FLORISTIC, FREQUENCY, AND VEGETATION LIFE-FORM SPECTRA OF A CERRADO SITE

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ABSTRACT

We used Raunkiaer's system to classify in life-forms the vascular plants present in 12 random 25 m^2 quadrats of a *cerrado* site. The study area is covered by *cerrado sensu stricto* and is located in the Valério fragment, at about 22º13'S and 47º51'W, 760 m above sea level, in the Itirapina Ecological and Experimental Station, São Paulo State, southeastern Brazil. The floristic spectrum considers the life-form of each species, while in the frequency spectrum, each species is weighted by its frequency. The vegetation spectrum does not consider the species at all, but only the individuals in each life-form class. In the floristic spectrum, the most represented life-forms were the phanerophytes and the hemicryptophytes, as in other *cerrado* sites. This spectrum differed significantly from Raunkiaer's normal spectrum, mainly due to under-representation of therophytes and over-representation of phanerophytes. The floristic and frequency spectra were similar, but both differed from the vegetation spectrum. We recommend the floristic spectrum when working at larger scales and a description of the phytoclimate is wanted. The vegetation spectrum is preferable when working at smaller scales and wanting a quantitative description of the physiognomy. The frequency spectrum is not recommended at all.

Key words: biological spectrum, life-form, *cerrado*, Raunkiaer, savanna, southeastern Brazil.

RESUMO

Espectros florístico, de freqüência e vegetacional de um sítio de cerrado

Usamos o sistema de Raunkiaer para classificar, em formas de vida, as plantas vasculares presentes em 12 parcelas aleatórias de 25 m^2 de cerrado. A área de estudo é coberta por cerrado *sensu stricto* e se localiza no fragmento do Valério, aproximadamente a 22º13'S e 47º51'W, a 760 m de altitude, na Estação Ecológica e Experimental de Itirapina, Estado de São Paulo. O espectro florístico considera a forma de vida de cada espécie; no espectro de freqüência, cada espécie é ponderada por sua freqüência e o espectro vegetacional não considera as espécies, mas sim os indivíduos em cada classe. No espectro florístico, as forma de vida mais bem representadas foram as dos fanerófitos e dos hemicriptófitos, como em outros cerrados. Esse espectro diferiu significativamente do espectro normal de Raunkiaer devido, principalmente, à sub-representação dos terófitos e à super-representação dos fanerófitos. Os espectros florísticos e de freqüência foram similares, mas ambos diferiram do espectro vegetacional. Recomendamos o espectro florístico para os trabalhos em escalas maiores e para descrição do fitoclima e o espectro vegetacional para os trabalhos em escalas menores e para descrição quantitativa da fisionomia. O espectro de freqüência não é recomendado em nenhuma situação.

Palavras-chave: espectro biológico, formas de vida, cerrado, Raunkiaer, savana, Itirapina.

INTRODUCTION

Plants can be grouped in life-form classes based on their similarities in structure and function (Mueller-Dombois & Ellenberg, 1974). A life-form is characterized by plant adaptation to certain ecological conditions (Mera *et al.*, 1999). Life-form study is an important part of vegetation description, ranking next to floristic composition (Cain, 1950). Raunkiaer (1934) proposed a system to classify plant life-forms based on the position and degree of protection of the renewing buds, which are responsible for the renewal of the plant's aerial body when the favorable season comes.

In Raunkiaer's (1934) system, the more pronounced the unfavorable season, the more protected the renewing buds. In his classification there are five major classes, arranged according to increased protection of the renewing buds: phanerophytes, chamaephytes, hemicryptophytes, cryptophytes, and therophytes. Raunkiaer's classification was modified, among others, by Mueller-Dombois & Ellenberg (1974), to include plant features in the favorable season. Even if sometimes strongly criticized (Sarmiento & Monasterio, 1983), Raunkiaer's system is still the simplest and, in many ways, the most satisfying classification of plant life-forms (Begon *et al.*, 1996).

Raunkiaer (1934) proposed the "biological spectrum" to express both the life-form distribution in a flora and the phytoclimate under which the prevailing life-forms evolved. The biological spectrum is the percent representation of the number of species belonging to each life-form in a given flora. Raunkiaer (1934) constructed a "normal spectrum" which could act as a null model against which different life-form spectra could be compared. Differences in the life-form distribution between the normal spectrum and a biological spectrum would point out which life-form characterizes the phytoclimate or the vegetation under study.

When working with a species list, every species has the same weight in the biological spectrum. This is called a floristic biological spectrum (Godron *et al.*, 1969). However, when the number of individuals, instead of species, of each life-form is counted, each class can be weighted by its abundance, giving rise to the vegetation biological spectrum, which indicates the phenomena relative to the vegetation rather than to the flora (Godron *et al.*, 1969). Also, the vegetation biological spectrum is more readily comparable

to biological spectra similarly constructed for other sites. Nevertheless, Raunkiaer (1934) stated that counting all plant individuals in a survey is too problematic, because it is not always possible to distinguish what an individual is. To avoid this, Raunkiaer (1934) proposed a frequency spectrum, where the number of sampling units in which the species is present is used to weight the species.

In the Brazilian cerrado, some studies have used Raunkiaer's system to classify the sampled species in life-forms. For instance, Mantovani (1983) classified a cerrado site flora in life-forms, constructed its biological spectrum, and compared it with other cerrado spectra obtained from Warming (1892) and Ratter (1980). Batalha *et al.* (1997) and Batalha & Mantovani (2001) carried out floristic surveys in two cerrado sites and also classified the species in life-form classes. In all these sites, higher proportions of hemicryptophytes and phanerophytes were found. The cerrado vegetation comprises a wide physiognomic range, from grassland to woodland, but with most physiognomies fitting the definition of tropical savannas (Coutinho, 1978). Since the importance of trees and shrubs increases from open to closed physiognomies (Coutinho, 1978), the proportion of phanerophytes also increases in this direction.

Our aim is to answer the following questions with respect to the life-forms of vascular species found in a cerrado site in Itirapina Municipality, southeastern Brazil: 1) Are the hemicryptophytes and phanerophytes the most represented life-forms in our survey, as in other cerrado sites (Warming, 1892; Ratter, 1980; Mantovani, 1983; Batalha *et al.*, 1997; Batalha & Mantovani, 2001)? 2) Is the floristic biological spectrum in the cerrado of Itirapina significantly different from Raunkiaer's normal spectrum? 3) If so, which classes characterize the Itirapina life-form spectrum? 4) Do the floristic, frequency, and vegetation spectra differ significantly from one anotherand between them and the normal spectrum?

MATERIAL AND METHODS

We carried out our study in a cerrado site, in the Municipality of Itirapina, São Paulo State, southeastern Brazil, approximately 22°13'S and 47°51'W, 760 m above sea level. The site is classified as cerrado sensu stricto following Coutinho's (1978) classification, which is a woodland according to Sarmiento (1984). The climate is Koeppen's Cwa,

that is, macrothermic temperate with rainy summers and not severely dry winters. The area belongs to the São Paulo State Forestry Institute and is surrounded by a pine plantation.

In this site, there is a permanent grid of 64 quadrats (each one with 25 m^2), where other researchers have developed studies on population dynamics and community structure. We randomly surveyed 12 quadrats in this grid in the middle of the rainy season (February 2001) and classified all vascular plants in life-forms, following Raunkiaer's (1934) system adapted by Mueller-Dombois & Ellenberg (1974).

We assigned the life-form of each species with the aid of an identification key (Mueller-Dombois & Ellenberg, 1974). Since we did not follow the individuals throughout the year, we used, in some cases, information from other studies that did so and classified the species in life-forms (Mantovani, 1983; Batalha *et al.*, 1997; Batalha & Mantovani, 2001). To avoid sampling seedlings, we included an individual in our sample only if its leaves were morphologically similar to leaves of an adult plant and presented no cotyledons. For caespitose plants, we defined as individuals very caespitose; for non-caespitose plants, we considered each isolated axis at soil level as an individual.

In the construction of the floristic and frequency spectra, we assigned each species to a single life-form class only, and always the one in which the renewing buds were less protected. In the vegetation spectrum, we counted the abundance of each life-form regardless of the species to which the individual belonged. For example, we classified a species as "phanerophyte" in the floristic and frequency spectra, even though some of their individuals were smaller than 50 cm. On contrary, in the vegetation spectrum, we classified the individuals of a phanerophytic species as "chamaephytes" or "phanerophytes", depending on their height, as recommended by Godron *et al.* (1969).

We used the data regarding the life-form of each species to construct the floristic, frequency, and vegetation spectra (Raunkiaer, 1934; Godron *et al.*, 1969). We compared the floristic spectrum to Raunkiaer's normal spectrum. In this case, to allow comparison we included lianas and epiphytes in the "phanerophyte" class, and geophyte and saprophyte, in the "cryptophyte" class, as originally proposed by Raunkiaer (1934).

To verify whether the floristic life-form spectrum was significantly different from that expected according to the normal spectrum, we applied the chi-square test (Zar, 1999). If there was a significant differences, we calculated the contribution percentage of each class in the chi-square value. In this case, the higher the difference between the expected and the observed in the life-form class, the higher the percentage of its contribution.

In the frequency life-form spectrum, we weighted each species by the number of quadrats in which it appeared, whereas in the vegetation spectrum, we weighted each life-form by its number of individuals. We compared the floristic, frequency, and vegetation spectra pairwisel with a homogeneity analysis (Zar, 1999) to test whether the life-form proportions were the same in both spectra. In this analysis, we considered only Raunkiaer's major classes (phanerophytes, chamaephytes, hemicryptophytes, cryptophytes, and therophytes). Since there was a low number of cryptophytes, we included them in the "hemicryptophyte" class, and did the analysis with four classes only.

We calculated Shannon-Wiener diversity index (Shannon, 1948) for the two classes with higher proportions in the vegetation life-form spectrum, and tested for differences between them with the t-test proposed by Hutcheson (1970).

RESULTS

In our survey, we sampled 113 species of which 75 were considered phanerophytes (52.21%); 13, chamaephytes (11.50%); 21, hemicryptophytes (18.58%); 1, geophyte (0.88%); 2, therophytes (1.77%); 14, lianas (12.39%); 2, epiphytes (1.77%); and 1, saprophyte (0.88%). In the floristic life-form spectrum (Fig. 1), the most striking feature was the high percentage of phanerophytes.

The comparison between the floristic life-form spectrum and Raunkiaer's normal spectrum indicated a statistically significant difference between them ($\chi^2 = 27.70$, p < 0.001). The observed proportions were higher than expected for the phanerophytes and chamaephytes and lower for the hemicryptophytes, cryptophytes, and therophytes. The highest contribution to the chi-square value was given by therophytes (39.57%), followed by phanerophytes (36.80%), cryptophytes (12.16%), hemicryptophytes (8.63%), and chamaephytes (2.84%) (Fig. 2).

In the frequency spectrum we recorded 516 occurrences and, in the vegetation spectrum, 2.834 individuals. The most represented classes in the floristic spectrum (phanerophyte and hemicryptophyte)

were also the most represented in the other two spectra, but their patterns of variation were different. The proportion of hemicryptophytes increased from the floristic to the vegetation spectrum, whereas the proportion of phanerophytes decreased (Table 1). The diversity indices of these classes were, respectively, 3.15 ± 0.10 nats/ind for the phanerophytes and 1.73 ± 0.01 nats/ind for the hemicryptophytes, values considered different by the t-test (t = 24.88, v = 533, p < 0.001).

According to the homogeneity analysis (Table 2), the floristic spectrum differed significantly from the vegetation spectrum (χ^2 = 45.28, p < 0.001),

but not from the frequency one (χ^2 = 2.08, p > 0.10). The frequency spectrum differed significantly from the vegetation one (χ^2 = 169.76, p < 0.001).

DISCUSSION

In the floristic life-form spectrum, the most represented classes were the phanerophytes and hemicryptophytes, as in other cerrado sites (Mantovani, 1983; Batalha *et al.*, 1997; Batalha & Mantovani, 2001). The proportion of phanerophytes was, however, higher in Itirapina than in the other sites, whereas the hemicryptophytes proportion was lower.
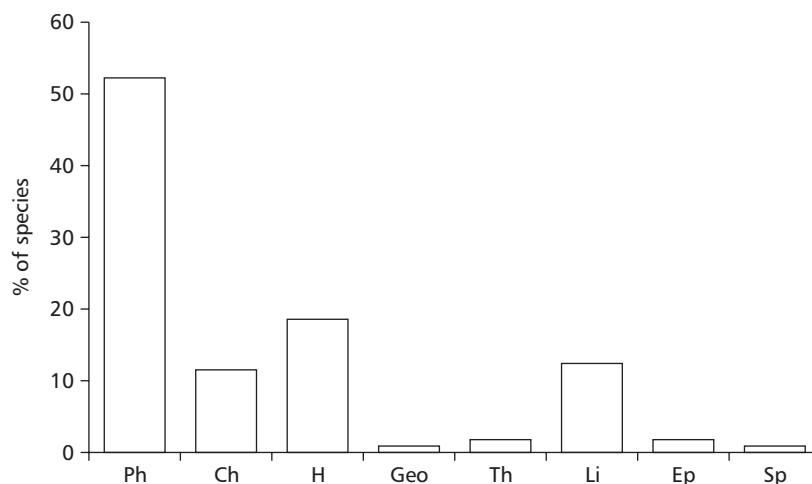

Fig. 1 — Floristic life-form spectrum of a *cerrado sensu stricto* site in Itirapina Municipality, São Paulo State, southeastern Brazil (approximately, 22º13'S and 47º51'W). Ph = phanerophyte, Ch = chamaephyte, H = hemicryptophyte, Geo = geophyte, Th = therophyte, Li = liana, Ep = epiphyte, Sp = saprophyte.

TABLE 1

Floristic, frequency, and vegetation life-form spectra of a *cerrado sensu stricto* site in Itirapina Municipality, São Paulo State, southeastern Brazil (approximately, 22º13'S and 47º51'W). Ph = phanerophyte, Ch = chamaephyte, H = hemicryptophyte, Cr = cryptophyte, Th = therophyte.

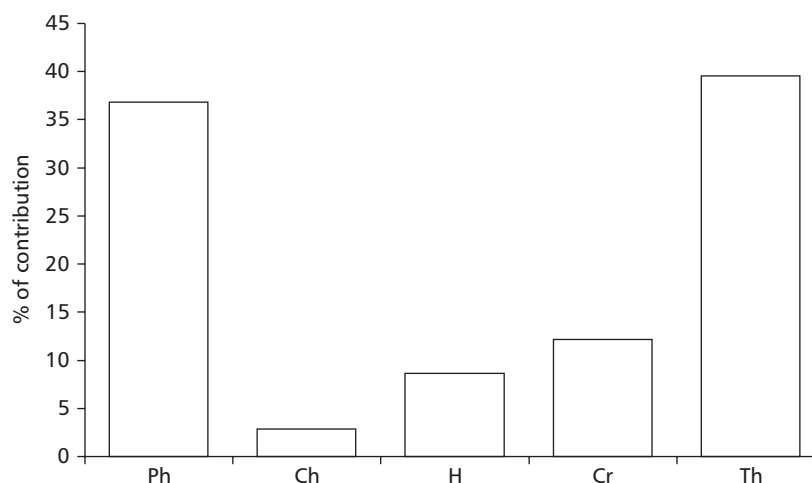| Life-forms	Life-form spectra		
	Floristic	**Frequency**	**Vegetation**
Ph	66.37	65.70	35.46
Ch	11.50	10.08	23.85
H	18.58	19.19	34.61
Cr	1.77	0.39	0.07
H + Cr	20.35	19.58	34.68
Th	1.77	4.65	6.00

Fig. 2 — Percentage of contribution of each class in the chi-square value in the comparison between the floristic life-form spectrum of a *cerrado sensu stricto* site in Itirapina Municipality, São Paulo State, southeastern Brazil (approximately 22º13'S and 47º51'W) and Raunkiaer's normal spectrum. The proportions were higher than expected for phanerophytes (Ph) and chamaephytes (Ch) and lower for hemicryptophytes (H), cryptophytes (Cr), and therophytes (Th).

TABLE 2
Comparison among floristic, frequency, and vegetation life-form spectra of a *cerrado sensu stricto* site in Itirapina Municipality, São Paulo State, southeastern Brazil (approximately 22º13'S and 47º51'W).

Spectra	χ^2	p
Floristic *vs.* frequency	2.08	> 0.10 **ns**
Floristic *vs.* vegetation	45.28	< 0.001 *******
Frequency *vs.* vegetation	169.76	< 0.001 *******

The cerrado vegetation presents a wide physiognomic variation, from grasslands to tall woodlands (Coutinho, 1978). In Itirapina, we sampled only one cerrado physiognomy (cerrado sensu stricto), which is close to the tallest physiogonomy of this vegetation type. In other studies (Mantovani, 1983; Batalha *et al.*, 1997; Batalha & Mantovani, 2001), more than one physiognomy was sampled, and open physiognomies (grasslands or scrublands) were included. Since the importance of trees and shrubs increases from open to closed physiognomies (Coutinho, 1978), the proportion of phanerophytes is also expected to increase in this direction. In open physiognomies, hemicryptophytes prevail, whereas in closed ones, phanerophytes is the best represented class (Batalha & Martins, 2002). In spite of this physiognomic variation, cerrado spectra formed a distinct group when compared with other vegetation types (Batalha & Martins, 2002).

Furthermore, there was a bias in our sampling in relation to the other surveys. In the other papers (Mantovani, 1983; Batalha *et al.*, 1997; Batalha & Mantovani, 2001), observation of all species was done in the field for at least one year, whereas our sampling was restricted to a few days in the middle of the rainy season. Hence, it is likely that, in our spectrum, all life-forms with underground renewing buds (hemicryptophytes and cryptophytes) or with an annual cycle (therophytes) were underestimated.

The life-form spectrum in Itirapina differed significantly from Raunkiaer's normal spectrum. The Itirapina cerrado life-form spectrum presented a higher proportion than expected of the life-form classes with renewing buds above the ground (pha-

nerophytes and chamaephytes) and a lower proportion than expected for the life-forms with renewing buds under the ground or in the seed in the unfavorable season (hemicryptophytes, cryptophytes, and therophytes). If, on the one hand, this is expected for closed physiognomies, on the other hand, the period of the year and the short period of time in which the sample was taken could result in an underestimation of the classes with renewing buds not exposed to the air, as previously stated.

When compared with the normal spectrum, the class with the highest contribution to the chi-square value in Itirapina was the therophytes. Although in our sample could have resulted in an underestimation of annual plants, the therophyte proportion is also low in life-form spectra of cerrado sites (Mantovani, 1983; Batalha *et al.*, 1997; Batalha & Mantovani, 2001; Batalha & Martins, 2002).

From the floristic to the vegetation life-form spectra, the classes with higher proportions (phanerophytes and hemicryptophytes) varied differently. Whereas the phanerophytes proportion decreased toward the vegetation spectrum, the hemicryptophyte proportion increased. This could be explained by the inclusion of young individuals of phanerophytes as chamaephytes in the vegetation spectrum and by the significantly higher diversity of phanerophytes in relation to the hemicryptophytes. Since there were more individuals of few species in the hemicryptophyte class, its relative importance increased towards the vegetation spectrum.

The floristic life-form spectrum differed significantly from the vegetation spectrum, but not that of frequency. The frequency and vegetation spectra were significantly different. According to these results, the frequency count provided no additional information in relation to the species list used to construct the life-form spectrum. On the contrary, the vegetation spectrum was quite distinct from the floristic one and provided a more accurate description of the vegetation physiognomy. Another advantage of the vegetation spectrum is that there is no need to recognize each species, since individuals are counted by their present life-form. The vegetation spectrum, as the name indicates, is applied when one wants to know the vegetation, rather than the flora, of a given site.

Buell & Wilbur (1948), in comparing life-form spectra based on species lists and frequency counts in a hardwood forest site, found a profound shift toward the less protected life-forms in the frequency spectra. They suggested frequency data as a basis for comparing life-form spectra of similar communities in different regions. However, our results indicated that this procedure would be not valid for cerrado sites.

Qadir & Shetvy (1986) studied four Lybian communities and compared the qualitative spectrum, based solely on floristics, and the quantitative one, based on importance value. When the life-form spectra were expressed on a quantitative basis, each community appeared quite distinct from the others (Qadir & Shetvy, 1986). The index they used is probably a better descriptor of the vegetation physiognomy than is the count of individuals, but using their index poses many more difficulties when collecting data in the field. Cain (1950) suggested that some measure of the relative dominance of each species in the community would provide the most significant data. We recommend the number of individuals as a measure of life-form abundance in the vegetation, since this procedure is relatively easy to use in the field and eliminates with the need for taxonomic identification of the species.

Frequency as a descriptor was proposed by Raunkiaer (1934) to avoid the problem of recognizing plant individuals in the field and counting all individuals of each species. Frequency is considered a measure of abundance, but it is influenced by the spatial distribution of the individuals (Mueller-Dombois & Ellenberg, 1974) and has a logarithmic, nonlinear relationship with density (Greig-Smith, 1983). Density may be obtained from frequency counts only if the spatial distribution of individuals is random, which is rarely the case for plant species (Greig-Smith, 1983). According to Greig-Smith (1983), instead of giving a measure of the bulk of material contributed by each species, frequency is an uncertain assessment of several different characteristics, thus, its principal value lies simply in the rapidity with which it is obtained.

Sarmiento & Monasterio (1983) criticized the applicability of Raunkiaer's system to tropical communities because it classifies life-forms supposing that the limiting factor for plant growth is low winter temperatures, which obviously is not an important ecological factor in such communities. Batalha & Martins (2002) discuss the importance and the relativity of the phytoclimate concept when applied to cerrado vegetation, suggesting that water stress, fire, water logging, oligotrophism, or aluminum toxicity can be analogous to low winter temperatures. The application of Raunkiaer's system, in this case,

would be not only possible but recommended if one intends to investigate which factors, besides climate, define the vegetation physiognomy in question.

CONCLUSIONS

When a biological spectrum is constructed with data collected in a single period, all life-forms with renewing buds not exposed to the air, i.e., hemi-cryptophytes, cryptophytes, and therophytes, are underestimated. Hence, care must be taken when comparing spectra constructed in different seasons. Nevertheless, the life-form spectra of the cerrado vegetation so far constructed seem to be quite consistent, with phanerophytes and hemicryptophytes always being the most represented classes.

Though restricted to a small cerrado site, our study did not support Raunkiaer's idea of the frequency spectrum as a good descriptor of the life-forms distribution in a certain plant community. The floristic life-form spectrum is recommended if working in sufficiently large areas, when it could provide an indication of the prevailing phytoclimate. We recommend the vegetation spectrum, when working in smaller areas, and desiring a more detailed description of the physiognomy or when local ecological factors are being studied. The frequency spectrum is not recommended at all, since it was not significantly different from the floristic one and because frequency is not a good estimator of abundance.

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