LOGGING IMPACTS ON LIANA REGENERATION AND DIVERSITY IN BELIZE

S Mesh[1], DT Cayetano[1], E Requena[2], E Alvarez[3], E Kay[1], A Finkral[4], A Roopsind[4], * & FE Putz[5]

[1] *University of Belize Environmental Research Institute, Price Center Road, Belmopan City, Belize.*

[2] *Toledo Institute for Development and Environment, Mile 1 San Antonio Road, Punta Gorda Town, Belize.*

[3] *Yalbac Ranch and Cattle Corporation, Mile ½ Iguana Creek Road, Spanish Lookout, Belize.*

[4] *The Forestland Group, Chapel Hill, NC 27514, USA*

[5] *Department of Biology, University of Florida, Gainesville, Florida 32641, USA*

aroopsind@gmail.com

Lianas play important ecological roles and are represented by large numbers of species in tropical forests, but to timber managers, they are a nuisance as they inhibit commercial tree recruitment and growth, increase the risk of injuries to forest workers and increase collateral damage during timber harvests. To determine the response of lianas to a low-intensity selective timber harvest (2.7 trees ha^{-1}, 2.9 m^3 ha^{-1}) carried out with reduced-impact logging (RIL) techniques, liana regeneration was measured on 11 log landings and each of their associated primary skid trails, secondary skid trails and felling gaps. The study was conducted 10 months after a timber harvest in a lowland mixed tropical forest in Belize. Liana diversity, abundance and modes of regeneration (i.e. seed versus vegetative sprouts) were assessed by taxonomic family. Lianas were least abundant on log landings that experienced complete topsoil removal. Similarly, taxonomic family diversity and Shannon's entropy based on Renyi's diversity profile were lowest on log landings. Lianas, particularly those that regenerated directly from seeds, increased in abundance from felling gaps to secondary skid trails to primary skid trails. Liana recruitment was dominated (in order of decreasing abundance) by species in the Fabaceae, Bignoniaceae and Dilleniaceae. Fabaceae contributed the majority of seed-origin liana regeneration while most vegetative sprouts were Bignoniaceae. The results indicated that the low intensity RIL harvest studied retarded liana regeneration only on log landings and did not result in liana proliferation or extreme changes in liana community composition.

Keywords: Climbing plants, reduced-impact logging, tropical forest, vines, timber harvest

INTRODUCTION

In many lowland tropical forests, lianas contribute large proportions of the woody stems, leaf areas and species, relatively smaller proportions of total biomass and critical inter-crown pathways and microhabitats for a variety of other taxa (Schnitzer et al. 2015). Although lianas tend to proliferate after conventional logging and other disturbances (Putz 1984, Schnitzer et al. 2004), it is less clear how they respond to low intensity, selective timber harvests carried out with reduced-impact logging (RIL) techniques. In this study, we investigated how liana regeneration responded to different disturbances associated with RIL in Belize. Lianas impede timber management in tropical forests when they reduce tree growth, limit recruitment and deform tree boles (Putz 1991, Schnitzer et al. 2000). Trees with lianas in their crowns that are connected with other trees often damage many more trees on their way to the ground when they are felled for timber or fall naturally (Appanah & Putz 1984). In response to these impacts, RIL guidelines typically call for pre-harvest liana cutting to kill the flexible stems that often survive falling and subsequently re-sprout (Putz & Holbrook 1991). The added advantage of pre-harvest liana cutting is decreased severity of post-logging liana infestations as well as increased safety for forest workers (Alvira et al. 2004).

The modes of regeneration (sprout or seed), densities, and taxonomic family representation of lianas were evaluated along a gradient of increasing logging impacts based on soil scarification and canopy opening. We hypothesised that liana recruitment density increases with disturbance intensity because lianas have biomechanically tough stems, resprout readily and benefit from associated increases in light and soil resources.

MATERIALS AND METHODS

Study site

The study was conducted in the 42,301 ha Laguna Seca property, managed with Forest Stewardship Council (FSC) certification by Yalbac Ranch and Cattle Corporation in Orange Walk District, Belize (17° 15' N, 89° 04' W; 88 m above sea level). Annual rainfall in this seasonally dry tropical forest averages 1400 mm with a distinct February–April dry season when mean monthly precipitation is <100 mm. The forest is subjected to hurricanes that over the past 5000 years made landfall about once per decade (McCloskey and Keller 2009). Storms are expected to increase in response to increases in sea surface temperature (Knutson et al. 2010). Laguna Seca has long been settled by humans, as indicated by its proximity to the Chan Chich Mayan archeological site and scattered artifacts in the study area. Modern commercial timber harvests began in the 1500s with the extraction of logwood (*Haematoxylum campechianum*) for export to Europe. Mahogany (*Swietenia macrophylla*) was subsequently the most exploited species, with a peak harvest of 4 million linear meters in 1846 (Jeal, personal communication). This closed canopy forest grows on thin soils over karstic limestone. In addition to mahogany, common canopy trees include Santa Maria (*Calophylum brasiliense*), cabbage bark (*Lonchocarpus castilloi*) and sapodilla (*Manilkara zapota*), with abundant palms (e.g., *Cryosophila stauracantha* and *Sabal mauritiiformis*) (Arevalo et al. 2016). The 350 ha study area was logged from March–May 2014 at an average intensity of 2.7 trees ha^{-1} (2.9 m^3 ha^{-1}). Timber harvest operations followed RIL protocols, with logging infrastructure built with a D6 Caterpillar bulldozer and logs yarded with a Caterpillar 525 skidder with rubber tires. Similar to some common approaches to RIL, most lianas in the harvest area were cut approximately six months prior to logging (Pinard et al. 1995). In a second pre-logging treatment, several weeks before logging, any remaining live lianas were cut in the areas immediately surrounding trees marked for felling.

Data collection

Liana densities and modes of recruitment (sprout or seed origin) approximately one year (8–12 months) after the timber harvest were sampled in randomly located 2 × 20 m (40 m^2) plots in each of the 11 log landings, in a randomly selected primary skid trail, secondary skid trail, and felling gap. Primary and secondary skid trails averaged 4 m and 3 m wide, respectively. Log landings were generally rectangular and averaged 1200 m^2. Felling gaps were irregular in shape, usually somewhat elongated and averaged 90 m^2 (Arevalo et al. 2016). Along a disturbance gradient based on canopy opening and soil disturbance, felling gaps were considered to be at the low end followed by secondary and primary skid trails, and then log landings as the most heavily disturbed due to complete canopy clearance and removal, or at least severe disturbance of much of the surface soil. All stems of lianas and free-standing woody plants 10–100 cm tall were enumerated and, by excavation, classified as either originating from seed or sprout. Lianas were identified to family in 10 of the 11 sites sampled.

Data analysis

Family-level diversity of lianas was compared among the four logging-induced habitat types using Renyi diversity profiles, based on logging disturbance type at the plot level. The shape of Renyi profile curves capture both diversity and evenness, where higher curve profiles are indicative of greater diversity and horizontal profiles are indicative of similar evenness among the taxa present (Kindt & Coe 2005). As the alpha parameter approaches zero, Renyi entropy weighs all possibilities equally regardless of their dissimilarities, when alpha = 0 on the abscissa, the value on the ordinate is a direct measure of taxonomic richness (logarithm of the number of taxa). The profile values for alpha = 1 on the abscissa is equivalent to the Shannon entropy on the ordinate axis whilst alpha = infinity represents the proportion of the most abundant taxon, with higher values corresponding to greater evenness (i.e. lower proportional contribution of the dominant taxon).

We modelled the abundance of lianas of seed and sprout origin with a negative binomial distribution with logging disturbance type as predictor variables. The negative binomial model accounts for the over-dispersion observed in the count data. Analysis was done in R, a language and environment for statiscal computing (Core Team 2016), with the biodiversity R package (Kindt & Coe 2005). Regression models were

built with the MASS package (Venables & Ripley 2002), and data and R code were uploaded on github (https://github.com/aroopsind/liana_belize_study.git).

RESULTS AND DISCUSSION

Lianas, comprised 31% of the 6071 woody plants enumerated in 1,760 m^2 directly disturbed by the timber harvest. The result resembled reports from unlogged tropical forests in which free-standing lianas < 1 m tall typically comprise 25-35% of all woody plants in that size class (Putz 1983, DeWalt & Chave 2004). Log landings had lower densities of lianas of seed origin and fewer free-standing woody stems overall, compared to the other disturbance categories (Figure 1). Lianas as a proportion of all woody stems were highest on primary skid trails (35%) followed by felling gaps (30%) and secondary skid trails (29%), with log landings having the lowest relative density (25%). The 95% confidence interval from the regression model for predicted liana abundance across all 11 sample plots was also smallest for log landings (10.6–21.5),

followed by felling gaps (30.7–60.0), secondary skid trails (35.8–69.7) and primary skid trails with the highest abundance (44.7–86.6) (Figure 2). About half (47%) of all liana stems in all sites were of sprout origin, but the proportion varied among disturbance categories.

Botanical family diversity, both absolute taxonomic richness and values for Shannon's entropy, were lowest on log landings. The proportion of individuals from the dominant taxonomic families on log landings were also higher than those observed in plots in other classes of logging disturbance where diversity metrics were higher (Figure 3). The ten families of lianas that dominate most neo-tropical lowland forests (Gentry 1988, Alvira et al. 2004, Macía & Svenning 2005, Schnitzer et al. 2012) also dominated our study site in Belize. Seventy-eight percent of all lianas encountered were Fabaceae, Bignoniaceae and Dilleniaceae. Fabaceae were the most abundant at all sites except for felling gaps where Bignoniaceae were more common (Figure 4). Fabaceae regeneration was dominated by plants of seed origin in felling gaps as well as on secondary and primary skid trails whereas on log
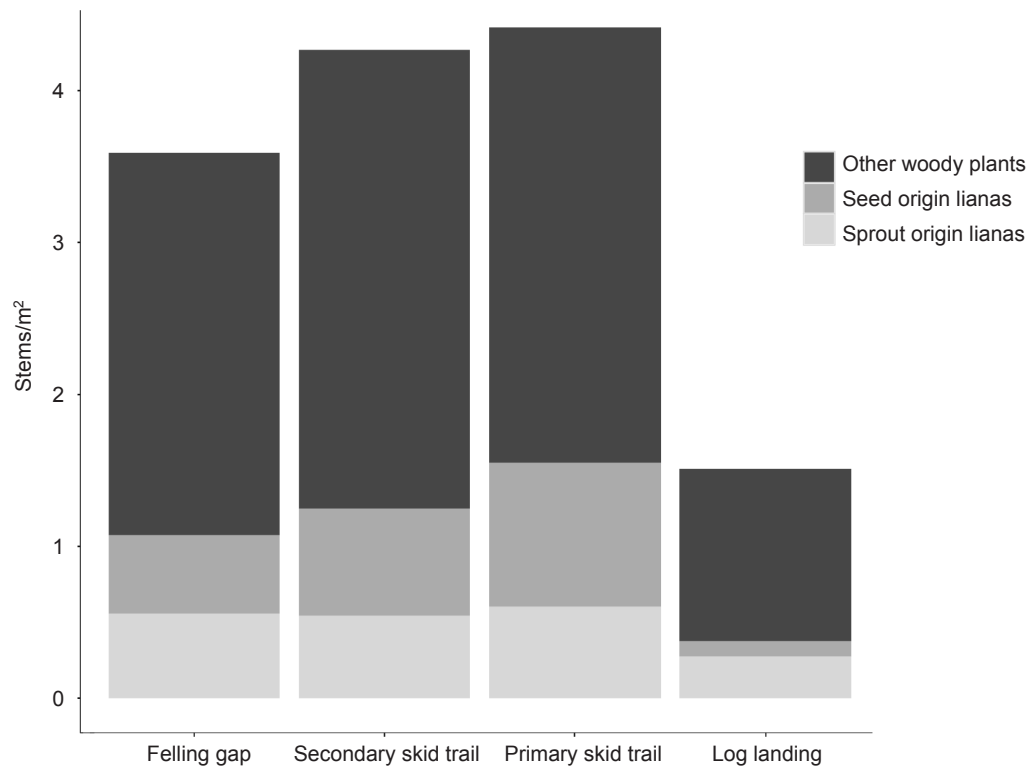

Figure 1   Densities (stems m^{-2}) of lianas of seed and sprout origin and other woody plants, 10 cm–1 m height, based on 11 sample plots of 40 m^2 in each logging disturbance category
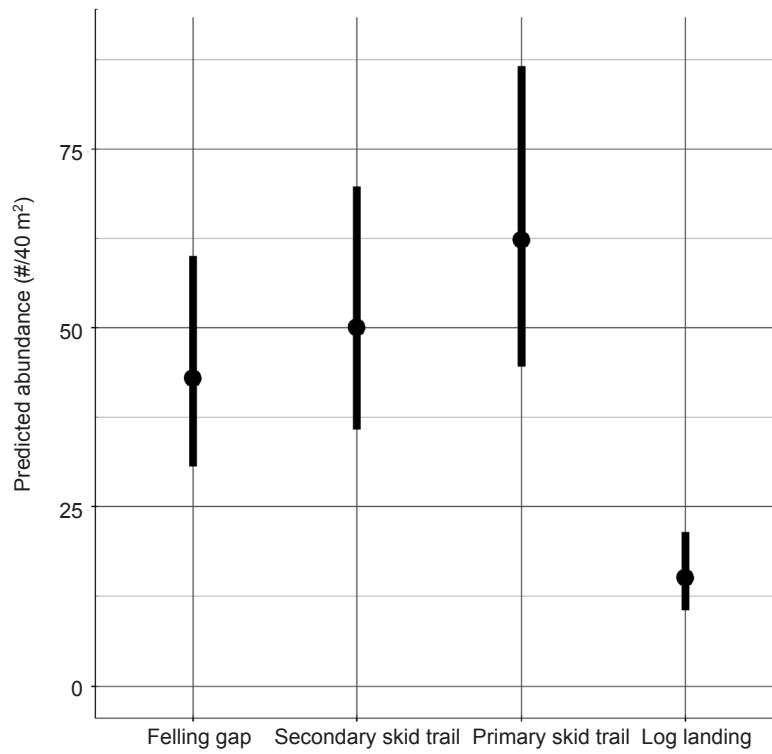
Figure 2   Predicted abundance of lianas of both sprout and seed origin across logging disturbances with 95% confidence intervals
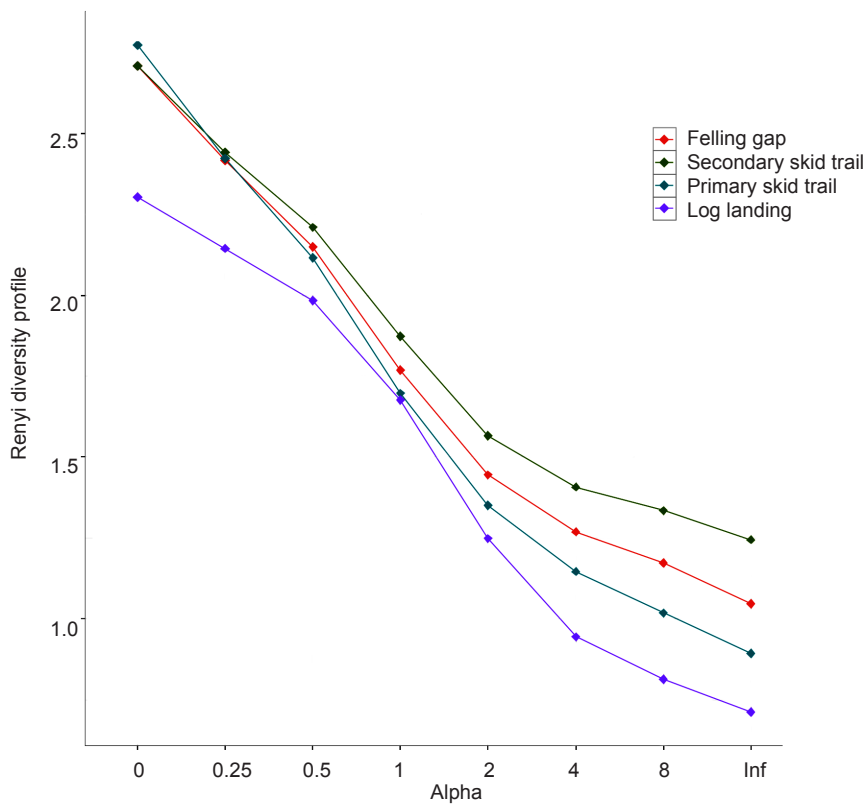
Figure 3   Renyi's diversity profiles across the different logging disturbance categories, y-axis values at alpha = 0 corresponds to botanical family diversity (logarithm of number of observed taxa), alpha = 1 represents the Shannon-diversity entropy and alpha = infinity (inf) characterises the evenness
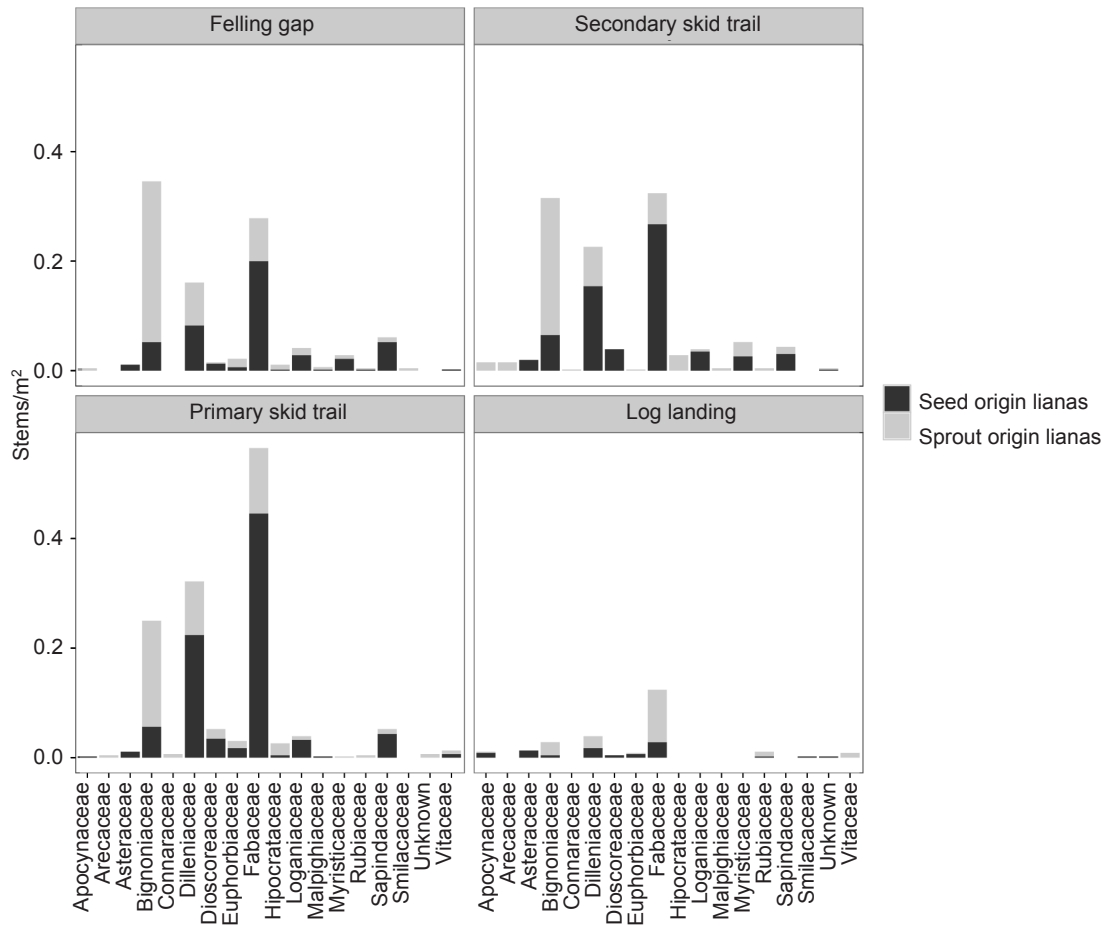
Figure 4 Total liana abundance by family and mode of regeneration (i.e. sprout or seed origin) in sites subjected to different logging-induced disturbances, 400 m² sampled in 10 replicates of each disturbance class with 40 m² sample plots

landings, sprout origin plants dominated (Figure 4). Similarly, seed regeneration of Dilleniaceae dominated in felling gaps and on primary and secondary skid trails, with sprouts more common on log landings. Sprouting was the prevalent mode of Bignoniaceae regeneration across all logging disturbances.

CONCLUSIONS

Partial support was found for the hypothesis of increasing liana regeneration with increasing logging disturbance, except on log landings that suffered nearly complete canopy clearing and topsoil removal. Liana regeneration by sprouting was dominated by Bignoniaceae across all logging disturbance categories, with sprouting as the primary mode of regeneration on log landings. At a harvest intensity of 2.5 tree ha^{-1}, which directly affected approximately 7% of the 350 ha

forest management unit, logging was not forseen as a major driver of change in liana abundance and diversity.

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