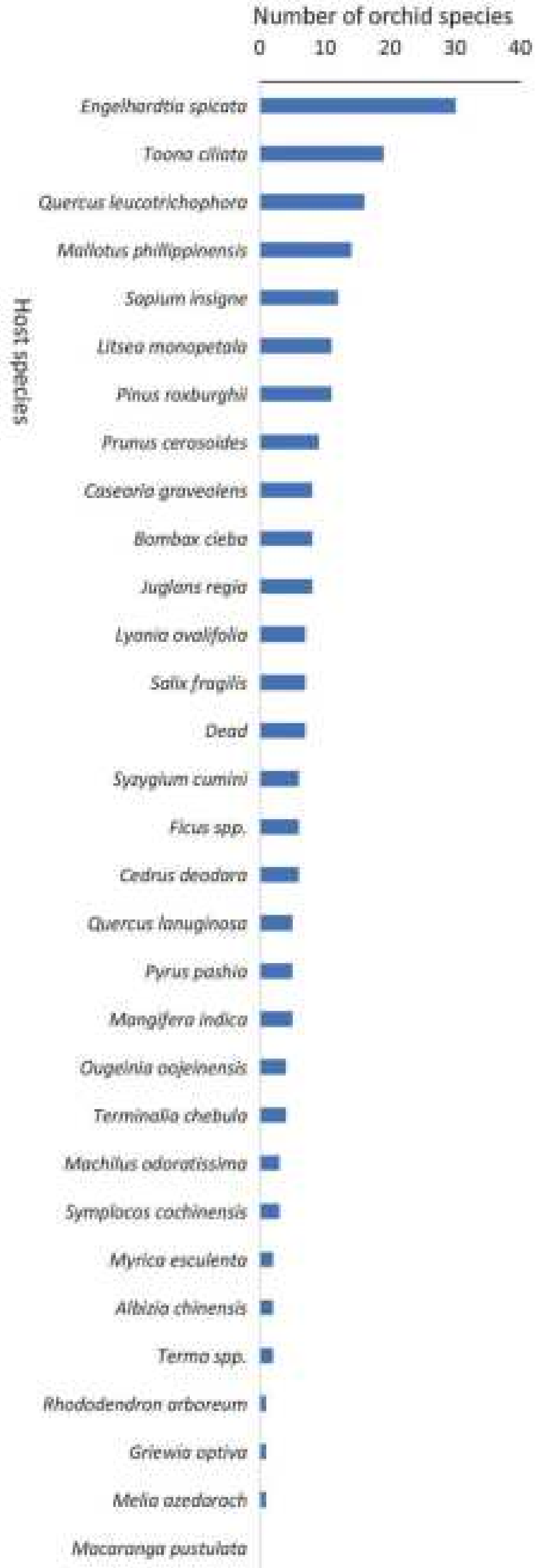

Fig. 3. Number of epiphytic orchid species found on different host species.

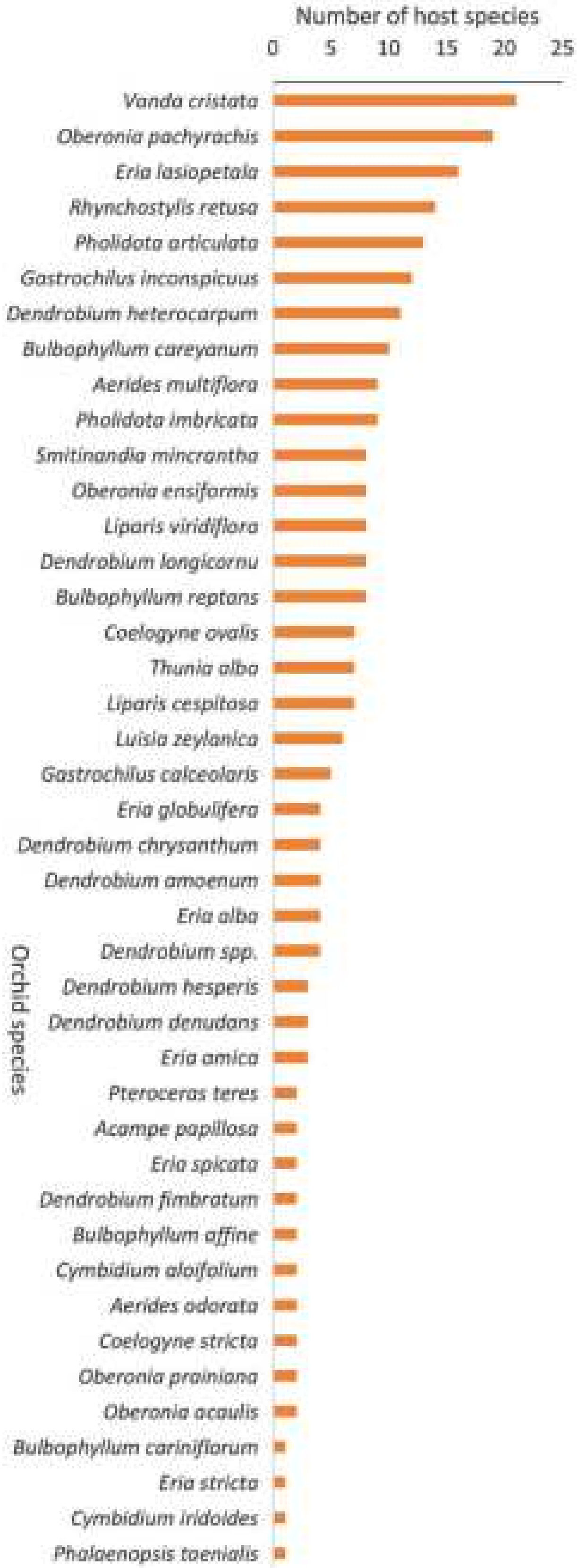

Fig. 4. Host range of epiphytic orchid species.

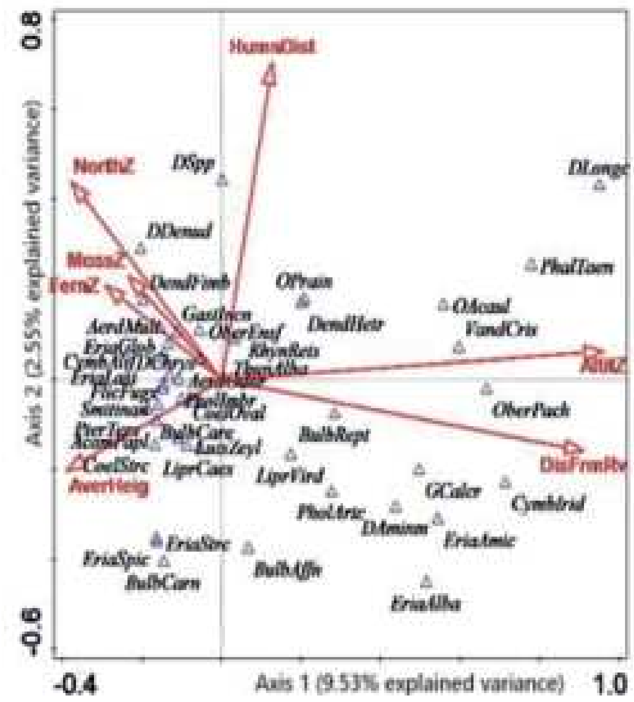

Fig. 5. CCA results (Axis 1, 9.53% explained variance; Axis 2, 2.55% explained variance) showing the association between orchid species composition and the different environmental variables.

Rhododendron arboreum). Trees such as *Engelhardtia spicata*, *Toona ciliata,* and *Quercus leucotrichophora* hosted maximum number of orchid species (Fig. 3). While species such as *Pinus roxburghii* hosted a high number of orchids, the average % cover was among the lowest. Orchid species such as *Vanda cristata*, *Oberonia pachyrachis,* and *Eria lasiopetala* are common epiphytes with broad host ranges (Fig 4). Four orchid species were found only on one host species each, thus showing narrow host ranges.

Factors Influencing Orchid Species Richness and Composition

Using the MLR, it was found that the environmental variables explained a highly significant amount of variance (61.4%) in the species richness of epiphytic orchids (R^2_{adj} = 0.614, F (7, 131) = 32.414, p<0.001). The analysis showed that fern cover, altitude, and northing did not significantly predict orchid species richness. However, human impact, tree height, and moss cover did predict species richness values highly significantly (p<0.001) and distance from river predicted the richness significantly (p<0.05). Moss and tree height showed a strong positive correlation, while human impact and distance from the river displayed a strong negative correlation with species richness.

The species composition of epiphytic orchids was highly significantly associated (p<0.005) with the environmental variables measured (northing, moss, fern, altitude, average tree height, distance from river, and human impact) (Fig. 5). Altitude and distance from the river, followed by human impact were seen to predict the orchid species composition most strongly. The total variance explained by these variables was 16.59%. A majority of the orchid species were associated with low altitude, near the river, high northing, high moss and fern cover, and high average tree height. Very few species such as those belonging to the genera *Dendrobium* were seen to occur in regions with moderate human impact, whereas the majority were associated with low human impact areas.

Discussion

This study indicates that there is a high diversity of epiphytic orchids among the different forest types of the Gori valley. Significant associations of orchid species richness and composition with environmental factors and host species were revealed.

Orchid Species Distribution and Variations in Richness, Abundance, and Composition

Species richness and abundance of epiphytic orchids differed between the villages, forest types, across altitudinal gradients, and human impact.

Forest Type

As in this study, epiphytic abundance is highest in riverine forest communities. The high species richness noted in the riverine forest can be attributed to the presence of high moisture due to close proximity to the river, which provides ideal conditions for the germination of orchid seeds (Jalal *et al.,* 2008). Epiphytic orchids are known to be found in localities with warm and wet climate (Adhikari *et al.*, 2015; Callaway *et al.*, 2002; Hsu *et al.,* 2014), as in the low-lying areas in the valley. This was in line with the finding that proximity to the river significantly predicted orchid species richness. Further, host trees in riverine forests are covered by mosses and bryophytes and grasp moisture throughout the year. Results obtained indicated that moss cover specially predicted orchid species richness significantly. The reasons for more epiphytes occurring on trees with high moss and fern cover is that these epiphytes are only found in communities with high moisture availability and may improve the living conditions for orchids by retaining more moisture on the tree surface (Migenis and Ackerman, 1993). Further the riverine forest type in some areas indicated high species richness despite intense land-use primarily in the form of agriculture, suggesting that agroforestry may not impact orchid richness as negatively as previously thought. The Banj and Rianj oak forests displayed low species richness and diversity, however the species composition was notedly unique. The lower species diversity and unique compositions can be attributed to the high altitude of these forest types.

Altitudinal Gradient

For the study, distance from river and altitude were highly positively correlated factors. It was seen that altitude significantly impacted species composition and distribution, with a decrease in orchid richness noted with increasing altitude. Epiphytic orchids in the valley were primarily concentrated in the $\geq$1000 m zone, representing the maximum of a distinct mid-elevation peak in species richness. The high species richness and diversity around 1000 m is due to the fact that this zone is chiefly dominated by moist riverine forest in the Gori valley and for epiphytic orchids, moisture and host species are key factors. The reasons to account for mid-elevation peaks in species richness are high humidity, intermediate productivity, maximum epiphytic habitat diversity due to peak in tree richness and the mid-domain effect (Grytnes, 2003). The mid-domain effect occurs due to geographical restrictions on species ranges in a constrained area (Colwell *et al.*, 2004). Further, the probability of the altitudinal ranges of several species coinciding is higher at mid-altitudes than for lower and higher altitudes, creating a richness bulge which is not determined by environmental patterns (Cardelús *et al.*, 2006). However, distribution patterns observed in total richness may not match with endemic richness in the valley (Vetaas and Grytnes, 2002). It has been proposed that in the Himalayan region, greatest endemic richness is found at high altitudes (>2000 m) (Shrestha and Joshi, 1996).

Human Impact

Epiphytic orchid species richness and abundance is maximum in primary forests, reducing towards greater intensity of human impact. This may be due to the alteration in micro-climatic conditions associated with diminished tree canopies. The village Lumti was found to have the highest species richness, which can be attributed to the very low human disturbance observed, especially as Transect 1 in Lumti is an Orchid Conservation Area (OCA). High human disturbance in areas reduces habitat availability for epiphytic orchids. Further, part of the study area contained road dust and dust emissions from bridge and road construction. These pollutants have been reported to alter local climatic conditions and bark pH, which adversely impacts the epiphytic orchids (Adhikari *et al.,* 2012b). A few exceptions (*Rhynchostylis retusa* and some species of *Dendrobium*) to this inverse relationship between orchid species richness and human impact were observed. This may be because *Rhynchostylis retusa* has been noted as an opportunistic species (Adhikari *et al.*, 2012b), able to grow in disturbed stretches. The same may be true for the species of *Dendrobium* identified. Overall, protected areas and unmanaged forests were the most suitable habitats for epiphytic orchids, thus requiring increased protection. Further, assuming that IVI values are inversely proportional to sensitivity, conservation of the rare and sensitive orchids, and their habitats should be prioritised.

Associations with Host Species

In the present study, composition of orchid communities was revealed to be significantly associated with host species. The maximum number of orchid species were recorded on host *Engelhardtia spicata,* which was in contrast to findings of previous studies (Jalal *et al.,* 2008) in the valley which found *Toona ciliata* to host maximum number of orchid species. This difference may be due to widespread flooding in the state in 2013, which severely impacted the Gori Valley and altered the forest community composition. In the Riverine forest, similar orchid species compositions were observed, due to similar microsite conditions. In the study area, host tree species found in the Chir Pine-mixed forest type, hosted a number of orchid species. This contrasted with the earlier finding of reduction in epiphytic orchids when *Pinus* is the main forest-forming genera by Acharya *et al.* (2011). This may be due to the mixed nature of this forest-type in the valley and the proximity to the river which leads to higher moisture than found normally in a Pine forest.

In the present study, orchid richness, abundance, and composition varied with the different host species. Tree height was seen as a highly significant factor showing positive correlation with orchid species richness and composition because tall trees provide larger area for colonisation than small trees (Timsina *et al.,* 2016). Further, the species with broad host ranges are widely distributed and hence are less vulnerable to environmental change, whereas the species that have single or fewer hosts are either extremely rare or patchily distributed in the valley. Consequently, they are highly vulnerable to fluctuations in environmental conditions and need to be granted high conservation priority. This study also indicated that *Toona ciliata, Engelhardtia spicata, Mallotus phillippensis* are the most favourable host tree species. From a local conservation perspective, *Quercus leucotrichophora* and *Engelhardtia spicata* require special focus due to the increasing pressure placed on these hosts as a result of their multiple uses (fodder, fuel, other).

Conservation Threats and Strategies

Primary threats recorded to epiphytic orchid species were habitat alteration, degradation and loss due to construction of motor roads, buildings, unmanaged forest fires, invasive alien species, and overexploitation. Further, in highly disturbed areas, high levels of invasive species *Eupatorium adenophorum* were noted. As in this study, these invasive species due to their ability to reproduce and spread rapidly, adversely impact local flora (Jalal, 2012), thereby impacting epiphytic orchids by reducing habitat/host availability. Any conservation plan for the protection of epiphytic orchids in inhabited areas should include identification and protection of forests, degraded and fragmented habitats, clusters of host trees and single native host trees, as these possess high orchid species richness and diversity. Some rare, endangered, and over-collected orchid species may require species-specific strategies. Studies on *in vitro* mass propagation and conservation of some of the Indian orchids have been made earlier by a few researchers (Balkrishna *et al*., 2020; Bhandari *et al*., 2018; Bhatti *et al*., 2017; Devi *et al*., 2018; Kumar *et al*., 2018, 2019; Kumari and Pathak, 2020; Lal and Pathak, 2020; Pathak *et al*., 2017; Prakash *et al*., 2018; Prakash and Pathak, 2019; Shapoo *et al*., 2020; Singh *et al*., 2019; Thakur and Pathak, 2020; Vasundhra *et al*., 2019). Thus, complementary approaches are urgently required to mass propagate and conserve orchids.

Conclusion

This study found a high diversity of epiphytic orchids and large variations in species richness, abundance, and species composition across different forest types. Orchid species richness and composition were significantly predicted by environmental factors, specifically, tree height, moss cover, human impact, and to a lesser extent distance from the river. Therefore, the results imply that the associations between epiphytic orchid populations and environmental predictors vary spatially. Future investigations should thus examine these associations at a larger scale spatially so as to evaluate the generality of these relationship patterns. Further, with the ever-increasing threat of climate change, it is important to study the relationships with environmental factors in more detail and the impact of future climate change on the epiphytic orchid communities and their hosts which is necessary to devise long-term conservation strategies.

Acknowledgement

The authors are thankful to the Wildlife Institute of India, Dehradun for support and facilities during the survey.

References

Acharaya, K. P., O. R. Vetaas, and H. J. B. Birks. 2011. Orchid species richness along Himalayan elevational gradients. *J. Biogeogr*., **38**(9): 1821-33.

Adhikari, Y., A. Fischer, and H. Fischer. 2012a. Micro-site conditions of epiphytic orchids in a human impact gradient in Kathmandu valley, Nepal. *J. Mt. Sci.,* **9**(3): 331-42.

Adhikari, Y. P., H. S. Fischer, and A. Fischer. 2012b. Host tree utilization by epiphytic orchids in different land-use intensities in Kathmandu valley, Nepal. *Plant Ecol.,* **213**: 1393-412.

Adhikari, Y. P., A. Fischer, and S. Pauleit. 2015. Sustainable conservation perspectives for epiphytic orchids in the central Himalayas, Nepal. *Appl. Ecol. Environ. Res.,* **13**: 753-67.

Ajayi, S. and R. Obi. 2015. Tree species composition, structure and Importance Value Index (IVI) of Okwangwo Division, Cross River National Park, Nigeria. *Int. J. Sci. Res*., **5**(12): 85-91.

Balkrishna, Acharya, Rajesh Juyal, Reema Devi, Jitender Kumar, Ankush Prakash, Promila Pathak, Ved Priya Arya, and Ashwani Kumar. 2020. Ethnomedicinal status and pharmacological profile of some important orchids of Uttarakhand (NorthWestern Himalayas), India. *J. Orchid Soc. India,* **34**: 137-47.

Bhandari, P. K., Julie Thakur, Sachin Sharma, and P. L. Uniyal. 2018. Orchid diversity in Basukedar region (Rudraprayag District) of Uttarakhand. *J. Orchid Soc. India,* **32**: 73-79.

Bhatti, S. K., Jagdeep Verma, Jaspreet K. Sembi, and Promila Pathak. 2017. Symbiotic seed germination of *Aerides multiflora* Roxb.- A study *in vitro. J. Orchid Soc. India,* **31:** 85-91.

Callaway, R. M., K. O. Reinhart, and G. W. Moore. 2002. Epiphyte host preferences and host traits: mechanisms for species specific interactions. *Oecologia*, **132**: 221-30.

Cardelús, C., R. Colwell, and J. Watkins. 2006. Vascular epiphyte distribution patterns: explaining the mid-elevation richness peak. *J. Ecol.,* **94**(1): 144-56.

Colwell, Robert K., Corsten Rahbek, and Nicholas J. Gotelli. 2004. The mid-domain effect and species richness patterns: What have we learn so far? *Am. Nat.,* **163**(3): 1-23.

Devi, K., S. S. Samant, S. Puri, and S. Dutt. 2018. Diversity, distribution pattern and indigenous uses of orchids in Kanawar Wildlife Sanctuary of Himachal Pradesh, North Western Himalaya. *J. Orchid Soc. India*, **32**: 17-23.

Fischer, A., M. Blaschke, and C. Baessler. 2011. Altitudinal gradients in biodiversity research: The state of the art and future perspectives under climate change aspects. *AFSV*, **11**: 35-47.

Grytnes, J. A. 2003. Ecological interpretations of the mid-domain effect. *Ecol. Lett.,* **6**: 883-88.

Hsu, R. C. C., J. H. D. Wolf, and W. L. M. Tamis. 2014. Regional and elevational patterns in vascular epiphyte richness on an East Asian Island. *Biotropica*, **46**: 549-55.

Jalal, J. S. 2012. Status, threats, and conservation strategies for orchids of Western Himalaya, India. *J. Threat. Taxa*, **4**(15): 3401-09.

Jalal, J. S., G. S. Rawat, and P. Kumar. 2008. Abundance and habitat types of orchids in Gori Valley, Eastern Uttarakhand. *J. Orchid Soc. India,* **22**(1-2): 63-67.

Kumar, A., S. S. Samant, L. M. Tewari, and S. Paul. 2018. Diversity, distribution, indigenous uses and status of orchids in Kalatop-Khajjiar Wildlife Sanctuary, Chamba district, Himachal Pradesh. *J. Orchid Soc. India*, **32**: 93-98.

Kumar, V., O. Prakash, A. Singh, M. Lal, S. Marpa, S. S. Samant, and M. Bodh. 2019. Status, distribution and conservation of orchids in Great Himalayan National Park of Himachal Pradesh, NorthWestern Himalaya. *J. Orchid Soc. India*, **31**(1-2): 1-8.

Kumari, Anamika and Promila Pathak. 2020. Medicinal orchids of Shimla hills, Himachal Pradesh (NorthWestern Himalayas), threats, and conservation measures. *J. Orchid Soc. India,* **34**: 45-56.

Lal, Roshan and Promila Pathak. 2020. Substratum analysis of some therapeutically significant and/or endangered orchids of Shimla hills (Himachal Pradesh), NorthWestern Himalayas and their conservation. *J. Orchid Soc. India,* **34**: 101-11.

Migenis, L. E. and J. D. Ackerman. 1993. Orchid-phorophyte relationships in a forest watershed in Puerto Rico. *J. Trop. Ecol.,* **9**: 231-40.

Pangtey, Y. P. S., S. S. Samant, and G. S. Rawat. 1991. *Orchids of Kumaon Himalaya*. Bishen Singh Mahendra Pal Singh, Dehradun, India.

Pathak, Promila, Shivani Verma, Ankush Prakash, and K. C. Mahant. 2017. Regeneration competence of an ornamentally important epiphytic orchid, *Rhynchostylis gigantea* (Lindl.) Ridl. through leaf segments: A study *in vitro*. *J. Orchid Soc. India*, **31**: 97-101.

Prakash, Ankush and Promila Pathak. 2019. Orchids of Water Catchment Wildlife Sanctuary, Shimla (Himachal Pradesh), NorthWestern Himalayas: Their diversity, status, indigenous uses, and conservation status. *J. Orchid Soc. India*, **33**: 65-77.

Prakash, O., S. S. Samant, V. Kumar, A. K. Yadava, and S. Dutt. 2018. Orchid Diversity of Pangi Valley of Himachal Pradesh, North Western Himalaya. *J. Orchid Soc. India*, **32**(1-2): 45-54.

Samant, S. S., R. S. Rawal, and U. Dhar. 1995. Epiphytic Orchids of Askot Wildlife Sanctuary in Kumaun Himalaya, India. *Environ. Conserv*., **22**: 71-74.

Shapoo, Gowhar A., Zahoor A. Kaloo, Aijaz Hasaan Ganie, and Seema Singh. 2020. Development of agro-techniques for *ex situ* conservation of *Dactylorhiza* Neck. ex Nevski (Orchidaceae) species growing in Kashmir Himalaya, India. *J. Orchid Soc. India*, **34**: 123-30.

Shrestha, T. B. and R. M. Joshi. 1996. *Rare, Endemic and Endangered Plants in Nepal.* WWF Nepal Programme, Kathmandu, Nepal.

Singh, A., S. S. Samant, S. Naithani, V. Kumar, and T. Barman. 2019. Ecological assessment of sub-alpine and alpine orchids of Great Himalayan National Park in Himachal Pradesh, NorthWestern Himalaya. *J. Orchid Soc. India*, **33**: 1-9.

Thakur, Babita and Promila Pathak. 2020. *In vitro* propagation of *Herminium lanceum* (Thunb. ex Sw.) Vuijk (Orchidaceae), through asymbiotic seed germination: A therapeutically important and endangered orchid from NorthWestern Himalayas. *J. Orchid Soc. India,* **34**: 61-67.

Timsina, B., M. B. Rokaya, and Z. Münzbergová. 2016. Diversity, distribution and host-species associations of epiphytic orchids in Nepal. *Biodivers. Conserv.,* **25**: 2803-19.

Vasundhra, Promila Pathak, and Ankush Prakash. 2019. *In vitro* shoot induction and regeneration potential of floral buds in *Crepidium acuminatum* (D.Don) Szlach., a medicinal ayurvedic plant from NorthWestern Himalayas. *J. Orchid Soc. India*, **33**: 43-48.

Vetaas, O. R. and J. A. Grytnes. 2002. Distribution of vascular plant species richness and endemic richness along the Himalayan elevation gradient in Nepal. *Glob. Ecol. Biogeogr.,* **11**: 291-301.