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Influencia del tamaño de parcela en el análisis de la distribución y los efectos de la altitud sobre los patrones espaciales de palmito en la selva tropical submontana, Ibirama, Brasil

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SUMMARY

The knowledge about the behavior of the species and its analysis is very important in order to support management and conservation techniques. Therefore, the aims of this study were to analyze spatial distribution of palm heart (*Euterpe edulis*) and verify the influence of altitude on spatial distribution. The spatial distribution was calculated with the indexes of Payandeh, Hazen and Morisita. To assess the influence of altitude on spatial distribution, we calculated Kolmogorov-Smirnov test of complete spatial randomness with altitude as covariate and we also calculated an estimate of the intensity as a function of altitude. The study was developed in a seed collection area in Floresta Nacional (FLONA) in Ibirama, Santa Catarina. Sampling consisted of five ten-meter-wide strips. False coordinates of *E. edulis* with more than 10 cm of diameter at breast height were recorded. *Euterpe edulis* showed spatial clustered distribution in all plot sizes and all indexes used. Morisita was the best index for describing spatial distribution. The occurrence of *E. edulis* was higher in intermediate altitude. Therefore, it is recommended to take into consideration the existence of clusters and of altitude influence in order to promote management and conservation of this species.

Key words: Payandeh index, Hazen index, Morisita index.

RESUMEN

El conocimiento acerca del comportamiento de las especies y de cómo analizarlo es muy importante para amparar las técnicas de manejo y conservación. De tal modo, el objetivo de este estudio fue analizar la distribución espacial del palmito (*Euterpe edulis*) y evaluar la influencia de la altitud en su distribución espacial. La distribución espacial fue calculada con los índices de Payandeh, Hazen y Morisita. Con el objetivo de evaluar la influencia de la altitud, fue empleada la prueba de Kolmogorov-Smirnov para la aleatoriedad espacial completa con la altitud como una covariable. También se estimó la intensidad como función de la altitud. El estudio se realizó en el área de recolección de semillas de la Floresta Nacional (FLONA) de Ibirama, Santa Catarina, Brasil. La muestra fue compuesta de cinco zonas de 10 metros de amplitud. Falsas coordenadas de *E. edulis* con más de 10 cm de diámetro a la altura del pecho fueran registradas. *Euterpe edulis* mostró distribución espacial reunida en todos los tamaños de las unidades utilizadas. El índice de Morisita fue aquel que mejor describió la distribución espacial. La ocurrencia de *E. edulis* fue superior en altitudes intermedias. Por lo tanto, se recomienda tener en cuenta los grupos y la influencia de la altitud para promover el manejo y la conservación de esta especie.

Palabras clave: índice de Payandeh, índice de Hazen, índice de Morisita.

INTRODUCTION

Spatial distribution of species consists of relevant information for ecological analyses because it helps to understand forest dynamics and formation. Spatial distribution depends on complex environmental and ecological factors (Capretz 2004). Biotic and abiotic conditions such as soil, water and light are factors that influence species spatial distribution (Silva *et al*. 2009).

The measurement of clustering and dispersion of a species is crucial to determine how the species uses resources and how it should be used as a resource (Condit *et al*. 2000). Therefore, a management and conservation plan for a species should be based on dispersion features (Austin 2002).

There are several methods to study spatial distribution. The most common methods to analyze spatial distribution are based on quadrats (Silva *et al*. 2009), however, the size of the sample can influence on this analysis (Zhang *et al*. 2013). Furthermore, technical features such as density and frequency are very helpful in understanding how tree species are distributed (Oosting 1956). In this context, it is

important to assess how the size of the plot will influence on the results of spatial distribution in quadrat methods.

The palm heart (*Euterpe edulis* Mart.) is a key plant of tropical rainforests (Capretez 2004) and has a historical legacy in Brazil once it became commercially important. Its products are oil, fruit, heart, stipe (in constructions) and leaves (in several products) (Bondar 1964, Milanesi *et al*. 2013). It is known that spatial distribution of *E. edulis* is cluster (Anjos *et al*. 1998, Oliveira *et al*. 2001, Costa Silva *et al*. 2003), and that this species prefers areas rich in water content; however, there is no specifications regarding the relationship of this species with altitude. Therefore, this study aimed at analyzing the spatial distribution of *E. edulis* in different plot sizes, as well as at understanding the influence of altitude on spatial distribution.

METHODS

The study was carried out in a seed collection area in Floresta Nacional (FLONA) in Ibirama, a Federal Conservation Unit, located in the municipalities of Ibirama, Apiúna and Ascurra, in the region of Vale do Itajaí, Santa Catarina State, Brazil. The climate was classified as humid subtropical (Cfa) according to Köeppen climate class. Mean annual temperature variation is 17.0 ºC to 19.1 ºC with maximum monthly temperature ranging from 23.5 °C to 26.0 °C and minimum of 11.8 ºC to 15.4 ºC. Total annual rainfall can vary from 1,320 mm to 1,640 mm (Ministério do Meio Ambiente 2008).

Soil was classified into red-yellow Acrisol, Cambisols and two types of Neossols. Relief was classified as mountainous. The native vegetation of the area was classified as Submontane Tropical Rainforest, in a stage of advanced regeneration. The area went through forest exploitation in the 1970s, when the species of highest commercial value were removed (Ministério do Meio Ambiente 2008).

Five ten-meter-wide strips towards magnetic north were installed. The strips were arranged in a parallel position distant 150 m one from the other. With total length of 250 m for strip 01, 200 m for strip 02, 225 m for strip 03, 250 m for strip 04 and 275 m for strip 05. *Euterpe edulis* palms within these strips with a diameter at breast height of more than 10 cm had their false geographical coordinates recorded and the size limit of diameter at breast height was correspondent to reproductive stage (Raupp *et al*. 2009). Data were collected from March to April 2008.

The different plot sizes were obtained by the subdivision of the strips in different lengths, with amplitude of five meters (from 05 to 125 m), which resulted in twenty-five different plot sizes (figure 1), with total sampled area for each plot size being different, depending on length. For example, plots 5 m in length covered the total area of all strips; however, plots 10 m in length did not cover the total area, because strip 2 has 225 m, hence 5 m remain without analysis.

In order to understand the spatial distribution, we calculated absolute density and frequency (Oosting 1956);
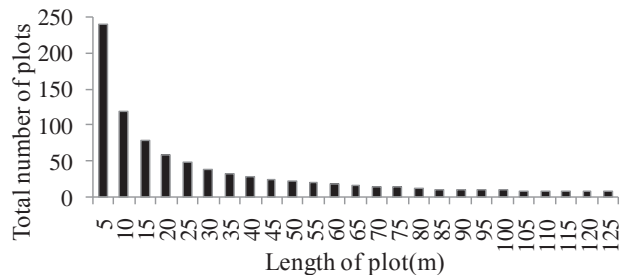
Figure 1. Different plot sizes, with length from 5 to 125 m, and total number of plots.

Diferentes tamaños de unidades de muestreo, ancho 5-125 m, y número total de parcelas.

Payandeh index (Payandeh 1970); Hazen index (Hazen 1966); and Morisita index (Morisita 1959) and assessed by its stability in different plot sizes by coefficient of variation. The Payandeh index denotes cluster when the index value is higher than 1.5, tending to cluster when index value is between 1.5 and 1 and random when index value is less than 1. Hazen index is analyzed by the chi-square test; if the value of the index is higher than the tabulated value for 99 % probability, then the data are clustered (degree of freedom ranged from 239 for 5 m long plots until 8 for 125 m long plots) and the Morisita index is clustered when the value index is higher than 1, and it was tested by the chi-square test.

We obtained points of altitude with GPS and described the whole altitude profile through the polynomial regression analysis. To evaluate the altitude influence on *E. edulis* density we calculated Kolmogorov-Smirnov test of CSR (Complete Spatial Randomness) with altitude regression as covariate and we also calculated an estimate of the intensity as a function of altitude. The calculations were made with software R (R CORE TEAM 2013) and the package '*spatstat*' (Baddeley and Turner 2005).
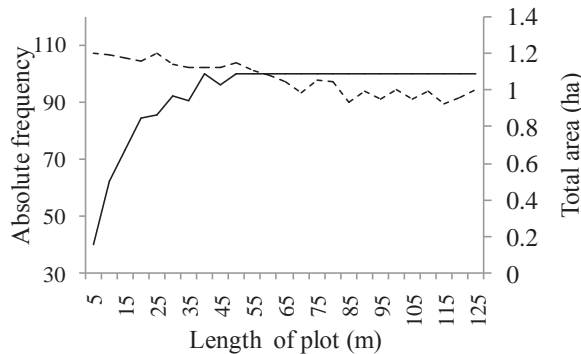
RESULTS

Absolute density ranged from 136.7 to 155.4 individuals per hectare, depending on plot size. The lowest density was observed in plots of 05 and 25 m, and the highest occurred in plots of 115 m (this plot size was the smaller sampled area at 0.92 ha). The absolute frequency increased according to the increase in the size of the plots (figure 2).

The graphical representation of spatial distribution (figure 3) demonstrates areas with high and low concentration of *E. edulis*. The analysis of figure together with absolute density and frequency indicates that the species tends to cluster.

Spatial distribution of *E. edulis* was clustered based on Payandeh, Hazen (with $P < 0.01$) and Morisita (with $P < 0.01$) indices, in all plot sizes (table 1). Nevertheless, they
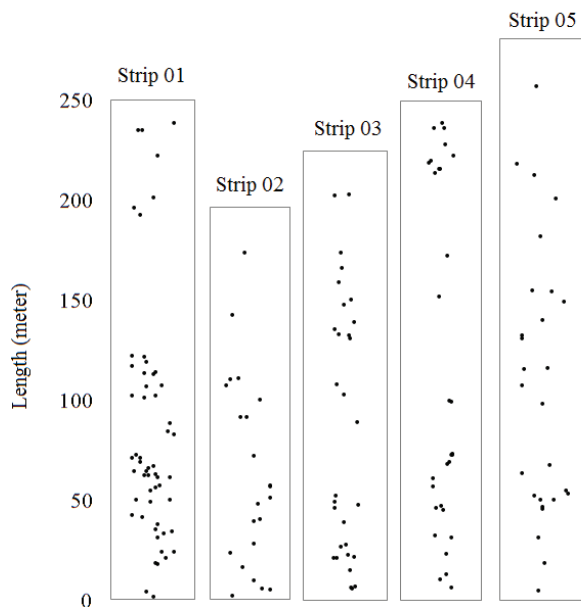
were different in variation: the coefficient of variation was 37 % for Payandeh, 75 % for Hazen and 11 % for Morisita index. For Morista and Hazen the index values decreased, and for Pyandeh the index values increased for larger plots, indicating that cluster was weaker, probably because the standard deviation increases for larger plots (figure 4).

The altitude of seed collection area in Floresta Nacional (FLONA) in Ibirama varied between 329 and 369 m. The polynomial regression analysis represented the profile of altitude as well. Strip 01 has the lowest altitudes. This strip crosses a watercourse at length of 150 m. The other strips have similar profile, tending to increase in altitude until one specific point, which is the peak, and then altitude decreases (figure 5).

The Kolmogorov-Smirnov test of CSR result indicated that altitude influenced the occurrence of *E. edulis* in strip 01 (D = 0.2665, $P < 0.01$), in strip 02 (D = 0.3465, $P < 0.01$), and strip 04 (D = 0.339, $P < 0.01$), and no influence was observed in strip 03 (D = 0.1734, $P = 0.2929$) and strip 05 (D = 0.2022, $P = 0.1912$).

Figure 2. Absolute frequency (full line) of *Euterpe edulis* and total area (dotted line), based on plot size, length range from 5 to 125 m and width of 10 m.

Frecuencia absoluta de *Euterpe edulis* basado en el tamaño de la unidad de muestro, con intervalo de longitudes de 05 a 125 m y la anchura de 10 m.

Figure 4. Plot size influence index scores with standard deviation bars.

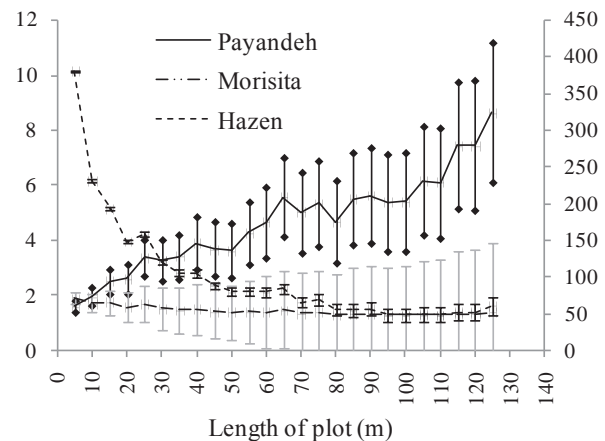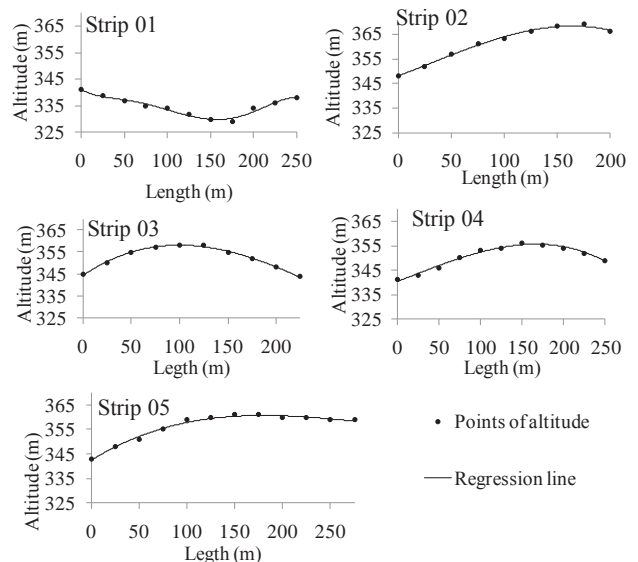Puntajes de índice de influencia del tamaño de parcela, con sus desviaciones estándar.

Figure 3. Distribution of *Euterpe edulis* in strips 01, 02, 03, 04 and 05 at FLONA in Ibirama.

Distribución de *Euterpe edulis* en las bandas 01, 02, 03, 04 y 05 en FLONA Ibirama.

Figure 5. Profile altitude in strips 01, 02, 03, 04 and 05 at FLONA in Ibirama.

Perfil de altitud en las bandas 01, 02, 03, 04 y 05 en FLONA Ibirama.

Table 1. Payandeh, Hazen and Morisita indices for all plot sizes, with length from 5 to 125 m.

Índices Payandeh, Hazen y Morisita para todos los tamaños de las parcelas, ancho 5-125 m.

Index	Lenght of plot (m)								
	5	10	15	20	25	30	35	40	45
Payandeh	1.59	1.96	2.51	2.60	3.36	3.26	3.39	3.89	3.68
Morisita	1.87*	1.69*	1.72*	1.56*	1.68*	1.51*	1.46*	1.49*	1.41*
Hazen	380.4*	230.7*	193.3*	147.9*	158.0*	120.5*	105.1*	104.9*	88.4*
	Lenght of plot (m)								
	50	55	60	65	70	75	80	85	
Payandeh	3.62	4.26	4.65	5.57	5.01	5.34	4.66	5.49	
Morisita	1.36*	1.41*	1.39*	1.47*	1.36*	1.37*	1.28*	1.32*	
Hazen	79.7*	80.9*	79.0*	83.5*	65.2*	69.5*	55.9*	54.9*	
	Lenght of plot (m)								
	90	95	100	105	110	115	120	125	
Payandeh	5.63	5.37	5.39	6.14	6.09	7.42	7.44	8.64	
Morisita	1.32*	1.28*	1.28*	1.29*	1.27*	1.32*	1.30*	1.36*	
Hazen	56.3*	48.3*	48.5*	49.1*	48.7*	52.0*	52.1*	60.4*	

Where: * $P < 0.01$

The estimate of intensity as a function of terrain slope indicates that in strips 02 to 05 there is a tendency for the species to appear in big number at intermediate altitude from 340 to 350 m, and the density decreases at higher altitude, on top. Strip 01 presented behavior different from that presented by the others and smaller density in lower altitude (figure 6).

DISCUSSION

The observed low density in plots with 05 and 25 m of length was caused by the enlargement of the sampled area without more inclusion of individuals of *E. edulis*. The density of *E. edulis* in tropical rainforests is highly variable (table 2). The density detected in this study was intermediate, however, the minimum diameter at breast height for most studies cited is five, and it should provide higher densities.

As the plot size enlarged the probability of *E. edulis* presence in each plot increased. The increase of a species frequency along with the enlargement of the plot size or the number of plots is always expected. Thus, in order to compare studies we must take into account the size and number of plots.

The frequency was similar to the one observed in other studies, 78 % in plots of 10 m x 20 m (Negrelle 2006) and 100 % in plots of 10 m x 90 m (Aguiar 2003).

All spatial distribution methods estimated cluster pattern, in all different sizes, despite the knowledge that cluster intensity declines with increasing spatial scale (Zhang

et al. 2013). The Morisita index did not show variation among different plot sizes and was a consistent index for spatial distribution analyses. Payandeh index, despite its simplicity, proved to be as efficient as Morisita index. The cluster pattern may have occurred in all plot sizes due to high frequency and density of the species. This was reflected in the case of Payandeh index that was clustered in all sizes because the ratio between the variance and the average has remained nearly constant.

Euterpe edulis showed cluster and wide dispersion in ground. Other studies also show clustered spatial distribution of *E. edulis* (Anjos *et al.* 1998, Oliveira *et al.* 2001, Costa Silva *et al.* 2003). The seed-dispersion pattern of this species can explain its behavior (autochoric and zoochoric); zoochoric seed-distribution tends to properly distribute the species in ground, and autochoric seed-dispersion form distribution patterns clustered (Zhang *et al.* 2013), besides the fact that seedlings of *E. edulis* show preference for sites near to the mother plant (Bovi *et al.* 1990, Puerta-Piñero and Lázaro, 2013), and the highest probability of survival and growth of seedlings is higher at a distance of 4 m from the mother plant (Silva Matos and Watkinson 1998).

The lack of influence of altitude calculated by Kolmogorov-Smirnov test in strip 05 could be explained by the characteristics of altitude, which in this strip presented little variation. However it was not possible to explain what happened with strip 03, because, even with the lack of influence of altitude for Kolmogorov-Smirnov test, the estimate of intensity as a function of terrain slope indicates behavior similar to that presented by other strips.
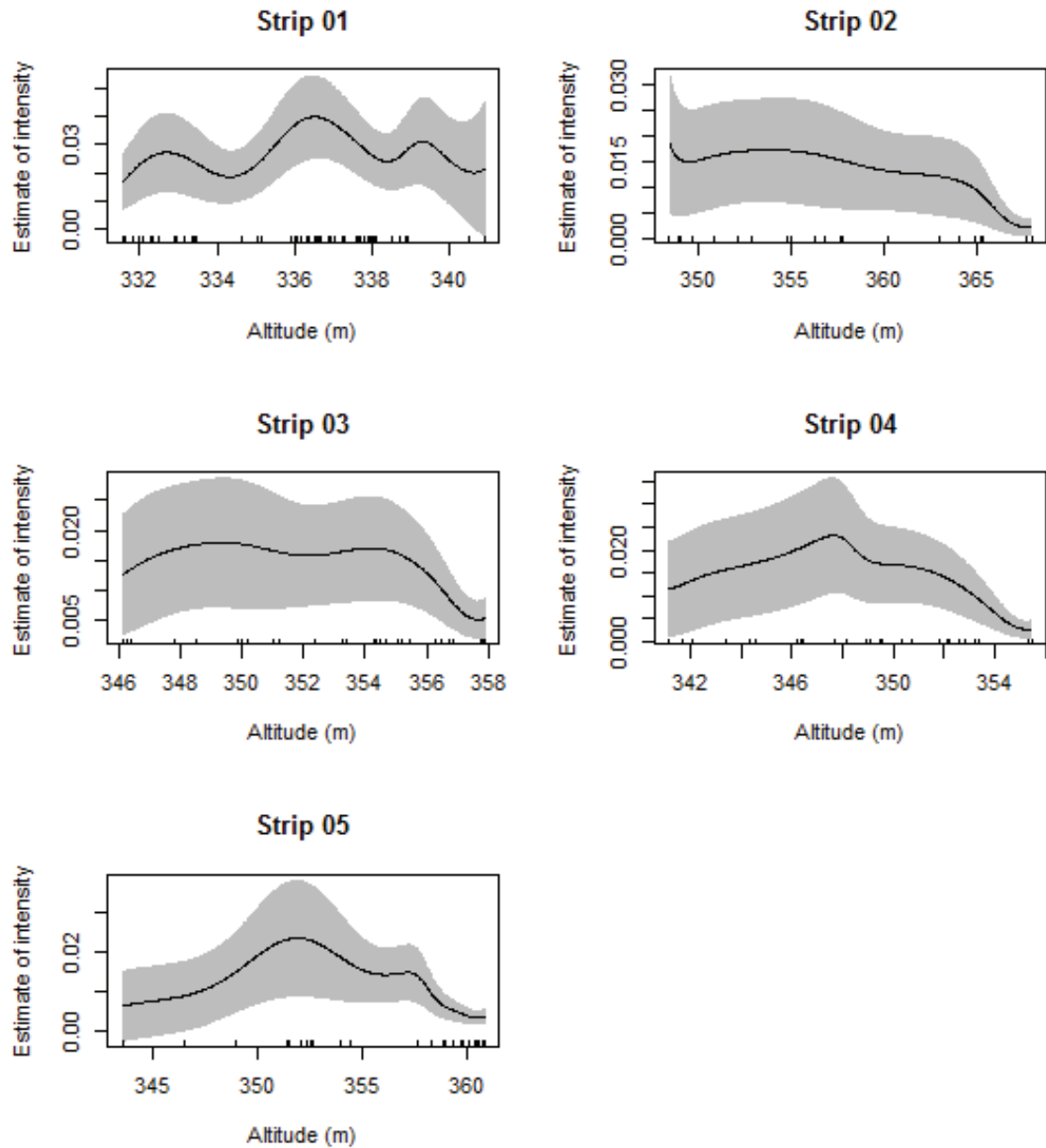
Figure 6. Estimate of intensity of *Euterpe edulis* (number per unit of area) as a function of altitude, for each strip and altitude profile.
Estimación de la intensidad de *Euterpe edulis* como una función de la pendiente del terreno, para cada pista y perfil de la altitud.

Table 2. Density of *Euterpe edulis* in different studies of tropical rain forests.
Densidad de *Euterpe edulis* en diferentes estudios de la selva tropical submontana.

Density (individuals/hectare)	Inclusion DBH (cm)	Plot size (m)	Citation
88	05	10x20	Negrelle (2006)
188,19	05	10x90	Aguiar (2003)
730 (in 1999) and 759 (in 2001)	05	10x25	Ghoddosi (2005)
143	05	10x10	Campos *et al*. (2011)
101	10	10x10	Raupp *et al*. (2009)

The superior frequency of *E. edulis* in intermediate altitude could be associated with high intensity of catastrophic winds, which may cause tree fall and create conditions that favor the regeneration of *E. edulis,* with better growth in clearing areas (Nakazono *et al*. 2001). Although the species show association with higher soil moisture (Silva Matos and Alves 2008, Silva Matos and Watkinson 1998), the absence of species near a watercourse in strip 01 probably occurred because of higher canopy height, disfavoring regeneration of *E. edulis*, and not because of the watercourse itself. The low frequency of *E. edulis* in the top could have occurred due to the influence of rain. Silva Matos and Watkinson (1998) found that the rain carries most of dispersed seeds. Thus, the influence of altitude may reflect only the influence of physical factors such catastrophic winds, rain and biotic factors such as canopy height. Hence the occurrence of the species may not be directly influenced by altitude, although more studies investigating these relationships are needed.

The species *E. edulis* is on the Official List of the Brazilian Flora Endangered Species; therefore, its exploitation is forbidden. The Normative Instruction No. 6 of the Ministry of Environment, Article 5th, states that action plans should be developed so that any species considered endangered could be taken off the list. Thus, the management and conservation of this species should take into account the existence of these palm heart groups. If its logging is allowed in the future, it should respect the clustered spatial distribution and avoid logging an entire group, looking for the preservation of genetic population variability. Seed collection should also take into account the different clusters to maximize variability. The clustered spatial distribution facilitates collection of pulp fruit, the only form of exploration allowed for *E. edulis*.

The wide distribution of the species in the field and its clustered distribution pattern indicate a potential species for management, although its exploitation is prohibited. When analyzing a managed site, Raupp *et al*. (2009) observed a large amount of seedling and immature individuals, indicating the species potential to regenerate.

CONCLUSIONS

All indices used to describe spatial patterns demonstrate a clustered spatial distribution for *Euterpe edulis*; however, the Morisita index is the best for the analysis of spatial distribution because it is little influenced by plot size.

The management of this species should avoid eradication of cluster formations.

Moreover, the influence of altitude or physical and biotic factors should be considered for management. It is also necessary to observe the frequency of strong winds in the region because even if it favors the establishment of regeneration it is important to conduct management carefully avoiding further damage.

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