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Potential tree species extinction, colonization and recruitment in Afromontane forest relicts

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Abstract

Tree species regeneration determines future forest structure and composition, but is often severely hampered in small forest relicts. To study succession, long-term field observations or simulation models are used but data, knowledge or resources to run such models are often scarce in tropical areas. We propose and implement a species accounting equation, which includes the co-occurring events extinction, colonization and recruitment and which can be solved by using data from a single inventory. We solved this species accounting equation for the 12 remaining Afromontane cloud forest relicts in Taita Hills, Kenya by comparing the tree species present among the seedling, sapling and mature tree layer in 82 plots. A simultaneous ordination of the seedling, sapling and mature tree layer data revealed that potential species extinctions, colonizations and recruitments may induce future species shifts. On landscape level, the potential extinction debt amounted to 9% (7 species) of the regional species pool. On forest relict level, the smallest relicts harbored an important proportion of the tree species diversity in the regeneration layer. The average potential recruitment credit, defined as species only present as seedling or sapling, was 3 and 6 species for large and small forest relicts, while the average potential extinction debt was 12 and 4 species, respectively. In total, both large and small relicts are expected to lose approximately 20% of their current local tree species pool. The species accounting equations provide a time and resource effective tool and give an improved understanding of the conservation status and possible future succession dynamics of forest relicts, which can be particularly useful in a context of participatory monitoring.

Zusammenfassung

Die Regeneration der Baumarten bestimmt die zukünftige Struktur und Zusammensetzung eines Waldes, aber sie wird häufig in kleinen Waldresten behindert. Um die Sukzession zu untersuchen, werden langfristige Feldstudien unternommen oder Simulationsmodelle benutzt, aber Daten, Kenntnisse und Ressourcen um solche Modelle zum Laufen zu bringen sind meistens knapp, was tropische Gebiete anlangt. Eine Artenbilanzgleichung wird von uns vorgeschlagen und angewendet,

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die gleichzeitige Ereignisse wie Aussterben, Einwanderung und Nachwuchsrekrutierung berücksichtigt und mit Daten aus einer einzigen Erhebung gelöst werden kann. Wir lösten solche Artenbilanzgleichungen für die zwölf verbliebenen Nebelwaldrelikte in den Taita-Bergen (Kenia), indem wir die Präsenz der Baumarten unter den Keimlingen, Schösslingen und bei den reifen Bäumen an 82 Sammelstellen miteinander verglichen. Eine gleichzeitige Ordination der Daten für Keimlinge, Schösslinge und reife Bäume zeigte, dass potentielle Aussterbeereignisse, Besiedlungen und Nachrücken von Nachwuchs zukünftige Artenverlagerungen nach sich ziehen können. Auf der Landschaftsebene belief sich die potentielle Aussterbeschuld auf 9% (7 Arten) des regionalen Artenpools. Auf der Ebene des Waldfragments beherbergten die kleinsten Relikte einen wichtigen Anteil der Baumartendiversität in der Regenerationsschicht. Das durchschnittliche Nachwuchsguthaben, definiert als Arten, die nur als Keimlinge oder Schösslinge angetroffen wurden, betrug 3 bzw. 6 Arten für große bzw. kleine Waldrelikte, während die durchschnittliche Aussterbeschuld 12 bzw. 4 Arten ausmachte. Insgesamt, nehmen wir an, dass sowohl große als auch kleine Relikte ungefähr 20% ihres aktuellen Baumartenpools verlieren werden. Die Artenbilanzgleichungen bieten ein zeit- und ressourcenschonendes, effektives Arbeitsmittel und vermitteln ein verbessertes Verständnis des Schutzstatus und möglicher zukünftiger Sukzessionsdynamiken von Waldrelikten. Dies kann sich im Kontext des partizipatorischen Monitoring als besonders nützlich erweisen.

Keywords: Community structure; Forest succession; Late-successional species; Regeneration; Restoration; Secondary forest; Species accounting equation; Species turnover; Taita Hills

Introduction

Destruction and loss of natural habitat are major causes of biodiversity decline and species extinction (Tilman, May, Lehman, & Nowak 1994; Fahrig 2002; Brose 2011). Forests are one of the largest terrestrial biomes and are severely threatened by anthropogenic habitat deterioration with an estimated loss of 13–20 million hectares each year, of which one third is located in the tropics (FAO 2011, p. 179; Hansen et al. 2013). Many plant populations strive to survive in small forest relicts (Ewers & Didham 2006) and the succession of tree species in these forest patches is a central theme in plant community ecology, restoration, and land management (Cook, Yao, Foster, Holt, & Patrick 2005).

The succession within these forest relicts is driven by three major events, which can alter the species composition of forest relicts: extinction, colonization and the recruitment of seedlings and saplings to the mature tree layer. In forests, there is a time-lagged response of species to habitat modifications (Hylander & Nemomissa 2009; Metzger et al. 2009; Jackson & Sax 2010), because of the long life span and regeneration time of trees (Vellend et al. 2006). The future extinction of a species due to events that happened in the past is known as delayed extinction and quantified as extinction debt (Tilman et al. 1994; Hylander & Nemomissa 2009; Jackson & Sax 2010). Although only the preservation of large areas of primary forest can safeguard the complete species pool (Gibson et al. 2011), a substantial number of forest species can survive for a long time in small and degraded forest relicts before they become extinct (Helm, Hanski, & Pärtel 2006; Vellend et al. 2006; Kuussaari et al. 2009). Especially the failure of species regeneration is a threat to future forest biodiversity and composition because species persistence depends on the availability of seeds, seedlings and saplings (Benítez-Malvido & Martínez-Ramos 2003; Lawes, Joubert, Griffiths, Boudreau, & Chapman 2007; Farwig, Sajita, Schaab, & Böhning-Gaese 2008; Albrecht, Neuschulz, & Farwig 2012). The extinction of a species that at present remains in the regional species pool (local species extinction, Fig. 1, 1a), can be counterbalanced by a recolonization of this species from the regional species pool (autochthonous colonization, Fig. 1, 2a). However, when a species is present in one relict only, its extinction in this patch will result in the disappearance of the species from the region (regional species extinction, Fig. 1, 1b). Colonization credit is the number of species yet to colonize a forest relict (Jackson & Sax 2010; Piqueray, Cristofoli, Bisteau, Palm, & Mahy 2011). Such establishment of species within forest relicts is a gradual process because it depends on several external factors like landscape structure and ability of newly arrived seeds to germinate, or internal factors like succession or management (Laurance et al. 2006; Kirika, Böhning-Gaese, Dumbo, & Farwig 2010). Moreover, forest relicts are often characterized by new abiotic conditions (e.g. altered irradiance, temperature regime or soil moisture), and biotic conditions (e.g. herbivory, seed dispersal or pollination) (Cadenasso & Pickett 2000). Two types of colonization can be defined, depending on the origin of the species. The colonization by a species present in the regional species pool, can be defined as an autochthonous species colonization (Fig. 1, 2a), while the colonization by a species absent in the regional species pool (e.g. invasion by an exotic species or the colonization by a new species as an effect of changed climatic conditions) can be defined as an allochthonous species colonization (Fig. 1, 2b). The number of species only present in the regeneration layer may complement the future tree layer composition and can therefore be defined as recruitment credit. For instance, the number of species absent from the