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Studying canopy arthropods in New Caledonia: how to obtain a representative sample

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ABSTRACT. Canopy arthropods were sampled by insecticide fogging to study their community structure in two New Caledonian primary rain forests. The representativeness of these samples was analysed by two different methods: the diversity-area relationship and the relationship between the distribution of the taxa and the sample size, using Pielou's method. The results showed that the higher the degree of aggregation, the higher must be the minimum sample size to ensure a stable distribution. In the same way, the higher the diversity index, the higher must be the sample size to ensure a representative sample of the community. In this study, 40 sample units of 1 m^2 were used, although, samples of 9 to 25 m^2 seem to be sufficient according to the distribution of the taxa sampled. Five to 30 m^2 should be sufficient to ensure representative samples of the whole community for estimating diversity.

KEY WORDS: biodiversity, canopy arthropods, distribution index, diversity index, fogging, New Caledonia, representative sample, sample size

INTRODUCTION

Many studies of biodiversity aim to provide an estimate of the number of species in the world (Erwin 1982, Gaston 1991, Hodkinson & Casson 1991; May 1988, 1990, 1992; Stork 1988, 1993). There are several ways to achieve this. One way is to make full inventories and to describe the fauna and the flora. However, the description of species takes such a long time that biodiversity will have disappeared by the time it is completely known (see Hammond 1992, Stork 1993). A second way is to estimate and extrapolate from the number of species in a sample. Arthropods of tropical forests are one of the critical groups, due to their abundance and diversity. Nevertheless, most studies do not take into consideration how representative is the sample of the population considered (Braithwaite 1991). An efficient or sufficient sample should be ensured in the sense that it is stable and also reproducible (Heck *et al.* 1975, Miller &

Wiegert 1989, Wolda 1981). The sampling technique should be as precise as possible in time and space. Knockdown insecticidal fogging of trees can provide canopy arthropods samples clearly defined in time and space to analyse taxa distributions and community diversity versus sample size. In the present paper, canopy arthropods were sampled by fogging to estimate their diversity in two New Caledonian primary rain forests (Guilbert 1997, Guilbert *et al*. 1994). Before analyzing the diversity of the fauna, the efficiency of the sampling method was tested using Pielou's pooled-quadrats method (Pielou 1975). The method was adapted to a distribution index and a diversity index to determine the minimal sample size necessary to obtain a representative sample of a given taxa separately in the first case, and for the whole community in the second case.

METHODS

Study sites

Canopy arthropods were sampled at two sites in different forest types of New Caledonia. One was located on the east coast, close to the sea on the peninsula of Népoui, in the relict sclerophyll forest of Pindaï (North Province, 30 m asl) on limestone and conglomerates. The other was located in dense evergreen forest to the north of the Grand Lac de Yaté, in Rivière Bleue Provincial Park (South Province, 160 m asl) on ultramafic alluvium (Bonnet de Larbogne *et al.* 1991). The maximum height of the canopy was *c*. 25 m at Rivière Bleue and 10–15 m at Pindaï. These two sites have different vegetation (Jaffré & Veillon 1990, Jaffré *et al.* 1993) and climate, notably a large difference in annual rainfall (Guilbert 1994).

Sampling

The arthropods were sampled by knockdown insecticidal fogging. A portable fogging machine was used (Dyna-fog, Golden Eagle Backpack 2980™) to release a fast killing pyrethrum-based fog (Cyfluthrin, water and polyhydric alcohol). The fogger was operated from the ground, dispersing the fog upward into the trees. The arthropods, which had dropped onto the sheets for 2 h after fogging, were collected on 40 randomly placed collecting trays. The whole of the 40 trays cover around 140 m^2. Trays were 1 m^2 white plastic sheets. Each collecting tray is called a sampling unit below. The arthropods were washed off the sheets into collecting pots with water and a wetting agent (Tipol). The samples were stored in 95% alcohol and later sorted to order level. The most species rich groups Araneae, Coleoptera, Diptera, Hemiptera, Hymenoptera and Orthoptera were sorted to family. Each site was sampled four times a year to cover seasonal variations: sample 1 was taken in July 1992, sample 2 in October 1992, sample 3 in January 1993 and sample 4 in May 1993. For more details about the method see Guilbert *et al.* (1994).

Statistical analyses

Most of the methods which allow determination of optimal sample size are empirical and provide an approximate value (Cancela da Fonseca 1965). Magurran (1988) recommends Pielou's method (Pielou 1975) as it can be adapted to provide a minimum viable sample size if sampling units are placed at random. In this study, it was used with two kind of indices: a distribution index to define the sufficient sample size for each taxa taken individually and a diversity index to define the sufficient sample size for the whole community.

Distribution index. The relative variance as an aggregation index (Cancela da Fonseca 1966): $s^2/\bar{x}$ was used, where s^2 = variance, $\bar{x}$ = mean. It depends upon the sample size. It was tested using the χ^2-statistic and the t-test (Greig-Smith 1964). Two cases among twelve analysed and representing different distributions found will be presented in this paper: the Tingidae and the Formicidae sampled at Pindaï in October 1992.

Diversity-area relationship. Shannon index (Shannon & Weaver 1949):

$$\sum p_i \log p_i,$$

p_i = relative abundance of taxon i, were used. It does not require a distribution hypothesis. The Shannon index does not depend on the sample size, it assumes that the sample is just a part of an undefined community. Two examples among the two sites and the four seasons analysed will be presented here: the samples of Rivière Bleue and Pindaï in October 1992.

Each index was estimated for increasing sample sizes, by adding randomly one by one the sample units from 2 to 40 m^2, to achieve a diversity-area curve. Each addition of a sample unit, the indices were estimated from 500 iterations using the bootstrap technique. When the resulting curve reached a plateau, the sample size was considered to be sufficient.

Representative sample. To ensure the representativeness of the sample, the slope of the diversity-area curve was found. The sample was said to be representative when the asymptote was reached. The slope of this part of the curve must be equal to zero. It will be linear and written as $y = ax + b$ with $a = 0$. The linearity of this portion considering the last 20 sample units was analysed by linear least squares regression, with the null hypothesis of the slope being zero tested by the t-test.

All statistical analyses were performed using the SAS statistical package (SAS Inc. 1988), except for the bootstrap technique which was achieved with a program written by M. Baylac in PASCAL.

RESULTS

Distribution index

The Tingidae and the Formicidae sampled at Pindaï in October 1992 showed an aggregated distribution ($s^2/\bar{x} = 3.42$ and 43.02, respectively, $P \leq 0.002$ and

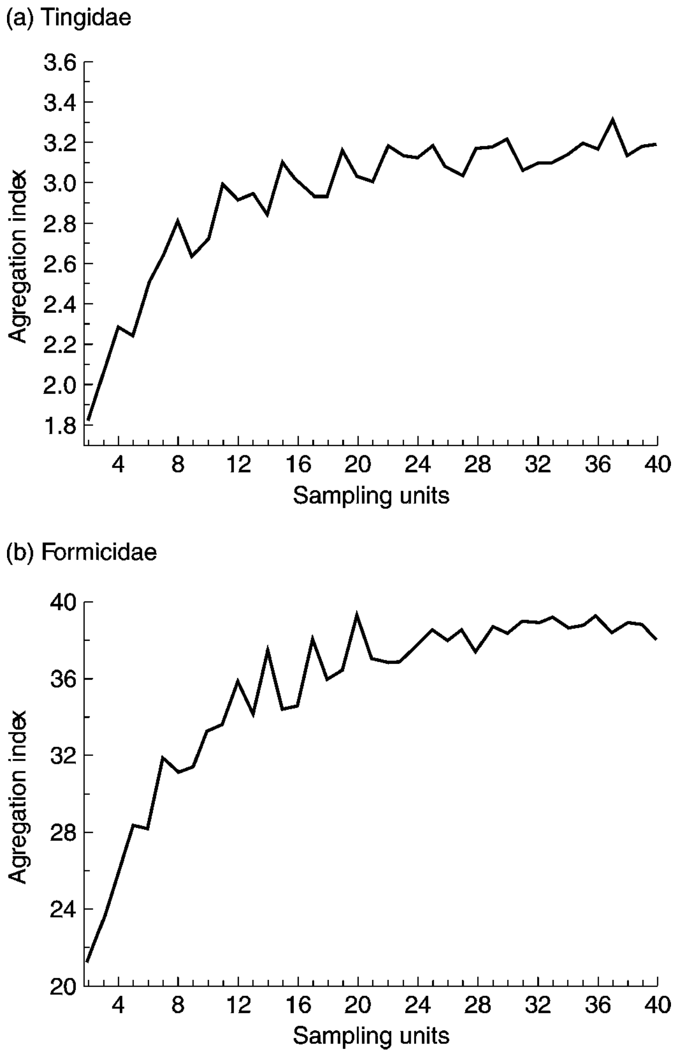

Figure 1. Change in the aggregation index with the sample size for (a) the Tingidae and (b) the Formicidae sampled in October 1992 in New Caledonian forest.

0.0001, respectively). The index of relative variance varied according to the sample size, until it reached a plateau where it stabilised (Figure 1). For the Tingidae, the index increased until the 8th unit and then, increased slightly but fluctuated from the 9th or 12th units. It reached a plateau around the 20th unit. For the Formicidae, the index increased sharply until the 12th unit, still increased but fluctuated between the 13th and the 24th units and then, the curve reached a plateau at the 25th unit.

The analysis of other cases showed that the smaller the degree of aggregation, the quicker the index stabilised. Then, for cases which were randomly distributed, the index oscillated around an average value since the first sample units. For some randomly distributed cases, the index decreased progressively to a value around which it stabilised. These cases showed lower abundances than the others, and also, the confidence intervals of their indices were excessively large and therefore provided an imprecise estimate of the mode. Others indices could have been used. For example, Morisita's index, used as a distribution index, gave approximately the same results to the relative variance measure.

Diversity index

Diversity was higher at Rivière Bleue than at Pindaï in October 1992 (Figure 2). It increased sharply for small sample sizes and stabilised at different values. At Rivière Bleue, it reached a plateau *c.* 15 m^2; while at Pindaï, a plateau was reached at 12–13 m^2.

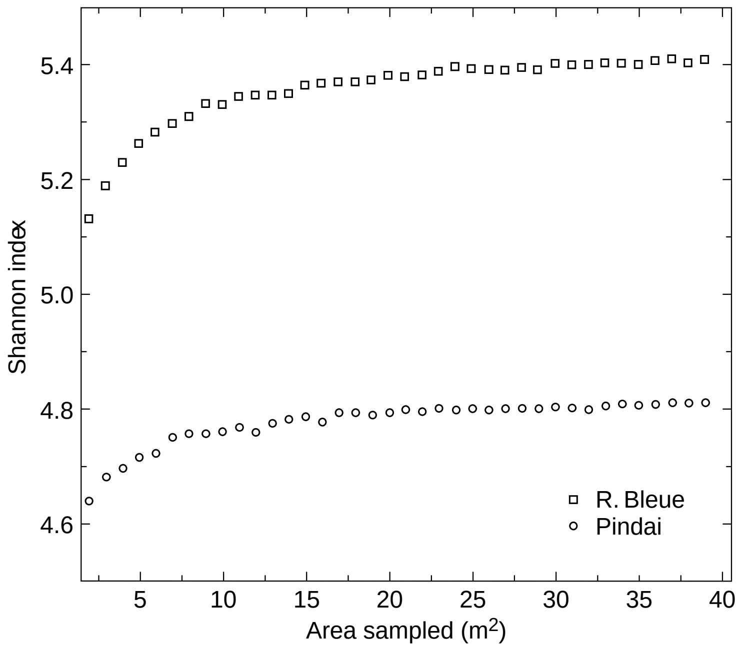

Figure 2. Change in the Shannon index with the sample size for the whole community sampled at Riviére Bleue and Pindaï, New Caledonia, in October 1992.

The analysis of other samples showed that the higher the initial value of the index, the more it increased. It increased sharply for small samples and stabilised at different values according to the site and season. For example, the diversity-area curve for the sample of Pindaï in January 1993, where the diversity was low, did not present a plateau. Other indices could also have been used. For example, the Brillouin index showed the same tendencies as the Shannon index, despite some small differences due to the information carried by the index.

Representative sample

The analysis of the linearity of the position considering the last 20 units showed that the residuals were autocorrelated at Rivière Bleue but independent at Pindaï. The corresponding relationship described was thus non-linear for Rivière Bleue and linear for Pindaï. However, as for Rivière Bleue, the gradient of the curve at Pindaï was not equal to zero even though small (slope = 0.00144 and 0.00084, respectively, $P \leq 0.0001$ for both). When considering the last 10 sample units, the curves appeared linear, but for so few units, the regressions explained only a small part of the variance. The results were not statistically significant for some of the samples, even though the slopes were close to zero.

DISCUSSION

Samples of 20–25 m^2 seemed to be sufficient to ensure a stable distribution of the aggregated taxa; whereas, fewer samples units were sufficient for taxa that were randomly distributed, provided that these taxa are abundant enough. The Tingidae and the Formicidae showed an aggregated distribution and required approximately the same minimum sample size although they differed in abundance (60 and 1131 individuals, respectively) and in behaviour. It appears that 5–10 m^2 units comprised a representative sample for low diversity sites, whereas samples of 20 m^2 were not sufficient to ensure a strictly representative sample for high diversity sites where 30 m^2 should be enough.

The number of taxa and their abundance tended always to increase even if slightly and the taxa distribution tended to be modified when the sample size increased. There will always be rare taxa in the community for which the distribution is unstable and which will make the community diversity increase (Colwell & Coddington 1994). In addition, the real distribution of taxa could be hidden by the sample strategy (Chessel 1978). The distribution of taxa and community diversity depend up on the scale of observation and sample unit size and number (Magurran 1988). In addition, the sufficient sample size tends to differ according to forest type and season as seen by Wolda (1983).

Conclusion

Both approaches, one based on taxa distributions and the other based on community diversity, are complementary. In the one hand, distribution indices give information for each taxon separately. In our study, 20–25 m^2 were enough to ensure a stable sample of the aggregated taxa. In the other hand, diversity indices permit a definition of minimal sample size for the whole community and 30 m^2 was shown to be necessary in this study.

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