Forest dynamics during successional stages in a tropical coastal sand dune

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Abstract

Long-term ecological research is very important to detect the forest dynamics relating to disturbance and environmental changes. This study aimed to clarify the stand structure and species composition changes in the Bang Boet coastal sand dunes, southern Thailand. Three permanent transect plots were established in 2012 and all woody plants with a diameter at breast height larger than 1 cm were tagged, measured and identified every year during the study (2013–2017). The rates of changes were analyzed, particularly growth rates, mortality rates and recruitment rates. The results showed increasing trends for species density, basal area and stem density, whereas mean stem diameter tended to decrease. Recruitment and growth rates decreased from the initial levels, while the mortality rates increased with stand development. However, the recruitment rates were higher than the mortality rates during the successional stages. In addition, the rates of change of community attributes varied only slightly and were close to zero; as a consequence, the reduction in recruitment, growth rates and the increase in mortality rates almost balanced.

Introduction

Understanding forest successional stages is required when designing management and conservation strategies (Gutiérrez and Huth, 2012). Within the coastal zone it is critical for management to take into account the dynamic nature and vulnerability of the various systems (Avis and Lubke, 1996). Long-term ecological research is important to understand the forest dynamics relating to their disturbances and environmental changes over a range of spatial and temporal scales. The forest structure and species composition change during stand development (Franklin et al., 2002), especially among tree species widely used and their interrelated forest attributes—stem density, basal area, and species density (Norden et al., 2017). Coastal sand dunes are a component of coastal ecosystems and maintain the natural coastal processes (Natural England and RSPB, 2014). However, forest dynamics studies in tropical coastal sand dunes are less documented. Therefore, this study aimed to clarify the stand structure and species composition changes of the Bang Boet coastal sand dune, southern Thailand.

Materials and Methods

The study was conducted at the Bang Boet coastal sand dune (10°55′22″–10°56′6″N, 99°29′25″–99°29′49″E), Chumphon province, southern Thailand. Three permanent transect plots (10 m × 100 m) were established 300 m apart in 2012 covering both windward and leeward aspects. All woody plants with a diameter at breast height (DBH) larger than 1 cm were tagged, measured and the species were identified. Tree monitoring was done every year (2013–2017); all new tree were recruited and dead trees were recorded.

Quantitative data were analyzed: basal area (BA, measured in square meters per hectare), mean stem diameter (measured in centimeters), stem density (measured in stems per hectare) and species density (measured in species per hectare). The rates of change (RC), mortality rates (M), recruitment rates (R) and growth rates (G) were calculated following van Breugel et al., (2006) and ordinary least square regression analysis was used to examine the relationships.

Results and Discussion

Community structure

The overall structures showed an increasing trend for species density, BA and stem density; in contrast, mean stem diameter decreased. Low species density was detected and was in the range 19–30 species per 0.1 ha plot among transects. High mean (± SD) stem density was detected. However, large variation also found (4,017±1,108 stem/ha); in particular, stem density was lowest on the windward aspect, indicating that the sand dune aspect influenced plant succession (Duran et al., 2008). In addition, there was slow growth in BA and mean stem diameter (8.57±1.30 m^2/ha and 4.06±0.47 cm, respectively), even though, they increased in the late succession stages. These attributes increased during the succession stages, indicating temporal scales, with particularly long periods of succession inducing high community-level attributes (van Breugel et al., 2006; Holm et al., 2012).

The RC values for stem density, BA and mean stem diameter varied among and within transects during the study periods. The RC values of community attributes decreased and were close to zero. The stem density RC was significantly and negatively related with the RC of mean stem diameter ($R^2 = –0.74$, $p < 0.0001$). In addition, the mean stem diameter also decreased due to a large tree with three stems blowing over following strong winds on the windward aspect, indicating how crucial environmental factors highly influenced stand development, particularly soil properties, strong wind and salt spray (Maun, 2009).

Forest dynamics

The recruitment rates based on the number of stems (R_{NS}) and basal area (R_{BA}) trended to decrease, in contrast with both mortality rates (M_{NS} and M_{BA}, respectively). However, the recruitment rates were higher than mortality rates (Fig. 1). In addition, the net rates of these community attributes were very low and almost zero (R_{NS}, 0.07/yr; R_{BA}, 0.12/yr; M_{NS}, 0.03/yr; M_{BA}, 0.04/yr). The mean growth rate (G_{BA}) of the community throughout the study period was quite low (0.03/yr), indicating the succession trajectories trended to balance as forest communities grew older (van Breugel et al., 2006).

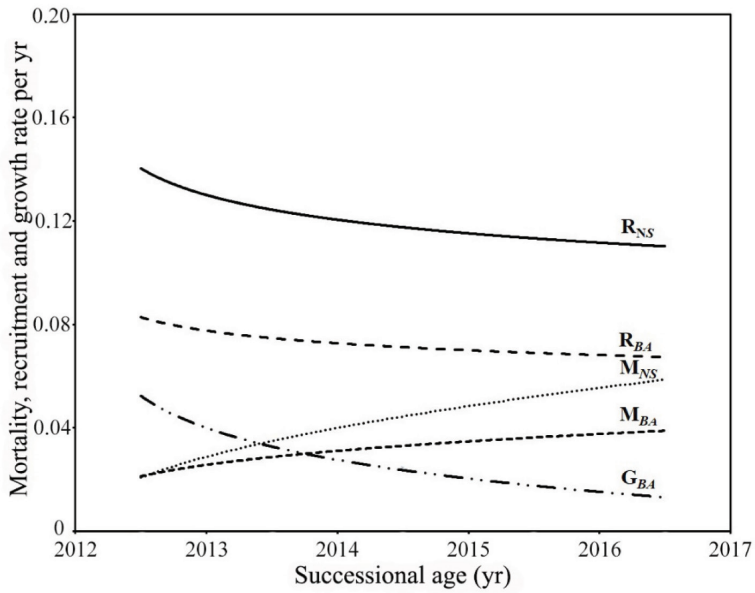

Fig. 1 Relationship between mortality (M), recruitment (R) and growth (G) rates for net stocking (NS) and basal area (BA) at the Bang Boet coastal sand dune

There were low quantitative net changes in the community structure, which responded to critical environmental factors. Erratic rainfall coupled with strong winds were responsible for the paucity of vegetation and the maintenance of mobile sand dune systems along the coastal (Avis and Lubke, 1996). Therefore, the restoration programs on coastal sand dunes should focus on suitable species which are highly adapted to these crucial factors.

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