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SHORT COMMUNICATION – Conservation of Nature

Comparing Data Collection Methods in Phenological Evaluations of *Himatanthus drasticus*

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Abstract

We present a case study focusing on collection methods and phenological data analyses. Qualitative, semi-quantitative, and quantitative approaches were compared in terms of their efficiencies for describing flowering and fruiting intensities and phenophase synchrony in *Himatanthus drasticus* growing in a gallery forest in the Chapada Diamantina mountains, Brazil. Our results showed that phenophase intensity and synchrony were respectively each best. Determined using quantitative and qualitative methods We reinforce the importance of clearly defining research aims, as quantitative data collections require considerably greater field efforts than qualitative evaluations, especially concerning forest trees.

Keywords: intensity, reproductive phenology, synchrony.

Phenophase synchrony and intensity are criteria of fundamental importance for examining the seasonal timing of plant life history events. Phenological synchrony is considered the simultaneous occurrence of the same type of event among distinct individuals (or species); the intensity, or amplitude, of a life-phase phenomenon considers the quantification of that phenological activity, which can be measured considering individuals, populations, species, or communities (Newstrom et al., 1994). A wide variety of methods for data collection, evaluation, and analysis have been employed to examine the synchrony and intensity of plant phenological events using qualitative, semi-quantitative, and quantitative methods (Bencke & Morellato, 2002; Morellato et al., 2010a, Alexander & Woeste, 2016). Semi-quantitative approaches establish predefined scales without the use of exact measurements (Fournier, 1974; Pugas et al., 2018; Araujo & Lobo 2020) or percentages of canopy cover (Lenza & Klink, 2006). Intensity analyses, on the other hand, are measured or estimated (Bencke & Morellato, 2002; Castro-Díez et al., 2003), and most evaluations of synchrony have been based on qualitative data (Augspurger, 1983; Bolmgren, 1998; Bencke & Morellato, 2002; Morellato et al., 2010b; Baldauf et al., 2014; Rodriguez-Pérez & Traveset 2016; Andreacci et al., 2017; Araujo & Lobo 2020; Rosa et al., 2020). New techniques have used both semi-quantitative and quantitative data (Freitas & Bolmgren, 2008; Valverde et al., 2016).

We compared the intensities and synchronies of flowering and fruiting using different data collection methods (qualitative, semi-quantitative, and quantitative), and hypothesized that semi-quantitative or quantitative data would provide better evaluations than qualitative data for examining tropical arboreal phenology.

We followed the flowering and fruiting of *Himatanthus drasticus* (Mart.) Plumel, (Apocynaceae) trees (1.80 - 7.0 m tall), growing in a gallery forest (12° 33'S x 41° 24'W; 500 m a.s.l.) in the Chapada Diamantina mountains in northeastern Brazil, a region with dry winters and rainy summers. *H. drasticus* is endemic to Brazil and occurs in Amazonian, Caatinga, and Cerrado domains (Flora do Brasil, 2020, under construction).

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The phenophases of flower budding, flowering, and immature and mature fruit production were followed from May/2014 to April/2015 in 44 marked individuals. Data collection was based on: (i) quantitative methods - direct counts of flower buds, flowers, and mature and immature fruits; (ii) semi-quantitative methods (Fournier, 1974) - which used five class categories (0 – 4) at 25% intervals, with the intensities of the phenophases being measured as the ratio of the sum of categories multiplied by 100 and the maximum Fournier number (4) multiplied by the number of individuals (San Martin-Gajardo & Morellato, 2003); and, (iii) qualitative methods – presence or absence of a phenophase (expressed as the percentage of individuals) (Frankie et al., 1974). Phenophase intensities were measured using analogous approaches. Synchrony analyses were based on qualitative methods: (i) the Augspurger index (1983), obtained by calculating the synchrony of each sampled individual, where the sum of the months in which an individual demonstrated a phenophase is added to the number of months in which the other individuals exhibited that phenophase – with a result equal to 1 indicating perfect synchrony, while a result equal to 0 indicates no synchrony; (ii) the Bencke & Morellato (2002) index, based on the percentage of individuals in the population manifesting a certain phenological event - which ranges from asynchrony, to low or high synchrony; (iii) circular statistics (Morellato et al., 2010b) performed using Oriana 4.02 software (Kovach 2013). For each phenophase we calculated the length of the mean vector (r - the degree of temporal aggregation or synchrony of phenophase activity) - with high *r* values (> 0.5) indicating synchronous phenological activities. The Rayleigh test (Z) determined if the data were distributed uniformly throughout the year ($p > 0.05$) (Zar, 2010).

Additionally, intraspecific synchrony was analyzed using semi-quantitative and quantitative data according Freitas & Bolmgren (2008), taking into consideration the overlap between individuals and the degree of flowering and fruiting intensity within that time span. Phenophase intensity was calculated using the numbers of flowers or fruits produced by an individual, divided by the maximum number recorded during the time span considered (one month) (Nassar & Ramirez, 2004). We calculated the synchronies between the individuals sampled and the overall synchrony of the population. The resulting values ranging from 0 to 1; with 1 indicating perfect synchrony and 0 indicating no synchrony.

The resulting graphs are quite different in terms of their flowering and fruiting peaks, with quantitative measures of intensity better expressing resource offerings. In general, the analyses of synchrony of flowering and fruiting in *H. drasticus* obtained from qualitative, semi-quantitative, and quantitative data indicated asynchrony (Augspurguer, Freitas and Bolmgren indexes and circular analysis) and/or low synchrony for all the phenophases evaluated. The Freitas and Bolmgren index showed the lowest synchrony values based on semi-quantitative and quantitative data. Only circular analysis demonstrated synchrony of immature fruit production, showing a unimodal distribution of this phenophase (Figure 1; Table 1).

Our hypothesis was therefore partially confirmed, as phenophase intensities were best revealed by quantitative and semi-quantitative data and would, for example, favor interpretations of links with resource availability for pollinators and dispersers (Freitas & Bolmgren, 2008; Souza & Funch 2015). The qualitative method did not generate easily distinguishable intensity peaks. Data collection using the Fournier method, however, has been widely employed in phenological studies due to its efficiency and standardized measurements (Menezes et al., 2018). Quantitative methods require more intensive field efforts, although they proved to be more accurate in demonstrating the intensities of flowering and fruiting as resources invested in pollination and dispersal processes of *H. drasticus*.

There were no significant differences between the qualitative, quantitative, and semi-quantitative data in terms of identifying phenophase synchrony. The indices used here require large numbers of sampled individuals to sustain adequate and reliable conclusions (Augspurger, 1983; Bencke & Morellato, 2002; Freitas & Bolmgren, 2008; Morellato et al., 2010b), as they consider the percentages of individuals in a population that manifest a given phenophase, or employ combinatorial analyses to infer the average possibility of events occurring in the same period, comparing each individual with the others.

We therefore conclude that the methods used to examine phenophase intensities and synchronies yield distinct results that can complement each other, making it important to clearly define the objectives of the project and choose the most appropriate methods of data collection and analysis. We therefore suggest the use of quantitative methods to determine the intensities of flowering and fruiting in studies with tropical trees producing large flowers and fruits that can be easily quantified visually, but qualitative data to examine synchrony, as it requires lower investments in field observations.

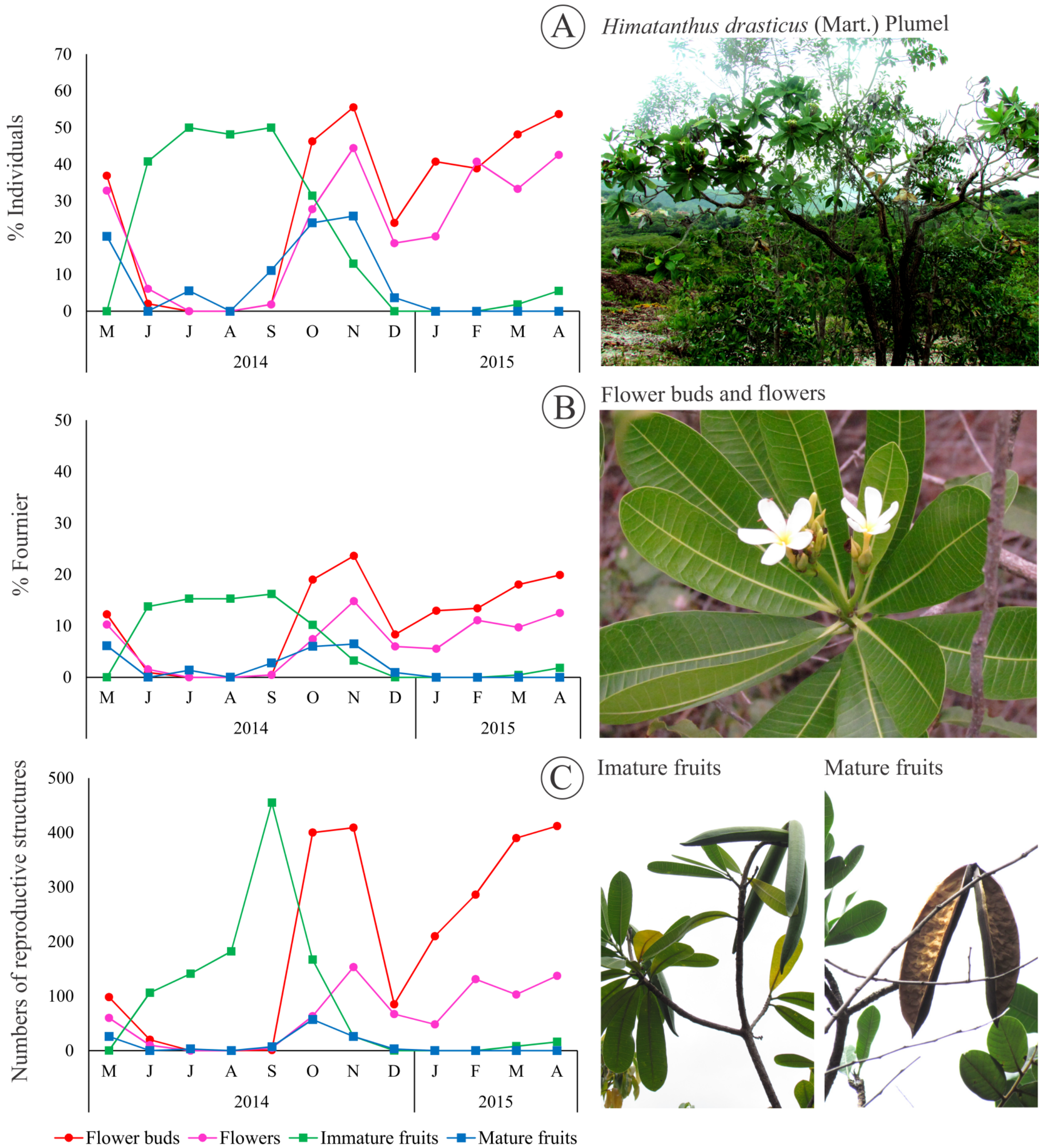

Figure 1. Flowering and fruiting of *Himatanthus drasticus* between May/2014 and April/2015 in a gallery forest along the Lençóis River, in the Chapada Diamantina Mountains in northeastern Brazil. **(A)** Synchrony of individuals; **(B)** Estimated intensity (Fournier); **(C)** Quantified intensity. To the right, images showing the species habit, flower buds, flowers, immature fruits and mature fruits.

Table 1. Synchrony indices for the flowering and fruiting phases of *H. drasticus*, between May/2014 and April/2015 in a gallery forest along the Lençóis River, in the Chapada Diamantina Mountains in northeastern Brazil.

Analysis		Flower buds	Flowers	Immature fruits	Mature fruits
Bencke and Morellato					
Qualitative		1.9 - 55.6	1.9 - 51.0	1.9 - 50.0	3.7 - 49.0
Augspurguer					
Qualitative		0.37	0.32	0.32	0.21
Freitas and Bolgrem					
semi-quantitative		0.11	0.01	0.1	0.02
Quantitative		0.06	0.01	0.08	0.02
Circular					
Qualitative	*r*	0.404	0.382	0.732	0.037*
	Z	28.414	21.191	67.015	0.099*
	P	< 1E-12	6.26E-10	< 1E-12	0.906*

Note: *Values that may be less reliable because of low fruiting frequencies (uniform distribution – p > 0.05)

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