

# POPULATION STRUCTURE OF *Araucaria angustifolia* IN THE IGUAÇU NATIONAL PARK

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## Abstract

The aim of this study was to analyze the population structure, regeneration and spatial distribution of *Araucaria angustifolia* (Bertol.) Kuntz. within a natural forest and in forest edge with agricultural monoculture. All araucaria individuals from 10 cm high were recorded in 200 plots of 10 x 10 m. 479 individuals were sampled (416 at the edge and 63 inside). Of these, 33 were females, 37 males, 49 juveniles and 360 regenerating individuals. The population structure performance was similar to standard inverted-J. Regenerating individuals had mainly the aggregate distribution pattern, while juveniles, males and females had a uniform pattern. Density of the canopy affected frequency of the individuals, where higher frequencies at higher densities were observed, indicating that regeneration of this species is more effective in shadowed environments. Due to the large number of individuals sampled in different size classes, the Iguaçú National Park is an important conservation remaining of *A. angustifolia*.

**Keyword:** Density canopy; mixed temperate rain forest; spatial distribution; regeneration.

## Resumo

*Estrutura populacional de Araucaria angustifolia no Parque Nacional do Iguaçú.* O objetivo do presente trabalho foi analisar a estrutura populacional, regeneração e distribuição espacial de *Araucaria angustifolia* (Bertol.) Kuntz no interior de uma floresta natural e na borda de uma floresta com monocultura agrícola. Todos os indivíduos de araucária a partir de 10 cm de altura foram registrados em 200 parcelas de 10 x 10 m, sendo amostrados 479 indivíduos (416 na borda e 63 no interior). Desses, 33 eram fêmeas, 37 machos, 49 juvenis e 360 regenerantes. A estrutura da população apresentou padrão semelhante ao J-invertido. Os indivíduos regenerantes apresentaram principalmente o padrão agregado de distribuição, já para os juvenis, machos e fêmeas o padrão foi uniforme. A densidade do dossel influenciou a frequência de indivíduos, sendo observadas maiores frequências em maiores densidades, indicando que a regeneração da espécie é mais efetiva em ambientes sombreados. Devido ao grande número de indivíduos amostrados em diferentes classes de tamanho, o Parque Nacional do Iguaçú representa um importante remanescente na conservação de *A. angustifolia*.

**Palavras-chave:** Densidade do dossel; Floresta Ombrófila Mista; distribuição espacial; regeneração.

## INTRODUCTION

The current state of depletion of the Mixed Ombrophylous Forest or Araucaria Forest (MOF) is directly related to its most characteristic species, *Araucaria angustifolia* (Bertol.) Kuntze, which, due to the high quality of its timber, suffered great exploitation over its history (DUARTE *et al.*, 2002); SANQUETA *et al.*, 2010). Reduction of MOF remains resulted in degradation of araucaria population, hindering natural regeneration (SHIMIZU *et al.*, 2000) and taking the species to the *status* of “critically endangered” by the *Red List of Threatened Species* – IUCN (FARJON, 2012) and “endangered” in the *Livro Vermelho da Flora do Brasil* (Carlucci *et al.*, 2013). Although being threatened, *A. angustifolia* plays a key role in the structure and working of this ecosystem, being the species with the higher economic value of the AF, serving as resource for humans and animals, favoring the resilience of this

phytogeographical unity (DUARTE; DILLENBURG, 2000; MATTOS *et al.*, 2007; OLIVEIRA *et al.*, 2009).

Some authors initially suggested a pioneering behavior of araucaria, who was supposed to develop only under great light intensity (REITZ; KLEIN, 1966). Souza *et al.* (2008) described araucaria as a pioneer species with long life cycle, intolerant to shadowing, and depending on disturbances for its recruiting. However, some more recent works indicated its regenerative capacity with low light intensities in natural environments (PALUDO *et al.*, 2009; VALENTE *et al.*, 2010; EMER; FONSECA, 2011), and in controlled conditions (INOUE *et al.*, 1979; INOUE; TORRES, 1980; DUARTE; DILLENBURG, 2000; FRANCO; DILLENBURG, 2007).

Aggregated standard distribution of regenerating individuals is normal, while for young and adults, uniform distribution is the most observed (PALUDO *et al.*, 2009).

Even with their great social, economic and ecologic importance, araucaria's natural populations are little studied in biological terms (MANTOVANI *et al.*, 2004), demographic (PALUDO *et al.*, 2009), spacial (ANJOS *et al.*, 2004), regenerative (PALUDO *et al.*, 2009; VALENTE *et al.*, 2010; RIOS, 2010) and in terms of light intensity influence on their growth (DUARTE; DILLENBURG, 2000; DUARTE *et al.*, 2002). Furthermore, the few studies on these aspects in different growth conditions (for example core forest or edge with monoculture) don't include the most significant remaining of the Subtropical Forest of Southern Brazil, the Iguaçu National Park (ParNa Iguaçu) (PRIMACK; RODRIGUES, 2001).

The great reduction and fragmentation of the MOF, currently restricted to conservation units (RIBEIRO *et al.*, 2009), and the lack of knowledge on autecology of the species, create gaps in the definition of adequate techniques for its management and conservation. This way, to know how the population structure of the species behaves in different natural environments and at different distances from the edges will allow to understand how the growing fragmentation of these areas and the consequent diminution of core areas have influence on the population structure of the most important native forest species of the wood economy in Southern Brazil (SCHEEREN, 1999).

In this context, this work aims to evaluate the structure, standard distribution, and the canopy's density effect on regeneration of *Araucaria angustifolia* in different growth conditions (edge and core) in the Iguaçu National Park, assuming that the species has different behaviors close to the edge and in the core of the forest.

## MATERIAL AND METHODS

### Study area

The study area includes two phytocenoses of the Mixed Ombrophylous Forest (MOF), typical and exclusive formation of the Southern Brazil highlands, with representation of tropical and temperate floras, with dominance of *Araucaria angustifolia* (Bertol.) Kuntze (RODERJAN *et al.*, 2002). The study was conducted in the Iguaçu National Park (ParNa Iguaçu), a federal conservation unit of integral protection (RYLANDS; BRANDON, 2005). ParNa Iguaçu covers 185,262.50 ha, according to the Brazilian Institute of Environment and Natural Resources (IBAMA, 1999), forming one of the main areas with native vegetation in the state of Paraná. With the exception of the Brazilian Serra do Mar, it represents, together with the São Joaquim National Park, SC, the last remaining of the original Atlantic Forest with core bigger than 50,000 ha, being the only fragment with areas 12 km far from the edge (RIBEIRO *et al.*, 2009).

The Mixed Ombrophylous Forest, object of this work, is typical of the northern section of the park, fading into the Semi-Deciduous Seasonal Forest, extending along river valleys, along the north-south direction, in embossing areas with maximum altitudes slightly more than 600m (IBAMA, 1999).

Climate of the region, according to Köppen is Cfa, sub-tropical with minimum temperatures lower than 18 °C and maximum higher than 22 °C, with predominant rainfalls in summer, however without a distinct dry season, defined by the Environmental Institute of Paraná, (IAPAR, 2013).

Geological formation is volcanic, generally showing tholeiitic type basic composition and sporadically effusive acid and intermediary rocks, respectively of dacitic and andesitic type (SALAMUNI *et al.*, 1999).

### Parcels and population structure

The two sample sites of this work (Figure 1) are located in the municipalities of Santa Tereza do Oeste, PR (edge location) and Céu Azul, PR (core location), covering the northeastern and northwestern

sections of the Iguaçu National Park. According to information from the administrators of ParNa Iguaçu, the considered areas have no historic of burnings and/or recent signals of Forest Degradation, except for the selective extraction of some forest species – like the araucaria itself – mainly in the location close to the edge, in the recent past.

In each site were installed four sample parcels. The ones in the edge location are 50 meters from the forest edge itself (25°07'69.0"S and 53°39'52.6"O), an area close to an agricultural monoculture, at heights varying from 580 to 600 meters, part of the Gonçalves Dias river's micro-basin.

Parcels located in the core location are 4000 meters from the forest edge (25°08'08.5"S and 53°46'76.8"O), at heights varying from 580 to 600 meters, in the Floriano river's micro-basin.

Each parcel of 50 x 50 m (0.25 ha) was randomly plotted, with minimum distance of 50 m each other. The 0.25 ha parcels were divided into 25 sub-parcels of 10 x 10 m (100 m<sup>2</sup>). Thus, individuals were sampled in 200 parcels of 10 x 10 m, covering two ha of the total sampling area, being one ha in the edge location and one ha in the core location.

All araucaria specimens 10 cm or higher were assessed, and the ones with Diameter at Breast Height (DBH) bigger than 4.8 cm were marked with aluminum plates, having their diameter and height measured. When they did not show reproductive structures they were characterized as juvenile, and adults when they presented female strobilus (female adults) and male strobilus (male adults). Male and female strobilus were observed with a binocular, as suggested by Mantovani *et al.* (2004).

Regenerating individuals, the ones with DBH smaller than 4.8 cm, were divided into different height classes, according to Rios (2010): class 1) 10 to 50 cm; class 2) 50.1 cm to 1 m; and class 3) higher than 1m.

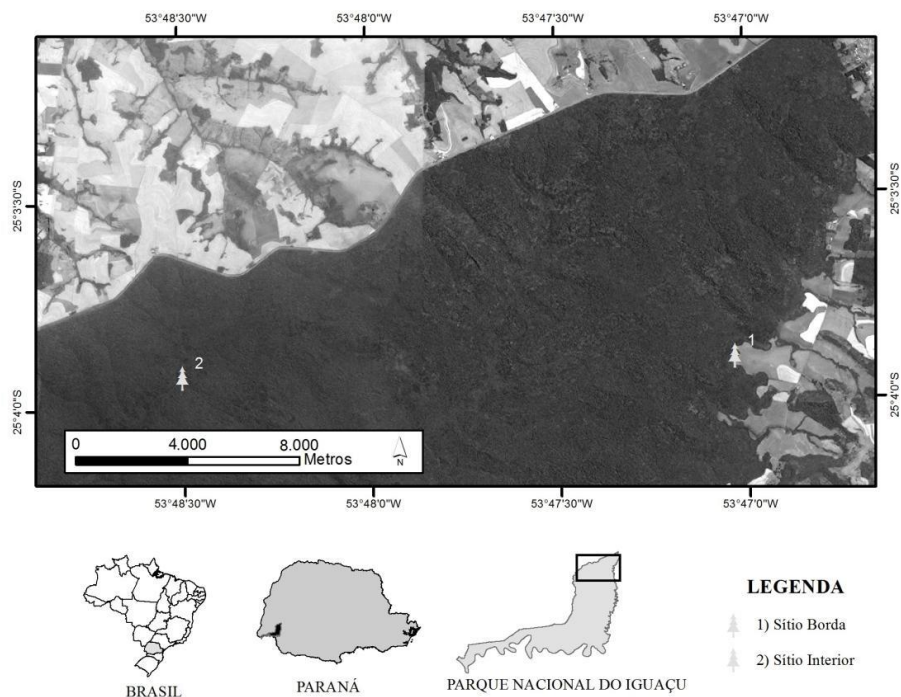


Figure 1. Paraná, Brazil, Iguaçu National Park and sites sampled.

Figura 1. Brasil, Paraná, Parque Nacional do Iguaçu e sítios amostrais.

### Density of forest's canopy

Analyses of the canopy's density were performed with a Lemmon (LEMMON, 1956) convex spherical densitometer, instrument made of a convex mirror, with its center divided in 24 quadrants.

Since the instrument has curved reflecting surface, overlapping in readings originated by lateral and above head observations may reduce precision (STRICKLER, 1959). Thus, to reduce canopy observations on sides and above the head of the observer, minimizing repeated observations as indicated by Kelley and

Kreuger (2005), readings of densitometer were considered according to modifications suggested by Strickler (1959). This modification allows calculation of mean density values without errors induced by duplicate points and requires less time, reducing confusion to observations (STRICKLER, 1959).

The technique consists in using just 17 points of the 24 quadrants, registering the ones covered by canopy. This way, to calculate means of density of each parcel, all 17 points covered by canopy in four measurements (north, south, east, west) were summed and multiplied by 1.5 and the percentage correction of canopy's density was assumed by this number. In order to obtain greater reading precision, measurements were performed in the central part of each sub-parcel (10x10), always by the same person at 1 meter distance from the ground (PALETTO; TOSI, 2009).

### Structural variables and statistical analyses.

Density of individuals was compared between areas through the Chi-squared test for homogeneity. Diametric classes between locations were assessed through the not-parametric Mann-Whitney-U test.

Quantitative variables diameter and height were assessed in the category of regenerating individuals, male, female and juveniles. Those data were analyzed in terms of distribution standard through the Kolmogorov-Smirnov & Lilliefors test, and homogeneity of variances was assessed through the Levene' test. If variables did not present normality, and they did not present homoscedasticity, they were compared between areas through the Mann-Whitney-U not-parametric test. Variables were also compared between genera (male and female), within each location using the same statistical method.

Sexual proportion was assessed through the Chi-squared test to evaluate homogeneity, expecting a classic genetic proportion of 1:1.

Dependence of female frequency in regeneration was assessed using the Chi-squared test for independence.

To analyze the standard special distribution, the Index of Morisita ( $I_d$ ) was used, being  $I_d=1$ , random distribution;  $I_d>1$ , grouped distribution;  $I_d<1$ , uniform distribution. In order to verify significance of the index, the Chi-squared test was used according to Krebs (1989).

Canopy' density between sites was assessed through the t-test for independent samples, since those data gave positive results in terms of normality and homoscedasticity.

Data of height and DBH were correlated with canopy's density through the Pearson's Coefficient of Correlation and their statistical significance was assessed through the t-test of correlation.

Frequencies of regenerating individuals were compared between canopy's densities classes (49 at 74% and 75 at 100%), independently on the assessed locations, through the Mann-Whitney-U test.

Statistical tests were performed using the XLSTAT 2013 software at 5% level of probability.

## RESULTS AND DISCUSSION

In the two sampling locations were totally recorded 479 araucaria individuals, 33 females, 37 males, 49 juveniles and 360 regenerating individuals (Table 1). Density of individuals between locations was statistically significant ( $\chi^2=20.04$ ;  $p<0.05$ ), being observed 416 individuals.ha<sup>-1</sup> in the edge location and 64 individuals.ha<sup>-1</sup> in the core location.

Density of individuals in the edge (416 ind.ha<sup>-1</sup>) may be considered high compared to the works by Paludo *et al.* (2009) (100 ind.ha<sup>-1</sup>), Mantovani *et al.* (2004) (32 ind.ha<sup>-1</sup>), Navares (2005) (23 ind.ha<sup>-1</sup>), and Ligner *et al.* (2007) (64 ind.ha<sup>-1</sup>). Although the sampled population in the core location had the lowest density of individuals (64 ind.ha<sup>-1</sup>), these results are in contradiction with Fontoura *et al.* (2006) who reported absence of araucarias at the distance of 250 meters from the forest edge. This low density standard was also observed by Backes (2001), Duarte *et al.* (2002), Navares *et al.* (2005), Puchalski *et al.* (2006) and Valente *et al.* (2010), who reported low density of araucaria in communities with advanced successional aging, characteristic of the core location of this work.

Despite the difference in density, it was possible to verify that the two populations presented a similar structural standard ( $U=372$ ;  $p=0.35$ ), with tendency to inverse-J (Figure 2), characteristic of dynamic and unevenly aged populations (KOLEHMAINEN; MULTIKAINEM, 2007). However, they did not present characters of a balanced forest, because they did not show a constant reduction rate in number of plants following diameter increase (MEYER, 1952).

Table 1. Individuals sampled at different sites in the National Park Iguaçú.

Tabela 1. Indivíduos amostrados nos diferentes sítios, no Parque Nacional do Iguaçú.

Classes	Edge site				Core site			
	DA	DR	FA	FR	DA	DR	FA	FR
Females	24	5.7	21	11.5	9	14.29	6	15.8
Males	29	6.9	25	13.7	8	12.7	7	18.4
Juvenile	46	11.07	26	14.2	3	4.76	3	7.9
R1	179	43.2	52	28.4	14	22.2	7	18.4
R2	107	25.7	42	23.0	25	39.6	12	31.6
R3	31	7.45	17	9.3	4	6.3	3	7.9
Total	416				63			

R1: Regenerating 1; R2: Regenerating 2; R3: Regenerating 3; DA: Absolute density; DR: Relative density; FA: Absolute frequency; FR: Relative frequency.

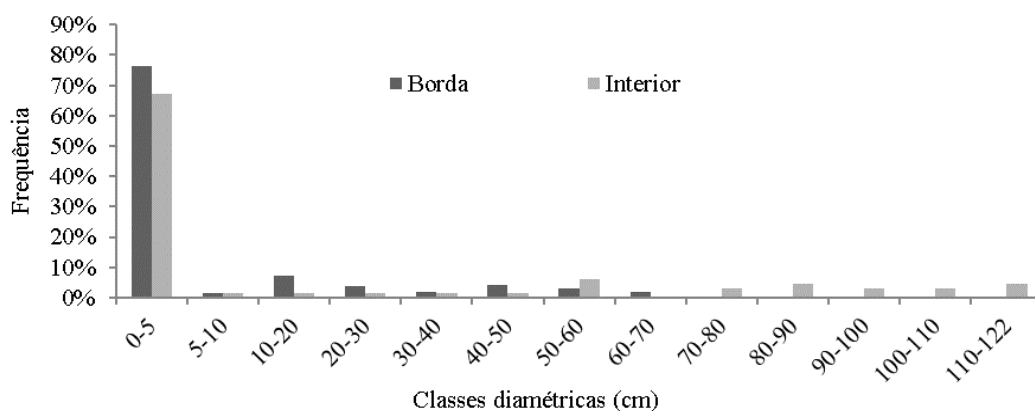


Figure 2. Frequencies of individuals by diameter classes in sample sites of the Iguaçú National Park.

Figura 2. Frequências dos indivíduos por classes diamétricas nos sítios amostrais do Parque Nacional do Iguaçú.

The reduced number of trees in the core site between classes from 60 to 70 cm diameter, and in the edge site starting from 70 cm diameter, may indicate that there have been a previous disturbance (PINHEIRO; MONTEIRO, 2009). Lack of individuals in the bigger diameter classes in the forest edge site corroborates the conservation *status*, being characterized as a less conserved in the intermediate stages of succession caused by proximity to the conservation area limits and possible timbering in the past (WATZLAWICK *et al.*, 2013). In the core site, lack of individuals in the classes from 60 to 70 cm also suggests alteration in the population structure, as suggested by Felifili *et al.* (1988), where in most of the cases discontinuities, flattening and even total absence of trees are observed, in some of the diametric classes.

The structural standard found may be in relation with the physiological characteristics of araucaria, which presents the bank of seedlings as regeneration strategy, for having recalcitrant seed (DUARTE *et al.*, 2002). Thus, the greater density of individuals in the smaller size classes would be in relation to intrinsic factors of the species.

The smaller density of individuals in the forest core site might be influenced by formation of a dense layer of herbaceous species, affecting light intensity and consequently inhibiting regeneration of the species, corroborating data from Einig *et al.* (1999).

However, it is known that araucaria survives in areas with moderate shadowing (INQUE *et al.*, 1979; INQUE; TORRES, 1980; DUARTE; DILLEMBURG, 2000). Therefore, proximity to forest edge seems to favor regeneration of the species, which has seeds with great nutritive reserves and then favoring its rapid initial growth (EINIG *et al.*, 1999; ZANDAVALLI, 2006). Another factor that might be related to low density of individuals in the lower size classes in the forest core location would be seeds collection by anthropic intervention (SOUZA, 2007). However, it is believed that this is not the case in the studied area, for it is a conservation area of total protection and the studied site presents difficult access, for these

reasons it is believed that seeds collection would not be convenient for population living near the ParNa Iguçu. On the other hand, predation pressure of small rodents might have negative influence on regeneration of species in the denser canopy forests (IOB; VIEIRA, 2008; GUGLIELME; GRANADE, 2006) like the core forest site.

This way, it is believed that low density of araucaria in the most preserved areas like the one under study is a characteristic of the species and its distribution pattern would be more related to broad-leaved trees systems that are in competition, and not to environmental conditioning factors (ZANDAVALLI, 2006) (e.g. light intensity). This characteristic suggests that the aging pattern of araucaria's natural forest populations might be useful in the description of the preservation *status* of the assessed phytocenosis. It is thus that arises the hypothesis that high densities are characteristics of less preserved areas, encountered in initial and intermediary stages of succession, and that low densities are characteristics of more preserved areas characterized by more advanced succession stages.

Correlating diameter and height of individuals it was possible to observe that males showed statistically significant differences of DBH ( $U=22.500$ ;  $p=0.001$ ) and height ( $U=37$ ;  $p=0.007$ ) between locations, and the individuals of the core site presented greatest values for these variables. Thus, 75% of males had DBH up to 103 cm and height up to 25 m, while 75% of males of the edge site had DBH up to 50 cm and heights up to 20 m.

In the evaluation of females, only DBH showed significant differences ( $U= 54$ ,  $p=0.02$ ), with 75% of females in the core site had DBH up to 85 cm and 75% of females in the edge site had DBH up to 61 cm. Juvenile individuals did not show significant differences between sites ( $p>0.05$ ).

These results corroborate with the structure of sites, where the core forest is the most preserved area, in most advanced succession stages, presenting individuals with biggest DBHs and heights.

Making correlations between genera in the edge sites it was possible to verify statistically significant differences in the values of DBH between males and females ( $U=206, 500$ ;  $p=0.01$ ), where 75% of females presented DBH up to 60 cm and 75% of edge site males had DBH up to 50 cm. Initially, this result was not expected, because araucaria is a dioecious species and females should have more energy consumption, reducing their growth rate. However, this relation was not observed in this study, neither by Paludo *et al.* (2009), where the biggest diameter of female individuals was attributed with previous timbering of the area with selective strategy, before it turned into a preservation area. There was no statistically significant between DBH and height in genera of the core site ( $p=0.05$ ).

The expected sexual proportion (1:1) in the two sampling sites was statistically proved, both in the edge ( $\chi^2=0.236$ ;  $p=0.627$ ) and in the core sites ( $\chi^2=0.029$ ;  $p=0.864$ ).

It was possible to observe independence of females in regeneration ( $\chi^2=41.72$ ;  $p<0.05$ ), result also found by Paludo *et al.* (2009) and Souza *et al.* (2008). This independence of regenerating individuals in relation to the mother plant is supported by the "Escape hypothesis" theory, given by Janzen (1971) and Connell (1971), considering mortality of seeds and seedlings as strongly dependent on density. This fact was observed in this study, since there was no observed great number of regenerating individuals close to female plants. This distance also may be in relation with the great number of vertebrates, mainly rodents and big size birds, actuating simultaneously as spreaders and predators of seeds (VIEIRA; IOB, 2006).

Spatial distribution of araucaria in both sites (Table 2) was mainly aggregate, similar to works by Nascimento *et al.* (2001); Paludo *et al.* (2009); Valente *et al.* (2010), possibly reflecting the high population density mainly in the edge site. According to Cottam *et al.* (1953) and Pielou (1960), populations with aggregate spatial distribution standard have individuals occurrence in agglomerates, thus the chance of occurrence of one individual increases with the presence of another one. In *Podocarpus nagi* (Thunb.) Kuntze, aggregation of regenerating individuals may be explained by the low dispersion capacity of its seeds (NANAMI *et al.*, 1999), characteristic that probably has influence on the aggregate standard of araucaria individuals, for having heavy seeds with gravity dispersion mechanism (PALUDO *et al.*, 2009).

However, male individuals of the core site, young and regenerating individuals, belonging to class 3, showed uniform distribution pattern, just like males and females of the edge site. This way, the possibility of finding another individual is not conditioned to localization of the first one (KREBS, 1989).

Distribution of adult individuals does not necessarily reflect the same pattern of regenerating individuals, because their distribution reflects the recruitment spatial standard and is also influenced by mortality factors (CRAWLEY, 2005). On the other hand, it is believed that difference in distribution

pattern of regenerating class 3 between sites is influenced by difference in density of individuals (four individuals in the core site and 31 in the edge), and by mortality of regenerating individuals, which is probably bigger in the core site as result of predation (IOB; VIEIRA, 2008).

Table 2. Spatial pattern of individuals in the sample sites of the Iguaçu National Park.

Tabela 2. Padrão espacial dos indivíduos nos sítios amostrais do Parque Nacional do Iguaçu.

Classes	Core site		Edge site	
Females	Id=1.39; $\chi^2=0.2$	Uniform	Id=10; $\chi^2=9.5$	Aggregate
Males	Id=0.95; $\chi^2=0.51$	Uniform	Id=1.58; $\chi^2=0.36$	Uniform
Young	Id=3.49; $\chi^2=3.8$	Aggregate	Id=0; $\chi^2=0.53$	Uniform
R1	Id=2.36; $\chi^2=1.68$	Aggregate	Id=9.23; $\chi^2=1.66$	Aggregate
R2	Id=2.69; $\chi^2=6.15$	Aggregate	Id=9.93; $\chi^2=4.15$	Aggregate
R3	Id=6.45; $\chi^2=8.95$	Aggregate	Id=13.33; $\chi^2=0.008$	Uniform

R1: Regenerating 1; R2: Regenerating 2; R3: Regenerating 3; Id: Morisita index;  $\chi^2$ : Chi-squared value.

In species with high mortality rate depending on density, adult individuals tend to present less aggregate distribution than seedlings (CRWLEY, 2005). This characteristic was observed in this study, where mature individuals mainly presented uniform distribution pattern, both in the core and the edge sites.

Anjos *et al.* (2004) obtained different results, where more preserved and less exploited areas showed random and aggregate distribution. In preserved areas, but with uncontrolled seed harvesting by humans, distribution pattern was regular and aggregate. Souza *et al.* (2008) also met different results, where, in preserved sites, distribution pattern of females was random. Those differences reflect different population structure and conservation *status* of the analyzed sites, being aggregate and uniform pattern the normally observed araucaria distribution standard.

Initially, all classes of regenerating individuals were grouped in a single category, and compared between sites. Just diameters showed statistical significance ( $U=3704$ ,  $p=0.0001$ ), while height values were statistically equivalent ( $p>0.05$ ). Regenerating individuals in the core site showed bigger diameters, with 75% of diameter values up to 0.95 cm, while in the edge site, for 75% of individuals, diameter was up to 0.63 cm.

Separating classes of regenerating individuals allowed to verify that diameter of regenerating individuals 1 (R1) presented significant difference between sites ( $U=716.500$ ;  $p=0.007$ ), with 75% of R1 of the core site had diameters up to 0.63 cm. In the edge site representatives of R1 had smaller values, 75% of seedlings with diameter up to 0.47 cm. Height values were considered equivalent between sites ( $p>0.05$ ). Regenerating individuals class 2 (R2) also showed similar pattern to R1, with just diameter presenting statistical difference ( $U=716.500$ ;  $p=0.001$ ). Individuals of the core site had bigger diameter values, 75% of them with diameter up to 0.95 cm, and between individuals of the edge, 75% up to 0.70 cm. However, this pattern was not observed in regenerating individuals class 3 (R3), where only height presented significant difference between sites ( $U=24$ ,  $p=0.04$ ). Thus, class R3 of the internal site presented lower height values with 75% of individuals up to 123 cm, while in the edge site 75% of individuals had height up to 194 cm.

This result is different from what found by Inoue and Torres (1980), performing an experiment in greenhouse, where they obtained results showing increased height development depending on increased shadowing. However, Franco and Dillenburg (2007) relate that this increased height investment in shadowed plants is temporary, and this might be the case of this work.

Therefore, it is believed that, in the most preserved areas inside the forest, regenerating araucaria individuals are investing more in diametric growth than individuals of the edge site. This characteristic might be in relation with the greater density of individuals in the edge site, which are so close each other to hinder their diametric growth. According to Zanine and Ganade (2005), competition for nutrients in soil between close individuals may influence araucarias' growth, corroborating with the smaller diameter growth in denser areas.

Canopy's density between sites did not show statistical differences ( $t=130$ ;  $p>0.05$ ), neither relation between diameter and height of regenerating individuals and density of canopy ( $r=0.21$ ;  $p>0.05$ ). Thus, values found in different densities of canopy are believed to be independent. However, frequency of regenerating individuals presented significant differences ( $U=2237$ ,  $500$ ;  $p=0.02$ ), and environments

with greater canopy's density had greater frequencies. In parcels with canopy's density varying from 49 to 74%, absence of regenerating individuals was observed in 75% of parcels. In parcels with canopy's density from 75 to 100%, there were up to 3 regenerating individuals in 75% of these parcels.

Table 3. Height (cm) and diameter (cm) of regenerating per sample site of the Iguçu National Park.  
Tabela 3. Altura (cm) e diâmetro (cm) dos regenerantes por sítio amostral do Parque Nacional do Iguçu.

Regenerating classes	Edge site					Core site				
	N°ind.	Min	Av	$\sigma$	Max	N°ind.	Min	Av	$\sigma$	Max
Altura										
R1	179	10	39	0.24	50	14	13	35	0.29	50
R2	107	50	60	0.19	96	24	50	62	0.18	97
R3	31	100	152	1.22	500	4	100	112	0.60	125
Diameter										
R1	179	0.15	0.31	0.37	1.01	14	0.15	0.55	1.39	4.77
R2	107	0.31	0.63	0.25	1.11	25	0.47	0.79	0.24	1.27
R3	31	0.63	1.27	0.53	4.14	4	0.79	1.11	0.22	1.27

R1 (Regenerating 1); R2 (Regenerating 2); R3 (Regenerating 3); N°ind. (number of individuals); Min (minimum); Av (average);  $\sigma$  (standard deviation); Max (maximum).

Putting in relation frequency of regenerating individuals and density of canopy between sites, not a single regenerating individual was identified in the core site when canopy's density was from 49 to 74%. Thus, all individuals identified in the core site were found in parcels with the greatest canopy's densities values (75 to 100%).

Regenerating individuals found in the edge site were distributed in different densities of the canopy, 47 individuals (14%) were found in densities varying from 49 to 74% and 270 individuals (86%) were observed between 75 and 100% canopy's density.

Therefore, canopy's density seems to have more influence on density of individuals than on their diameter and height growth patterns.

Thus, it is possible to verify that frequency of regenerating individuals was bigger in the higher canopy's densities, supporting plasticity of araucaria's growth in more shadowed environments (INOQUE *et al.*, 1979; DUARTE; DILLENBURG, 2000; FRANCO; DILLENBURG, 2007; DUARTE *et al.*, 2002). This result gives strength to the idea that araucaria, in its juvenile stage, is a species tolerant to shadowing, not corroborating its classification as pioneer species, intolerant to shadowing.

## CONCLUSION

- Iguçu National Park represents an important remaining for preservation of araucaria's natural population, due to the high density of sampled individuals in different size classes. Despite the significant difference in density between sites, populations analyzed present similar structural patterns, with tendency to inverse-J. It is believed that the smaller density in the internal site is a characteristic of the species, where in more preserved areas with advanced successional stages, greater competition and predation pressure are the main causes of this result.
- Light intensity verified by means of canopy's density did not represent a restrictive factor to regeneration of the species, since the greatest density of regenerating individuals was verified in shadowed sites with denser canopies. Therefore, regeneration of the species in shadowed sites is proved, not corroborating classification of araucaria as a pioneer species.
- Distribution of regenerating individuals was mainly aggregate, and adults had uniform distribution. Due to less competition as consequence of lower densities, regenerating individuals of the core site had bigger diameter values. Thereby, importance of structure in araucaria forest populations is highlighted as indicative of the preservation conditions of the assessed phytocenosis. More preserved areas presented populations with lower density, while perturbed areas, in initial and intermediate succession stages, presented greater densities of individuals of this species.



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