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How reliable are data on arboreal ant (Hymenoptera: Formicidae) communities collected by insecticidal fogging?

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Abstract

Insecticidal fogging has proven to be an efficient method for sampling arboreal arthropods in tropical lowland rain forests. By exact positioning of the collecting funnels beneath the tree and by excluding arthropods from higher canopy levels, fogging can be a precise tool to collect for example ant communities in a tree-species specific way. Such clearly defined communities form a good model system for community analysis. Analysis, however, requires knowledge about how representative communities were sampled from the trees. In order to assess this, ant nests were located in the trees the day before fogging. For that purpose ants were attracted to bait (pieces of tuna and sugar-water) placed on all branches in the trees. Pursuing the ants from the baits made it easy to localize the ants' nests in the trees and to get information on the relative size of the colonies. Comparing these results with those obtained by fogging showed that fogging does not always describe abundance hierarchies correctly and that different species could be numerically dominant at the bait compared to the fogging samples. Particularly, abundances of stem-nesting species are underestimated indicating the necessity to correct ant abundances for a specific community-level analysis.

Key words: Core communities, ant nest localization, fogging efficiency

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Introduction

Ecosystem analysis requires the consideration of all types of habitats. In forest ecosystems these are – coarsely summarized – the soil, the understorey, the tree trunks, and the canopy. Despite the simplicity of this statement, the canopy has been largely neglected in research, mainly due to difficulty in access. This situation changed after ERWIN (1982) had introduced the insecticidal knockdown fogging technique. He discovered that arthropod diversity in tropical lowland rain forests is maximum in the canopy. Following studies showed that arboreal arthropod communities can be collected efficiently and in a tree specific way by fogging allowing the analysis of the diversity, structure, and aspects of the dynamics of these communities (e.g., HARADA & ADIS 1997, FLOREN & LINSENMAIR 2000). Arboreal Formicidae in tropical rain forests are a perfect example. In contrast to many other taxa, they are of moderate diversity, nest within trees and form long-lasting, distinguishable communities which can be subjected to the analysis of the mechanisms structuring these communities (FLOREN & LINSENMAIR 1997). It is, for example, still an open question whether ant communities follow predictable or deterministic trajectories in their long-term dynamics and to what extent communities are shaped by interspecific competition. Ant mosaic theory clearly states that communities are structured by interspecific competition and should be highly predictable because dominant ant species are associated with a defined set of subdominant species (ROOM 1975, LESTON 1978, JACKSON 1984). However, in contrast to this, recent findings from SE-Asian primary lowland rain forests show that tree specific ant communities can not be distinguished from random assemblages (FLOREN & al. 2001). This analysis requires representative and tree specific sampling. Although fogging has often been used to assess local ant diversity (WILSON 1987, ADIS & al. 1998a, LONGINO & al. 2002) there is little information about how reliable tree specific communities are collected (e.g., AGOSTI & al. 2000) because fogging does not provide information which species are nesting in a tree forming the core community. I achieved this knowledge by direct observations and nest localization in the trees. Here I emphasize that fogging data do not translate 1 : 1 into an accurate picture of ant communities but require additional investigations to assess numerical dominance hierarchies and species associations correctly.

Material and methods

Fogging method: My studies in the lowland rain forests of Sabah, Malaysia, which commenced 14 years ago, used insecticidal fogging to collect arthropods from individual trees. Nowadays, this method is well established in ecology (e.g., ADIS & al. 1998b), so it is not necessary to provide details here. I chose small trees of the lower canopy stratum (mainly *Aporusa lagenocarpa* A. SHAW and *A. subcaudata* MERR., Euphorbiaceae) for my study (average tree height 19 m, crown width ca. 10 m). As the investigations aimed at analyzing the diversity, structure, and dynamics of tree-specific ant communities, it was necessary to guarantee the tree selectivity of the fogging. This was achieved by stretching out a 100 m² cotton roof horizontally above the crown of the study tree (Fig. 1), which prevented intoxicated arthropods on taller neighbouring trees from falling into the collecting sheets (FLOREN & LINSENMAIR 1997). In order to collect arthropod communities as completely as possible, 80 to 90 % of a crown projection area was covered with collecting sheets installed one meter above the forest floor. The studied tree was climbed and fogging was carried out in the crown for ten minutes early in the morning, at a time when there was no wind drift.

Fig. 1: Fogging an understorey tree. The tree was isolated from the higher canopy by a large cotton roof stretched out above the top of the crown the day before fogging.

Ant nest localization in the trees: Whether ants were nesting in a tree or not was confirmed by nest localizations in 27 trees, which were carried out prior to fogging. In total, 30 trees were fogged 1996 and 1998. Ants were attracted to bait (sugar-water and pieces of tuna) that were placed in the whole crown on all branches within reach of the tree trunk the day before fogging. The ants usually discovered the bait very quickly. By pursuing the foraging ants, it was possible to locate their nests. In this way, most nests of the common ant species could be detected in about two hours. Beside nest localization, the number of ant individuals of a colony was roughly assessed by assigning the number of workers of a species at the bait and near the nest to abundance categories (see Tab. 1). This abundance classification had already been used to describe ant communities fogged earlier. Arboreal ant communities were numerically dominated by up to three species. The numerical difference between these species was not larger than 5 %. Species following in ranked abundance were found with at least 10 % less individuals of the dominant species. Furthermore, species with more than 100 individuals were distinguished from species collected with fewer individuals (less than 100 but more than 20 ants). Species found with at least 20 individuals were considered as rare and distinguished from singletons (species represented by a single ant). All species that were proven to nest in the tree were counted as members of the core community. Tree specific ant communities were well described by this classification (FLOREN & LINSEMAIR 2000).

Results and Discussion

Arboreal ants represented about 60 % of all arthropods in the trees and fogging proved to be highly efficient to sample this diversity. Many more ants were collected by fogging than at the bait (data not shown). All 30 foggings collected 72,264 ants, which were sorted to 231 species, while 87 ant species were sampled at the bait from which only few individuals were taken for identification. This difference is due to the fact that fogging samples ants from a broader community, for example species that had invaded the trees via crown overlap or species that were nesting in the trees but that were not attracted by the bait. Until today, 331 species of arboreal ants were collected from the trees in the investigated lowland rainforest of Kinabalu National Park, of which 73 species were singletons and 196 species were found with less than 20 individuals (FLOREN & LINSENMAIR 2005). The highest number of species ever found in a tree specific fogging sample was 61 (FLOREN & LINSENMAIR 1997) which is more than half of all species known from Germany and one third of all species known from Central Europe (SEIFERT 1996).

Due to the lack of autecological knowledge of tropical arboreal ant species dominance classification based on species abundance is commonly used as a surrogate of dominance hierarchies (see FLOREN & LINSENMAIR 2000). Tree specific communities, as described from the fogging samples, were structurally similar and showed a clear dominance hierarchy. On average, 60 % of all species of a community were rare (found with less than 20 individuals or as singletons) (FLOREN & LINSENMAIR 1997).

In general, fogging did not collect all individuals of an ant nest and also the bait samples gave only a rough impression about colony size. Despite that, the assessment of ant abundance hierarchies from the bait and the foggings corresponded well for most of the abundant species. Table 1 shows that neither fogging nor the bait samples differed significantly with respect to the number of species classified as dominants or those that occurred in higher numbers in a tree. As proven by the nest localizations, most of these species were nesting in the trees. However, the bait samples showed that in particular stem-inhabiting species could be dominant on the bait although they were found with only few individuals in the fogging samples. Examples are species of *Crematogaster* or *Pheidole*, which were often found building sheltered foraging trails. These species aggressively defended most bait in a tree, sometimes with thousands of workers, clearly indicating numerical dominance. Consequently, tree specific dominance hierarchies as derived from the fogging samples changed in various communities after considering these results (data not shown). On the other hand, observations inside the trees showed that some of the fogged dominant ant species, like *Dolichoderus cuspidatus* (SMITH, 1857) or *Pheidologeton* sp., had entered the study tree from neighbouring trees. Together with many of the rare species they were only short time members of the community. Beside the larger ant colonies, nests were discovered for many species represented by more than 20 but usually clearly less than 100 specimens. Examples are *Camponotus karawaiewi* MENOZZI, 1926, or species of *Polyrhachis*, *Oligomyrmex*, and *Paratrechina*. They nested in dead twigs, carton nests beneath the leaves, or in detritus accumulations, often in the outer part of a tree crown. Observations in the small tree

Tab. 1: Number of ant species of various abundance classes collected by canopy fogging (n = 30) and by hand collecting from bait (n = 27). Data are given as means and standard deviations (see text).

	Numerically dominant ant species	Species with > 100 individuals	Species with 21 - 100 individuals	Species with ≤ 20 individuals	Singletons
Fogging	1.23 ± 0.43	2.13 ± 2.06	3.37 ± 1.81	14.50 ± 6.38	12.33 ± 4.66
Bait samples	1.41 ± 0.57	2.11 ± 0.89	1.78 ± 0.89	1.56 ± 0.93	1.70 ± 1.71
MW U-test	n.s.	n.s.	$p < 0.001$	$p < 0.001$	$p < 0.001$

crowns showed that many of these species extended their foraging area to the crown centre. Significantly more species of this abundance category were sampled by fogging than at the bait but the difference was less pronounced than for species collected with less than 20 individuals. Little evidence was found that many of the rare species were nesting in the study tree and most had probably entered the tree from neighbouring trees. However, a very thorough investigation would be necessary to exactly determine how many species with small colonies were really nesting in a tree.

As indicated by the data, both fogging and baiting complement one another very well. Mapping ant nests in the trees demonstrated that ant abundances of stem nesting species cannot be assessed correctly by fogging. On the other hand, only few species (always singletons) were found at the bait that were not recorded by fogging such as *Anochetus* sp. (Ponerinae) or *Myrmoteras* sp. (Formicinae). These results show the advantages and limitations of the fogging method indicating the necessity of direct observations in the trees to describe arboreal ant community structure correctly.

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Zusammenfassung

Die Insektizidvernebelung ("canopy fogging") hat sich als hocheffiziente Methode zur Erfassung von Arthropoden in den Kronen tropischer Tieflandregenwälder erwiesen. Durch genaue Installation der Sammeltrichter unter der Baumkrone und den Ausschluss von Arthropoden aus höheren Kronenschichten können auch Ameisengemeinschaften in baumartenspezifischer Weise gesammelt werden. Solche klar gegeneinander abgrenzbare Gemeinschaften eignen sich als Modellsystem in der Gemeinschaftsökologie. Dies erfordert jedoch Informationen darüber, wie repräsentativ die Gemeinschaften in den Benebelungsproben abgebildet werden. Um dies zu untersuchen wurden die Ameisen in den Baumkronen am Tag vor der Benebelung mit Thunfisch und Zuckerwasser angeködert. Verfolgt man die angelockten Ameisen, lassen sich ihre Nester im Baum leicht lokalisieren und Informationen über ihre relative Größe ermitteln. Vergleicht man diese Ergebnisse mit denen der Benebelungsdaten, so zeigt sich, dass die Abundanzhierarchien in den Benebelungen nicht immer richtig abbildet werden und dass verschiedene Ameisenarten in den Benebelungsproben und an den Ködern zahlenmäßig dominieren. Insbesondere wurden die Häufigkeiten von in Stammhöhlen nistenden Arten durch die Benebelungen unterschätzt. Dies weist auf die Notwendigkeit hin, die Häufigkeiten in den Benebelungsproben für die Gemeinschaftsanalyse zu korrigieren.

References

ADIS, J., BASSET, Y., FLOREN, A., HAMMOND, P.M. & LINSENMAIR, K.E. 1998a: Canopy fogging of an over storey tree – Recommendations for standardization. – Ecotropica 4: 93-97.

ADIS, J., HARADA, Y.Y., FONSECA, C.R.D., PAARMANN, W. & RAFAEL, J.A. 1998b: Arthropods obtained from the Amazonian tree species "Cupiuba" *Goupia glabra* by repeated canopy fogging with natural pyrethrum. – Acta Amazonica 28: 273-283.

AGOSTI, D., MAJER, J.D., ALONSO, L.E. & SCHULTZ, T.R. 2000: Ants. Standard methods for measuring and monitoring biodiversity. – Smithsonian Institution Press, Washington, 280 pp.

ERWIN, T.L. 1982: Tropical forests: Their richness in Coleoptera and other arthropod species. – Coleopterist's Bulletin 361: 74-75.

FLOREN, A. FREKING A., BIEHL M. & LINSENMAIR, K.E. 2001: Anthropogenic disturbance changes the structure of arboreal tropical ant communities. – Ecography 24: 547-554.

FLOREN, A. & LINSENMAIR, K.E. 1997: Diversity and recolonisation dynamics of selected arthropod groups on different tree species in a lowland rain forest in Sabah, Malaysia with special reference to Formicidae. In: STORK, N.E., ADIS, J.A. & DIDHAM, R.K. (Eds): Canopy Arthropods. – Chapman & Hall, London, pp. 344-381.

FLOREN, A. & LINSENMAIR, K.E. 2000: Do ant mosaics exist in pristine lowland rain forest? – Oecologia 123: 129-137.

FLOREN, A. & LINSENMAIR, K.E. 2005: The importance of primary tropical rain forest for species diversity: an investigation using arboreal ants as an example. – Ecosystems http://dx.doi.org/10.1007/s10021-002-0272-8

HARADA, A.Y. & ADIS, J. 1997: The ant fauna of tree canopies in Central Amazonia: a first assessment. In: STORK, N.E., ADIS, J.A. & DIDHAM, R.K. (Eds): Canopy Arthropods. – Chapman & Hall, London, pp. 382-400.

JACKSON, D.A. 1984: Ant distribution patterns in a Cameroonian cocoa plantation: investigation of the ant mosaic hypothesis – Oecologia 62: 318-324.

LESTON, D. 1978: A neotropical ant mosaic. – Annals of the Entomological Society of America 71: 649-653.

LONGINO, J.T., CODDINGTON, J. & COLWELL, R.K. 2002: The ant fauna of a tropical rain forest: estimating species richness three different ways. – Ecology 83: 689-702.

ROOM, P.M. 1975: Relative distributions of ant species in cocoa plantations in Papua New Guinea. – Journal of Applied Ecology 12: 47-61.

SEIFERT, B. 1996: Ameisen, beobachten, bestimmen. – Naturbuch-Verlag, Augsburg, 352 pp.

WILSON, E.O. 1987: The arboreal ant fauna of Peruvian Amazon forests: a first assessment. – Biotropica 193: 245-251.