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Native and introduced land snail species as ecological indicators in different land use types in Java

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ABSTRACT

We investigated the effects of different land use types and environmental parameters on the number and abundance of native and introduced land snail species in East Java. 2919 specimens were sampled and assigned to 55 species of which 8 are introduced. Whereas species richness was highest in primary forest, the highest number of introduced species was found in agroforest. The snail assemblages in different habitat types differ much clearer in composition than in total species richness. Plantations and agroforest are dominated by introduced pulmonates with regard to number of individuals, while primary forest is dominated by native prosobranchs. The habitat requirements of the introduced pulmonates differ from those of the native species. In the study area, the abundance of native as well as introduced pulmonate species increased with increasing human impact. However, the abundance of introduced pulmonate species decreased with increasing density of the canopy cover, whereas the abundance of native pulmonate species increased with increasing canopy cover. The abundance of native prosobranch land snails also tends to increase with increasing canopy cover and with the availability of deadwood, but decreased with increasing human impact. Improving the canopy cover and retaining deadwood in plantations and agroforests might help to control the populations of introduced species or even prevent their establishment in these habitats. Land snails are good indicators for the long-term stability of natural habitats, because several species are restricted to undisturbed natural habitats and because of their low dispersal abilities. However, complete inventories of land snail species are costly. Therefore we propose two indices that can be scored with much less effort, namely the percentage of prosobranch individuals and the percentage of individuals of introduced species. Both indices are significantly correlated with the number of native species. Dense plantations and agroforests bordering primary forests may protect the latter from introduced species and help to conserve the native fauna by reducing desiccation and buffering the human impact on the primary forests.

1. Introduction

Human-mediated dispersal increasingly homogenized biotas worldwide. The influence of biogeographic barriers and long distances on the distribution of organisms is decreasing so that the ranges of human distributed species are primarily explained by the prevailing climate (Capinha et al., 2015). For a better understanding of the invasion risks and for conceiving measures to control introduced species and to conserve the native fauna, it is necessary to investigate the factors that determine the success of introduced species. Introduced species are not homogeneously distributed in the regions where they are introduced. An investigation of the success of introduced species in different land use systems can improve our understanding of the factors that facilitate the establishment and the expansion of introduced species.

Modified habitats that potentially facilitate the establishment and expansion of introduced species increasingly dominate tropical landscapes characterized originally by a rich native fauna and flora. Land snails are sensitive to habitat changes and they are characterized by a low active mobility, so that the composition of land snail assemblages reflects changes in environmental variables even if they vary across short distances. Thus, we studied land snails in Java, the most populous island in the world. Only about 6% of Java is still covered by primary forest (Margono et al., 2014). Java (and its adjacent satellite islands) has a rich land snail fauna including 205 land snail species, of which 12 species are introduced and

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63 are endemic (van Benthem Jutting, 1948, 1950, 1952; Loosjes, 1953; Butot, 1955; de Winter, 1983; Dharma, 1992, 2007, 2015; Whitten et al., 1997; de Winter and Vermeulen, 1998; Vermeulen and Whitten, 1998; Gomes and Thomé, 2004; Heryanto, 2011).

We studied native and introduced land snail species in three land use types: teak plantations, small-scale agricultural systems (hereafter 'agroforests'), and primary forest in East Java. We focused on the following questions. (i) How do the snail assemblages from these habitats differ? (ii) How many introduced land snail species occur in plantations, agroforests and primary forest? (iii) Which environmental variables affect the abundance of native and introduced snail species and the assemblage composition? (iv) Which indices might be used as simple indicators for disturbance versus long-term habitat stability? (v) Which measures might impede the establishment and expansion of introduced species?

2. Material and methods

2.1. Study area

The study area (8°20′S–8°24′S 112°26′E–112°31′E) is situated in the Kendeng Mountains in Malang regency, East Java, Indonesia (Fig. 1). The Kendeng Mountains are limestone hills with an altitudinal range from 0 to 650 m a.s.l. The climate of Malang is governed by the Asia-Australian monsoon. The west monsoon occurs during the Asian winter (December–February) and brings rain with a peak (350–400 mm) in January, while the east monsoon, which occurs during the Australian winter (June–August) results in a dry season with less than 100 mm monthly rainfall between June and October (mean annual rainfall about 2300 mm). Mean annual temperature is about 25 °C.

We investigated primary lowland rainforest and teak plantation bordered by primary forest in the Kondang Merak area, and agroforest and teak plantation bordered by agroforest near Kedungsalam village. The most distant plots were less than 12 km apart. Javanese agroforest (Tumpangsari) is a kind of home garden where the farmers usually cultivate maize or cassava or other low vegetation under growing trees such as teak or Cajeput tree (Scales and Marsden, 2008).

2.2. Sampling and determination

Sampling was conducted in May and November 2014. We selected 40 plots of 10 m × 10 m, 10 plots each from primary forest, teak plantation bordered by primary forest, teak plantation bordered by agroforest and agroforest. The plots were placed randomly within the different land use areas. A combination of visual searching and sorting a standardized volume of litter and soil is the most efficient method for land snail inventories if repeated visits are not possible (Emberton et al., 1996; Cameron and Pokryszko, 2005; Schilthuizen, 2011). Thus, all living slugs and snails as well as their empty shells were collected by two researchers for one hour at each plot. In addition, 5L of leaf litter and surface soil were sampled at each plot. Later, the litter samples were dried, fractioned by sieving and sorted. Several environmental variables were recorded at each plot, i.e. habitat type, altitude, percentage of canopy cover, density of herbaceous layer, presence of deadwood, stones and bare rock, amount of leaf litter, and degree of human impact (cultivation or removal of plants, presence of livestock, human trails, information from locals) (Supplementary Table S1).

All specimens were identified to species level using van Benthem Jutting (1948, 1950, 1952) and Vermeulen and Whitten (1998). The specimens are kept in the Museum Zoologicum Bogoriense (Indonesia) and the Zoological Museum of the University of Hamburg (Germany).

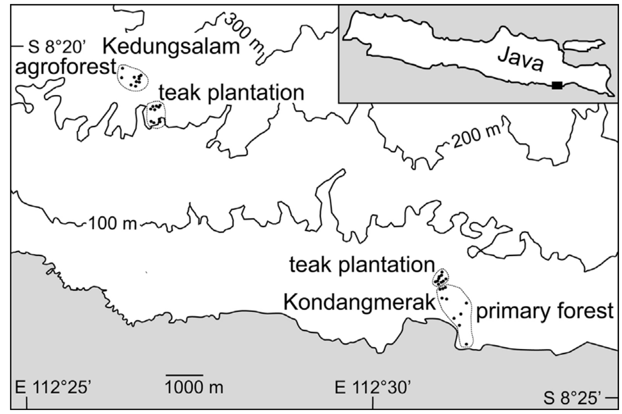

Fig. 1. Map of the study area in Malang showing the position of the 40 surveyed plots. Insert indicating the location of the study area in Java.

2.3. Comparisons of species richness and other indices between land use types

Species richness of different land use types was compared using abundance-based rarefaction (Colwell et al., 2012) as implemented in iNext online (Hsieh et al., 2013). Confidence intervals (95%) were calculated using 100 bootstrap replications. We explored the sample size dependence of the percentage of prosobranch individuals and the percentage of individuals of introduced species in different land use types using the dominance index in the species richness module of EcoSim (Gotelli and Entsminger, 2004).

2.4. Putative determinants of abundance and assemblage composition

We investigated putative determinants of abundance using multiple linear regression analyses with the statistical software R (R Core Team, 2012). We log-transformed abundances and tested the following environmental variables: density of the canopy cover (as a proxy for insolation and, as a consequence, temperature and desiccation on the forest floor) and of the herbaceous layer, presence of deadwood, stones and bare rock, amount of leaf litter and human impact (Supplementary Table S1).

Furthermore, we assessed the importance of the recorded environmental variables for determining the distribution of species and the composition of assemblages by fitting them onto an ordination plot. The ecological similarities between species and the assemblage composition were explored by a non-metric multidimensional scaling of the abundance data using quantitative Kulczyński distances (Faith et al., 1987). We used the 'vegan' package (Oksanen et al., 2013) for the statistical software R (R Core Team, 2012). Species scores were computed as implemented in the 'vegan'-function 'metaMDS' and the goodness of fit of the environmental variables was computed using the 'envfit' function in 'vegan'. Significance of the fit was tested based on 999 permutations. Finally, we assessed also the similarity of the plots based on the recorded environmental variables using categorical principal components analysis with the program SPSS Statistics version 23 (IBM).

3. Results

3.1. Land snail species richness in different land use types

In total, 2919 specimens belonging to 55 land snail species (1 neritimorph, 10 caenogastropod and 44 pulmonate species) were collected in the 40 studied plots (Table 1, Supplementary Table

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