Acta Oecologica 83 (2017) 1–14

Contents lists available at ScienceDirect

Acta Oecologica

journal homepage: www.elsevier.com/locate/actoec

The effect of altitude, patch size and disturbance on species richness and density of lianas in montane forest patches

Dharmalingam Mohandass [a, f, *], Mason J. Campbell [b], Alice C. Hughes [c], Christos Mammides [a, d], Priya Davidar [e]

[a] Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden (XTBG), Chinese Academy of Sciences, Menglun Town, Yunnan 666 303, PR China
[b] Centre for Tropical Environmental and Sustainability Science (TESS) and College of Science and Engineering, James Cook University, Cairns, Queensland, 4878, Australia
[c] Centre for Integrative Conservation, Xishuangbanna Tropical Botanical Garden (XTBG), Chinese Academy of Sciences, Menglun Town, Yunnan 666 303, PR China
[d] Guangxi Key Laboratory of Forest Ecology and Conservation, College of Forestry, Guangxi University, Daxuedonglu 100, Nanning, 530004, PR China
[e] Department of Ecology and Environmental Sciences, Pondicherry University, Kalapet, Puducherry 605 014, India
[f] Root and Soil Biology Laboratory, Department of Botany, Bharathiar University, Coimbatore 641 046, India

A R T I C L E I N F O

Article history:
Received 30 June 2016
Received in revised form
7 June 2017
Accepted 8 June 2017
Available online 17 June 2017

Keywords:
Climbing guilds
Dispersal mode
Liana abundance
Natural patches
Shade tolerance
Species-area relationships

A B S T R A C T

The species richness and density of lianas (woody vines) in tropical forests is determined by various abiotic and biotic factors. Factors such as altitude, forest patch size and the degree of forest disturbance are known to exert strong influences on liana species richness and density. We investigated how liana species richness and density were concurrently influenced by altitude (1700–2360 m), forest patch size, forest patch location (edge or interior) and disturbance intensity in the tropical montane evergreen forests, of the Nilgiri and Palni hills, Western Ghats, southern India. All woody lianas (≥1 cm dbh) were enumerated in plots of 30 × 30 m in small, medium and large forest patches, which were located along an altitudinal gradient ranging from 1700 to 2360 m. A total of 1980 individual lianas were recorded, belonging to 45 species, 32 genera and 21 families, from a total sampling area of 13.86 ha (across 154 plots). Liana species richness and density decreased significantly with increasing altitude and increased with increasing forest patch size. Within forest patches, the proportion of forest edge or interior habitat influenced liana distribution and succession especially when compared across the patch size categories. Liana species richness and density also varied along the altitudinal gradient when examined using eco-physiological guilds (i.e. shade tolerance, dispersal mode and climbing mechanism). The species richness and density of lianas within these ecological guilds responded negatively to increasing altitude and positively to increasing patch size and additionally displayed differing sensitivities to forest disturbance. Importantly, the degree of forest disturbance significantly altered the relationship between liana species richness and density to increasing altitude and patches size, and as such is likely the primary influence on liana response to montane forest succession. Our findings suggest that managing forest disturbance in the examined montane forests would assist in conserving local liana diversity across the examined altitudinal range.

1. Introduction

Throughout the tropical forests of the world, the diversity and abundance of plants is often associated with underlying environmental gradients and ecological interactions (Whittaker, 1962; Slik et al., 2009). Lianas (woody vines) are no exception with both their abundance and diversity varying in response to numerous abiotic and biotic factors (Gentry, 1991; Vázquez and Givnish, 1998; Schnitzer and Bongers, 2005; Homeier et al., 2010; Schinzter and Bongers, 2011; Laurance et al., 2014b; DeWalt et al., 2015; Mohandass et al., 2015; Campbell et al., 2015). In particular,

* Corresponding author. Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden (XTBG), Chinese Academy of Sciences, Menglun Town, Yunnan 666 303, PR China.
E-mail address: dmohandass997@yahoo.com (D. Mohandass).

http://dx.doi.org/10.1016/j.actao.2017.06.004
1146-609X/

several studies have investigated the response of liana diversity and abundance to the individual impacts of altitudinal variation, forest disturbance, forest fragmentation and patch area (Laurance et al., 2001; Parthasarathy et al., 2004; Jiménez-Castillo et al., 2007; Mohandass et al., 2014; Laurance et al., 2014a, 2014b). For instance, as a single factor, increasing altitude has previously been shown to result in decreased (though rarely increased) liana diversity and density in various montane forests (Gentry, 1991; Vázquez and Givnish, 1998; Bhattarai and Vetaas, 2003; Chettri et al., 2010). Moreover, in combination with increasing altitude, liana diversity has also been found to increase (also rarely to decrease) with increasing fragment area due to colonization and succession of natural forest patches (Gonzalez et al., 2010; Mohandass and Davidar, 2010; Mohandass et al., 2014; Hu et al., 2012). Conversely, liana species diversity has been found to decrease, despite increasing forest patch area, due to deforestation/excessive disturbance of patches and fragmentation related affects such as edge effects (Fletcher et al., 2007; Mohandass et al., 2014). This can lead to an enhanced, intra-patch extinction rate of lianas (Laurance et al., 2001; Pan, 2013). Therefore, understanding the nuances of the combined effects of altitude, forest patch size and disturbance intensity on liana species richness and density is important for determining natural expansion processes occurring within vegetation of a high-altitude landscape. Consequently, in the current study, we aim to examine how liana abundance responds to the combined effects of altitude and patch area, particularly as these factors have previously been examined in isolation but not in conjunction with one another.

Plants diversity and ecological processes such as dispersal, seedling growth and abundance may display significant variation between forest edge and forest interior habitats (Laurance, 1997; Benítez-Malvido and Lemus-Albor, 2005; Harper et al., 2005; Magrach et al., 2014). Edge-related changes in plant ecological processes may occur due to variations in abiotic conditions (light, soil moisture, etc.) on forest edges, relative to the forest interiors, which can result in measurable differences in forest edge structure, species composition and ecological interactions (Fagan et al., 1999; Chaplin-Kramer et al., 2015; Magnago et al., 2015). For example, previous studies have found certain species of trees (i.e. pioneer) and liana seedling survival and growth are higher along forest edges than in the forest interior (Benitez-Malvido and Martinez-Ramos, 2003; Laurance et al., 2006; Guzmán-Guzmán and Williams-Linera, 2006; López-Barrera et al., 2006). However, little is known of whether these ecological changes are transient or persistent and more importantly whether they are influenced by gradients such as altitude and fragment patch area. Therefore in this study we assessed the liana species richness responses of lianas within three eco-physiological guilds delineated by fruit dispersal, shade tolerance and climbing mechanism in relation to increasing altitude, patch size and forest patch location (edge or interior). Additionally, it is known that the functioning of these liana ecological guilds may be disrupted by natural and human disturbances (Addo-Fordjour et al., 2009, 2012, 2013). For instance, tree extraction is known to cause canopy gaps to develop which may become particularly acute in highly disturbed patches. Tree fall/extraction gaps may favor the proliferation and enhanced diversity of liana due to their clonal regenerative ability, the higher light availability and enhanced climbing trellis availability gaps afford (Schnitzer and Carson, 2001, 2010; Schnitzer and Bongers, 2005; Schnitzer and Carson, 2010; Ledo and Schnitzer, 2014). Therefore, this study is not only the first to examine the individual and combined effect of altitude, patch size and disturbance intensity on the liana community within the endangered upper montane forests of the Western Ghats of southern India, but also on the ecological functioning/guilds of this community. In summary, within this study we examined the following hypotheses: (1) liana species richness and density will decrease with increasing altitude between 1700 and 2360 m; (2) liana species richness and density will increase with increasing forest patch size; (3) liana species richness and density in the forest edge and forest interior zones will decrease with increasing altitude and increase with increasing patch size; (4) liana species richness and density will respond differently in the various eco-physiological guilds (shade tolerance, dispersal mode and climbing mechanism) to increasing altitude, patch size and disturbance intensity; and (5) disturbance intensity will influence liana species richness and density and interact synergistically with altitude and forest patch size.

2. Materials and methods

2.1. Study area

Lianas were inventoried in selected tropical montane evergreen forest patches of the Nilgiri and Palni hills of the Western Ghats, southern India. In the Nilgiri hills, inventories were conducted in five sites: Kodanadu, Ebanadu, Amaggal, Korakundah and Upper Bhavani reserve forest (Fig. 1). In Palni hills, the only study area was the Kukkal site. The altitude of the studied sites ranged between 1700 and 2360 m for both the Nilgiri and Palni hills. Across all altitudinal ranges, the local topography was generally steep, mountainous slopes. The bedrock of the study region is composed of gneisses, charnockites and schists (von Lengerke, 1977) and the soils are largely Andisols which contain a high percentage of iron and alumina (Meher-Homji, 1967; Caner et al., 2007).

The tropical montane evergreen forests of the Nilgiri and Palni regions occur as small discrete patches, confined to valleys and hollow depressions at high elevations (1500–2400 m), and usually range in size from 0.01 ha to 50 ha, although larger patches do occasionally occur. These forests are predominantly made up of evergreen, stunted, short-boled trees, seldom higher than 10 m and with a dense crown (Meher-Homji, 1967; Mohandass et al., 2014). The dominant tree genera across the study area were *Litsea* (Lauraceae), *Symplocos* (Symplocaceae), and *Syzygium* (Myrtaceae) (Mohandass and Davidar, 2009). However, in the forest of the Kukkal site, the trees were taller (30–40 m height) and the dominant tree genera were *Xantolis* (Sapotaceae), *Cassine* (Celastraceae), *Cinnamomum* (Lauraceae) and *Litsea* (Lauraceae) (Davidar et al., 2007).

Over a twelve year period (1996–2007), the mean annual rainfall recorded at the Korakundah Tea Estate, located 10 km away from the Upper Bhavani site and 15 km away from the Amaggal Reserve forest site, was 2108 mm. Between 2002 and 2007, the mean annual rainfall recorded at the Ootacamund Meterological station was 1590 mm, this station is 10–15 kms north-west of the Ebanadu field site and north-east of the Kodanadu field site respectively. Finally, over a four-year period (2001–2004), the mean annual rainfall for the Kukkal site was 1690 mm (Davidar et al., 2007). All the study sites received rainfall from both the South-west and North-east monsoonal rainfall patterns during the local wet season, whilst the local dry season occurred from December to March. The dry season in this case was defined as the series of continuous months where rainfall was less than 100 mm, which was between 4 and 7 months for the study area (Davidar et al., 2007; Mohandass et al., 2014). The general climate of the study area is cold and dry, with daily temperature ranging from 0 °C to 23 °C (Mohandass and Davidar, 2010) and frost may occur in the period December to February.