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Research

Distribution pattern of the epiphytic orchid *Rhynchostylis retusa* under strong human influence in Kathmandu valley, Nepal

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Abstract

We studied distribution pattern of the epiphytic orchid *Rhynchostylis retusa* (L.) Blume with respect to (i) site characteristics and host conditions, and (ii) the type and intensity of land use in Kathmandu Valley, central Nepal. We established a 1.5 km grid net and analyzed epiphytic orchids at each point, searching for 10 trees as close as possible to the grid point. There we analyzed bark water-holding capacity, bark pH, bark roughness and light intensity. We assessed the probability of the occurrence of *R. retusa* in different land use patterns. Our results indicated that *R. retusa* was not a host-specific orchid species. It was found on different host tree species. However, *Ficus religiosa* was the most common host species. The correlation between *R. retusa* occurrence and microclimate condition was weak. *R. retusa*, to a certain degree, preferred light intensity of 40-80% of full sun light, rough bark with pH around 6.5 and bark with a wide range of water holding capacity. The distribution pattern of *R. retusa* was influenced by certain types of land use. The probability to find *R. retusa* was highest in forest patches and parks and lowest in agricultural and dense populated area. The study reveals that to improve the population size of *R. retusa*, trees (mainly *Alnus nepalensis, Ficus religiosa* and *Schima wallichii*) should be planted in areas where the orchid species is recently missing.

Key words: *Ficus religiosa*, host, land use, microhabitat, urban area.

Introduction

Epiphytes are one of the most diverse groups in the plant kingdom and may contribute up to one third of the vascular plant species in tropical and subtropical forests (Migenis and Ackerman 1993). Epiphytes in some tropical and subtropical forests comprise more than one-third of the total vascular flora (Benzing 1990). Eighty percent of all vascular epiphytes are concentrated in only four families, and indeed over two-third of all epiphytic vascular species belong to the single family Orchidaceae (Gentry and Dodson 1987; Kress 1986; Madison 1977).

Species numbers and global distribution patterns of epiphytic orchids are fairly well known (Migenis and Ackerman 1993). There are about 800 genera and over 24,000 species of orchids so far reported from the world (Dressler 1993). Because of their complex biology, orchids are excellent indicators of overall forest diversity in an area (Christenson 2003). Kromer *et al.* (2005) found that epiphytic species richness peaks in the subtropical forests at an elevation of about 1500 m asl. In Nepal, similar results were found for epiphytic orchids (Chaudhary *et al*. 2002; Ghimire 2008). About 161 species of epiphytic orchids have been recorded from Nepal (Raskoti 2009) and most of them occur in tropical and subtropical forests (Chaudhary *et al.* 2002; Acharaya *et al*. 2011). Epiphytic orchids are abundant up to 1800 m asl

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and their frequencies of occurrence decreases with the increase in altitude (Bose *et al.* 1999).

Epiphytes usually grow on trees or shrubs without directly harming the hosts (Nieder *et al.* 2001). Epiphytes play a vital role in ecosystem functioning. They provide food and shelter for the wealth of animals, especially insects, and micro-organisms (Vance and Nadkarni 1990). Regardless of their significant role in ecosystems, epiphytes are seldom been studied in relation to forest ecosystems (Benzing 1990). Moreover, as orchids are species having storage organs and with high activity of polyphenoloxidase, they can function as bio-filters and air cleaners in hermetic capacity (Cherevchenko *et al.* 2001).

The life of epiphytes depends on the characteristics of host (Callaway *et al.* 2002; Partomihardjo *et al.* 2004) and disturbances factors (Barthlott *et al.* 2001). Previous studies have examined the influence of different host characteristics (e.g., bark rugosity, bark water holding capacity, age, growth, bark pH, through fall, sunlight intensity) on the distribution and diversity of epiphytes (Frei and Dodson 1972; Frei 1973; Callaway *et al.* 2002). Based on the microclimatic conditions of the host species, the epiphytes sometimes prefer a specific host species (Callaway *et al.* 2002).

The abundance and diversity of orchids is decreasing throughout the world, beginning with genetic erosion and ending up with local or global species loss. The main driving forces are habitat loss due to deforestation, agricultural and industrial expansion, urbanization, illegal collection and trade (Bajracharya 2005). There is urgent need to protect the orchid species in their natural habitat (Medhi and Chakrabarti 2009). Conventionally, habitat protection and species protection are two important strategies, which can prevent the species from extinction.

Both the ecology and distribution of epiphytic orchids, especially their microhabitat requirements and the human induced environmental changes, are scarcely known in the Himalayan region (but see Sharma 2010). Most of the researches on Nepalese orchids are related to floristic exploration and taxonomic description, while some address ecological and conservational issues (Bailes 1985; Bajracharya *et al.* 1994; Shakya *et al* 1994; Sparrow 1996; Chaudhary *et al.* 2002; Subedi 2002), none of them, however, addressed human influence on orchid distribution. Given the high rate of population depletion and their relatively high vulnerability, the study on epiphytic orchids in relation to host preference, microhabitat quality, including human disturbance is a pre-requisite to know the ecological response with their host and a changing environment (Callaway *et al.* 2002). Because of their high conservation value, it is a crucial need to study the ecology of epiphytic orchids in order to generate useful information to design their sustainable conservation and management strategies.

The aim of this paper is to explore the distribution pattern of epiphytic orchid *Rhynchostylis retusa* (L.) Blume (hereafter referred to as *Rhynchostylis*) in Kathmandu valley, Nepal. We have selected *Rhynchostylis* as an example of epiphytic orchid of the Himalaya which is under strong human influence. *Rhynchostylis* is a genus of three species, commonly known as ‘fox-tail orchid’ because of its brush-like spikes of colorful flowers (Bose *et al*. 1999). Due its beautiful flowers, *Rhynchostylis* ranks among the important Indian ornamental orchids (Vij *et al.* 1984). Most of the *Rhynchostylis* species found in the Asian region are endangered by deforestation (Le *et al.* 1999). We hypothesized that the recent distribution of *Rhynchostylis* is influenced not only by natural microhabitat conditions, e.g. bark water-holding capacity, bark pH, bark roughness, light intensity, tree size and age, but also by human induced environmental factors. Our main research questions are: (i) How does the distribution of *Rhynchostylis* relate to the type and characteristics of the host trees? (ii) Do the distribution of *Rhynchostylis* diverge under different human land use regimes?

Materials and Methods

STUDY AREA

We selected Kathmandu valley (27°38’–27°48’N 85°16’–85°32’E; altitude ranging from 1280 to 1490 m asl) in central Nepal as our study area, because (i) the valley is well known for the richness of epiphytic orchids, but (ii) it is the most urbanized place in Nepal. Kathmandu valley is surrounded by hills with forests, including Shivapuri Nagarjun National Park in the northern slope. The valley is densely populated by around 2.5 million people inhabiting an area of 172 km^2. The temperature in general is 19°C to 27°C in summer and 2°C to 20°C in winter. The annual average rainfall is 1400 mm with the absolute maximum during summer time (monsoon climate). There are only few isolated forest patches remaining in the valley, in the park areas and temple complexes, and therefore single trees or groups of several native tree species

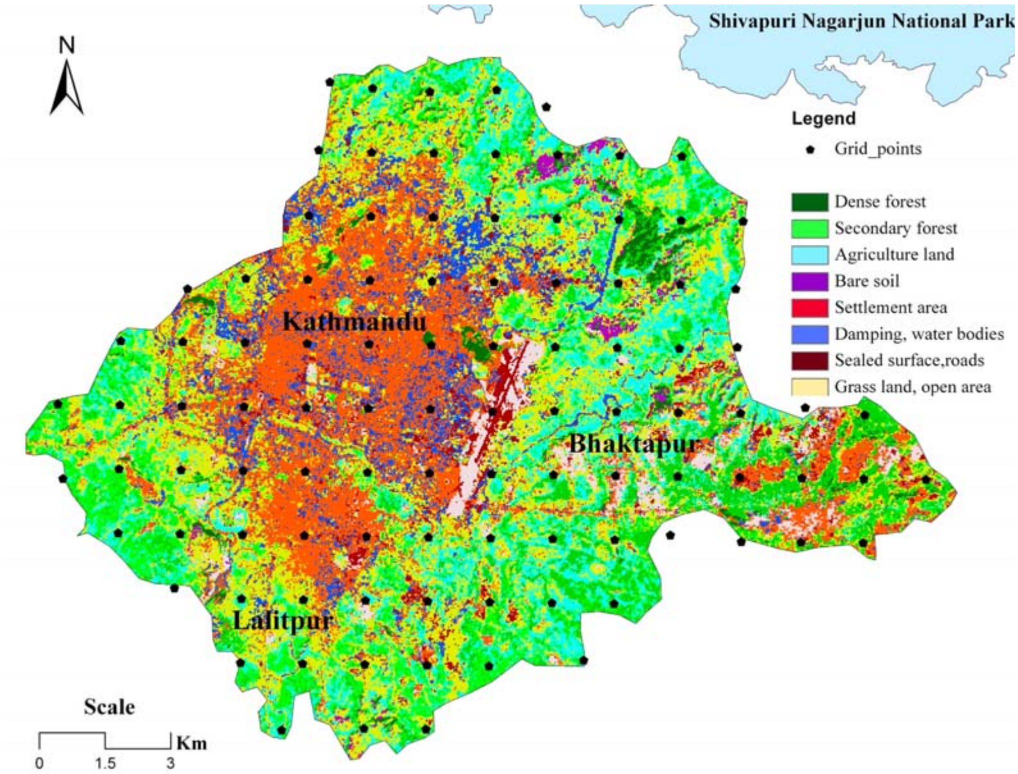

Figure 1. Study area showing maximum likelihood supervised classification of Landsat ETM+ scene 2011 including grid points in a (1.5*1.5 km) grid net with 8 classified land use categories.

including the religious tree *Ficus religiosa* represent as the possible habitat for epiphytic orchids. The most common tree species in Kathmandu valley are *Schima wallichii*, *Alnus nepalensis* and *Ficus religiosa*, while *Castanopsis indica*, *Myrsine capitellata*, *Salix babylonica*, *Pinus roxburghii* are also found. The present study sites falls within the inner areas of proposed outer ring road, including Kathmandu, Lalitpur and Bhaktapur districts of the Kathmandu valley (Figure 1).

STUDY SPECIES

Rhynchostylis is a monopodial epiphytic orchid (holo-epiphyte) that grows in the broadleaved forests along the lower Himalayan ranges. It can tolerate a wide range of temperature from 3°C to 31°C. Its abundance varies dramatically among tree species. It is mostly found as an epiphytic herb in the tropical and subtropical zones of central and east Nepal at 300-1800 m asl. According to Ghimire (2008) *Rhynchostylis* in Nepal favors *Bauhinia* sp., *Mangifera indica*, *Mallotus philippensis*, *Quercus glauca*, *Q. lanata*, *Rhododendron arboreum* and *Schima wallichii* as hosts; nevertheless, it has a very wide host range. Flowering time is from May to July (Rajbhandari and Bhattarai 2001).

FIELD SAMPLING

We used a systematic sampling strategy for the selection of sampling points within the study area. A grid net (distance of 1.5 km to each next point) was established (Figure 1). The elevation, latitude and longitude of each sampling point were recorded using geographic positioning system (GPS). Sampling was done based on plotless method proposed by Wolf *et al.* (2009). At each point, we studied the 10 individual trees (dbh >10 cm) that were closest to the grid point. If there was no tree growing at the exact sample point sampling followed up to a maximum radius of 300 m. The study area was classified into six land use categories: (i) agricultural land (ii) densely populated area, (iii) less populated area, (iv) mixed area (mixture of all categories), (v) park, and (vi) remnant forest patch.

Table 1. Host tree species of *Rhynchostylis* in Kathmandu valley.

Name of the species	Name of the species
Albizia chinensis (Osbeck) Merr.*	*Juniperus recurva* Buch.-Ham. ex D. Don
Alnus nepalensis D. Don**	*Kydia calycina* Roxb.
Araucaria bidwillii Hook.	*Litchi chinensis* (Gaertn.) Sonn.
Bombax ceiba L.	*Michelia champaca* L.
Butea monosperma (Lam.) Kuntze	*Morus nigra* L.
Callistemon citrinus (Curtis) Skeels	*Myrsine capitellata* Wall.*
Castanopsis indica (Roxb.) Miq.	*Nyctanthes arbor-tristis* L.
Celtis australis L.	*Pinus roxburghii* Sarg.
Choerospondias axillaris (Roxb.) B. L. Burtt & A. W. Hill	*Populus euramericana* Guinier
Cinnamomum camphora (L.) J. Presl	*Prunus cerasoides* D. Don*
Diospyros malabarica (Desr.) Kostel.	*Prunus cornuta* (Wall. ex Royle) Steud.*
Eucalyptus citriodora Hook.	*Prunus persica* (L.) Batsch.
Ficus benghalensis L.	*Phyllanthus emblica* L.
Ficus benjamina L.	*Pyrus communis* L.*
Ficus glaberrima L.	*Pyrus pashia* Buch.-Ham. ex D. Don*
Ficus religiosa L.**	*Ribes takare* D. Don
Fraxinus floribunda Wall.	*Salix babylonica* L.
Grevillea robusta A.Cunn. ex R. Br.	*Schima wallichii* (DC.) Korth.**
Hymenodictyon excelsum (Roxb.) Wall.	*Thuja orientalis* L.
Juglans regia L.	

Number of host tree individuals: ** > 20 and * >10-<20.

In each tree, we counted all the individuals of *Rhynchostylis*. Each tree was examined from different points thereby assuring a clear view of all tree parts (Migenis and Ackerman 1993). For larger trees, where the epiphytic orchid could not be identified from the ground, we applied rope-climbing technique (Mitchell *et al.* 2002). We collected information on site conditions: altitude, latitude, longitude, land use, and vegetation type; host tree characteristics: host dbh, exposure (field estimation), bark pH and water holding capacity; and orchid characteristics: growth form and sun intensity (field estimation). In each sampling point, we also identified all associated orchid species as well as their host trees with the help of standard reference (Shrestha 1998; Bose *et al.* 1999; White and Sharma 2000; Rajbhandari and Bhattarai 2001). Nomenclature follows Press *et al.* (2000).

HOST CHARACTERISTICS AS MICRO-SITE CONDITION

Bark pH: To determine the actual bark pH, we used a flat head electrode (Farmer *et al.* 1990). A 2 mm silicone tube was slipped over the end of the flat head electrode making slightly beyond the tip, being that, when pressed against the bark, this small space between the bark surface and the electrode's membrane could be filled with 0.025M KCl solution as these effectively enhances cation exchange (Schmidt *et al.* 2001). A stable equilibrium value represents the actual bark pH_{KCl} of host plant. We took the mean of two sides of each tree.

Bark water-holding capacity: Host preference of epiphytes is often determined by water holding capacity of tree bark (Callaway *et al.* 2002). We determined the water holding capacity of some common and highly preferred by *Rhynchostylis* host trees: *Alnus nepalensis, Ficus religiosa, Myrsine capitellata,* and *Schima wallichii.* Two other species, *Pinus roxburghii* and *Salix babylonica* are rather rare within the area but are quite preferred by *Rhynchostylis*. Therefore, these were also included in the study. To determine the water holding capacity, we calculated the amount of water that the bark could hold at saturation. We collected bark material from each of the seven selected host species. The bark material was air dried (10 h) and weighed (for dry mass). Each bark piece (10 g) was then put in water for 30 min, for each species in separate beakers. After 30 min, the wet bark material was gently soaked in filter paper and weighed at saturation (for wet mass). Water-holding capacity at saturation was defined as the percentage of water compared to the bark dry weight.

We sampled 5 bark replicates from different parts of the same tree to calculate the mean bark water-holding capacity.

Bark rugosity: Epiphyte abundance may be correlated with host bark rugosity (Benzing 1990). On the basis of roughness of bark, three different rugosity classes were visually identified: smooth, medium, and rough.

Sunlight intensity: Epiphytes may experience photo system damage in high light or may experience light limitation in deep shade (Callaway *et al*. 2002). We visually categorized light intensity that fall both at the levels of host trees and orchids in five equal classes from < 20%, 20-40, ≥40-60, ≥60-80 and >80% of full sunlight.

DATA ANALYSIS

All data were stored in MS-ACCESS. Analyses were performed using JMP® Statistical Discovery Software version 5.1.2 (SAS Institute Inc. 2009). We used polynomial regression to analyze the relationship of *Rhynchostylis* density (number of individuals per tree) with bark pH and tree size. One-way analysis of variance was executed to compare the density of *Rhynchostylis* among different light conditions and bark rugosity. However, pair-wise comparisons were made using t-test.

Results

Rhynchostylis was found on a wide range of hosts (Table 1). *Ficus religiosa* was the most common host tree species for *Rhynchostylis*, followed by *Alnus nepalensis* and *Schima wallichii*. We found *Rhynchostylis* in 62 out of 100 sample points, in 32 out of 100 points growing on *Ficus religiosa*. Seven other epiphytic orchid species were also associated with *Rhynchostylis* on the same tree (Table 2).

Bark pH showed unimodal relationship with the number of *Rhynchostylis* individuals (r^2 = 0.17, Prob>|t| p = 0.0002 and Prob>F p = 0.0007). *Rhynchostylis* preferred host bark pH value around 6.5 with a wide range of variance (Figure 2). The most common host tree species showed mean bark pH between 6.15 (*Pinus roxburghii*) and 6.61 (*Myrsine capitellata*). Comparison of mean bark pH between the pairs of common host tree species revealed that the value shown by *Pinus roxburghii* was significantly different than the value shown by other common host species, except *Salix babylonica* (Table 3). Similarly, mean bark pH of *Myrsine capitellata* was

Table 2. *Rhynchostylis retusa* and other epiphytic orchid species associated on the same host tree.

Orchid species	Present in no. of host
Rhynchostylis retusa (L.) Blume	264
Acampe rigida (Buch.-Ham. ex Sm.) Hunt.	14
Phalaenopsis taenialis (Lindl.) Christenson & Pradhan	6
Gastrochilus acutifolius (Lindl.) Kuntze	5
Bulbophyllum affine Wall. ex Lindl.	3
Vanda cristata Wall. ex Lindl.	6
Chilochista sp.	1
Dendrobium moniliforme (L.) Sw.	1

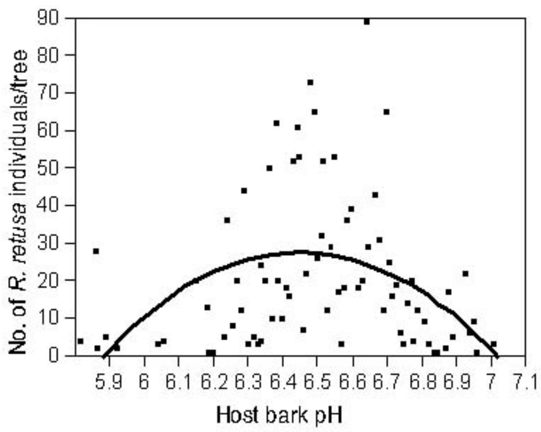

Figure 2. Number of *Rhynchostylis* individuals depending on host bark pH.

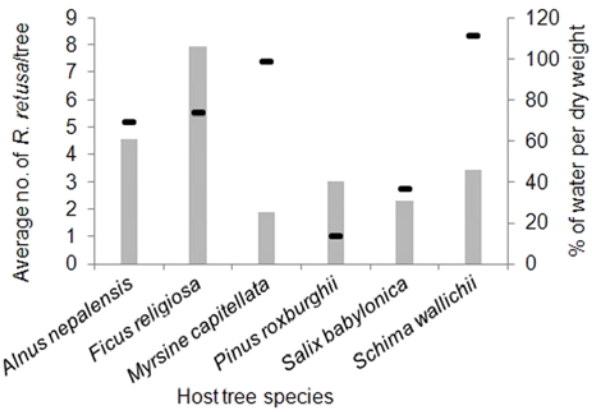

Figure 3. Number of *Rhynchostylis* on the most common host trees (indicated by bars), compared with the water holding capacity of tree bark (indicated by bold dash).

Table 3. Mean and standard deviation of bark pH for common host species. Significance level shown in the table represents pair-wise comparison of bark pH between common host trees based on t-test. Host species abbreviations are: Myr cap = *Myrsine capitellata*, Fic rel = *Ficus religiosa*, Aln nep = *Alnus nepalensis*, Sal bab = *Salix babylonica*, Sch wal = *Schima wallichii*, Pin rox = *Pinus roxburghii*.

Host species	Mean pH	Standard deviation	*n*	*p*-value (pair-wise comparison based on t-test)				
				Fic rel	Aln nep	Sal bab	Sch wal	Pin rox
Myrsine capitellata	6.61	± 0.15	15	0.052	0.057	0.023	0.035	0.008
Ficus religiosa	6.51	± 0.26	65	---	0.980	0.172	0.510	0.027
Alnus nepalensis	6.52	± 0.24	53		---	0.170	0.502	0.027
Salix babylonica	6.40	± 0.19	7			---	0.411	0.123
Schima wallichii	6.47	± 0.26	26				---	0.046
Pinus roxburghii	6.15	± 0.37	8					---

Table 4. Pair-wise comparisons (using student's t-test) of number of individuals of *Rhynchostylis* per host tree with different levels of bark rugosity.

Level	Level	Difference	95% confidence interval	*p*-value
Rough	Smooth	3.906	[1.505; 6.306]	0.001
Rough	Medium	2.403	[0.041; 4.766]	0.046
Medium	Smooth	1.502	[-0.109; 3.114]	0.067

significantly greater than those of *Salix babylonica* and *Schima wallichii*, but there was no significant difference in the mean bark pH between the rests of the pairs of common host species (Table 3). There was significant positive linear relationship between tree size (dbh) and the number of *Rhynchostylis* individuals (p = 0.001), indicating that large-sized trees offer more space for the growth of the orchid.

The water holding capacity of the different host trees species was different. *Schima wallichii* had the highest water holding capacity with 112% of bark dry weight, while *Pinus roxburghii* had the lowest (14%) (Figure 3). We found high number of *Rhynchostylis* individuals on *Ficus religiosa* and *Alnus nepalensis* having moderate water holding capacity of 74% and 70%, respectively. Only few *Rhynchostylis* individuals were found on *Schima wallichii*, although it had high water holding capacity.

The ranking of the host bark rugosity in facilitating the occurrence of *Rhynchostylis* was rough>medium>smooth. The density of *Rhynchostylis* was significantly different between trees with rough and smooth bark (Student's t-test, p = 0.001), whereas the difference in density between the other bark types were marginal or insignificant (Table 4, Figure 4).

Most of the *Rhynchostylis* individuals were found under intermediate light conditions of 40-60% (Figure 5). Analysis of variance showed significant difference in the number of *Rhynchostylis* individuals under different light conditions (p = 0.002). However, pair-wise comparison revealed that between 40-60% and 60-80% sunlight intensity, the number

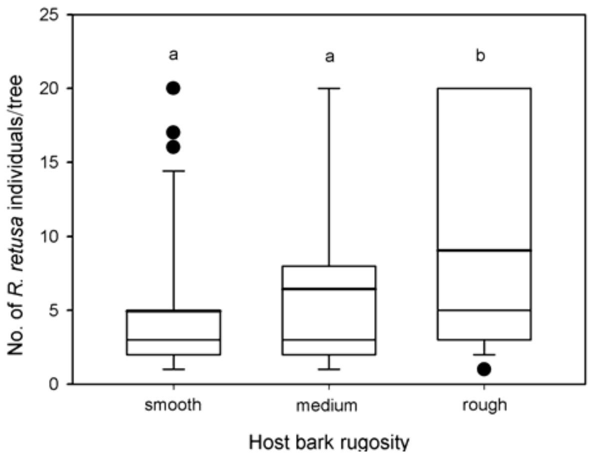

Figure 4. Number of *Rhynchostylis* individuals compared with host bark rugosity. Identical letters indicate that no significant difference in the number of individuals between groups (smooth vs. medium, smooth vs. rough, medium vs. rough) exist (pair-wise Student's t-test, $p<0.05$).

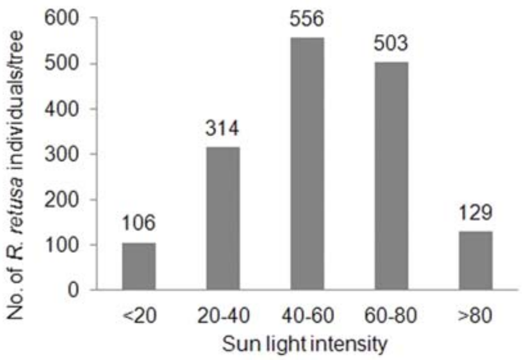

Figure 5. Distribution of *Rhynchostylis* in different light intensities (% of full sun light).

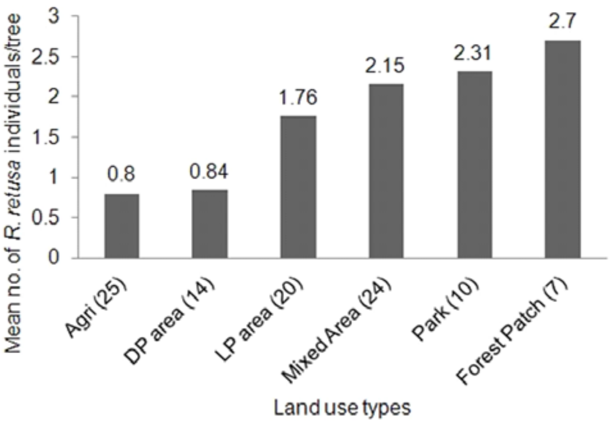

Figure 6. Mean number of *Rhynchostylis* individuals per tree in different land use types (Agri = agriculture, DP = densely populated, and LP = less populated areas). Values in parentheses represent number of sample points in each category.

of *Rhynchostylis* individuals was not significantly different (p = 0.084), but the number of individuals in these two levels of light intensities differed significantly when compared to the rest of the groups.

Average number of *Rhynchostylis* individuals per sample plot was highest in remnant forest patches, followed by park and temple complexes. The number was lowest in agricultural land and densely populated area, while the less populated area and the area used in a mixed way harbored intermediate number of *Rhynchostylis* (Figure 6). Isolated trees harbored lower number of *Rhynchostylis* individuals than the trees growing in groups, except some of very old and large trunked *Ficus religiosa*.

Discussion

MICROHABITAT OF *RHYNCHOSTYLIS*

The results of this study show that *Rhynchostylis* prefers a host bark pH ranging from 5.8 to 7.0 with a mean value for nearly all tested tree species around 6.5 and only for *Pinus roxburghii* a lower value (6.1). Many microsite factors may influence epiphyte colonization on trees, and bark pH alone is of less importance (Spier *et al*. 2010).

The water holding capacity of the bark of *Schima wallichii* was found to be higher than for any other host species tested (112% water compared to bark dry weight); but only few individuals of *Rhynchostylis* occurred. The most preferred host for *Rhynchostylis* was *Ficus religiosa*, although its water holding capacity was only around 75%. *Pinus roxburghii* was the poorest host with water holding capacity of 14%. Nevertheless, here *Rhynchostylis* was associated with other orchids (*Bulbophyllum affine* and *Dendrobium moniliforme*). The results indicate that water holding capacity itself is not important for the occurrence of *Rhynchostylis*. Callaway *et al.* (2002) and Bergstorm and Carter (2008) discussed several factors of pines hindering the growth of epiphytes, for instance, its bark resins content. Bark sloughability and low water-holding capacity probably worked together to make pines poor hosts for epiphytes.

Epiphytes prefer trees with rough bark than those possible hosts with smooth bark (Callaway *et al.* 2002). Our results indicate that *Rhynchostylis* also prefers rough bark. Rough-barked trees may be preferred hosts because seeds may become more easily lodged, and in such trees moisture retained for relatively longer periods of time (Zimmerman and Olmsted 1992). Most of the rough-barked trees in our study area belonged to *Ficus religiosa* and *Schima wallichii*, and indeed they harbor most or many *Rhynchostylis* individuals per tree (around 8 and 3, respectively; Figure 3). A similar result was found for *Psychilis monensis* by Tupac *et al.* (2007).

Our data suggest that *Rhynchostylis* accepts a wide range of light intensity. According to Callaway *et al.* (2002) light intensity is poorly correlated with epiphyte abundance. Our study, however, showed that the 40-80% light intensity seems to be preferred by *Rhynchostylis* (Figure 5). Few host species, like *Pinus roxburghii* and *Salix babylonica* harbor only few *Rhynchostylis* individuals, although offering the same light environment. The lower water holding capacity could be the reason to make both tree species as poor hosts for

Rhynchostylis. In addition, resin content in the bark of pine trees also hinders the growth of epiphytes (Callaway *et al.* 2002; Bergstorm and Carter 2008).

Altogether, we found that the microsite characteristics of the host tree species are influencing the probabilities of occurrence of *Rhynchostylis* to a certain degree. A very strong preference of *Rhynchostylis* for one host species or for one special site factor, however, cannot be found. This is in line with the results of Migenis and Ackerman (1993), while Callaway (1998) among epiphytic vascular species found some examples of such strong preference. Our study supports the earlier findings that large sized trees offer more space for the growth of orchid, and more substrate (humus) for the germination of their seeds and subsequent growth of seedlings (Heitz 1999; Bergstrom and Carter 2008; Hirata *et al.* 2009). Nevertheless, we also found a significant number of *Rhynchostylis* on small (dbh <5) trees and even on shrubs. Epiphytic orchids grow very slowly, especially by means of vegetative growth (Zotz 2007), and attain peak diversity and abundance in old stands of primary forests rather than in secondary forests of low tree size (Barthlott *et al.* 2001). One of the possible reasons is that forest structure developed over a long time, results in more complex, extensive, and stable habitats for epiphytes.

INTENSITY OF LAND USE AND *RHYNCHOSTYLIS*

Kathmandu valley is one of the most densely populated areas in the Himalayas, with still rapidely increasing population. Here pressure on natural resources is extremely high, specially cutting of trees in and around the valley. Our data revealed that the trees in the park and temple complexes, and remnant forest patches harbor more *Rhynchostylis* individuals than the trees in other land use types (Figure 6). Agricultural land and densely populated area harbor very low numbers of *Rhynchostylis* individuals per tree. This shows that stronger the human influence the lower will be the abundance of *Rhynchostylis*.

Population size of *Rhynchostylis* in all the studied land use types was small because not only the number of orchid individuals per tree was low but also the number of trees in such areas. Fortunately, in few points, *Ficus religiosa,* which harbored most of the *Rhynchostylis* populations, was preserved for religious purpose. Thus, protection of existing trees as well as additional plantation of host trees, especially *F. religiosa* is vital for conservation of *Rhynchostylis*. On the other hand, parks and remnant forest patches harbor higher number of *Rhynchostylis* individuals per host tree. Although there are only few forest patches and parks in Kathmandu valley, these are important for the stabilization of the *Rhynchostylis* population. There is no data on the former distribution of *Rhynchostylis* in Kathmandu valley, but the distribution pattern of this orchid in the study area makes it plausible to assume that the existing individuals mainly are relicts of previously larger populations.

CONSERVATION AND MANAGEMENT IMPLICATIONS

Our results clearly show that *Rhynchostylis* is mainly found either in groups of trees or in forest patches or park areas. To improve the population size of *Rhynchostylis* in Kathmandu valley, we suggest planting of new host trees in groups instead of single isolated trees. These trees should be planted in areas where *Rhynchostylis* population still exists to be able to provide suitable habitats for the orchids in the future. Our study shows that suitable host trees are *Alnus nepalensis, Ficus religiosa* and *Schima wallichii*. We suggest that habitats with a mixture of mature trees are essential for the conservation of large, viable populations of epiphytic orchids in longer run.

According to Zotz (2007), the growth and maturation of epiphytic orchids is extremely slow. The time from germination to maturation is estimated to be one decade (Hietz 1999). This reflects that a long-term management plan is needed where to make sure that enough suitable host trees are available for orchid colonization. This includes both protection of existing host trees and planting of new ones. Long-term studies are further needed to understand the relationship between temporal variation in environmental conditions and functioning of epiphytic orchid populations. Studying how sub-tropical epiphytes are affected by microclimate and intensity of land use yield critical information for the conservation of wild orchids in the face of ongoing rapid land-use and environmental changes.

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References

Acharaya K.P., Vetaas O.R. and Birks H.J.B. 2011. Orchid species richness along Himalayan elevational gradients. *Journal of Biogeography,* 38(9): 1821–1833

Bailes C.P. 1985. *Orchids in Nepal: Conservation and Development of Natural Resources*. Advisory report and recommendations. Royal Botanic Garden Kew, UK.

Bajracharya D.M. 2005. *The Genus* Eria *Lindl. (Orchidaceae) of the Himalayas*: *a Taxonomic Revision*. Ph.D. Dissertation. Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal.

Bajracharya D.M., Shakya L.R. and Chettri M. 1994. Need for conservation of some of endangered orchids of Ilam district. In: *Proceeding of the Second National Conference on Science and Technology*, pp. 663–669. Royal Nepal Academy of Science and Technology (RONAST), Kathmandu, Nepal.

Barthlott W., Neuerburg V.S., Nieder J. and Engwald S. 2001. Diversity and abundance of vascular epiphytes: a comparison of secondary vegetation and primary montane rain forest in the Venezuelan Andes. *Plant Ecology* 152: 145–156.

Benzing D.H. 1990. *Vascular Epiphytes General Biology and Related Biota*. Cambridge University Press, Cambridge, UK.

Bergstrom B.J. and Carter R. 2008. Host-tree selection by an epiphytic orchid, *Epidendrum magnoliae* Muhl. (green fly orchid), in an inland hardwood hammock in Georgia. *Southeastern Naturalist* 7: 571–580.

Bose T.K., Bhattacharjee S.K., Das P. and Basak U.C. 1999. *Orchids of India*. Naya Prakash Bidhan Sarani, Calcutta, India.

Callaway R.M. 1998. Are positive interactions species-specific? *Oikos* 82: 202–207.

Callaway R.M, Reinhart K.O., Moore G. W., Moore D.J. and Pennings S.C. 2002. Epiphyte host preferences and host traits: mechanisms for species-specific interactions. *Oecologia* 132: 221–230.

Chaudhary R.P., Subedi A., Shakya L.R., Karki, D. Vetas O.R. and Gupta V.N.P. 2002. Orchid diversity in Arun River and Marsyangdi River Valley of Nepal: distribution and conservation priorities. In: *Vegetation and Society* (R.P. Chaudhary, B.P. Subedi, O.R. Vetaas and T.H. Aase, eds.), pp. 108–117. Tribhuvan University, Kathmandu, Nepal and University of Bergen, Bergen Norway.

Cherevchenko T., Zaimenko N.V. and Martynenko O.I. 2001. Effect of Microgravity on Biology of Development and Physiological-Biological Peculiarities of Orchids with Different Morphoecotypes. In: *Microgravity Research and Aplications in Physical Sciences and Biotechnology*, (O. Minster and B. Schürmann, eds.), pp. 191. European Space Agency, ESA SP-454.

Christenson E. 2003. *Mschu Picchu: A Handbook to the Orchids of the Machu Picchu National Sanctuary*. The Peruvian Trust Fund for National Parks and Protected Areas (PROFONAPE), Lima, Peru.

Dressler R.L. 1993. *Phylogeny and Classification of the Orchid Family*. Harvard University Press, Cambridge, USA.

Farmer A.M., Bates J.W. and Bell J.N.B. 1990. A comparison of methods for the measurement of bark pH. *Lichenologist* 22(2): 191–197.

Frei J.K. 1973. Orchid ecology in a cloud forest in the mountains of Oaxaca, Mexico. *Bulletin of the American Orchid Society* 42: 307–314.

Frei J.K. and Dodson C.H. 1972. The chemical effect of certain bark substrates on the germination and early growth of epiphytic orchids. *Bulletin of the Torrey Botanical Club* 99: 301–307.

Gentry A.H. and Dodson C.H. 1987. Diversity and biogeography of Neotropical vascular epiphytes. Annals of Missouri Botanical Garden 74: 205–233.

Ghimire M. 2008. Epiphytic orchids of Nepal. *Banko Janakari* 18(2): 53–63.

Heitz P. 1999. Diversity and conservation of epiphytes in a changing environment. *Proceedings of the International Conference on Biodiversity and Bioresources: Conservation and Utilization,* pp. 23–27. Phuket, Thailand.

Hirata A., Kamijo T. and Saito S. 2009. Host trait preferences and distribution of vascular epiphytes in a warm-temperate forest. *Plant Ecology* 201: 247–254.

Kress W.J. 1986. The systematic distribution of vascular epiphytes: an update. *Selbyana* 9: 2–22.

Kromer T., Kessler M., Gradstein S.R. and Acebey A. 2005. Diversity patterns of vascular epiphytes along an elevational gradient in the Andes. *Journal of Biogeography* 32: 1799–1809.

Le Bui van, Hang Phuong N.T., Anh Hong L.T. and Thanh Van K.T. 1999. High frequency shoots regeneration from *Rhynchostylis gigantea* (Orchidaceae) using thin cell layers. *Plant Growth Regulation* 28: 179–185.

Madison M. 1977. Vascular epiphytes: their systematic occurrence and salient features. *Selbyana* 2: 1–13.

Medhi R.P. and Chakrabarti S. 2009. Traditional knowledge of NE people on conservation of wild orchids. *Indian Journal of Traditional knowledge* 8(1): 11–16.

Migenis L.E. and Ackerman J.D. 1993. Orchid-phorophyte relationships in a forest watershed in Puerto Rico. *Journal of Tropical Ecology* 9: 231–240.

Mitchell A.W., Secoy K. and Jackson T. 2002. The Global Canopy Handbook. Techniques of Access and Study in the Forest Roof. Global Canopy Programme, Oxford, UK.

Nieder J. P. and Michaloud G. 2001. Epiphytes and their contribution to canopy diversity. *Plant Ecology* 153: 51–63.

Partomihardjo T., Eizi S. and Junichi Y. 2004. Development and distribution of vascular epiphytes communities on the Krakatau Islands, Indonesia. *South Pacific Studies* 25: 7–26.

Press J.R., Shrestha K.K. and Sutton D.A. 2000. Annotated Checklist of the Flowering Plants of Nepal. British

Museum (Natural History), London, UK. And Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Rajbhandari K.R. and Bhattarai S. 2001. *Beautiful Orchids of Nepal*. Keshab R. Rajbhandari and Sushila Bhattarai, Kathmandu, Nepal.

Raskoti B.B. 2009. *The Orchids of Nepal*. Bhakta Bahadur Raskoti and Rita Ale, Kathmandu Nepal.

SAS Institute Inc. 2009. *JMP® Statistical Discovery Software Version 5.1.2*. SAS Campus Drive Cary, NC, USA.

Schmidt J., Kricke R. and Feige G.B. 2001. Measurements of bark pH with a modified flathead electrode. *Lichenologist* 33: 456–460.

Shakya L.R., Bajracharya D.M. and Chettri M.K. 1994. *Conserving the Threatened Orchids of Kathmandu Valley*. Report Series 8. WWF (World Wildlife Fund) Nepal Program, Kathmandu, Nepal.

Sharma A. 2010. *Diversity and Distribution Pattern of Epiphytic Orchids along Bhote Koshi Gorge (Upper Tamakoshi Valley), Dolakha, Central Nepal*. MSc. Dissertation, Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal.

Shrestha K. 1998. *Dictionary of Nepalese Plant Names*. Mandala Book Point, Kantipath, Kathmandu, Nepal.

Sparrow O. 1996. Orchids in the Nepal Himalaya distribution and ecology – part 3. *Orchid Review* 104: 105–108.

Spier L., Van Dobben H. and Van Dort K. 2010. Is bark pH more important than tree species in determining the composition of nitrophytic or acidophytic lichen floras? *Environmental pollution* 158(12): 3607–3611.

Subedi A. 2002. Orchids around Pokhara valley of Nepal. LI-BIRD Occasional Paper No.1, Local Initiatives for Biodiversity, Research and Development, Pokhara, Nepal.

Tupac O.J., Aragon S. and Ackerman J.D. 2007. Site variation in spatial aggregation and phorophyte preference in *Psychilis monensis* (Orchidaceae). *Biotropica* 39(2): 227–231.

Vance E.D. and Nadkarni N.M. 1990. Microbial biomass and activity in canopy organic matter and the forest floor of a tropical cloud forest. *Soil Biology and Biochemistry* 22: 677–684.

Vij S.P., Sood A. and Plaha K.K. 1984. Propagation of *Rhynchostylis retusa* BL. (Orchidaceae) by direct organogenesis from leaf cultures. *Botanical* Gazette 145: 210–214.

White K. and Sharma B. 2000. *Wild Orchids in Nepal*. The Guide to the Himalayan Orchids of the Tribhuvan Rajpath and Chitwan Jungle. White Lotus Press, Bangkok 10501, Thailand.

Wolf J.H.D., Gradstein S.R. and Nadkarni N.M. 2009. A protocol for sampling vascular epiphyte richness and abundance. *Journal of Tropical Ecology* 25: 107–121.

Zimmerman J.K. and Olmsted I.C. 1992. Host tree utilization by vascular epiphytes in a seasonally inundated forest (Tintal) in Mexico. *Biotropica* 24: 402–407.

Zotz G. 2007. Johansson revisited: the spatial structure of epiphyte assemblages. *Journal of Vegetation Science* 18: 123–130.