COMMUNICATION

**SPECIES DIVERSITY AND ABUNDANCE PATTERNS OF EPIPHYTIC ORCHIDS IN ARALAM WILDLIFE SANCTUARY IN KERALA, INDIA**

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Species diversity and abundance patterns of epiphytic orchids in Aralam Wildlife Sanctuary in Kerala, India

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Abstract: Species diversity and abundance patterns of epiphytic orchids were studied in Aralam Wildlife Sanctuary, in the Western Ghats of northern Kerala. Habitats sampled were wet evergreen (EVEG), montane wet evergreen (MEVG), moist deciduous (MDEC), and semi evergreen (SEVG), on a gradient of altitude from 60 to 1,589 m. Selective tree scanning on linear line transects was deployed (n= 40) across spatial units. A total of 39 orchid species were recorded. Rarefied species richness was maximum in the EVEG (20) habitat. Best suited rank abundance models were analysed for epiphytic orchids in each habitat and checked for significant differences. Bootstrap and Jackknife-1 estimators and species accumulation curves suggested higher species richness than observed, therefore more effort in sampling was needed in order to record all epiphytic orchids of the area. The difference in species richness between habitat types was not statistically significant (ANOVA). 38% of recorded epiphytic orchid species were endemic.

Keywords: Endemic, Orchidaceae, terrestrials, Western Ghats.
INTRODUCTION

Epiphytes, a significant group of slow growing plants (Benzing 1990), are more associated with tropical rain forests compared to temperate forests (Webb 1959; Richards et al. 1996). Orchidaceae are dominant among tropical rainforest epiphytes, possibly due to adaptations to temporary water stress in different climates and microclimates (Benzing 2004). Orchids make major contributions to the forest communities they inhabit (Nadkarni 1994) and they are also valued for their horticultural, medicinal, ethical, and edible prospects.

The Western Ghats is home to 310 orchid species, of which 123 are not found elsewhere (Jalal & Jayanthi 2012), and in Silent Valley National Park 50% of total epiphytes recorded are orchids (Kumar 1999). The Western Ghats are now inhabited by almost 50 million people, which has resulted in extensive transformation of landscapes, over exploitation of natural resources, habitat degradation, habitat loss, and encroachment. Selective removal of orchids for ornamental and medicinal purposes without considering their ecological attributes is globally identified as a threat to orchids (Huang 2011). In order to have a conservation strategy for specific species or groups in a region, it is important to know their ecology. However, taxonomic confusion persists in the region over endemic orchid species and sub species. In a moist lowland forest in the eastern Himalaya, selective logging was found to affect structural complexity of trees and hence associated microclimates, gradually threatening pteridophytes, non-orchids, and orchids (Padmawathe et al. 2004). The extensive forests of the Western Ghats become a challenge for an ecologist when groups such as orchids with random distribution is in focus. Epiphytes have been associated with trunk size in tropical evergreen forest in the Western Ghats (Annaselvam & Parthasarathy 2001). Apart from taxonomic explorations, diversity and ecology of Dendrobium in Chotanagpur plateau (Kumar et al. 2011), epiphytic orchid diversity from farmer managed forests in the Western Ghats (Sinu et al. 2011), habitat studies of medicinal orchids (Jalal & Rawat 2009), and conservation strategies for orchids of western Himalaya (Jalal 2012) are the only existing ecological works on orchids from India.

In order to fill this gap, the authors have examined ecological aspects of epiphytic orchids in the Western Ghats of Kerala. This study deals with the epiphytic orchids in Aralam Wildlife Sanctuary (WS) in Kannur district of northern Kerala. Aralam WS falls in Wayanad Plateau in the southern Western Ghats. The objectives of this study were to assess patterns of species diversity, abundance, and endemism among epiphytic orchids in Aralam WS.

STUDY AREA

The Aralam WS is situated between 11.900–11.983°N 75.783–78.950°E spanning around 55 km² (Figure 1). The elevation varies from 60m to ca. 1,589m from mean sea level with two major peaks, the Katti Betta (1,145 m) and the Ambalapara (1,589 m). The temperature varies from 21°C to 40°C in the lower altitudes and 8 °C to 25 °C at the higher reaches. The south-west and the north-east monsoons together give annual rainfall between 3,745 mm and 5,052mm. The Sanctuary land slopes from the east to the west, is drained by the Cheenkannippuzha, which flows to the west. Aralam WS is known for the west coast tropical evergreen forest where the unique Dipterocarpus-Mesua-Palaquium sub-type is seen (Nair 1991). There are about 490 ha of Teak and Eucalyptus plantations within the forest area (Manju et al. 2009). Apart from this, the vegetation of the Sanctuary can be classified into low (0–800 m) and medium (801–1,450 m) elevation types of wet evergreen, semi evergreen, moist deciduous, and high elevation (>1,450m) montane wet evergreen or hilltop evergreen forest (Champion & Seth 1968; Ramesh 2001). The floristic composition of Ambalapara region differs considerably from shola forests (Menon 1999; KFD 2009; Manju et al. 2009). The trees of this part are stunted, usually below 20m, belonging to Laurales and Myrtales, with trunks of heavy loads of epiphytic plants. Therefore, the vegetation from 1,450 to 1,700 m elevation is treated as high elevation/montane wet evergreen forest (MEVG).

The animal diversity of the Sanctuary was comparatively well studied (Radhakrishnan 1996; Abraham & Easa 1999; Nair 2001, 2003; Sreekumar & Balakrishnan 2001 etc), but reports on plant diversity are very few (Menon 1999) and mostly limited to bryophytes and pteridophytes (Manju et al. 2009; Dantas et al. 2016; Rajesh & Vijisha 2016). So far, 47 orchid species have been reported from the Sanctuary of which 20 are endemic to India (KFD 2009).

METHODS

Field sampling

Field sampling was done from September to November in 2015. Selective tree scanning (to ensure
representation of vertical distribution and diversity of orchids on linear line transects (to enable spatial scaling of orchids in heterogeneous habitats) was developed (Sebastian et al. 2017) through trial and error integrating sampling of vascular epiphyte richness and abundance (SVERA, Wolf et al. 2009) and line transects (Jacquemin et al. 2007). Transects were laid 100 m from each other in linear direction in different habitat types based on the presence of epiphytic orchids (see Table 1). A line transect was laid after finding a host tree with at least three individuals of orchids on it. Then, the next neighbouring tree was selected at the 10th meter point from the first individual and this was repeated until data collected from a total of 10 individual trees from each line transect. Data on three levels of sampling were taken from each transect. Data on characteristics of habitat, host tree, and the substrate (immediate surrounding) of orchids were recorded. Due to limitations in canopy access, orchid species were identified with a pair of binoculars (VORTEX 8X42) from ground, using the field key (Pradhan 1976, 1979; Abraham & Vatsala 1981; Joseph 1982; Kumar & Manilal 1994, 2004).

Statistical analysis
Statistical analysis of data from 40 transects was performed using statistical software R (version 3.5.0) and PAST 3.19. Orchids were ranked based on their abundance to check on singletons and doubletons. Due to the difference in the number of transects in different spatial units, rarefied diversity indices were estimated. Different habitats were compared using graphical representation of diversity indices and dominance indices in point plots to focus on difference with the help of error bars from bootstrap sampling. Rank abundance model (rad) for habitats was prepared using the best suited model (with lowest Akaike Information Criteria, AIC) to visualise the site diversity/dominance. In order to understand total species richness of epiphytic orchids in Aralam, total species was estimated based on incidence-based estimators. Species accumulation curve was prepared for species across transects in habitats using random accumulator function based on individual accumulation model. The rarefied species richness was compared across habitats. The significance of difference was tested using ANOVA and Welch T-test. The proportion of endemic species richness and abundance in the sample was plotted as a bar diagram and has been compared with a previous research paper.

RESULTS AND DISCUSSION

Patterns in species diversity and abundance
In total, we found 2,831 individuals belonging to 39 species of epiphytic orchids (a complete species list is given in Table 2) from 400 individual trees (of >10cm GBH) spread across 40 transects. Also, 29 terrestrial orchids (of which, nine were unconfirmed species but morphologically distinct) were recorded from the study area. Bulbophyllum fischeri and B. fuscopurpureum were found growing both as epiphyte and terrestrial forms. The host trees sampled were grouped into 96 species and 15 unidentified species that were morphologically distinct. Among orchids, Gastrochilus acaulis was present in all habitats followed by Cleisostoma tenuifolium, Cottonia peduncularis, and Liparis viridiflora in three habitats each. The common species with the highest abundance was Cleisostoma tenuifolium. Two species
were recorded with single individuals (singletons) and another six species were represented by two individuals (doublet) each.

Species Abundance Distribution (SAD) model, based on rank abundance of species for each habitat (Figure 2), explained the diversity of respective habitats with the help of basic models Null, Pre-emption, and Lognormal. Rank abundance models with least AIC values suggested an abundance model for each vegetation (habitat) type (Table 3). The relative abundance of species against their rank in EVEG habitat, best explained by the Null model, indicates that individuals are randomly distributed among observed species. Whereas, the Log normal model explained ranking based on relative abundance in MDEC and SEVG habitats as the abundance of species are in normal distribution with high evenness among species. Pre-emption model fitted to MEVG habitat describes least evenness among species with respect to the distribution of individuals. Interestingly, MEVG habitat had four dominant species: Bulbophyllum fischeri, Sirlhookera lanceolata, Coelogyne nervosa, and Conchidium microchilos, while other species were barely represented.

EVEG habitat recorded 20 species with just 579 individuals, whereas SEVG habitat recorded 12 species with the highest abundance of 1,253 (Table 4). Biodiversity indices such as Shannon-Weiner index, Margalef & Fisher alpha showed variations with high diversity in EVEG, and the lowest was in SEVG habitat (Figure 3). Meanwhile, in a comparison of Simpson 1-D values (Figure 4), a dominance index that accounts for diversity and evenness between habitats, only EVEG and MEVG were significantly different from each other (Mann-Whitney pairwise test, df= 3, at p= 0.05). MEVG habitat had only one species in common with other habitats. Six species were found shared between MEVG and EVEG habitat with more or less equal individuals. MEVG significantly differed from EVEG with the presence of five unique species, and of which species, Bulbophyllum fischeri was well represented in number of individuals. Furthermore, higher abundance of species, Dendrobium nutans in MEVG from that of EVEG habitat could have also contributed to it. EVEG habitat with Simpson 1-D value 0.92 indicated highest diversity amongst and SEVG habitat the lowest with 0.74. SEVG habitat showed maximum abundance per species and the abundance distribution across species was found to be in normal distribution with high evenness.

The transects were standardised and rarefied species richness was estimated for minimum and maximum abundances. Total species richness was estimated for Aralam WS based on this rarefied data. One species per transect was added on average in accumulation of species for total species richness. The species observed, Sobs, was close to the bootstrap estimator which predicted a total of 46 species whereas, Chao estimator provided the highest predicted richness, 74 for the WS. This indicates the need of more transects to get a better picture about the distribution pattern of species and abundance of epiphytic orchids of Aralam WS. The relationship between species and individuals in each habitat was plotted (Figure 5). The number of species initially increased in a strong and steady manner along with the addition of individuals in habitats such as EVEG and MDEC. This clearly indicated the spacing of species in these habitats were not too far from each other. At the same time, the pattern of species accumulation was very gradual in MEVG and SEVG habitats in the beginning as a result of larger spacing between species in a wider area when compared to shorter spacing in EVEG and MDEC. Then the addition of individuals to species in SEVG reached an asymptote indicating that epiphyte assemblage in SEVG is not as diverse as other habitats but represented by high abundance. A comparison between rarefied species richness for minimum and maximum abundances in habitat types was tested (Figure 6). However, they were not statistically significantly different from each other (ANOVA at p =0.05, df= 3). MEVG shared only one common species between SEVG and MDEC. However, MDEC and SEVG had nine common species. Lastly, EVEG shared six species with MDEC; seven species with MEVG; seven species with SEVG. Four habitats shared only one species in common.

The total extent of the study area is just 55 km² and it contains at least four major habitat types, other than plantations and riparian forests. The distribution of different habitats within the study area is highly contiguous and not continuous that creates several ecotones at places. Although the present study covered maximum area in each habitat the present results clearly shows the diversity in microhabitats and microclimates within each habitat type as the estimated species richness (74 species) differed greatly to that of observed species richness (39 species). Therefore, an approach involving identification of different microhabitat and microclimate zones should be deployed to maximise the likelihood of recording maximum species in the study area. Further, species abundance pattern (Figure 2) across different habitats varies greatly and different habitats fit in with different SAD models with different patterns of distribution of species.
Orchids in Aralam Wildlife Sanctuary
Sebastian et al.

Endemism

Endemism among epiphytic orchids of Aralam WS deserves further attention, as 29% of total orchids (N= 62) and 38% of epiphytic orchids (N= 39) from the area were endemic to the Western Ghats (Figure 7). Abundance of endemic orchids alone made up 28% of total abundance. However, the difference in endemic species richness and abundance between habitats was not significant (Kruskal Wallis test, \( p = 0.8 \)). Interestingly, of these endemic orchids, eight species were seen only in one habitat and five species in two habitats each. However, associations amongst species with respect to habitat could not be identified with sample size as low as 40 transects. Furthermore, three terrestrial endemics were also recorded. These terrestrial endemics such

**Table 2. The list of identified epiphytic and terrestrial orchids from Aralam Wildlife Sanctuary, Kannur.**

| Species              | Epiphytic | Terrestrial | Endemic** |
|----------------------|-----------|-------------|-----------|
| Aerides crispa       | +         | -           | -         |
| Aerides ringens      | +         | -           | -         |
| Bulbophyllum fischeri| +         | +           | -         |
| Bulbophyllum fuscopurpureum | +     | +           | -         |
| Bulbophyllum neilgherrense | + | -           | -         |
| Bulbophyllum tremulum| +         | -           | -         |
| Chiloschista pusilla | +         | -           | -         |
| Cleisostoma tenuefolium | +    | -           | +         |
| Coelogyne mossiae    | +         | -           | +         |
| Coelogyne nervosa    | +         | +           | +         |
| Conchidium exile     | +         | +           | +         |
| Conchidium microchilos| +       | +           | -         |
| Cottonia peduncularis| +        | -           | -         |
| Cymbidium aloifolium | +         | -           | -         |
| Dendrobium aquem     | +         | -           | +         |
| Dendrobium macrostachyum | +    | -           | -         |
| Dendrobium microbulbon| +        | +           | +         |
| Dendrobium jerdonianum| +       | -           | -         |
| Dendrobium ovatum    | +         | -           | +         |
| Dendrobium panduratum| +         | -           | -         |
| Eria reticosa        | +         | -           | -         |
| Gastrochilus acaulis | +         | -           | -         |
| Gastrochilus flabelliformis| +       | -           | -         |
| Phalaenopsis deliciosa| +       | -           | -         |
| Liparis elliptica    | +         | -           | -         |
| Liparis viridiflora  | +         | -           | -         |
| Oberonia branoniana  | +         | -           | +         |
| Oberonia santapauli | +         | -           | +         |
| Oberonia tenuis      | +         | -           | -         |
| Papilionanthe subulata| +       | -           | -         |
| Pholidota imbricata  | +         | -           | -         |
| Pomatoscapa spicata  | +         | -           | -         |
| Porpax jerdoniana    | +         | -           | +         |
| Porpax reticulata    | +         | -           | -         |
| Rhynchosylis retusa  | +         | -           | -         |
| Seidenfadeniella rosea| +        | -           | +         |
| Siriookeria lanceolata| +        | -           | -         |
| Smithsonia straminea | +         | -           | +         |
| Bulbophyllum stocksii| +         | -           | -         |
| Calanthe sylvatica    | -         | -           | -         |
| Cheirostylis flabellata| -      | -           | -         |
| Disperis neilgherrensis| -     | -           | -         |
| Eria alboflora       | -         | -           | +         |
| Habenaria gibsonii var. gibsonii| - | - | + |
| Habenaria longicorniculata| -    | -           | -         |
| Habenaria perrotettiana| -      | +           | -         |
| Mellea gracilis      | -         | -           | -         |
| Pecteilis gigantea    | -         | -           | -         |
| Satyrium nepalense    | -         | -           | -         |
| Siriookeria latifolia | -       | -           | +         |
| Tania biornis         | -         | -           | -         |
| Tropidia angulosa     | -         | -           | -         |
| Brachycorythis Iantha | -         | +           | -         |
| Liparis sp.*          | -         | -           | -         |
| Liparis sp.2*         | -         | -           | -         |
| Bulbophyllum sp.*     | -         | -           | -         |
| Bulbophyllum sp. 2*   | -         | +           | -         |
| Cheirostylis sp.*    | -         | -           | -         |
| Oberonia sp.*        | -         | -           | -         |
| Spiranthes sp.*      | -         | -           | -         |
| Zeuxine sp.*          | -         | +           | -         |

*genus with unconfirmed species. ** Endemics (Jalal 2012; Kumar et al. 2000; Jayalakshmi 2016).
as *Eria albiflora, Brachycorythis iantha* and *Habenaria perrotettiana* belonged to MEVG habitat but data was not sufficient to check if relationships existed with the habitat. Chao and ACE estimators suggested all endemic epiphytes of Aralam had been obtained through sampling from 40 transects. Species estimation for endemic epiphytes in Aralam WS was compared with that of entire southern western Ghats in Kerala (Figure 8). Species accumulation curve was almost stabilized at 181th transect for data on endemic epiphytic orchids from entire southern Western Ghats in Kerala (Refer Sebastian et al. 2017). Further, high endemic epiphytic species diversity and abundance was observed in EVEG habitat followed by MEVG in Aralam WS.

**CONCLUSION**

The total number of epiphytic orchid species recorded in this study was 62, higher than noted...
It is remarkable that all four habitat types possessed distinct epiphytic orchid diversity, and that sharing occurred mostly along transition zones. Based on different diversity indices explored, EVEG was the most diverse habitat for epiphytic orchids. Next, MDEC, MEVG, and SEVG habitats shared a more or less equal number of species. As Annaselvam & Parthasarathy (2001) discussed, sometimes epiphytic orchids that preferred deciduous trees in low wet evergreen forests contributed largely to abundance. As per the rate of species accumulation in response to individuals, EVEG habitat clearly varied from other habitats as was also indicated by the dominance index. Nonetheless, with few more transects all habitats could have added new species. In MEVG habitat the best explained rad model pre-emption was rather steep compared to suggested models for other habitats. This indicated less species evenness in MEVG habitat. Generally, log-normal models indicate habitats that are at equilibrium or perturbation is maintained, here for SEVG and MDEC. Whereas undisturbed forest such as EVEG and MEVG, however, may not necessarily be at equilibrium and do not fit log normal, a model for undisturbed habitat. A hierarchy based on dominance was evident in MEVG with less species evenness and therefore best explained by dominance pre-emption model. Null model for EVEG indicated a more neutral community with no species interactions among them and species equivalence or in other words more random. This might be because of the random distant presence of species or individuals in EVEG when compared with MDEC, where the species distribution was rather closer. Because of the absence of distinct patterns in composition from sampled data there...
Orchids in Aralam Wildlife Sanctuary

Sebastian et al.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 July 2021 | 13(8): 19060–19069

Table 4. Orchid diversity across habitat types.

|  | EVEG (N= 12) | MDEC (N= 6) | MEVG (N= 9) | SEVG (N= 13) |
|---|---|---|---|---|
| Rarefied species richness* | 20 | 13 | 12 | 12 |
| Individuals | 579 | 679 | 317 | 1253 |

*Rarefied at 301 individuals

Figure 7. Pattern of (left) abundance (abd) and (right) species diversity (sp) of endemic epiphytic orchids in total sampled orchids from Aralam WS.

Figure 8. (left) Species richness and estimated richness using Chao in Aralam WS (right) species accumulation of endemic epiphytic orchids from 181 transects in the southern Western Ghats of Kerala, showing the observed and the estimated Chao-1 means (Refer: Sebastian et al. 2017).

was no significant difference between species richness across habitats. The trend of results suggested a possible preference of epiphytic orchids towards evergreen habitats. The two habitats of evergreen nature gathered 27 epiphytic orchid species of a total 39 species.

Wet evergreen and montane wet evergreen habitats from low to high elevations also supported both epiphytic and terrestrial endemic orchids in Aralam WS. It is suggested that long term research in these habitats could throw light on new perspectives on distribution of Endemic orchids. This area is located in Nilgiris-Silent valley-Wayanad-Kodagu region, a centre of endemism in the Western Ghats. This probably contributed to the high rate of endemism. Of 62 orchid species, 18 represented endemic orchids of the Western Ghats. Endemic orchids obtained from Aralam WS exhibited similar distribution patterns in as other studies (Sebastian et al. 2017).

The results obtained shows that all studied habitat
types contribute to epiphytic orchid diversity and abundance in Aralam WS. An integrated approach to address both epiphytic and terrestrial orchids might pave the way to understanding the pattern of endemism among orchids. The location, size and diversity of the Aralam WS provides an opportunity for scientists to do a full-fledged experimental study on the mechanisms behind its floral and faunal diversity.

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