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Biology-Botany

Phenology of *Butia catarinensis* in the Southern Coastal Region of Santa Catarina, Brazil

Fenologia de *Butia catarinensis* no litoral sul de Santa Catarina, Brasil

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ABSTRACT

This study evaluated the phenology of *Butia catarinensis* in shrubby Restinga and under the understory of eucalyptus monoculture (*Eucalyptus saligna* and *Eucalyptus paniculata*) along the southern coast of Santa Catarina, Brazil. Phenological data were collected monthly over a one-year period. *Butia catarinensis* exhibits an annual, asynchronous reproductive cycle, showing higher flowering and fruiting rates in spring and summer, with reduced reproductive activity during winter. Precipitation had minimal influence on its reproductive cycle; however, higher temperatures and increased solar radiation positively correlated with the development of green and ripe fruits year-round. The lack of significant differences between the two study environments indicated that the eucalyptus monoculture microclimate did not affect flowering and fruiting quantities of *B. catarinensis*, though it may have influenced phenophase timing, potentially accelerating, delaying, or extending these events.

Keywords: Atlantic forest; Non-timber forest products (NTFP); Phenological behavior; Restinga

RESUMO

Este estudo avaliou a fenologia de *Butia catarinensis* em Restinga Arbustiva e em sub-bosque de monocultura de eucalipto (*Eucalyptus saligna* e *Eucalyptus paniculata*), no litoral sul de Santa Catarina, Brasil. O levantamento fenológico ocorreu mensalmente durante 12 meses. *Butia catarinensis* possui ciclo reprodutivo anual e assincrônico, apresentando maiores índices de floração e frutificação na primavera e no verão e menores índices de estruturas reprodutivas durante o inverno. A precipitação pouco influenciou no ciclo reprodutivo, em contrapartida, maiores temperaturas e altos níveis de radiação solar influenciaram positivamente no desenvolvimento dos frutos verdes e dos frutos maduros ao longo do ano. A ausência de diferenças significativas nos resultados dos dois ambientes revelou que o microclima formado pela monocultura de eucalipto não influenciou na quantidade de floração e frutificação de *B. catarinensis*, mas pode ter influenciado no período de ocorrência e no pico das fenofases, acelerando, retardando ou prolongando esses eventos.

Palavras-chave: Floresta atlântica; PFNM; Comportamento fenológico; Restinga

1 INTRODUCTION

At the beginning of the 20th century, timber extraction for commercialization, civil construction, and the clearing of areas for agriculture and livestock farming were some of the main causes of degradation in the Atlantic Forest (Coradin et al., 2011). In the Restinga (Sampaio et al., 2006), a coastal ecosystem associated with the Atlantic Forest biome, the situation was no different. This ecosystem extends for approximately 5,000 km along the Brazilian coast (Lacerda et al., 1993; Tonhasca, 2005; Coutinho, 2006; Almeida & Zickel, 2009) and plays a fundamental role in the dynamics of coastal environments, providing various ecosystem services, including habitat for numerous species, soil stability, filtering functions for continental waters, atmospheric carbon fixation, and acting as a barrier and mitigator in tidal dynamics (Worm et al., 2006; Barbier et al., 2011; Duarte et al., 2013). Despite this, the Restinga is extremely vulnerable to the effects of climate change (Bellard et al., 2012) and to forms of use and occupation that, historically, have influenced the occupation rates of this territory and, consequently, the structure and dynamics of this vegetation (Cohenca, 2016; Santos et al., 2017). Additionally, the expansion of *Pinus*, *Eucalyptus*, and pasture plantations over native Restinga areas is significant, as detected by Cohenca (2016) in a study on the influence of land use and cover changes in the coastal zone of southern Santa Catarina.

Furthermore, it is estimated that the southern and southeastern portions of the Atlantic Forest biome may experience an increase of approximately three degrees in temperature and 25% to 30% in precipitation by 2100 (RAN1, 2013). It is important to note that temperature and precipitation are directly involved in regulating the biological, chemical, and reproductive processes of plant species, influencing the development and distribution of plants (Beier, 2004; Alberton et al., 2014; Morellato et al., 2016). In line with this, studies reveal that tropical species have more restricted physiological tolerance limits due to the low annual climatic seasonality in these environments (Talora & Morellato, 2000). Therefore, these organisms may not be able to adapt to very intense changes, leading to a threat of extinction (Colwell et al., 2008; Collevatti et al., 2011; Lima et al., 2017; Silva, 2018).

In this context, *Butia catarinensis* Noblick & Lorenzi (Arecaceae), a palm species endemic to the southern region of Brazil and naturally occurring in sandy and rocky soils, dunes, and coastal grasslands of the Restinga in Santa Catarina and Rio Grande do Sul (Elias et al., 2019), is listed as Endangered (EN) by the Official List of Threatened Flora Species in the State of Santa Catarina (Resolução n. 51, 2014; Elias et al., 2019). According to Kumagai and Hanazaki (2013a, 2013b), the species has significant ecological and socioeconomic importance for the southern region of Santa Catarina, where the local population utilizes products and by-products obtained through sustainable management of the species. However, studies on *B. catarinensis* are still incipient, especially regarding the reproductive biology of the species.

In a study carried out in four important electronic databases (SciVerse Scopus, Science Direct, Web of Science, and SciELO), only 35 studies on the species were indexed, most of which dealt with biochemical and nutritional attributes, ethnobotanical aspects, and uses of the species (Kumagai & Hanazaki, 2013a, 2013b; Elias et al., 2015; Cruz et al., 2017; Hoffman et al., 2018; Cunha et al., 2020). Despite its importance, studies that address the distribution and dynamics of this species in the Restinga, its occurrence, as well as ecological and biological aspects, are still incipient, with only four works: Rosa et al. (1998) with a study on the reproductive biology of *B. catarinensis* (previously identified as *Butia capitata* (Mart.) Becc); Soares et al. (2014), and Elias et al. (2018, 2019) with studies on native palms in Santa Catarina and Rio Grande do Sul. Research on reproductive and vegetative phenology is scarce and has been limited to species with greater economic significance (Henderson et al., 1995). Wild species, with little recognition in national and global markets, are often scientifically neglected (Moura et al., 2010).

Aiming to contribute to knowledge about *B. catarinensis* and to provide support for conservation initiatives, as well as potential sustainable exploitation in association with eucalyptus monoculture, this study seeks to characterize the phenological behavior of *B. catarinensis* in two distinct environments on the southern coast of Santa Catarina.

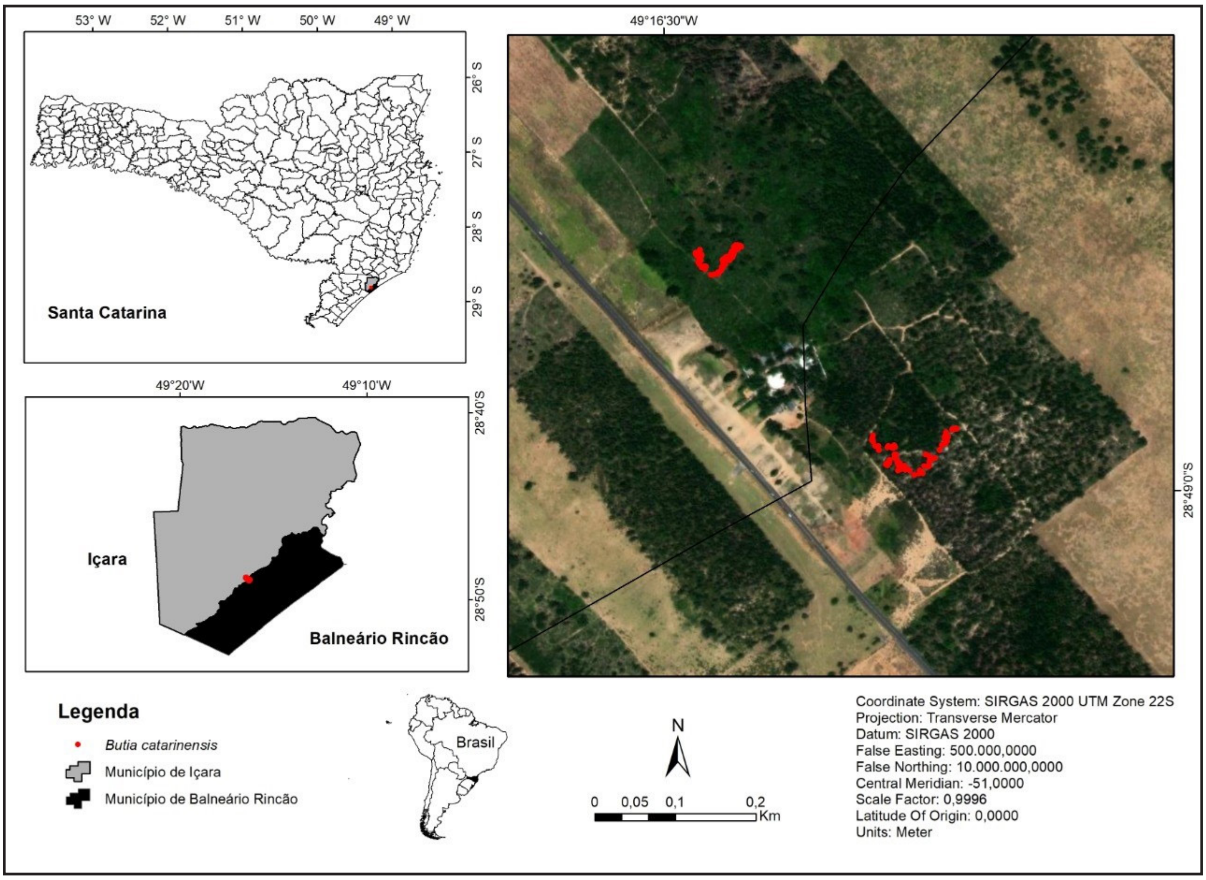
2 MATERIALS AND METHODS

2.1 Study Area

The study was conducted in the municipalities of Içara and Balneário Rincão in southern Santa Catarina, Brazil (Figure 1). The study area is located at the border of the two municipalities and has two visibly distinct environments: a) shrubby Restinga (Resolução n. 261, 1999) in a medium stage of ecological succession (28°48’85”S and 49°16’47”W) in the municipality of Içara, which predominantly features native species (*Myrsine coriacea* (Sw.) R.Br. ex Roem. & Schult., *Vitex megapotamica* (Spreng.) Moldenke, and *Ilex theezans* Mart. ex Reissek) and some invasive exotic individuals of *Pinus elliottii* Engelm. and *Eucalyptus saligna* Sm. sporadically distributed around the area (Figure 1); and b) shrubby Restinga associated with eucalyptus monoculture (*E. saligna* and *Eucalyptus paniculata* Sm.) (28°48’98”S and 49°16’32”W) in the municipality of Balneário Rincão, with an understory presenting characteristics of shrubby Restinga in the initial stage of ecological succession, and species such as *B. catarinensis*, *Dodonaea viscosa* Jacq., and *Erythroxylum argentinum* O.E.Schulz (Figure 2).

The climate of the region is classified, according to Köppen, as humid mesothermal, without a defined dry season and with hot summers (Cfa) (Alvares et al., 2013). During the evaluated period, the highest rainfall rates occurred between March and June of 2021, with a total accumulation of 595.8 mm, and June being the month with the highest volume of rain (271 mm). Conversely, the months of July and August 2021 recorded the lowest rainfall volumes, totaling 62.2 mm. In terms of temperatures, on average there was a variation from 9.0 ºC in July 2021 to 28.9 ºC in January 2021, and the highest solar radiation levels occurred in February (270.4 W/m²), while the lowest were in June 2021 (101.6 W/m²), as shown in Figure 3.

Figure 1 – Location of the study area, characterized by shrubby Restinga (intermediate stage of ecological succession) on the left and eucalyptus monoculture (*Eucalyptus* spp.) on the right, with undergrowth consisting of species characteristic of shrubby Restinga, in the municipalities of Balneário Rincão and Içara, southern Santa Catarina, Brazil



Source: Authors (2022)

Figure 2 – General view of the study area characterized by shrubby Restinga in an intermediate stage of succession (a), located in the municipality of Içara, and Restinga associated with eucalyptus monoculture (b), in the municipality of Balneário Rincão, southern Santa Catarina, Brazil

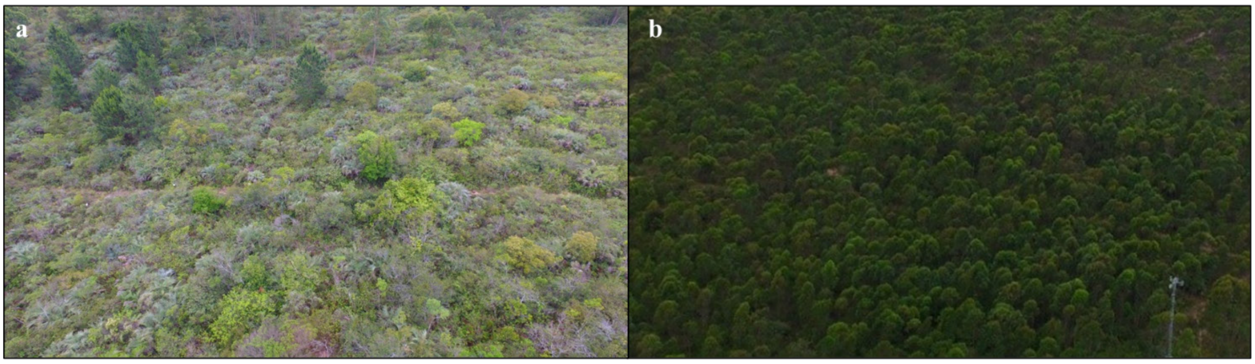


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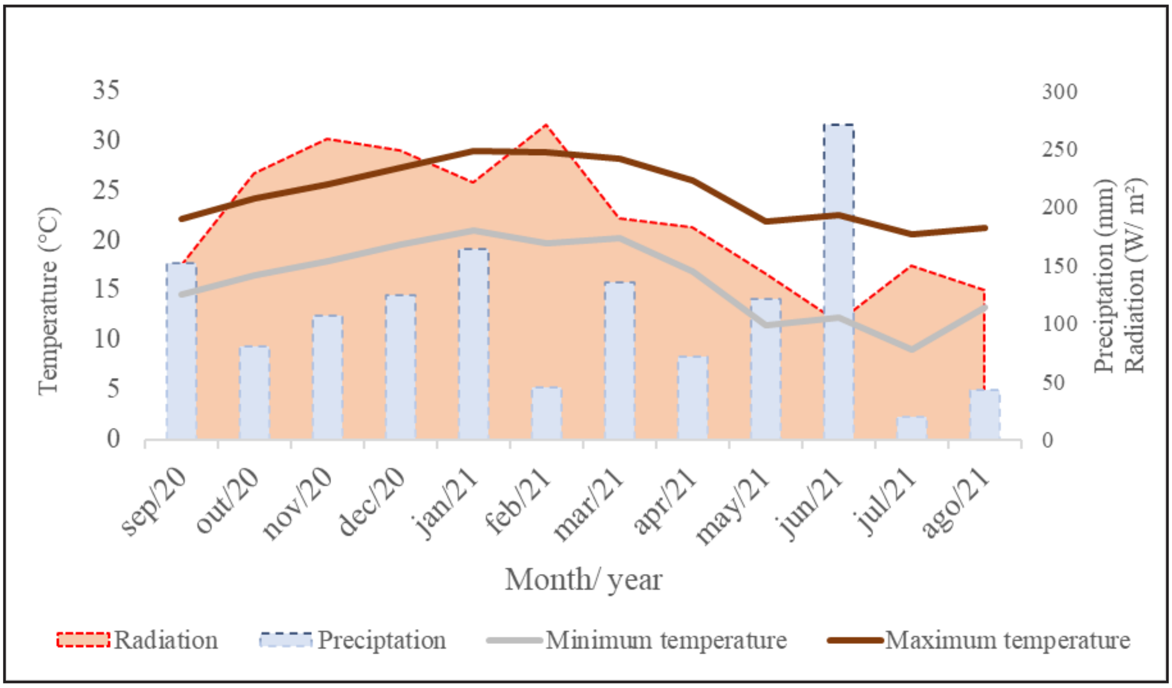
Figure 3 – Climatic characterization of the municipality of Balneário Rincão, Santa Catarina, Brazil. Monthly precipitation accumulation (plotted area); monthly averages of maximum and minimum temperatures (lines), and monthly averages of solar radiation (columns) for the period from September 2020 to August 2021. Source: Epagri/Ciram/Inmet, Jaguaruna, Santa Catarina)



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2.2 Phenological Survey

For the study of phenophases, 130 individuals of *B. catarinensis* (≥ 80 cm) were selected, with 65 individuals present in the shrubby Restinga area and 65 individuals associated with eucalyptus monoculture (*Eucalyptus* spp.). All individuals were marked in the field with sequentially numbered tags, georeferenced, and monitored monthly over a period of 12 months. The method of Alencar and Anderson (1978), adapted to the number of observed phenophases, was adopted, observing the phenological state present in each cluster of palm individuals monthly. The phenophases were: 1) closed sheaths; 2) cluster with exposed buds; 3) cluster with open flowers; 4) cluster with fallen flowers; 5) cluster with green fruits; 6) cluster with ripe fruits; 7) cluster with fallen fruits; and 8) palm without reproductive structures.

The percentage of individuals in a particular phenophase was calculated monthly, using presence (1) and absence (0) data for the phenophase relative to the total number of individuals in the sample (N), multiplied by 100. The percentage of individuals in a particular phenophase, or Activity Index (IA), allows the assessment of synchrony among individuals of a population, as the greater the number of individuals exhibiting the same phenophase in the same time interval, the greater the synchrony of that population (Morellato et al., 1990; Bencke & Morellato, 2002).

The intensity of each reproductive phenophase was estimated according to the semi-quantitative method proposed by Fournier (1974), assigning a value of 0 for the absence of the phenophase and values from 1 to 4 in 25% intervals (1 = 1-25%; 2 = 26-50%; 3 = 51-75%; 4 = 76-100%) for the presence of the phenophase. Thus, a discrete variable was transformed into a quantitative variable, expressed as a percentage.

The Fournier Intensity Index (IIF) provided an estimate of the abundance of flowers and fruits produced in each study area (Bencke & Morellato, 2002). The Fournier intensity percentage was calculated monthly by summing the individual values of the intensity categories of all individuals in each phenophase, divided by the maximum possible value (total number of individuals multiplied by four), according to the formula (Fournier, 1974): IIF=[(Σ fournier).(4N)-1].100.

Meteorological data (averages of maximum and minimum temperatures, solar radiation, and precipitation accumulation) were obtained from Epagri, located in the municipality of Jaguaruna, southern Santa Catarina.

The degree of synchrony of the populations or Activity Index (IA) was obtained using the method suggested by Bencke and Morellato (2002), where, in each phenophase, the percentage of occurrence of the population was verified and categorized as follows: asynchronous population (< 20% occurrence), slightly synchronous (20% to 60% occurrence), and synchronous (> 60% occurrence).

Subsequently, in each environment, the percentage of occurrence and intensity of each phenophase was correlated with meteorological variables such as temperature (minimum and maximum), precipitation, and sunlight in the months corresponding to the study period.

2.3 Data Analysis

Statistical analysis was performed using the IBM Statistical Package for the Social Sciences (SPSS). The investigation of the distribution of variables in terms of normality was carried out using the Shapiro-Wilk test (Field, 2009). The comparison of the evaluated quantitative parameters between the natural area and the area associated with commercial eucalyptus planting was performed through the application of the Mann-Whitney U test (Vieira, 2018).

To investigate the existence of a correlation between climatic variables and the occurrence of the phenophase in each population, the Kendall's τ coefficient was calculated (Field, 2009). For this evaluation, the following relationship was considered: null relation: $\tau = 0$; weak relation: $\tau \leq 0.3$; regular relation: $0.3 < \tau < 0.6$; strong relation: $0.6 < \tau < 0.9$; very strong relation: $0.9 < \tau < 1.0$; full relation $\tau = 1.0$ (Callegari-Jacques, 2011). The inferential analysis was performed using a significance level of α = 0.05 (Andrade & Ogliari, 2007), version 21 (SPSS Inc.).

3 RESULTS

From the 65 individuals sampled in each population, 58 (89%) in the natural population and 45 (69%) in the population associated with eucalyptus monoculture exhibited at least one of the phenophases during the monitored period. The others did not present reproductive structures during the evaluated period.

In general terms, the flowering of *B. catarinensis* began with the emission of closed spathes and ended with clusters of fallen flowers. More than one phenophase occurring simultaneously in the same cluster was observed.

Throughout the monitoring of the reproductive phenophases of *B. catarinensis*, small fluctuations in activity and intensity indices between the two evaluated environments were noted. However, these fluctuations (differences) were not statistically significant ($p > 0.05$) (Table 1).

The emission of the phenophase “closed sheaths” occurred throughout the evaluation period for the population associated with eucalyptus monoculture, while for the natural Restinga environment, there were no records in February and March, when temperatures reached the highest values. In both populations, an increase in spathe emissions was noted at the end of winter and the beginning of spring (August to November), when temperatures were milder (between 13 °C and 25 °C).

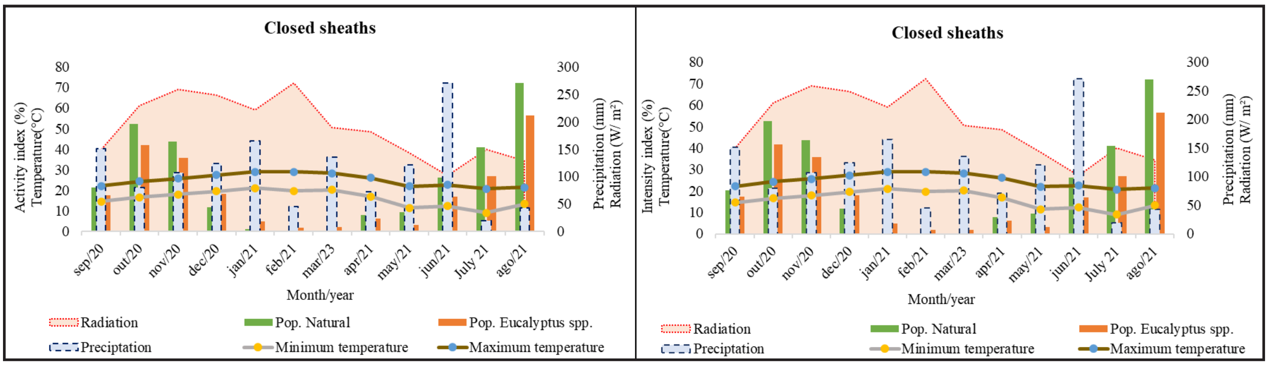
The peak activity of closed sheath emission occurred in August for both populations, however, in the natural environment, the *B. catarinensis* population showed synchrony with 68% Activity Index (AI) while in the population associated with eucalyptus monoculture it showed less synchrony compared to the natural environment with 49% AI (Figure 4). The occurrence of this phenophase showed a negative correlation only in the natural population for the variable average maximum temperature. Although significant, it is considered a regular correlation (0.3 >τ <0.6) according to the parameters established by Callegari-Jacques (2011). The correlation between the occurrence of closed sheaths emission with this same variable in the population associated with eucalyptus monoculture was considered a weak negative correlation (τ= -0.233; p=0.299).

Table 1 – Comparison of variances, minimum and maximum values of activity and intensity indices between the Restinga population in an intermediate stage of succession (Natural) and the Restinga population associated with eucalyptus monoculture (*Eucalyptus* spp.), on the southern coast of Santa Catarina, Brazil using the Mann-Whitney U Test

Activity index Phenophases	**Area**		**Value - p**[†]
	Natural	***Eucalyptus***	
Closed sheaths	17,69(0,00-67,69)	17,16(3,08-41,54)	0,843
Cluster with exposed buds	0,77 (0,00-9,23)	0,77 (0,00-12,31)	0,999
Cluster with open flowers	0,77 (0,00-9,23)	0,00 (0,00-10,77)	0,932
Cluster with fallen flowers	0,00 (0,00-6,15)	0,00 (0,00-6,15)	0,887
Cluster with green fruits	6,15 (0,00-52,31)	3,08 (0,00-38,46)	0,590
Cluster with ripe fruits	0,00 (0,00-9,23)	0,00 (0,00-13,85)	0,713
Cluster with fallen fruits	0,77 (0,00-60,00)	2,31 (0,00-46,15)	0,671
Palm without reproductive structures	32,56 (23,85-90,77)	60,00 (47,69-95,38)	0,101
Intensity index Phenophases	**Area**		**Value - p**[†]
	Natural	***Eucalyptus***	
Closed sheaths	14,04 (0,00-64,62)	12,69 (1,92-45,77)	0,755
Cluster with exposed buds	0,19 (0,00-3,85)	0,19 (0,00-5,77)	0,977
Cluster with open flowers	0,38 (0,00-2,69)	0,00 (0,00-3,08)	0,843
Cluster with fallen fl owers	0,00 (0,00-1,54)	0,00 (0,00-1,54)	0,932
Cluster with green fruits	2,69 (0,00-33,46)	1,92 (0,00-1,54)	0,999
Cluster with ripe fruits	0,00 (0,00-2,31)	0,00 (0,00-4,23)	0,713
Cluster with fallen fruits	0,38 (0,00-58,46)	0,77 (0,00-45,00)	0,755
Palm without reproductive structures	46,15 (33,85-90,77)	60,00 (46,15-95,38)	0,114

[†] Value obtained after Mann-Whitney U test application. Source: Authors (2022)

Figure 4 – Activity and intensity index of closed sheaths emission of *Butia catarinensis* in Restinga at an intermediate stage of succession (Natural) and in association with eucalyptus monoculture on the southern coast of Santa Catarina. For the left graph, axis 1 represents the scale for the activity index and the averages of maximum and minimum temperatures. For the right graph, axis 1 represents the scale for the intensity index and the averages of maximum and minimum temperatures. In both graphs, axis 2 represents the scale for precipitation and radiation

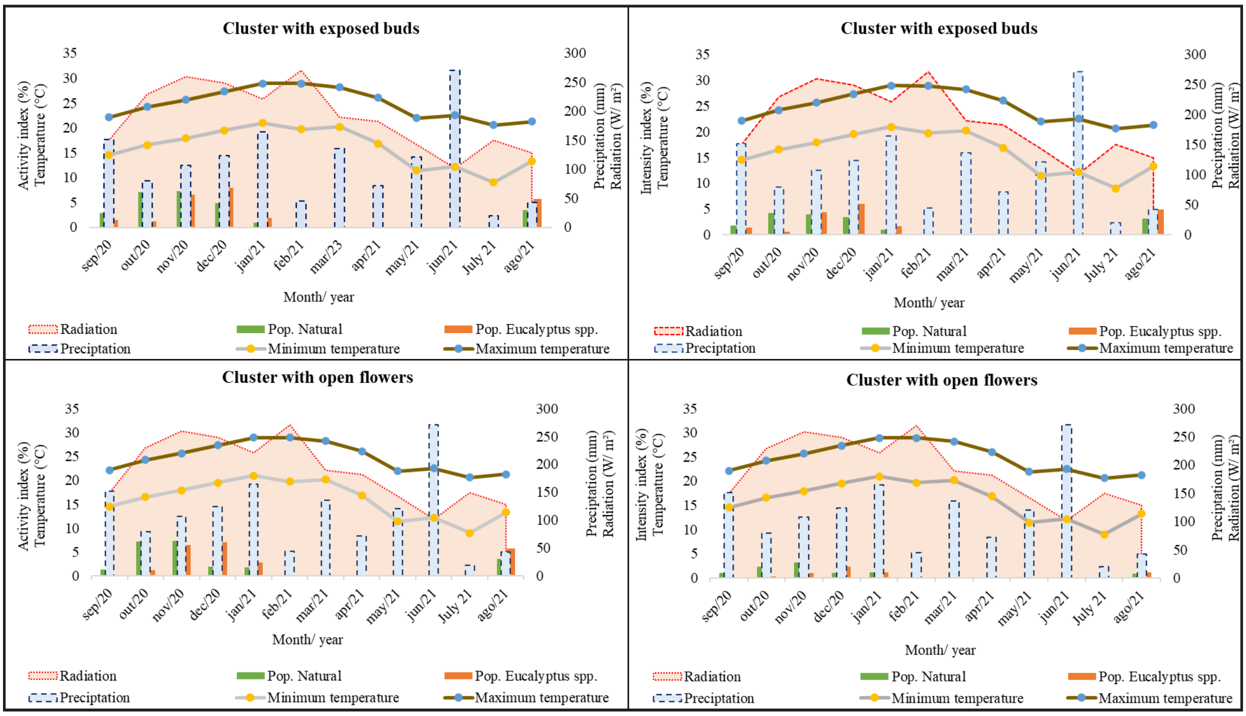


Source: Authors (2022)

In both populations, the emission of exposed buds and open flowers occurred from August to January, with peaks of activity and intensity recorded in spring (October and November) in the natural population and in summer (December) in the population associated with eucalyptus monoculture (Figure 5).

Regarding the synchrony index in both phenophases and populations, the occurrence indices were less than 20%, indicating asynchrony of these fenofases in the evaluated populations. The AI of *B. catarinensis* in the natural population in the months of October and November (peaks) was 9% in both phenophases; in the population associated; and in the population associated with eucalyptus monoculture, these indices were 12% for exposed buds and 9% for open flowers.

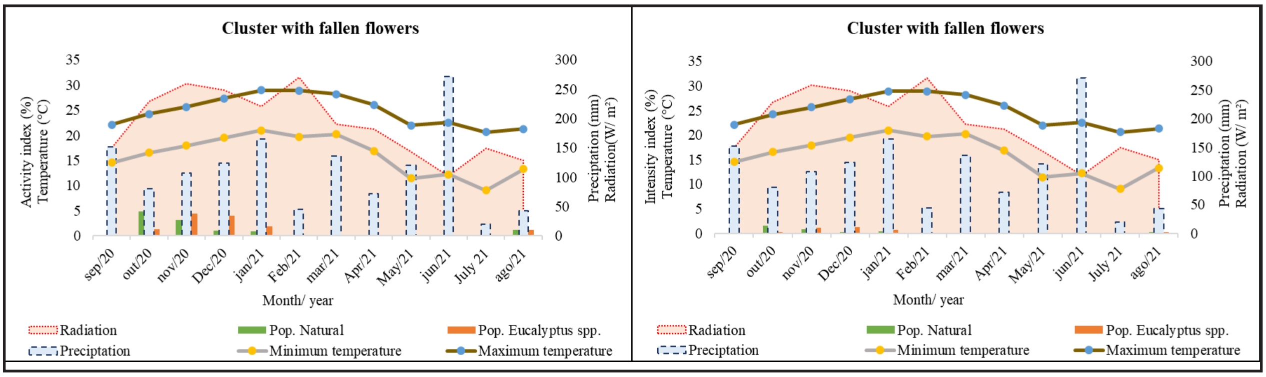
Figure 5 – Activity and intensity index of the phenophases “cluster with exposed buds” and “cluster with open flowers” of *Butia catarinensis* in Restinga at an intermediate stage of succession (Natural) and Restinga in association with eucalyptus monoculture (*Eucalyptus* spp.) on the southern coast of Santa Catarina, Brazil. For the left graph, axis 1 represents the scale for the activity index and the averages of maximum and minimum temperatures. For the right graph, axis 1 represents the scale for the intensity index and the averages of maximum and minimum temperatures. In both graphs, axis 2 represents the scale for precipitation and radiation



Source: Authors (2022)

In both populations, the phenophase “cluster with fallen flowers” was recorded from August to January, with activity peaks in spring (October and November) for the population in a natural environment (AI = 6%); and in spring-summer (November and December) in the population associated with eucalyptus monoculture (AI = 6%). This phenophase did not show correlations with climatic variables (Figure 6). Additionally, it is noteworthy that the synchrony indices were less than 20%, indicating that these phenophases were not synchronous between populations.

Figure 6 – Activity and intensity index of the phenophase “cluster with fallen flowers” of *Butia catarinensis* in Restinga at an intermediate stage of succession (Natural) and in association with eucalyptus monoculture (*Eucalyptus* spp.) on the southern coast of Santa Catarina, Brazil. For the left graph, axis 1 represents the scale for the activity index and the averages of maximum and minimum temperatures. For the right graph, axis 1 represents the scale for the intensity index and the averages of maximum and minimum temperatures. In both graphs, axis 2 represents the scale for precipitation and radiation



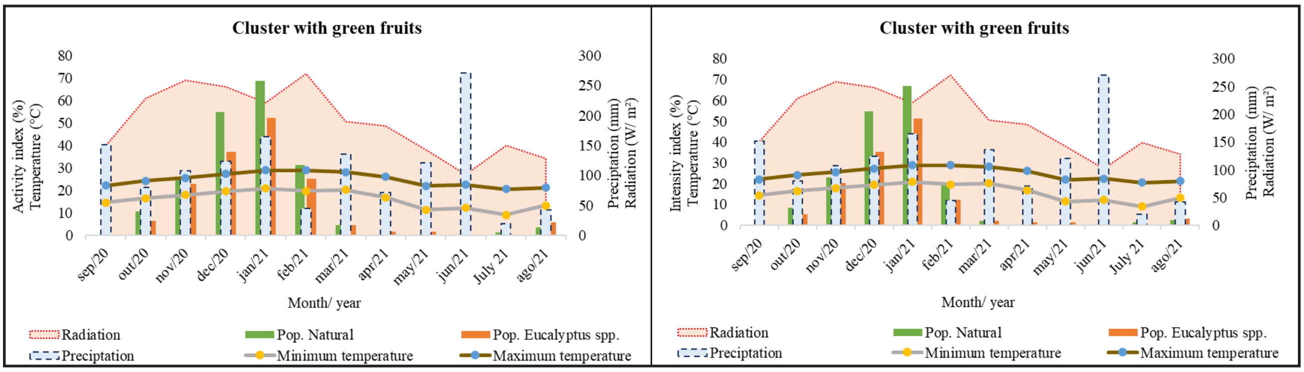
Source: Authors (2022)

The fruiting of *B. catarinensis* began with the phenophase “cluster with green fruits” and ended with the phenophase “cluster with fallen fruits”. The occurrence of clusters with green fruits was recorded from July to March in the population in a natural environment and from August to May in the population associated with eucalyptus monoculture. In both populations, there was an increase in this phenophase at the end of spring and the beginning of summer (December and January), months in which the average maximum temperatures reached the highest values (> 28°C).

The occurrence of this phenophase showed a positive correlation with the variables: average minimum temperature (τ= 0.572; p= 0.012), average maximum temperature (τ= 0.509; p= 0.025), and solar radiation (τ= 0.572; p= 0.012); in the natural environment and only with the average minimum temperature variable (τ= 0.485; p= 0.035) in association with eucalyptus monoculture. All were considered regular correlations (0.3 <τ <0.6).

In both populations, the highest values of AI occurred in the month of December; an AI of 52% for the population in a natural environment and an AI of 38% for the population associated with eucalyptus monoculture (Figure 7). It was noted that the values of this index were between 20% and 60%, demonstrating that this phenophase was slightly synchronous in both populations.

Figure 7 – Activity and intensity index of the phenophase “cluster with green fruits” of *Butia catarinensis* in Restinga at an intermediate stage of succession (Natural) and in association with eucalyptus monoculture (*Eucalyptus* spp.) on the southern coast of Santa Catarina, Brazil. For the left graph, axis 1 represents the scale for the activity index and the averages of maximum and minimum temperatures. For the right graph, axis 1 represents the scale for the intensity index and the averages of maximum and minimum temperatures. In both graphs, axis 2 represents the scale for precipitation and radiation

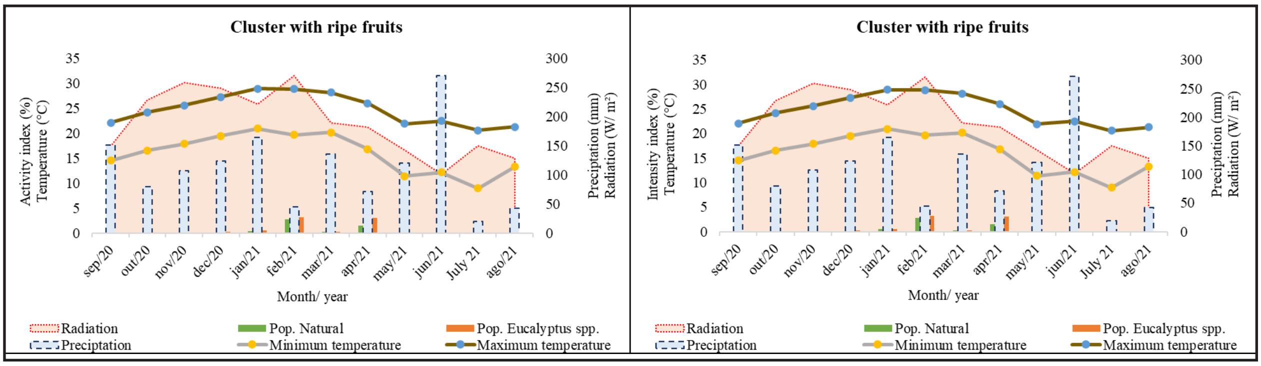


Source: Authors (2022)

The ripening of fruits began in December for the *B. catarinensis* population associated with the commercial eucalyptus monoculture and in January for the population in a natural environment. In both, this phenophase remained until April, reaching its peak of activity and intensityand intensity in February. In that month, the AI was around 9% for the *B. catarinensis* population in a natural environment and 14% for the population associated with eucalyptus monoculture, demonstrating asynchrony of this phenophase in both populations (Figure 8).

In the natural environment population, the occurrence of this phenophase showed a regular positive correlation with minimum temperature (τ= 0.587; p= 0.017) and a strong positive correlation (0.6 <τ <0.9) with maximum temperature (τ= 0.668; p= 0.006). In the population associated with eucalyptus monoculture, the occurrence of this phenophase showed a strong correlation with the variables of average minimum temperature (τ= 0.619; p= 0.011) and average maximum temperature (τ= 0.695; p=0.004).

Figure 8 – Activity and intensity index of the phenophase "Cluster with ripe fruits" of *Butia catarinensis* in a natural environment and in association with eucalyptus monoculture (*Eucalyptus* spp.) on the southern coast of Santa Catarina, Brazil. For the left graph, axis 1 represents the scale for the activity index and the averages of maximum and minimum temperatures. For the right graph, axis 1 represents the scale for the intensity index and the averages of maximum and minimum temperatures. In both graphs, axis 2 represents the scale for precipitation and radiation

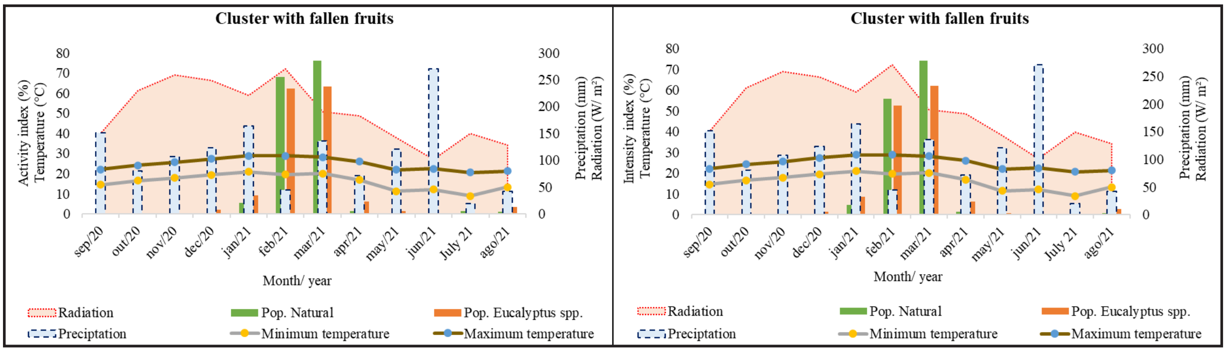


Source: Authors (2022)

Regarding the phenophase "cluster with fallen fruits," in the population associated with eucalyptus monoculture, it began in December and continued until May. In the natural population, it started in the following month (January) and ended in the previous month (April). However, in both populations, the peak of activity and intensity of this phenophase was in March (Figure 9). It is noteworthy that a small occurrence of clusters with fallen fruits was recorded in the months of July and August, resulting from the fall of green fruits that did not reach maturation.

The synchrony of this phenophase in both populations was considered slightly synchronous, as the values were between 20% and 60%, and only in the population associated with eucalyptus monoculture there was a correlation with the variables average minimum temperature (τ= 0.526; p=0.022) and average maximum temperature (τ= 0.461; p=0.046).

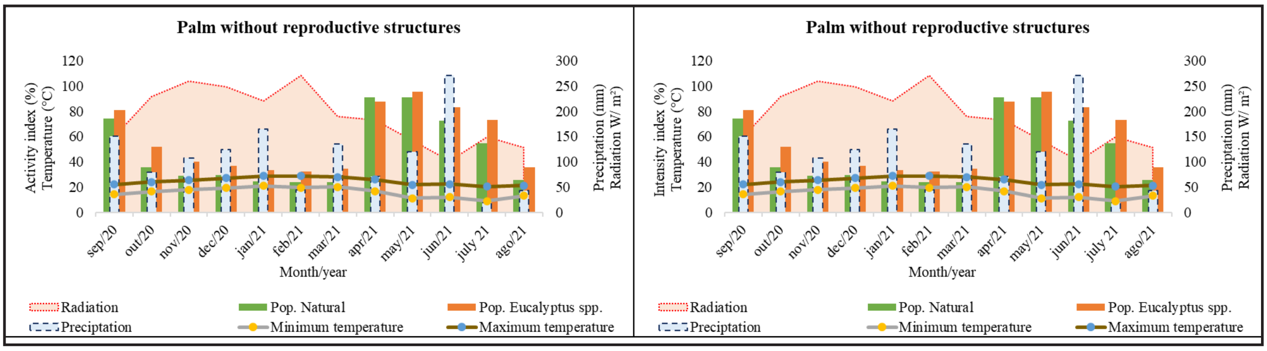
Figure 9 – Activity and intensity index of the phenophase “cluster with fallen fruits” of *Butia catarinensis* in Restinga in a medium stage of succession (Natural) and in association with eucalyptus monoculture (*Eucalyptus* spp.) on the southern coast of Santa Catarina, Brazil. For the left graph, axis 1 represents the scale for the activity index and the averages of maximum and minimum temperatures. For the right graph, axis 1 represents the scale for the intensity index and the averages of maximum and minimum temperatures. In both graphs, axis 2 represents the scale for precipitation and radiation



Source: Authors (2022)

In both populations, the absence of reproductive structures (spathe, flowers, and fruits) was observed throughout the evaluation period. It was noted that this phenophase was more active and intense (indices > 85%) during April and May, a period when temperatures were lower. Both populations were considered synchronous for this phenophase, as the AI values were higher than 60% (Figure 10). The occurrence of this phenophase showed a regular negative correlation with the variable minimum temperature (τ= -0.462; p=0.032) only with the population associated with eucalyptus monoculture.

Figure 10 – Activity and intensity index of the phenophase "Palm without reproductive structures of Butia catarinensis in Restinga at an intermediate stage of succession (Natural) and in association with eucalyptus monoculture (Eucalyptus spp.) on the southern coast of Santa Catarina, Brazil. For the left graph, axis 1 represents the scale for the activity index and the averages of maximum and minimum temperatures. For the right graph, axis 1 represents the scale for the intensity index and the averages of maximum and minimum temperatures. In both graphs, axis 2 represents the scale for precipitation and radiation



Source: Authors (2022)

4 DISCUSSION

In the shrubby Restinga at an intermediate stage of succession, the reproductive period of *B. catarinensis* began with the emission of closed sheaths and ended with fruits falling, both in the month of April. In the population of *B. catarinensis* associated with eucalyptus monoculture, the emission of closed sheaths was continuous throughout the year, and the fruits remained on the cluster until May. However, in both populations, the reproductive phenophases showed a marked increase in production and intensity during defined periods (seasonality); therefore, for the populations studied, the reproductive cycle of *B. catarinensis* can be considered annual (Newstrom et al., 1994).

It is important to highlight that the absence of differences in activity and intensity indices between the two evaluated environments revealed that the microclimate formed by eucalyptus monoculture did not influence the activity and intensity of flowering and fruiting of *B. catarinensis* in the populations studied on the southern coast of Santa Catarina. This pattern differs from what was expected, considering that, despite the proximity between the analyzed populations, the environments hosting them differ in various aspects (allelopathy influence, sunlight incidence, temperature, and humidity), which can interfere directly or indirectly with the phenological behavior of this species (Barceló Coll et al., 2005; Simões-Jesus & Castellani, 2007; Castro et al., 2012; Morellato et al., 2016; Viraponge et al., 2017).

Regarding the analysis of the activity index of each phenophase, it was verified that *B. catarinensis* can be classified as asynchronous, since most of the phenophases showed low synchrony (< 20%) (Bencke & Morellato, 2002). This pattern was similar to that observed in *Oenocarpus bataua* in the state of Pará (Maciel et al., 2021) and in *Attalea maripa* in the Eastern Amazon (Pires et al., 2016). In these studies, the absence of synchrony was mainly associated with the presence of long periods of flowering and fruiting (eight to twelve months) in the studied species. However, in the case of *B. catarinensis* on the southern coast of Santa Catarina, flowering and fruiting were available for a shorter period (four to six months). Therefore, the asynchrony of these populations may be influenced by ecological or biological factors of the genus, as a similar pattern was observed by Rosa et al. (1998) with *B. catarinensis* (previously described as *B. capitata*) in the municipality of Laguna, Santa Catarina, and by Azambuja (2009) with *B. odorata* (previously described as *B. capitata*) in Rio Grande do Sul.

The absence of reproductive structures in palms already in reproductive stages is common and was verified by Padilha et al. (2016) when observing the production of clusters of *B. odorata* in Rio Grande do Sul, as well as by Ruiz and Alencar (2004), Pires et al. (2016), and Begnini et al. (2013) when evaluating the phenology of other genera in Arecaceae. According to Bernacci et al. (2008), the variation in the annual number of reproductive plants that develop inflorescence may be related to the alternation in resource allocation, in which some plants use resources for their growth, maintenance, and reproduction; or by resource competition among individuals occurring in close proximity, as is the case with *butiazais* (Marchi et al., 2018), where individuals may limit each other's reproductive output over a period of time.

Regarding the flowering period, the continuous presence of closed sheaths throughout the year or most of it was also recorded by Ruiz and Alencar (2004), Pires et al. (2016), and Maciel et al. (2021) with other genera of Arecaceae in northern Brazil. Rosa et al. (1998), when analyzing the phenology of *B. catarinensis*, reported the absence of closed sheaths only in March, April, and May, months following what was observed in this work (February and March). According to Ruiz and Alencar (2004), the continuous or long-term presence of closed sheaths throughout the year can be explained by the prolonged duration of the event in the plant, as when the individual begins to emit inflorescences, most of the new leaves already have a new floral bud in formation.

The occurrence of activity and intensity peaks for the phenophases "cluster with exposed buds" and "cluster with open flowers" in November and December is similar to the results found by Rosa et al. (1998) with *B. catarinensis* in Santa Catarina; Schwartz (2008) and Azambuja (2009) with *B. odorata* in Rio Grande do Sul (December and January); Castro et al. (2007) and Begnini et al. (2013) with *Euterpe edulis* and *Syagrus romanzoffiana* in the coastal regions of São Paulo and Santa Catarina; and Talora and Morellato (2000) and Medeiros (2005). According to these authors, peak flowering in spring and summer is often associated with conditions of higher temperature, precipitation, and longer photoperiod (Begnini et al., 2013); however, in climates with little seasonality, as in the period evaluated, environmental factors likely have less influence on the phenophases than in notably seasonal environments

(Talora & Morellato, 2000). This may justify the absence of significant correlations for the phenophases: "cluster with exposed buds," "cluster with open flowers," and "cluster with fallen flowers" with the climatic variables evaluated.

Regarding fruiting, the occurrence of "cluster with green fruits" for most of the evaluated period (between July and May), with peaks occurring between December and January, and "cluster with ripe fruits" occurring from December to April, with activity and intensity peaks in February, was similar to findings by Rosa et al. (1998) and Azambuja (2009) with *B. catarinensis* and *B. odorata* on the coasts of Santa Catarina and Rio Grande do Sul. This pattern of weak seasonality in fruiting may suggest that the climate is not a limiting factor for fruit production in *B. catarinensis* in southern Santa Catarina (Bencke & Morellato, 2002). Castro et al. (2007) and Beginini et al. (2013) in their studies of the phenology of other genera of Arecaceae obtained peaks of fruiting a little later. *Euterpe edulis* on the coast of São Paulo had peaks of activity and intensity of green fruits in March, as well as a peak of cluster with ripe fruits in March and April (Castro et al., 2007); and *S. romanzofiana* had the highest incidence of cluster with green fruits between January and February and cluster with ripe fruits in June and July (Begnini et al., 2013).

The presence of positive correlations (regular and strong) of the phenophases: "cluster with green fruits," "cluster with ripe fruits," and "cluster with fallen fruits" with temperature variables reinforced the understanding that high temperatures influence the development and maturation of fruits of *B. catarinensis* on the coast of Santa Catarina. A similar pattern was found by Medeiros (2005) when observing the phenology of tree species in the Restinga of São Paulo and by Guimarães (2006) when observing the flowering and fruiting of tree species in the Restinga of Santa Catarina.

The highest index of absence of reproductive structures was observed in the autumn-winter period following the senescence of the fruits. The presence of a negative correlation for this phenophase with minimum temperature corroborates the finding that the reduction in the number of reproductive structures is directly related to lower temperatures in these seasons. A similar pattern was found by Rosa et al. (1998) and Azambuja (2009) in other populations of *Butia* in southern Brazil.

In both populations, the absence of correlations for the phenophases: “cluster with exposed buds,” “cluster with open flowers,” and “cluster with fallen flowers” with climatic variables was notable. Furthermore, only the precipitation variable showed no correlations with any of the reproductive phenophases of *B. catarinensis* on the southern coast of Santa Catarina. This contrasts with findings by Azambuja (2009), who recorded correlations of this variable with flower development in *B. odorata* on the coast of Rio Grande do Sul, and by Castro et al. (2007) and Begnini et al. (2013) regarding the development of inflorescences and green fruits in other palms on the Brazilian coast.

According to Henderson et al. (2000), this pattern of absent significant correlation between flowering and fruiting phenophases and climatic variables is natural, as the phenological patterns of species are primarily influenced by endogenous attributes (physiological, nutritional, and genetic) and ecological factors (pollination, predation, and competition) rather than by climatic variables alone. Notably, during the monitoring period, the occurrence of floral visitors, primarily bees, on the flowers of *B. catarinensis* was recorded, suggesting that this palm is entomophilous. Research conducted in Northern and Southern Brazil highlights the importance of insect pollination, mainly by bees, in the flowering and subsequent fruiting success of palms (Venturieri, 2008; Dorneles et al., 2013).

5 CONCLUSIONS

This study evidenced that *B. catarinensis* has an annual and asynchronous reproductive cycle, with higher rates of flowering and fruiting in spring and summer and lower rates of reproductive structures during winter. Unlike *E. edulis* and *S. romanzoffiana*, also native to the Atlantic Forest, which showed a peak in fruiting, particularly in fruit maturation, during autumn and winter.

The absence of significant correlations between the phenophases of flowering and climatic variables suggests that other factors may also play a role in initiating and developing these phenological events; in this study, entomophilous pollination stands out as a potential influencing factor in flowering. Furthermore, it is noted that precipitation had little influence on the reproductive cycle of this species. In contrast, higher temperature values (minimum and maximum), as well as high levels of solar radiation, positively influenced the development of clusters with green fruits and clusters with ripe fruits throughout the year.

Additionally, the absence of significant differences in activity and intensity indices between the two environments evaluated revealed that the microclimate formed by eucalyptus monoculture did not influence the quantity of flowering and fruiting of *B. catarinensis*, but it may have influenced the period of occurrence and the peak of the phenophases, accelerating, delaying, or prolonging the occurrence and intensity of these events in the species. This result can be explained by the fact that, although the eucalyptus monoculture creates its own microclimate, with additional shade and humidity and reduced direct solar radiation, these factors do not appear to be sufficient to significantly alter the phenology of *B. catarinensis*. However, this alteration in the microclimate, even if subtle, affects the plant's physiological response time. Conducting a phenological study using microclimatic data from the eucalyptus monoculture is necessary to identify how these small variations impact the synchrony and intensity of phenophases.

Finally, this study provides information that can assist in predicting the behavior of *B. catarinensis* in response to climate change. It also presents the first phenological survey of this palm under eucalyptus understory in southern Brazil. The data from this survey can offer insights for potential sustainable exploitation of *B. catarinensis* fruits in consortium with eucalyptus monoculture as a strategy to increase income for silviculturists in the region.

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REFERENCES

Alberton, B., Almeida, J., Helm, R., Torres, R., Menzel, A. & Morellato, L. P. C. (2014). Using phenological cameras to track the green up in a cerrado savanna and its on-theground validation. *Ecological Informatcs*, *19*, 62-70. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S1574954113001325?via%3Dihub. doi: https://doi.org/10.1016/j.ecoinf.2013.12.011

Alencar, J. C. & Anderson, A. B. (1978). *Projeto de pesquisa sobre 21 espécies de palmeiras na Reserva Florestal Adolpho Ducke*. Manaus: Instituto Nacional de Pesquisas da Amazônia.

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Gonçalves, J. D. M. & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, *22*(6), 711-728. Retrieved from https://www.schweizerbart.de/papers/metz/detail/22/82078/Koppen_s_climate_classification_map_for_Brazil?af=crossref. doi https://doi.org/10.1127/0941-2948/2013/0507

Andrade, D. F & Ogliari, P. J. (2007). *Estatística para as ciências agrárias e biológicas: com noções de experimentação*. Florianópolis: UFSC.

Almeida, E. B. Jr., & Zickel, C. S. (2009). Fisionomia Psamófila-Reptante: Riqueza e Composição de espécies na Praia da Pipa, Rio Grande do Norte, Brasil. *Pesquisas, Botânica,* (60), 289-299.

Azambuja A. C. (2009). *Demografia e fenologia reprodutiva de Butia capitata (Mart.) Becc. (Arecaceae) em Arambaré, Rio Grande do Sul* (Master's thesis). Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C. & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological monographs*, *81*(2), 169-193. Retrieved from https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/10-1510.1. doi https://doi.org/10.1890/10-1510.1

Barceló Coll, J., Nicolas Rodrigo, G., Sabater Garcia, B. & Sanchez Tames, R. (2005). *Fisiología Vegetal*. Madrid: Pirámide.

Begnini, R. M., Silva, F. R. & Castellani, T. T. (2013). Fenologia reprodutiva de *Syagrus romanzoffiana* (Cham.) Glassman (Arecaceae) em Floresta Atlântica no sul do Brasil. *Biotemas*, *26*(4), 53-60. Retrieved from https://periodicos.ufsc.br/index.php/biotemas/article/view/2175-7925.2013v26n4p53. doi https://doi.org/10.5007/2175-7925.2013v26n4p53

Beier, C. (2004). Climate change and ecosystem function - full-scale manipulations of CO2 and temperature. *New Phytologist*, *162*(2), 243-251. Retrieved from https://nph.onlinelibrary.wiley.com/doi/10.1111/j.1469-8137.2004.01064.x. doi: https://doi.org/10.1111/j.1469-8137.2004.01064.x

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. & Courchamp, F. (2012). Impacts of climate change on the future of biodiversity. *Ecology Letters*, *15*(4), 365-377. Retrieved from https://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2011.01736.x. doi: https://doi.org/10.1111/j.1461-0248.2011.01736.x

Bencke, C. S. C. & Morellato, L. P. C. (2002). Estudo comparativo da fenologia de nove espécies arbóreas em três tipos de floresta atlântica no sudeste do Brasil. *Revista Brasileira de Botânica*, *25*(2), 237-248. Retrieved from https://www.scielo.br/j/rbb/a/GcPKcCkfDVB3RvZCVbZgcMD/?lang=pt. doi: https://doi.org/10.1590/S0100-84042002000200012

Bernacci, L. C., Martins, F. R. & Santos, F. A. M. (2008). Dinâmica populacional da palmeira nativa jerivá, Syagrus romanzoffiana (Cham.) Glassman em um fragmento florestal no sudeste do Brasil. *Acta Botânica Brasílica*, *22*, 119-130. Retrieved from http://ww1.infobibos.com.br/Artigos/2006_3/Jeriva/index.htm

Callegari-Jacques, S. M. C. (2011). *Bioestatística princípios e aplicações*. Porto Alegre: ArtMed.

Castro, E. R., Galetti, M. & Morellato, L. P. C. (2007). Reproductive phenology of Euterpe edulis (Arecaceae) along a gradient in the Atlantic rainforest of Brazil. *Australian Journal of Botany*, *55*(7), 725 -735. Retrieved from https://www.publish.csiro.au/bt/BT07029. doi: https://doi.org/10.1071/BT07029

Castro, E. R., Côrtes, M. C., Navarro, L., Galetti, M. & Morellato, L. P. C. (2012). Temporal variation in the abundance of two species of thrushes in relation to fruiting phenology in the Atlantic rainforest. *Emu*, *112*(2), 137-148. Retrieved from https://www.tandfonline.com/doi/abs/10.1071/MU11023. doi: https://doi.org/10.1071/MU11023

Cohenca, D. (2016). *Modelagem de cenários de ocupação no litoral sul de Santa Catarina utilizando técnicas de análise geoespacial*. (Master's thesis in geography). Universidade Federal de Santa Catarina, Florianópolis, SC, Brazil.

Collevatti, R. G., Nabout, J. C. & Diniz, J. A. F°. (2011). Range shift and loss of genetic diversity under climate change in Caryocar brasiliense, a Neotropical tree species. *Tree Genetics & Genomes*, *7*, 1237-1247. Retrieved from https://link.springer.com/article/10.1007/s11295-011-0409-z#citeas. doi: https://doi.org/10.1007/s11295-011-0409-z

Colwell, R. K., Brehm, G., Cardelus, C. L., Gilman, A. C. & Longino, J. T. (2008). Global warming, elevational range shifts, and lowland biotic attrition in the wet tropics. *Science*, *322*(5899), 258-261. Retrieved from https://www.science.org/doi/10.1126/science.1162547. https://doi.org/10.1126/science.1162547

Resolução Conama n. 261, de 30 de junho de 1999. Aprovar, como parâmetro básico para análise dos estágios sucessivos de vegetação de restinga para o Estado de Santa Catarina, as diretrizes constantes no Anexo desta Resolução. Retrieved from http://conama.mma.gov.br/.

Resolução Consema n. 51, de 05 de dezembro de 2014. Reconhece a Lista Oficial das Espécies da Flora Ameaçada de Extinção no Estado de Santa Catarina e dá outras providências. Retrieved from https://www.ima.sc.gov.br/index.php/biodiversidade/biodiversidade/flora.

Coradin, L., Siminski, A. & Reis, A. (2011). *Espécies nativas da flora brasileira de valor econômico atual ou potencial: plantas para o futuro: Região Sul*. Brasília: MMA.

Coutinho, C. L. (2006). O conceito de bioma. *Acta Botanica Brasilica*, *20*(1), 13-23. Retrieved from https://www.scielo.br/j/abb/a/RhxPXykYPBPbCQCxz8hGtSn/?lang=pt. doi: https://doi.org/10.1590/S0102-33062006000100002

Cruz, P. N., Pereira, T. C., Guindani, C., Oliveira, D. A., Rossi, M. J. & Ferreira, S. R. (2017). Antioxidant and antibacterial potential of butia (*Butia catarinensis*) seed extracts obtained by supercritical fluid extraction. *The Journal of Supercritical Fluids*, *119*, 229-237. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0896844616303436?via%3Dihub. doi https://doi.org/10.1016/j.supflu.2016.09.022

Cunha, M. R., Lima, E. C., Lima, D. R., Silva, R. S., Thue, P. S., Seliem, M. K., Farooq, S., Glaydson, S. R. & Larsson, S. H. (2020). Removal of captopril pharmaceutical from synthetic pharmaceutical-industry wastewaters: Use of activated carbon derived from *Butia catarinensis*. *Journal of Environmental Chemical Engineering*, *8*(6), e104506. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S2213343720308551?via%3Dihub. doi: https://doi.org/10.1016/j.jece.2020.104506

Dorneles, L. L., Zillikens, A., Steiner, J. & Padilha, M. T. S. (2013). Biologia da polinização de *Euterpe edulis* Martius (Arecaceae) e associação com abelhas sociais (Apidae: Apini) em sistema agroflorestal na Ilha de Santa Catarina. *Heringia*, *Série Botanica*, *68*(1), 47-57. Retrieved from https://isb.emnuvens.com.br/iheringia/article/view/38.

Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I. & Marbà, N. (2013). The role of coastal plant communities for climate change mitigation and adaptation. Nature *Climate Change*, *3*, 961-969. Retrieved from https://www.nature.com/articles/nclimate1970. doi: https://doi.org/10.1038/nclimate1970

Elias, G. A. & Santos, R. (2016). Produtos Florestais Não Madeireiros e Valor Potencial de Exploração Sustentável da Floresta Atlântica no sul de Santa Catarina. *Ciência Florestal*, *26*(1), 235-248. Retrieved from https://periodicos.ufsm.br/cienciaflorestal/article/view/21117. doi: https://doi.org/10.5902/1980509821117

Elias, G. A., Lima, J. M. T. & Santos, R. (2019). Threatened flora from the State of Santa Catarina, Brazil: Arecaceae. *Hoehnea*, *46*(1), 1-6. Retrieved from https://www.scielo.br/j/hoehnea/a/YHb4H6z9Jq4yhbb7D46PFFF/. doi: https://doi.org/10.1590/2236-8906-32/2018

Elias, G. A. Soares, K. P., Bortoluzi, R. L. C. & Santos, R. (2018). Palmeiras (Arecaceae) em Santa Catarina, sul do Brasil. *Iheringia, Série Botânica*, *73*(2), 88-107. Retrieved from https://isb.emnuvens.com.br/iheringia/article/view/417. doi: https://doi.org/10.21826/2446-8231201873202

Field, A. P. (2009). *Descobrindo a estatística usando o SPSS* (2nd ed.). Porto Alegre: Artmed.

Fournier, L. A. (1974). Un método cuantitativo para la medición de caracteristicas fenológicas en árboles. *Turrialba*, *24*, 422-423. Retrieved from https://www.scienceopen.com/document?vid=2242189e-658c-42f6-9204-35ab1c5b0fca.

Guimarães, T. B. (2006). *Florística e fenologia reprodutiva de plantas vasculares na restinga do Parque Municipal das Dunas da Lagoa de Conceição, Florianópolis, SC* (Master's thesis). Universidade Federal de Santa Catarina, Florianópolis, SC, Brazil.

Henderson, A., Galeano, G. & Bernal, R. (1995). *Field guide to the palms of the Americas*. Princeton: Princeton University Press.

Henderson, A., Fischer, B., Scariot, A., Pacheco, M. A. W. & Pardini, R. (2000). Flowering phenology of a palm community in a central Amazon Forest. *Brittonia*, *52*(2), 149-159. Retrieved from https://link.springer.com/article/10.2307/2666506. doi: https://doi.org/10.2307/2666506

Hoffmann, J. F., Lopes Crizel, R., De Ávila Madruga, N., Barbieri, R. L., Rombaldi, C. V. & Chaves, F. C. (2018). Flavan-3-ol, flavanone, flavone, flavonol, phenolic acid, and stilbene contents of four *Butia* species (Arecaceae). *Fruits*, *73*(2), 125-137. Retrieved from https://www.pubhort.org/fruits/73/2/5/index.htm. doi: https://doi.org/10.17660/th2018/73.2.5

Kumagai, L. & Hanazaki, N. (2013a). Ethnobotanical and ethnoecological study of *Butia catarinensis* Noblick & Lorenzi: contributions to the conservation of an endangered area in southern Brazil. *Acta Botânica Brasílica*, *27*(1), 13-20. Retrieved from https://www.scielo.br/j/abb/a/RfN5Wyz9zBFdMPHp4WBFgby/?lang=en. doi: https://doi.org/10.1590/S0102-33062013000100002

Kumagai, L. & Hanazaki, N. (2013b). Economic Botany of an endemic palm species (*Butia catariensis* Noblick & Lorenzi) in Southern Brazil. *Ethnobotany Research and Applications*, *11*, 143-152. Retrieved from https://ethnobotanyjournal.org/index.php/era/article/view/800.

Lacerda, L. D., Araújo, D. S. D. & Maciel, N. C. (1993). Dry Coastal ecosystems of the tropical Brazilian coast. In Maarel, E. Van (ed.). *Dry coastal ecosystems: Africa, America, Asia and Oceania*. (pp. 477-493). Amsterdam: Elsevier.

Lima, J. S., Mejia, L. B., Ribeiro, M. S. L. & Collevatti, R. G. (2017). Climatic changes can drive the loss of genetic diversity in a Neotropical savanna tree species. *Global Change Biology*, *11*, 4639-4650. Retrieved from https://onlinelibrary.wiley.com/doi/10.1111/gcb.13685. doi https://doi.org/10.1111/gcb.13685

Maciel, A. R. N. A., Oliveira, M. S. P., Brandão, S. P. & Mira, R. F. (2021). Fenologia reprodutiva do patauazeiro (*Oenocarpus bataua* Mart.) cultivado nas condições de Belém-PA. *Research, Society and Development*, *10*(11), e376101119627. Retrieved from https://rsdjournal.org/index.php/rsd/article/view/19627. doi https://doi.org/10.33448/rsd-v10i11.19627

Marchi, M. M., Barbieri, R. L., Sallés, J. M., & Costa, F. A. D. (2018). Flora herbácea e subarbustiva associada a um ecossistema de butiazal no Bioma Pampa. *Rodriguésia*, *69*(2), 553-560. Retrieved from https://www.scielo.br/j/rod/a/kNKjRVNjLrtMyHkZHx8mWJK/?lang=pt. doi https://doi.org/10.1590/2175-7860201869221

Medeiros, D. P. W. (2005). *Fenologia e síndromes de dispersão na floresta de restinga da RPPN Nossa Senhora do Outeiro de Maracaípe, Ipojuca, Pernambuco* (Master's thesis). Universidade Federal Rural de Pernambuco, Recife, PE, Brazil.

Morellato, L. P. C., Leitão, H. F. F°., Rodrigues, R. R. & Joly, C. A. (1990). Estratégias fenológicas de espécies arbóreas em floresta de altitude na Serra do Japi, Jundiaí, São Paulo. *Revista Brasileira de Biologia*, *50*(1), 149-162.

Morellato, L. P. C., Alberton, B., Alvarado S. T., Borges, B., Buisson E., Camargo, M. G. G., Cancian, L. F., Carstensen, D. W., Escobar, D. F. E., Leite, P. T. P., Mendoza, I., Rocha, N. M. W. B., Soares, N. C., Silva, T. S. F., Staggemeier, V. G., Streher, A. S., Vargas, B. C. & Peres, C. A. (2016). Linking plant phenology to conservation biology. *Biological Conservation*, *195*, 60-72. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0006320715302123?via%3Dihub. doi: https://doi.org/10.1016/j.biocon.2015.12.033

Moura, R. C. D., Lopes, P. S. N., Brandão, D. D. S. Jr., Gomes, J. G., & Pereira, M. B. (2010). Biometria de frutos e sementes de Butia capitata (Mart.) Beccari (Arecaceae), em vegetação natural no Norte de Minas Gerais, Brasil. *Biota Neotropica*, *10*(2), 415-419. Retrieved from https://www.scielo.br/j/bn/a/9hbvpLRZ96hFmjbZqxHSzHw. doi: https://doi.org/10.1590/S1676-06032010000200040

Newstrom, L. E., Frankie, G. W. & Baker, H. G. (1994). A new classification for plant phenology based on flowering patterns in lowland tropical forest trees at La Selva, Costa Rica. *Biotropica*, *26*(2), 141-159. Retrieved from https://www.jstor.org/stable/2388804?origin=crossref. doi: https://doi.org/10.2307/2388804

Padilha, H. K. M., Mistura, C. C., Villela, J. C. B., Rivas, M., Heiden, G. & Barbieri, R. L. (2016). Avaliação da produção de cachos de frutas em palmeiras de Butiá (*Butia odorata* (Barb. Rodr.) Noblick & Lorenzi). *Magistra*, *28*(3/4), 419-426. Retrieved from https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1079425/avaliacao-da-producao-de-cachos-de-frutas-em-palmeiras-de-butia-butia-odorata-barb-rodr-noblick--lorenzi-.

Pires, H. C. G., Santos, R. L., Cabral, B. S., Silva, V. M., Nogueira, G. A. & Ferreira, P. R. N. (2016). Padrão Fenológico de *Attalea maripa* (Aubl.) Mart. em Áreas de Pastagens na Amazônia Oriental. *Floresta e Ambiente*, *23*(2), 170-179. Retrieved from https://www.scielo.br/j/floram/a/JQXHZSCcJGnZkRphsnmyZSf/?lang=pt. doi: https://doi.org/10.1590/2179-8087.048313

RAN1. (2013). *Base científica das mudanças climáticas: Primeiro Relatório de Avaliação Nacional*. FAPESP. Retrieved from http://www.pbmc.coppe.ufrj.br/documentos/RAN1_completo_vol1.pdf

Rosa, L., Castellani, T. T. & Reis, A. (1998). Biologia reprodutiva de *Butia capitata* (Martius) Beccari *var. odorata* (Palmae) na restinga do município de Laguna, SC. *Revista Brasileira de Botânica*, *21*(3), 281-287. Retrieved from https://www.scielo.br/j/rbb/a/VDmgRdZwxdBDqhJ3jz8FTMC/. doi https://doi.org/10.1590/S0100-84041998000300007

Ruiz, R. R. & Alencar, J. C. (2004). Comportamento fenológico da palmeira patauá (*Oenocarpus bataua*) na reserva Florestal Adolpho Ducke, Manaus, Amazonas, Brasil. *Acta Amazonica*, *34*(4), 553-558. Retrieved from https://www.scielo.br/j/aa/a/pjWBg7FYTFbNM9GJGpTNN5K/?lang=pt. doi: https://doi.org/10.1590/S0044-59672004000400007

Sampaio, D., Souza, V. C., Paula-Souza, J. & Rodrigues, R. R. (2006). *Árvores da Restinga*: *Guia Ilustrado para a identificação das espécies da Ilha do Cardoso.* São Paulo: Neotrópica.

Santos, R. D., Elias, G. A., Guislon, A. V., & Zanoni, I. Z. (2017). Vegetação arbustivo-arbórea em uma restinga de Jaguaruna, litoral sul do Estado de Santa Catarina, Brasil. *Revista Ambiente & Água*, *12*(1), 99-111. Retrieved from https://www.scielo.br/j/ambiagua/a/Hf6DqRBxxZsDbBXb436xvBH/. doi: https://doi.org/10.4136/ambi-agua.1952

Schwartz, E. (2008). *Produção, fenologia e qualidade dos frutos de Butia capitata em populações de Santa Vitória do Palmar* (Ph.D's thesis). Universidade Federal de Pelotas, Pelotas, RS, Brazil.

Silva, P. L. A. (2018). *Biodiversidade e mudanças climáticas no Brasil: levantamento e sistematização de referências*. Brasília: WWF Brasil.

Simões-Jesus, M. F. & Castellani, T. T. (2007). Avaliação do potencial facilitador de *Eucalyptus* sp. na restinga da Praia da Joaquina, Ilha de Santa Catarina, SC. *Biotemas*, *20*(3), 27-35. Retrieved from https://periodicos.ufsc.br/index.php/biotemas/article/view/20665.

Soares, K. P., Longhi, S. J., Witeck, L. Neto, & Assis, L. C. D. (2014). Palmeiras (Arecaceae) no Rio Grande do Sul, Brasil. *Rodriguésia*, *65*(1), 113-139. Retrieved from https://www.scielo.br/j/rod/a/R8cpsjTCck7zkLyygP8QGdJ/. doi: https://doi.org/10.1590/S2175-78602014000100009

Tarola, D. C. & Morellato, P. (2000). Fenologia de espécies arbóreas em floresta de planície litorânea do sudeste do Brasil. *Revista Brasileira Botânica*, *23*(1), 13-26. Retrieved from https://www.scielo.br/j/rbb/a/VRNgVhnjFztQxjgsH7H4fDw/. doi: https://doi.org/10.1590/S0100-84042000000100002

Tonhasca, A. Jr. (2005). *Ecologia e história natural da Mata Atlântica*. Rio de Janeiro: Interciência.

Venturieri, G. (2008). Floral biology and management of stingless bees to pollinate assai palm (Euterpe oleracea Mart., Arecaceae) in eastern amazon. In Benficalvarez, C. A. & Landeiro, M. (ed.). *Pollinators Management in Brazil* (pp. 10-13). Brasília: Ministério do Meio Ambiente.

Vieira, S. (2018). *Bioestatística: tópicos avançados: testes não paramétricos, testes diagnósticos, medidas de associação e concordância*. Rio de Janeiro: GEN Guanabara Koogan.

Viraponge, A., Endress, B. A., Gilmore, M. P., Horn, C. & Romulo, C. (2017). Ecology, livelihoods, and management of the *Mauritia flexuosa* palm in South America. Global *Ecology and Conservation*, *10*, 70-92. Retrieved from https://www.sciencedirect.com/science/article/pii/S2351989416301032. doi: https://doi.org/10.1016/j.gecco.2016.12.005

Worm, B. Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., Jackson, J. B. C., Lotze, H. K., Micheli, F. Palumbi, S. R., Sala, E., Selkoe, K. A., Stachowicz, J. J. & Watson, R. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science*, *314*(5800), 787-790. Retrieved from https://www.science.org/doi/10.1126/science.1132294. doi: https://www.science.org/doi/10.1126/science.1132294

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