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Author(s): Vincent Vedel, Axel Cerdan, Quentin Martinez, Christopher Baraloto, Fréderic Petitclerc, Jérôme Orivel and Claire Fortunel
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## SHORT COMMUNICATION

# Day-time vs. night-time sampling does not affect estimates of spider diversity across a land use gradient in the Neotropics

**Vincent Vedel**[1,2], **Axel Cerdan**[2], **Quentin Martinez**[2], **Christopher Baraloto**[3], **Fréderic Petitclerc**[4], **Jérôme Orivel**[4] and **Claire Fortunel**[3,5]: [1]Laboratoire d'entomologie Entobios, 5 Bis rue François Thomas, 97310 Kourou, Guyane Française. E-mail: entobios@gmail.com; [2]UAG, UMR Ecologie des Forêts de Guyane, BP 709, 97387 Kourou Cedex, France; [3]INRA, UMR Ecologie des Forêts de Guyane, BP 709, 97387 Kourou Cedex, France; [4]CNRS, UMR Ecologie des Forêts de Guyane, BP 709, 97387 Kourou Cedex, France; [5]Department of Biology, University of Maryland, College Park, MD, USA

**Abstract.** To obtain a reliable description of spider communities, robust sampling protocols are crucial. However, it remains unclear if descriptions of spider communities in tropical habitats require both day and night sampling. Here we tested whether sampling both day and night in high and low vegetation strata would lead to better diversity estimates of spider communities than sampling at only one period of the day. We determined spider taxonomic diversity in a network of 12 plots in French Guiana along a vegetation gradient. We found high alpha diversity of spiders as expected for a tropical area at every site. We showed strong differences in spider alpha and beta diversity between high and low vegetation strata, while they were similar between day and night sampling. Our results suggest that collecting spiders at only one period is sufficient to describe the diversity of spider communities across land use types in the neotropics.

**Keywords:** Araneae, community, sampling protocol, night, day

An essential first step towards a better understanding of arthropod communities is a reliable description of community composition and abundance via a robust sampling protocol. Sampling needs to represent accurately the target group and also to optimize the ratio of data quality to sampling effort. However, although a common sampling protocol is beginning to be globally used (Cardoso 2009), some parameters still need to be tested and improved.

Spiders inhabit almost every terrestrial habitat (Cardoso et al. 2009). They have developed various hunting strategies (e.g., ambushing, wandering, web building, door trapping) in order to hunt efficiently and to minimize interspecific competition (Cardoso et al. 2011). This variety of feeding behaviors increases the difficulty of sampling the whole spider community entirely and precisely. To cover such wide spatial and temporal activities, several sampling protocols combining passive and active techniques have been established to optimize sampling effort in space and time (Coddington et al. 1991, 2009; Cardoso 2009; Vedel et al. 2011; Vedel & Lalagüe 2013). To examine the spatial distribution of spiders, one of the parameters is to study strata. Some sampling techniques are specifically used to collect spiders from a vegetation stratum. The most efficient techniques, commonly used on boreal forest and Mediterranean habitats, are the pitfall traps and nocturnal hand collecting for leaf litter, the sweep net for lower understory vegetation and the beating tray for higher understory vegetation (Vedel & Lalagüe 2013). In addition to spatial distribution, the time of sampling may represent an essential factor for sampling spider communities (Coddington et al. 1991; Sorensen et al. 2002; Cardoso et al. 2008, 2009). Indeed, most spiders are active only at night, while a smaller community is active only during the day, and an even smaller proportion is active during both periods (Foelix 2013). It has thus been argued that sampling has to be conducted both day and night to capture spiders with both diurnal and nocturnal activities (Cardoso et al. 2009; Vedel & Lalagüe 2013). Spider species inhabiting the leaf litter are foraging during their active period (very often at night) and are hiding in burrows to rest. Some sampling methods (e.g., pitfall traps and nocturnal hand collecting) can catch them only when they are in their active period out of their burrow. In understory vegetation layers, where more than the three quarters of spider species found in tropical habitats live (Coddington et al. 2009), spiders forage and rest on the same habitat, on the vegetation. Nevertheless, it remains unclear whether diurnal and nocturnal sampling is necessary to characterize the hyperdiverse tropical arachnid communities.

Here we aimed at assessing whether sampling both day and night with multiple methods would lead to better estimates of spider community diversity than sampling at only one period of the day across vegetation strata along a gradient of land use in French Guiana. We expected to find that, to acquire meaningful measures of spider diversity, it is not necessary to sample both during the day and at night in the understory vegetation of tropical forests.

We established a network of 12 plots within a 20-km$^2$ area along the road Degrade Saramaka, near Kourou, in French Guiana. Local climate is typically equatorial with a rather constant temperature across the year around 26°C and with high humidity divided into two main seasons: one with high precipitation from December until June and the other with little precipitation from July to November.

Three 50 m x 50 m plots were located in each of four land-use types. Each plot from one land-use type had similar vegetation communities. These four land types therefore represented a gradient of vegetation from higher cover to lower cover of vegetation, respectively: (i) undisturbed tropical forest, (ii) forest edge, (iii) agricultural land after slash and burn, and (iv) garden.

We used the optimized and standardized protocol originally established by the widely used COBRA protocol for arthropods (Cardoso 2009; Cardoso et al. 2009), and further adapted to tropical rain forests (Vedel & Lalagüe 2013). Spiders were sampled at two vegetation strata: high understory (tree samplings) using beating trays, and low understory (grasses, forbs, shrubs and tree seedlings) using sweeping nets during two periods: day time (0800–1200) and night time (2100–2400). The sampling effort was of one hour per technique per day period per plot (four hours on each plot). Sampling was conducted 15–29 July 2013, i.e., during the end of the raining season.

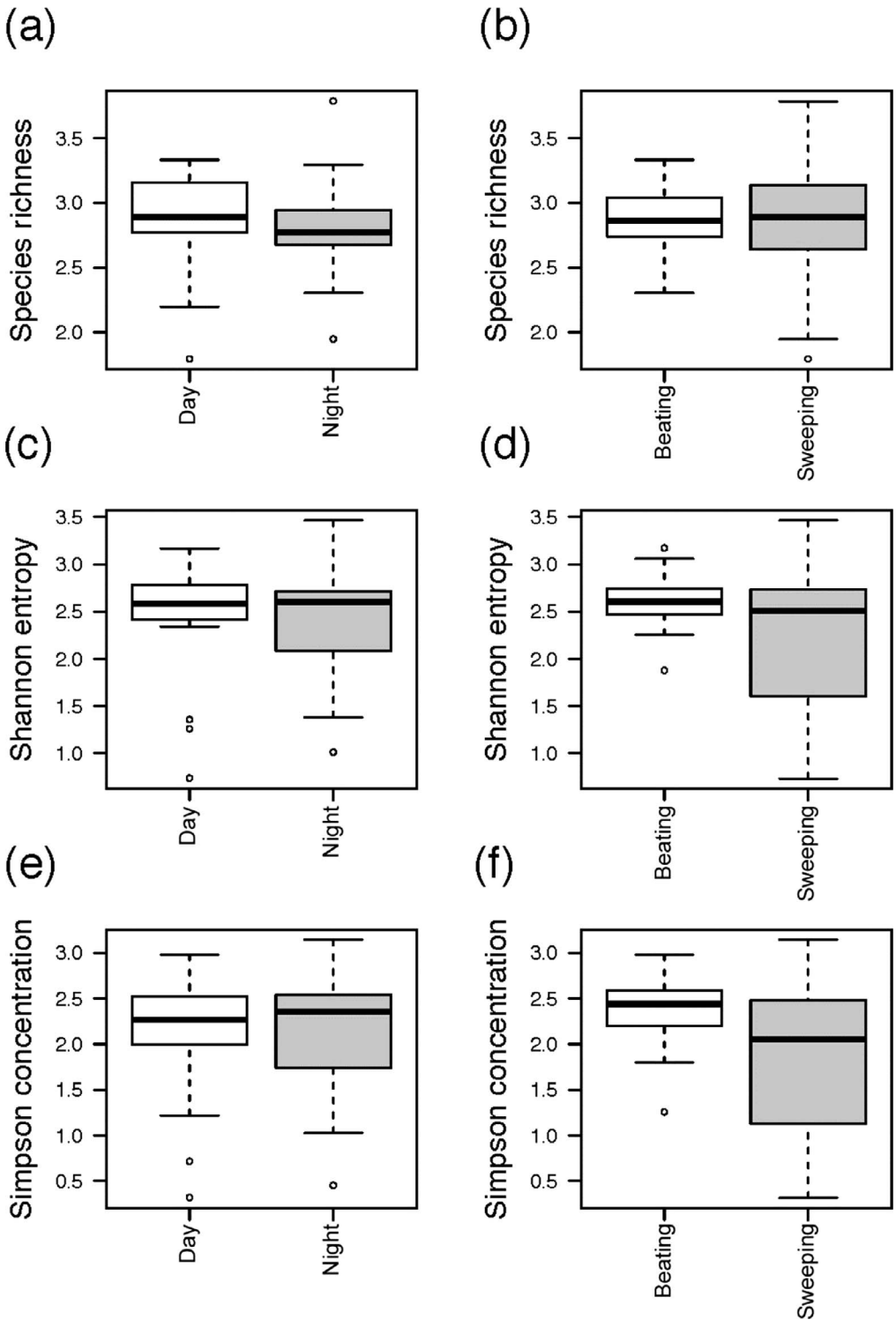


Figure 1.—Boxplots of species richness (a, b), Shannon entropy (c, d) and Simpson concentration (e, f) by sampling time and vegetation strata.

Samples were placed in tubes filled with ethanol (70%) and labeled after sampling technique (beating, sweeping) and period of the day (day, night) in each plot. For each sample, we sorted and identified individual spiders at the species level, defining morpho-species (M-S) only when there was no matching species in the literature (Brescovit et al. 2002; Levi 2002; Proszynski 2007; Vedel et al. 2013). If juvenile spiders were old enough to be identified at the species level, we included them. No M-S was defined by only juveniles. We collected a total of 2292 individuals belonging to 39 families, 100 genera and 414 morpho-species. Following the classification described in Cardoso et al. (2011), each species was assigned to a functional guild relating to feeding behavior.

We used rarefaction curves to assess species richness from the results of sampling. We characterized the alpha diversity of spider

Table 1.—Influence of sampling period and vegetation strata on spider alpha diversity. *F* statistics are shown with significance test (**: $P < 0.01$; *: $P < 0.05$; ns: not significant).

| | Daytime | | Vegetation strata | | Daytime X vegetation strata | |
|---|---|---|---|---|---|---|
| Species richness | 0.493 | ns | 0.445 | ns | 1.292 | ns |
| Shannon entropy | 0.132 | ns | 5.433 | * | 0.513 | ns |
| Simpson concentration | 0.021 | ns | 7.339 | ** | 7.339 | ns |

communities as (i) species richness, (ii) Shannon entropy and (iii) Simpson concentration (Jost 2007). We determined the beta diversity of spider communities as distance matrices of taxonomic compositions using the Bray-Curtis metrics, calculated (i) with species presence-absence and (ii) with species abundances (Legendre & De Cáceres 2013).

To test the effect of sampling time (day/night), vegetation strata (high/low understory) and their interaction on spider taxonomic alpha diversity, we used three-way analysis of variance (ANOVA). To test the effect of sampling time and vegetation strata on spider taxonomic beta diversity, we conducted a permutational multivariate analysis of variance for partitioning distance matrices between the two sources of variation.

All analyses were conducted in the R 3.0.2 statistical platform (R Development Core Team 2011), using the package vegan (Dixon 2003).

We found a high alpha taxonomic diversity of spider species in every habitat and stratum. For comparison, here 414 M-S were identified for 2292 individuals collected (intensity = 5.54) while the averages of other tropical sites (reviewed in Coddington et al. 2009) are 303.75 M-S for 3170.8 individuals sampled (intensity = 10.45). In boreal white spruce stands, 3070 specimens were collected representing 76 species (intensity = 40.40). Because different sampling protocols and indices were used for the earlier studies, their indices are comparable to ours only in that they suggest the high species richness of the sites we sampled.

We also found no variation in spider alpha diversity between sampling times and no interaction between sampling time and vegetation strata (Table 1, Fig. 1a, c, e). Although we found no change in species richness between vegetation strata, we showed that Shannon entropy and Simpson concentration were higher in the high understory than in low understory (Fig. 1b, d, f).

Table 2.—Influence of sampling period and vegetation strata on spider beta diversity, calculated for species presence-absence and for species abundances. *F* statistics are shown with significance test (***: $P < 0.001$; *: $P < 0.05$; ns: not significant).

| | Daytime | | Vegetation strata | |
|---|---|---|---|---|
| Beta diversity: | | | | |
| Species presence-absence | 1.0834 | ns | 2.4051 | *** |
| Species abundance | 1.1791 | ns | 1.5505 | * |

We showed no influence of sampling time on spider beta diversity, calculated without and with species abundances (Table 2). However we found a strong effect of vegetation strata in spider beta diversity, calculated without and with species abundances (Table 2). This confirms that it is essential to consistently use both sampling methods (sweeping and beating) to capture the spider diversity in the two vegetation strata (Cardoso et al. 2009; Vedel & Lalagüe 2013). Figure 2 illustrates that low and high understories form two different clusters, with species abundances and with species presence-absence. Spider beta diversity was thus more similar within vegetation strata of the 12 plots than between vegetation strata of one plot.

The lack of differences in spider alpha and beta diversity during day or night sampling suggests that collecting spiders at only one time during the day appears to be sufficient to describe the diversity of spider communities across vegetation types in this area in the Neotropics.

Our findings confirm the only two studies using similar experimental designs, where vegetation strata were separated and where the leaf litter stratum was not included, though they were performed in temperate forests (Coddington et al. 1996; Dobyns 1997). In contrast, studies finding an opposite result from ours used generally another experimental or analytical design, therefore making a comparison of the final results difficult. Coddington et al. (1991) found differences between day and night sampling, but collecting techniques including leaf litter sampling were not separated, which biases the overall results. Also respectively in temperate and in tropical habitats, two other studies show the same results as Coddington et al. (1991) but also did not separate sampling techniques for the soil and the vegetation (Green 1999; Sorensen et al. 2002). Finally, in Mediterranean habitats, results are also ambiguous. Beta-diversity varied depending on the statistical

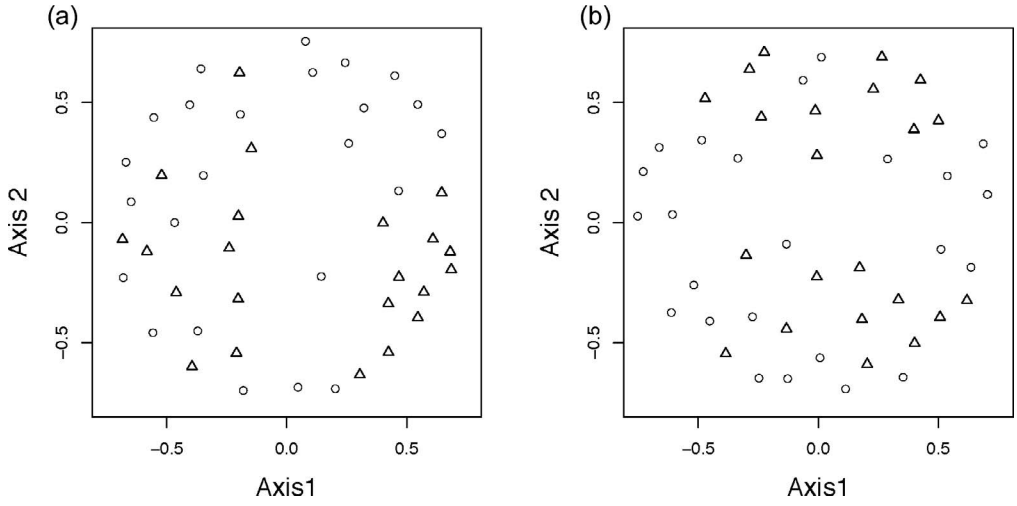


Figure 2.—Taxonomic beta similarity between vegetation strata based on species abundance (a) and based on species presence-absence (b), plotted on the two main axes determined by non-metric multidimensional scaling. Circles stand for high understory, and triangles stand for low understory.

test applied: the Spearman correlation did not find any differences between day and night sampling although the Anosim analysis did (Cardoso et al. 2008). A third study found no difference between day and night sampling for the beating techniques but a richer community of spiders collected by sweeping during night time (Cardoso et al. 2008). This supports the need for further tests to assess the generality of our findings in other ecosystems.

To optimize sampling, we thus recommend sampling spiders on vegetation at different strata by using these two techniques (sweeping lower understory vegetation and beating higher understory vegetation) at night, where the sampling of the leaf litter is efficient (data not shown).

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