Maria Franco Trindade Medeiros
Bárbara de Sá Haiad *Editors*

Aspects of Brazilian Floristic Diversity

From Botany to Traditional Communities

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ISBN 978-3-031-07452-3 ISBN 978-3-031-07453-0 (eBook)
https://doi.org/10.1007/978-3-031-07453-0

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

About the Book

This initial presentation of the book will lead us to understand its eclectic proposal through the description of its structural line.

Aspects of Brazilian Floristic Diversity: From Botany to Traditional Communities presents several botanical aspects with a broader view through the chapters of each part. Certainly, our intention is not to exhaust all possibilities of approach within botany but to show aspects of Brazilian floristic diversity.

The sequence of parts of the book will act as a thematic guide through which we will permeate various areas of botany, allowing us the cognitive understanding that will constitute the unit of the book as a whole.

Thus, within each part, we will have the unique opportunity to come across different botanical areas and the specific approach to each one of them. The common theme of all chapters lies in the treatment of diversity and conservation, whether algae or angiosperms, as well as material and immaterial culture.

The themes are grouped into parts aiming to show the vast and deep research possibilities in the field of botany. The intention is precisely to offer a comprehensive approach to botany, emphasizing its *spectrum* of knowledge, as well as a pedagogical strand that respects each different line of botanical research, considering its own language and content development and, as it were, respecting the values and positions of the researchers/authors and their epistemological structure.

Following this thought, an opening commentary is presented in each part of the book, giving us a good perspective of what we will find in the next pages that constitute the book as a whole.

Following this thought, first of all, we will have a brief scenario at the opening of each part, in which a good perspective of what will be found in the chapters of that part will be presented. Thus, throughout the parts that will compose the book as a whole, we can be well situated in the *Aspects of Brazilian Floristic Diversity: From Botany to Traditional Communities.*

Finally, wishing a good reading, this is an invitation to a deeper experience in the field of botany.

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Part I
Angiosperms Reproductive Aspects

This part will address the reproductive aspects of the angiosperms as one of the various areas of Botany that will be discussed in the chapters of *Aspects of Brazilian Floristic Diversity: From Botany to Traditional Communities*. Here, certain aspects will be presented that will allow us to have a deeper comprehension of this theme, having as a guide the experiences of research carried out in the Brazilian territory, which will be the first step of our journey through this book.

So, in Part I, we will have the opportunity to understand phenology as a multidisciplinary science that can transit from individual to a population range for searching the recurrent biological events. In this perspective, flowering phenology in long-term studies can be very useful for better understanding and assessing the diversity and availability of floral resources of a community in the current scenario of global climate change.

Also, we will see that dioecy, the occurrence of separate male and female individuals in a population, can be evaluated by studying the dimorphic sexual system, the pollination system, the attributes related to visitor attraction, and the floral visitors of dioecious species to better understand flora structure and functioning in a specific vegetation type.

Finally, going into another approach, the floral reproductive development as a gene-controlled process that involves organogenesis of reproductive whorls and male and female gametophytes development will be discussed. This subject will be addressed through a critical analysis of literature data combining the elements of structure and functionality during gametophytes development and by considering the entire programmed cell death processes, commonly recruited to cause sterility in unisexual flowers. The intention of this data analysis will be to show the significance of these events in the reproductive development of neotropical plants.

Chapter 1
Flowering Phenology in a *Restinga* Community: 7 Years of Study

Ana Tereza Araújo Rodarte, Cristine Rodrigues Benevides, Marina Muniz Moreira, Alexandre Verçosa Greco, Luciene Campos São Leão, Patrick de Oliveira, Thiago Ávila Medeiros, and Heloisa Alves de Lima

Abstract Since changes in climate can generate phenological shifts and temporal mismatches between plants and their pollinators, long-term studies of flowering phenology have become more common in the scenario of global climate change. Although in tropical environments, flowering cycles are diverse, irregular, and complex, the existing phenology studies have evaluated mainly tree species over short periods. We characterized, over 7 years, flowering events of a restinga (sandy coastal plain) plant community in southeastern Brazil, including 829 individuals, 78 species, and 36 families, with diverse life forms. In restinga, the general flowering strategy is annual, regular, with intermediate duration, although some species show continuous, sub-annual, or supra-annual strategies. Plants of various life forms flower continuously or sub-annually, whereas only trees flower annually. We recorded flowers throughout all the study years, but the highest rates of flowering activity and intensity occurred in the warmer and wetter season (October to March). Nectar, oil, pollen, and resin were available to pollinators throughout the year. We found significant positive correlations between the indexes of activity and intensity and the mean temperature and day length, but not precipitation. Our results suggest a high predictability of flowering periods and availability of floral resources for pollinators throughout the year.

Keywords Atlantic Forest · Climatic change · Floral resource

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M. F. T. Medeiros, B. de Sá Haiad (eds.), *Aspects of Brazilian Floristic Diversity*,
https://doi.org/10.1007/978-3-031-07453-0_1

1.1 Introduction

Phenological studies on flowering in plant communities are important for understanding plant reproduction and the spatiotemporal organization of floral resources available to animals (Newstrom et al. 1994a). The distribution of flowering events of the plant species in a community is selected over time by abiotic and biotic factors (van Schaik et al. 1993). Tropical environments are highly challenging for phenological studies because of the wide range of interactions and the environmental heterogeneity in these regions (Ramírez 2002). In temperate ecosystems and dry tropical forests, climatic seasonality directly influences plant phenology (Morellato et al. 2013; van Schaik et al. 1993). In contrast, most tropical forests have less pronounced climatic seasons; the highly diverse plant species with different life forms can provide blooms at any time of the year, with varying frequencies, regularities, and synchronisms, resulting in diverse and complex phenological patterns (Morellato et al. 2013; van Schaik et al. 1993). Therefore, tropical areas provide reliably and continuously available plant resources that support a rich spectrum of forage animals (Morellato et al. 2016).

Phenological studies in tropical environments focus mainly on tree species of forest vegetation and over short periods of time, mainly 1 or 3 years (Morellato 2008; Morellato et al. 2016), making it difficult to understand the factors that shape flowering patterns in plants with different life forms (Newstrom et al. 1994b). Long-term phenological data are rare but are beginning to gain significance in light of the importance of understanding phenological patterns in communities and, more recently, as a tool for understanding plant sensitivity to global climate change (Morellato 2008; Morellato et al. 2016; Dunham et al. 2018). Changes in period, duration, and amplitude of flowering events caused by climate changes have been reported (Primack et al. 2004; Morellato et al. 2016; Dunham et al. 2018) and may result in imbalances in the interactions between plants and their pollinators (Morellato et al. 2016).

The *restingas* are part of the Atlantic vegetation complex. They are distributed along the coastal plain formed by marine sediments of Quaternary origin. *Restinga* flora arose mainly from the Atlantic Forest (Scarano 2002, 2008). This environment is stressful due to the sandy soil with low water retention, low air humidity, and strong sea wind action (Rizzini 1979; Scarano 2002). Scarano (2002) proposed that epiphyte and hemi-epiphyte plants of the Atlantic Forest would have been mainly responsible for the colonization and diversification of Atlantic Forest marginal environments. Canopy plants are undemanding of resources from the substrate and, once migrating, would have been able to settle as terrestrial plants on sandy soils, creating conditions for the establishment of other species (Scarano 2002, 2008). This facilitation process would be the main explanation for the high diversity found in an environment with such low environmental potential (Scarano 2002, 2008). *Restinga* vegetation has been considered stable and little sensitive to climate fluctuations (Scheel-Ybert 2000, 2002). Paleoenvironmental studies have shown that the *restinga* vegetation of the southeastern coast of Rio de Janeiro state (RJ) did not vary in diversity through the second half of the Holocene (5500–1400 years BP)

(Scheel-Ybert 1999, 2000, 2001). The *restinga* at Maricá, RJ, does not have well-defined climatic seasons and did not have a dry season during the years 1989–2000 (Mantovani and Iglesias 2001); however, there are relatively frequent records of water deficit in the last 10 years, in July and August (INMET/RJ). In general, the mean monthly rainfall decreases significantly during the winter, but months with high rainfall in the winter and low rainfall in the summer are often recorded, characterizing an irregular rainfall distribution pattern (Mantovani and Iglesias 2001).

This study characterized the flowering phenophase of the species occurring in a *restinga* vegetation community at Maricá over 7 years. We analyzed the frequency, duration, regularity, and the percentages of activity (Bencke and Morellato 2002b) and intensity (Fournier 1974) of the flowering period of the species, relating them to the possible influences of climate variables. The following questions guided our work: (1) What are the flowering phenological strategies in this community? (2) Are there abiotic variables with significant potential to trigger flowering in the area? (3) Do flowering phenophases follow seasonal rhythms in this community? (4) Is the distribution of floral resources such as pollen, nectar, oil, and resin predictable through the year?

1.2 Material and Methods

1.2.1 Study Site

We conducted the study in the Maricá *restinga*, an environmentally protected area located on the border of the districts of Barra de Maricá and Itaipuaçu, municipality of Maricá, Rio de Janeiro state, Brazil (22°57′45″S to 42°53′33″W and 22°57′52″S to 42°53′48″W) (Fig. 1.1a).

The Maricá *restinga* is composed of two sandy ridges (inner and outer) formed between 3500 and 5500 years ago, respectively, in episodes of the last marine transgressions (Perrin 1984) (Fig. 1.1b). The study site contains a shrubby-arboreal formation that encompasses three typical *restinga* physiognomies: (1) flooded open shrubby area, located in periodically flooded places (Fig. 1.1b); (2) non-flooded open shrubby area, with thickets interspersed with bare spaces (Fig. 1.1b–d); and (3) non-flooded closed arboreal area, with dense vegetation (Fig. 1.1b, d).

1.2.2 Climate

The climate is Aw tropical humid (Köppen 1948), with rainy summers and dry winters (Mendonça and Danni-Oliveira 2007). Climatic data for the Maricá *restinga* from 2004 to 2010 were provided by the *Instituto Nacional de Meteorologia* for Maricá Station, located inside the protected area (22°055”S to 42°049”W). We calculated day length according to Pereira et al. (2001) and Varejão-Silva (2000)

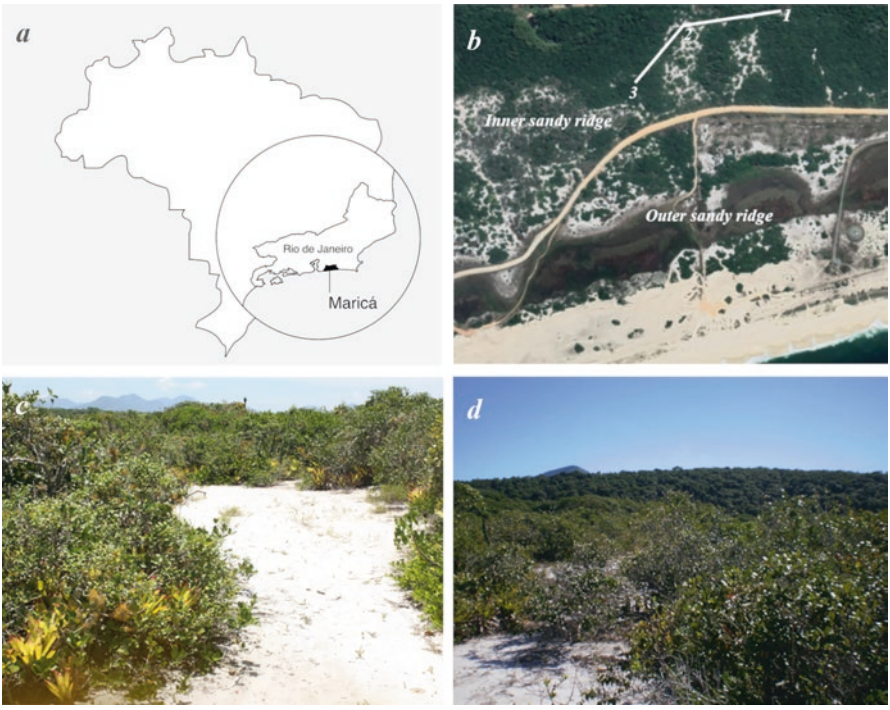

Fig. 1.1 The Maricá *restinga*. (**a**) Location of Maricá, Rio de Janeiro state, Brazil. (**b**) Aerial view of the study area, showing the transect across the inner sandy ridge and the three physiognomies (1, 2, and 3) sampled. (**c**) View of area 2 (non-flooded open shrubby area). (**d**) View of area 2 (non-flooded open shrubby area) in foreground and of area 3 (non-flooded and closed arboreal area) in background

(Fig. 1.2a). We considered two seasons: warmer/wetter (October to March) and colder/drier (April to September) (Figs. 1.2 and 1.3). The mean annual temperature ranged from 22.9 °C (2004) to 24.6 °C (2005). July was the coldest month in all years (Fig. 1.2b), with mean temperatures ranging from 19.5 °C (2010) to 21.8 °C (2005). In the warmer/wetter months (October to March), the mean temperature ranged from 25.6 °C (January 2004) to 28.5 °C (February 2010).

Total annual rainfall ranged from 1197.8 mm (2007) to 1435.8 mm (2005) (Fig. 1.2c). We recorded water deficits in the years 2004 (August, 15.1 mm; September, 31.2 mm; October, 38.2 mm), 2005 (August, 5.7 mm), 2007 (March, 33 mm; June, 33.8 mm; August, 30.6 mm; September, 16.6 mm), 2008 (August, 32 mm), and 2010 (August, 36.3 mm; September, 33.3 mm) (Fig. 1.3). Higher rainfall volumes were recorded from October to March of 2007–2008 and 2009–2010. Atypical rain peaks occurred in June 2004 and 2010 (Fig. 1.3). Although we have considered these two seasons (warmer/wetter and colder/drier), the temperature varied much less than the rainfall, which varied widely from year to year (Fig. 1.2b, c).

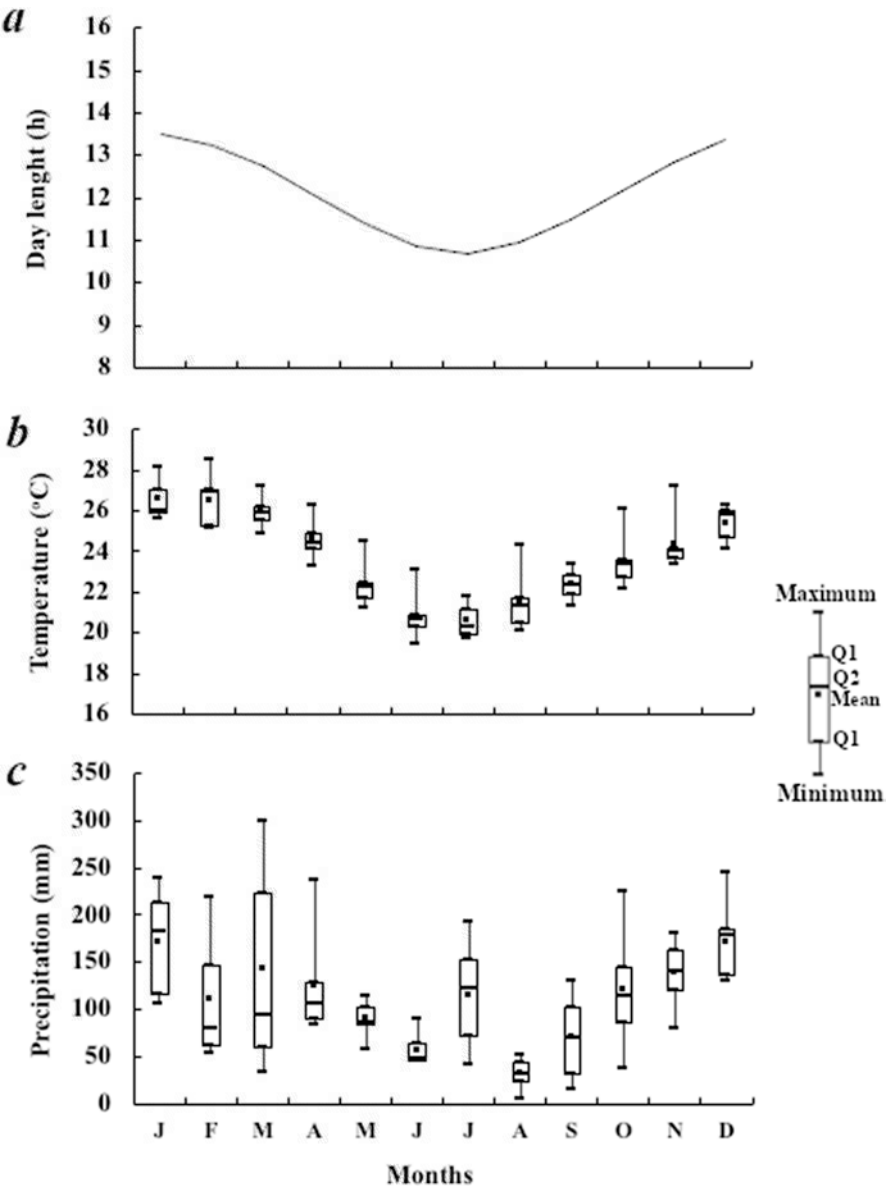

Fig. 1.2 (**a**) Day length (h), (**b**) box plots of monthly temperature (°C), (**c**) precipitation (mm) data for 2004–2010 in the Maricá *restinga*, Rio de Janeiro state, southeastern Brazil. (Source: INMET/RJ)