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Long-term seedling dynamics along an altitudinal gradient in Doi Suthep-Pui National Park, Chiang Mai Province, Thailand

Dokrak Marod[a], Prapawadee Nutiprapun[b,*], Sutheera Hermhuk[a], Mamoru Kanzaki[c]

[a] Department of Forest Biology, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand
[b] Department of Tropical Forestry, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand
[c] Division of Forest Biomaterials, Graduate School of Agriculture, Kyoto University, Kyoto 606-8502, Japan

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*Corresponding author.
E-mail address: gogigolf@hotmail.com (P. Nutiprapun).

Abstract

Nowadays, climate change is a serious problem in forest ecosystems, especially with regard to the seedlings which are very important in the regeneration process. This study focused on seedling dynamics based on environmental factors. A transect permanent plot (30 m × 600 m) was established along an altitudinal gradient (900–1,020 m above mean sea level) covering deciduous dipterocarp forest (DDF), ecotone forest (ETF) and lower montane forest (LMF). Subplots of 10×10 m were established, resulting in 180 subplots, with seedling quadrats (1×1 m) set up in the corner of each subplot. Seedling dynamics data were collected monthly in each seedling quadrat for 4 yr. Environmental factors in the forest (temperature, light intensity and soil moisture content) were monitored along with the seedling census.

The results identified 7,797 individuals and 116 species, 85 genera and 42 families of emerged seedlings. The most abundant species was *Quercus brandisiana* (57.4%), followed by *Litsea martabanica* (9.6%). Massive recruitment occurred in July 2015; nine species joined the recruitment and *Q. brandisiana* accounted for 98.9%. Massive mortality occurred in April 2016; 65 species died due to severe drought associated with the 2016 El Niño event. The temperature and light intensity were significantly different ($p < 0.001$) among forests. DDF had the highest temperature and light intensity followed by ETF and LMF. ETF had a moderate environment, as this forest type contained coexisting species such as *L. martabanica* and *Tarennoidea wallichii*. The results indicated that an ETF environment supported coexisting regeneration of deciduous and evergreen species.

Introduction

Climate is a major determinant of global forest vegetation and an effective influence on the distribution and structure of forest ecosystems, including forest vegetation changes along altitudinal gradients that result from changes in environmental factors (Takahashi et al., 2003). Altitudinal gradients have high potential for studying the responses of plant to geophysical influences (Körner, 2007). Recently, climate change has been recognized as a serious problems for forest ecosystems, especially for seedlings as the most important and critical stage in the regeneration process of a plant population; they generally suffer high mortality due to their sensitive to environmental conditions and soil water shortages during severe drought (Leck et al., 2008; Santana et al., 2012),. Differences in the environment along an altitudinal gradients may affect seedlings specifically and seedling dynamics could be explained using their relationship with environmental factors and the regeneration of seedlings determines population dynamics (Delerue et al., 2015). Therefore, this study aimed to understand how the environmental factors along altitudinal gradients potentially drive seedling emergence and survival.

Materials and Methods

Data collection

The research was conducted in Doi Suthep-Pui National Park, Chiang Mai province, northern Thailand. The study site covered an altitudinal gradient range of 900–1,020 m above mean sea level (amsl), containing three forest types consisting of deciduous dipterocarp forest (DDF; 900–940 m amsl), lower montane forest (LMF; 941–980 m amsl and ecotone forest (ETF; 981–1,020 m amsl). Seedling quadrats (1 m × 1 m) were established in three lines along the altitudinal gradient, at 10 m intervals, with 60 quadrats per line, totaling 180 quadrats. All seedlings in the quadrats were tagged and identified. Monitoring was done every month and seedling recruitment and mortality changes were recorded from January 2013 to December 2016.

Environmental factors (air temperature, light intensity and soil moisture content) were also monitored. The temperature and light intensity were recorded automatically every hour using Hobo data loggers set up along seedling quadrats every 50 m at 1.3 m above ground level. Soil moisture content data were collected based on soil moisture sensor readings taken during seedling monitoring at three random points in every single plot.

Data analysis

Seedling data in each plot were grouped by forest type based on the forest altitudinal range as above. Environmental data were analyzed using one-way repeated-measures analysis of variance to test the significance for each area using the R software program (R Core Team, 2013). The survival rate was analyzed and grouped into cohorts. A seedling cohort was defined as a group of the same species seedlings massively recruited in the same time and same forest type. This analysis focused on the activities of a particular cohort, as a subset of all data to obtain clearer results and to more easily compare different groups.

Results and Discussion

Environmental changes

Average temperature and light intensity during the 5 yr study were significantly different ($\alpha = 0.05$, $p < 0.001$) among forest types. DDF had the highest values followed by ETF and LMF. Furthermore, soil moisture content was significantly different ($\alpha = 0.05$, $p < 0.001$), with intermediate moisture content recorded in ETF. Therefore, the variation in environmental changes was related to the altitudinal gradient.

Seedling dynamics

In total, 7,797 emerged seedlings were identified from 116 species, 85 genera and 42 families. The highest number of seedling recruits were *Q. brandisiana* from the Fagaceae (57.4%) followed by *L. martabanica* from the Lauraceae (9.6%) and *Castanopsis acuminatissma* from the Fagaceae (5.0%). The highest number of seedling recruitments was in DDF followed by ETF and LMF. The mean diversity index (Shannon-Wiener index) for the area was 2.12; however, ETF had the highest value (3.12) followed by LMF and DDF (2.33 and 1.11, respectively).

Massive recruitment involving nine species occurred in July 2015, with *Q. brandisiana* accounting for 98.9% of these recruitments. In contrast, massive mortality occurred in April 2016, involving individuals from 65 species due to drought associated with the 2016 El Niño event. All the cohorts emerged from 2013 suffered high mortality during the El Niño event.

Seedlings of *Q. brandisiana*, a deciduous species, emerged both in DDF and LMF but they had a higher survival rate in DDF (52.37%/yr) than in LMF (15.79%/yr) because seedlings could not survive in the high shading in LMF. While seedlings of *L. martabanica*, an evergreen species, emerged in all three forest types, they had high seedling mortality in LMF and ETF and *T. wallichii* presented the same trend.

These results suggested that even evergreen species can survive in DDF, indicating that various adaptations regarding seedling regeneration could be detected. Thus, there was a high number of coexisting species in ETF which represented an intermediate environment and supported a broader range of seedling establishment. Likewise, a study in tropical forest reported the El Niño drought effects on seedlings mortality with nearly 90% mortality and low soil moisture (Gilbert et al., 2001). Moreover, drought stress is the main factor in seedling mortality, not only directly in that the plant lacks water but also through exacerbation of the effects of non-drought factors such as pathogens, herbivores or light competition (Engelbrecht et al., 2005). The El Niño event caused a harsh drought on the site and this impacted seedling population demography. These impacts on the seedlings possibly caused changes to the whole forest ecosystem along the altitudinal gradient. Continuous monitoring of the forest is recommended to detect any further impact of climate change and to adapt forest ecosystem management.

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