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ARTICLE

Seed dispersal by birds on artificial perches in reclaimed areas after surface coal mining in Siderópolis municipality, Santa Catarina State, Brazil

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ABSTRACT: (Seed dispersal by birds on artificial perches in reclaimed areas after surface coal mining in Siderópolis municipality, Santa Catarina State, Brazil). The Coal Basin of Santa Catarina state, Brazil, has approximately six thousand hectares of degraded areas due to the exploitation of mineral coal. Nowadays, several areas are under reclaim process, which includes soil recovery and reintroduction of vegetation. In the study area, located in Siderópolis municipality, Santa Catarina state, vegetation reintroduction was carried out with several grass and arboreal pioneer species. In an area of one hectare, 12 artificial perches with collectors were placed. For one year period, seeds were recovered in the collectors and visual observation of the birds that rested on the perches was carried out. A total of 23 species of seeds were recovered. More seeds of pioneer and early secondary species were significantly dispersed when compared to late successional categories. Four pioneer and early secondary species produced seeds during long periods, mainly in the months were food resources are scarce. No statistically significant difference was found between the distance from the seed source and the number of species or the number of seeds recorded. Fourteen bird species used the artificial perches, with four being considered potential dispersers due to their food habits and to their frequency of visits to the perches. Results indicate a high efficiency of the artificial perches on the arrival of seeds of the initial successional species and highlighted the importance of seed sources close to degraded areas, as well as the presence of generalist birds to assure the seed dispersal for long distances.
Key words: Atlantic rainforest, seed rain, successional categories, fruit phenology.

RESUMO: (Dispersão de sementes por aves sob poleiros artificiais em áreas reabilitadas após mineração de carvão a céu aberto em Siderópolis, Santa Catarina, Brasil). A Bacia Carbonífera Catarinense possui aproximadamente seis mil hectares de áreas degradadas pela exploração de carvão mineral. Atualmente, muitas destas áreas estão em processo de recuperação que consiste, principalmente, na restituição do solo e reintrodução da vegetação. Na área do estudo, situada no município de Siderópolis, a reintrodução da vegetação foi realizada com diversas espécies de gramíneas e espécies arbóreas pioneiras. Em uma área de um hectare foram instalados doze poleiros artificiais com coletores. Durante um ano, as sementes foram recolhidas nos coletores e foram realizadas observações focais das aves que pousaram nos poleiros. Foram encontradas sementes de 23 espécies. Foram dispersas significativamente mais sementes de espécies pioneiras e secundárias iniciais do que das categorias sucessionais mais tardias. Quatro espécies pioneiras e secundárias iniciais produziram sementes durante longos períodos, principalmente nos meses onde há escassez de alimento. Não foram encontradas diferenças significativas no efeito da distância da fonte de sementes, tanto quanto ao número de espécies, quanto ao número de sementes registradas. Quatorze espécies de aves utilizavam os poleiros artificiais, das quais quatro foram consideradas dispersores potenciais devido a seus hábitos alimentares e suas freqüências nos poleiros. Os resultados indicam alta eficiência da instalação de poleiros artificiais na chegada de sementes de espécies sucessionais iniciais e evidenciaram a importância tanto da presença de fontes de sementes nas proximidades de áreas degradadas, como a presença de aves generalistas para assegurar a dispersão de sementes por longas distâncias.
Palavras-chave: Floresta Atlântica, categorias sucessionais, chuva de sementes, fenologia de frutificação.

INTRODUCTION

The Atlantic Forest biome suffered and yet suffers intense destruction and fragmentation, being left only 7% of its original configuration, as small fragments (SOS Mata Atlântica 2001). Habitat fragmentation is a process in which a large and continuous habitat area is reduced and divided in several fragments, leading to a rupture in the gene flux among populations present in those habitats (Kageyama *et al.* 2003). The fragmentation has consequences on the structure and dynamics of plant communities (Rui *et al.* 2005) which were documented by several authors (Young & Mitchell 1994, Murcia 1995, Tabanez 1997). Some studies considered that forest fragments located in areas of intense human action are similar to ocean islands separated from continents to which they were connected at some point in the past (Laurence & Bierregaard 1997). These fragments, sometimes, are located in the middle of large degraded areas, suffering a strong human pressure. Therefore, huge modifications in the ecological functions of these forests can be observed, for example, uneven reproduction and

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growth rates in the populations, and modifications in the pollination and dispersion of seeds by animals, which can put at risk the maintenance of plant populations in the fragments. Despite the implication of fragmentation in the biodiversity maintenance, several of its short, medium, and long time effects are not fully understood (Colli *et al.* 2003).

In Santa Catarina state, topographical, climate, and lithological conditions favored the establishment of several migratory events of settlers of European origin in the Dense Ombrophilous Forest in the South of Santa Catarina state, starting deforestation and agricultural activities (Teixeira *et al.* 1986). In the south region of Santa Catarina state, especially close to the Coal Basin, in addition to the agriculture activities, the coal extraction industry contributed for the reduction of the vegetal covering. Activities related to the mineral coal exploitation in the south region of Santa Catarina state, are causing, since 1876, environmental degradation, especially on the surface water resources and on the plant covering, leading to a habitat fragmentation (Belolli *et al.* 2002). Thus, the Federal Supreme Court determined that coal industries in Santa Catarina should recover the areas that were degraded due to mineral coal mining in the south region of the state (personal communication). However, the environmental reclamation promoted in the areas impacted by surface coal mining, are not presenting the same level of diversity found in the Dense Ombrophilous Forest that once covered these areas (Pfadenhauer & Winkler 1978, Citadini-Zanette 1999). One reason may be the lack of seeds and the great distance from the seed source which can reduce the seed rain in landscapes dominated by low diversity and vegetation in an early stage of succession (McClanahan & Wolfe 1993).

Despite several studies demonstrating that the presence of seeds of forest species under isolated trees in open areas is a result of seed deposition by birds, experimental research using artificial perches as a recruitment site for seeds is rare (McDonnell & Stiles 1983, McClanahan & Wolfe 1993, Robinson & Handel 1993, Aide & Cavelier 1994, Holl 1998, Melo *et al.* 2000). The advantage of this technique when compared to traditional techniques of plant recruitment is that the flower composition of the vegetation that will cover the area will be similar to the adjacent areas. The recruitment of the seeds under the perches or isolated trees depends on the distance from the seed source and on relatively intact areas of native forest (Cambell *et al.* 1990). These forest remnants contribute to the increase of species diversity in areas that are in reclaim process, especially those areas that are in an advanced stage of recovery harboring a high diversity of species (Martins 2005). Thus, there is a concern about the preservation of areas adjacent to sites of coal extraction. However, little information about seed dispersal in reclaimed areas after coal extraction in Santa Catarina state is available. In the presented study, artificial perches were added to a reclaimed area after surface coal mining, in Siderópolis municipality, close to a forest remnant with the purpose to analyse the seed rain under these perches as well as the bird communities that used the perches. Our specific questions are:

1) Which species have their seeds dispersed by birds in reclaimed areas after surface coal mining using artificial perches?

2) Which successional categories dominate in the seed rain on the artificial perches?

3) Does the distance from de seed source influence the quality or the amount of seeds dispersed by birds?

4) Which birds are potential seed dispersers on the perches in the reclaimed area?

METHODS

Study Site

The study area is located in the sub-basin of the Fiorita river that belongs to the Hydrographic Basin of the Araranguá river, in the northeast region of Siderópolis municipality, Santa Catarina state (SC), Brazil. This region, located in the coordinates 28º35'S and 49º 25'W, has areas with high coal mining activities. The 'Companhia Siderúrgica Nacional' (CSN), responsible for the coal extraction in the area, calls the area 'Campo Malha II Leste', were activities related to coal extraction were developed until 1981 (IPAT/UNESC 2002) (Fig. 1). Mean rainfall in the region is between 1,400 and 1,600 mm/year, with no rainfall monthly indices below 60 mm. The climate in the region is the mesotherm with mean temperatures of the coldest month below 18ºC and above 3°C, and mean temperature of 28°C in the warmest months (Ometto 1981).

Originally, the vegetation found in the study area is classified as Dense Submontane Ombrophilous Forest, with an altitude of about 170 m (Teixeira *et al.* 1986). The vegetation is characterized by the presence of large trees, of approximately 25m, and also by an understory composed by small plants of natural regeneration, few nanophanerophytes and camephytes, small palm trees and herbaceous lianas that are present in a large amount (IBGE 1992). Currently, the vegetation in the region does not show this formation anymore, there are only few forest remnants in advanced regeneration stage in the vicinity of large areas degraded by coal mining.

According to the environmental project for reclamation of degraded areas by coal mining by the Institution of Environmental and Technological Researches for the areas in Siderópolis municipality, reclamation activities of the study area begun at the end of 2002 (IPAT/UNESC 2002). The scheduled activities included the removal of pirita waste, remodeling of the land, treatment of lake waters and covering the sterile soil with a layer of clay between 20 and 50cm, and the incorporation of calcareum, peat, and organic and chemical fertilizers for the clay soil. The area was vegetated with three species of Poaceae: *Melinis minutiflora* P. Beauv., *Brachiaria humidicola*

Figure 1. Locality of the study area in Sideròpolis municipality, Santa Catarina state (IPAT/UNESC (2002).

Rendle, and *Paspalum saurae* Parodi and with pioneer species such as *Mimosa scabrella* Benth. (Fabaceae), *Mimosa bimucronata* (DC) O. Kuntze (Fabaceae), and *Trema micrantha* (L.) Blume (Cannabaceae).

Perch Additions

Considering that propagule sources for the reclaimed area will be originated from the remnant located around the chosen area for the addition of the artificial perches, and considering natural barriers found in the study area (such as Fiorita River and access roads), artificial perches were placed in an area of approximately one hectare bordering the North and West sides of the Fiorita River, and the South side of a forest remnant in advanced stage of recovery (Fig. 1). A total of 12 artificial perches with collectors were assembled and placed at a distance of 30 m from each other in five lines parallel to the forest remnant. In the first line only one perch was placed due to the shape of the chosen area, which was located about 30 m from the remnant; in the second, third and fourth lines were placed three perches with respective distances of 60 m, 90 m, and 120 m, and the fifth line, with two perches, showed a distance of 150 m from the seed source. Since the first line had only one perch, data obtained from this experimental unity were not considered in the statistical analyses. Twelve collectors without perches were placed between perches with collectors to act as controls.

Perches were made from posts of eucalyptus of 6m in length. Four landing points of 1 m in length and 1 cm in diameter were arranged perpendicularly in cross at four, five and six meters from the ground (Melo *et al.* 2000). For seed collection, twenty four square collectors were constructed with dimensions of 1.5 x 1.5 m (area of 2.25 m^2) using slats for square construction filled with nylon tissue, permeable to the water. Twelve of these collectors were placed at 0.80m from the ground, below the perches and the other twelve were placed, between collectors with perches. All collectors remained for one year in the area, from July 2006 to June 2007.

Seed arrival and seed identification

Observation of all collectors was carried out weekly from July 2006 to June 2007. All material found was removed, using a spatula, and placed in plastic bags identified with the number of the collector and the date of collection. In laboratory, samples were passed through sieves, observed with a stereo microscope and seed and fruits were separated from other material found in the collectors (e.g. leaves, insects, flowers, feces, twigs, etc). Only seeds with zoochoric dispersal were considered; seeds with anemochoric dispersal were not included in the analyses. Seeds were placed in labeled recipients, containing date of collection, number of collector and presence or absence of a perch. In addition to seed collections from the collectors, seeds of plant species with zoochoric dispersion were collected, along two transects with 500m in length each one, on the edge and inside the forest remnant adjacent to the study area. The identification of plant species followed the classification of the APG II system. The material found, and the lists of plant species from the phytosociological works carried out in the same region by IPAT/UNESC (2002), Santos (2003), and Martins (2005) also were used as reference for the identification of the seeds collected in the

Table 1. Plant species which seeds were found in the 12 collectors with perches in the study area, for a period of 12 months, with information about the number of seeds (N), months of occurrence and classification according to the successional category (PIO = pioneer; ES = early secondary; LS = late secondary; CLI = climax).

Family/Species	Month of occurrence	N	Succession Category
APOCYNACEAE			
Tabernaemontana catharinensis A. DC.	May	7	PIO
ARALIACEAE			
Schefflera morototoni (Aubl.) Mguire, Steyerm. & Frod	Apr, May, Jun	8	LS
ARECACEAE			
Euterpe edulis Mart.	Apr - Aug	41	CLI
CANNABACEAE			
Trema micrantha (L.) Blume	Oct, Jan - Jun	309	PIO
EUPHORBIACEAE			
Alchornea triplinervia (Spreng.) Müll. Arg.	Jan, Feb	32	ES
Croton celtidifolius Baill.	Dec - Mai	54	PIO
FABACEAE			
Mimosa scabrella Benth.	Oct - Dec	115	PIO
LAMIACEAE			
Aegiphyla sellowiana Cham.	Jun, Jan	5	ES
LAURACEAE			
Nectandra megapotamica (Spreng.) Mez	Jan	2	CLI
Ocotea puberula (Rich.) Nees	Dec - Mar	83	Cli
Ocotea sp.	Jun, Jan	3	CLI
MAGNOLIACEAE			
Magnolia ovata (A. St.-Hil.) Spreng.	Out, Feb	38	LS
MELASTOMATACEAE			
Miconia cabucu Hoehne	Sep - Mar	1,365	ES
MYRISTICACEAE			
Virola bicuhyba (Schott ex Spreng.) Warb.	Oct	1	LS
MYRSINACEAE			
Myrsine coriacea (Sw.) R. Br.	Sep - Mar, Jun	2,207	ES
PHYLLANTHACEAE			
Hyeronima alchorneoides Fr. Allem.	Jan, Mar - Jun	29	ES
RUBIACEAE			
Psychotria suterella Müll. Arg.	Jan, Feb	6	LS
SAPINDACEAE			
Matayba guianensis Aubl.	Dec, Jan	66	LS
SOLANACEAE			
Solanum variabile Mart.	Jan, Feb	23	PIO
URTICACEAE			
Cecropia glaziovii Snethl.	Aug – Oct, Jan - Jul	438	PIO
VERBENACEAE			
Citharexylum myrianthum Cham.	Feb - Apr	8	PIO
Undetermined family sp. 1	Oct, Jan	46	-
Undetermined family sp. 2	Dec	1	-
Total		**4,887**	

collectors and for the classification of the plant species as successional pioneer, early secondary, late secondary, and climax (Budowski 1970).

Bird observations

Observations of bird species that used the artificial perches were carried out monthly, between July 2006 and June 2007, for four hours during the morning, and four hours during the afternoon, corresponding to a sampling effort of 96 hours distributed in 12 samplings. Species identification followed the classification proposed by Sick (1997) with modifications suggested by CBRO (2006).

Data Analyses

With the purpose to detect statistically significant differences of distance effects from the forest remnant on the number of species and number of seeds found in collectors with perches, and to verify significant differences by season or successional category of seed species that were found under the perches, analyses of variance (ANOVA) followed by a Tukey test (Zar 1999) was performed. To explore associations of plant species with determined perches, a principal component analysis (PCA) was carried out. All statistical analyses were conducted using the program PAST version 1.78 (Hammer *et al.* 2001).

RESULTS

Seeds of 23 plant species were found in the 12 collectors with artificial perches during one year. Twenty-one seeds belonged to species of 17 families, and two species could not be identified (Table 1). Only seeds with anemochoric dispersion were found in the control

Table 2. Results of the Tukey test related to the successional categories of the species found in the collectors with perches during the study period, in Siderópolis, SC. Significant *P*-values (0.05) are shown in bold.

Successional category	Pioneer	Early secondary	Late secondary	Climax
Pioneer	-	0.688	**0.001**	**0.002**
Early secondary	1.569	-	**0.000**	**0.000**

collectors, especially seeds of *Melinis minutilfora* P. Beauv. and other grasses which were observed also in the collectors with artificial perches.

The survey of fruiting species carried out in the forest remnant adjacent to the area of placement of the artificial perches during the study period combined with data obtained from the phytossociological studies developed in the same region by IPAT/UNESC (2002), Santos (2003), and Martins (2005) resulted in a record of 135 plant species that could serve as food source for birds. Although these plant species may be a potential food source for the birds, only 16.4% of these species were found in the artificial perches. Approximately 60% of the 21 identified species belonged to the pioneer and early secondary successional categories (Table 1).

A total of 4887 seeds were collected in the twelve collectors with perches. The analysis of variance (ANOVA) followed by Tukey test, demonstrated that seeds of pioneer and early secondary species had a significantly higher dispersal than seeds of late secondary and climax species (Table 2). During study period, it was recorded a mean of 3.36 ± 1.03 seeds of pioneer species, 3.82 ± 1.33 seeds of early secondary species, 1.64 ± 0.67 seeds of late secondary species, and 1.73 ± 0.65 seeds of climax species in the 12 collectors with perches (Fig. 2).

The species with highest number of dispersed seeds from the forest remnants were *Myrsine coriacea* (Sw.) R. Br., *Miconia cabucu* Hoehne, and *Cecropia glaziovii* Snethl. with 45.2%, 27.9% and 9.0%, respectively. These three species represented 82.1% of the total number of seeds collected in the collectors with perches during the study period (Fig. 3).

The seed rain on the artificial perches was observed during the whole year, with high concentrations recorded between October 2006 and January 2007 (Fig. 4). A total of 81.6% of the seeds dispersed in the collectors during the study period were recovered in these four months. The total number of seeds in the twelve collectors varied between 1557 seeds collected in October and 14 seeds collected in August. A high richness of species in the collectors was recorded between January and March (Fig. 4).

The plant species *Cecropia glaziovii* presented a fruiting period of ten months, the longest among the species of which seeds were found in the collectors during the study period. It was followed by *Miconia cabucu* Hoehne, and *Myrsine coriacea* (Sw.) R. Br. both with eight months, and by *Trema micrantha* that presented seeds recorded in the collectors during seven months. The majority of species (61.9%) was recorded for a period between one and three months (Table 1). The highest number of species was recorded during summer, with a mean of 10.7 ± 4.04 species and the lowest richness was found during the spring and winter, with a mean of 4.7 ± 2.89 and 4.3 ± 4.04 species, respectively (Fig. 5). However, the analysis of variance (ANOVA) did not reveal statistically significant differences in the number of species during the four seasons of the year ($F_{[3.8]}$ = 2.387, p =0.145).

During the study period, a mean of 9.0 ± 1.0 species and 244.3 ± 107.0 seeds were recorded in the collectors at a distance of 60 m from the forest remnant. At a distance of 90m, 9.3 ± 2.1 species and 274 ± 170 seeds were recorded in average and at 120 m and 150 m a mean of 11.7 ± 1.5 species and 593.3 ± 734 seeds, and 12.5 ± 1.5 species and 734 ± 28.28, respectively. No statistically significant difference was found for the effect of distance from the seed source on the number of recorded species ($F_{[3,7]}$ = 2.693, p = 0.127). Similarly, there was no statistically significant difference between the source distance and the number of deposited seeds ($F_{[3,7]}$ =

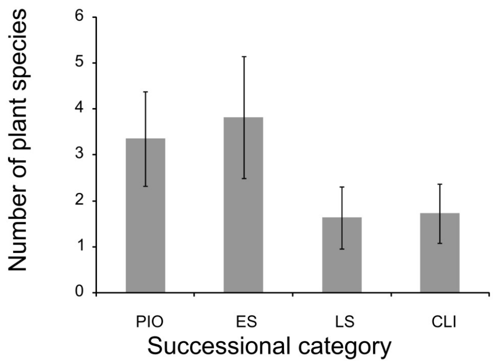

Figure 2. Number of plant species (mean ± SE; n = 12) found in the collectors with perches in relation to the successional category, during the study period in Siderópolis, SC. (PIO = pioneer; ES = Early-secondary; LS = Late-Secondary; CLI = climax).

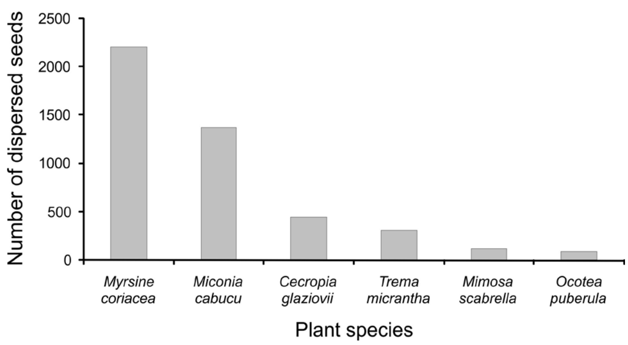

Figure 3. Ranking of species with highest number of dispersed seeds from the forest remnants found in the collectors with perches during the study period, in Siderópolis, SC.

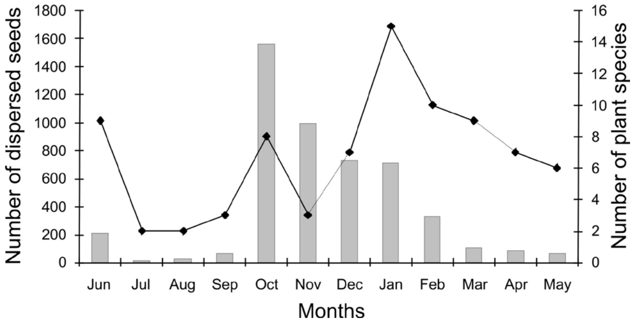

Figure 4. Monthly distribution of number of seeds (bars) and plant species (line) recovered from the collectors with perches during the study period, in Siderópolis, SC.

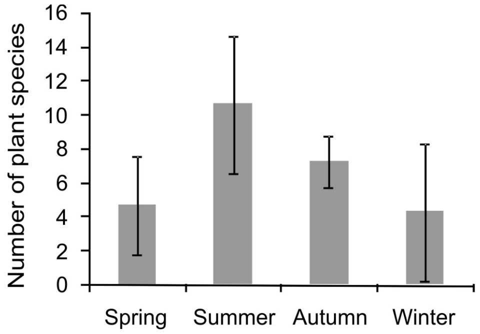

Figure 5. Number of plant species (mean ± SD) found in the collectors with perches by season during the study period, in Siderópolis, SC.

3.118, $p = 0.097$). No statistically significant difference was also found considering the effect of distance from the forest remnant and the number of species among ($F_{[3.12]} = 0.236$, $p = 0.87$) or within seasons (spring: $F_{[3.8]} = 0.333$, $p = 0.08$; summer: $F_{[3.8]} = 0.916$, $p = 0.476$; fall: $F_{[3.8]} = 0.545$, $p = 0.665$; winter: $F_{[3.8]} = 0.506$, $p = 0.689$). Similarly, the number of seeds at different distances was not significant among seasons ($F_{[3.12]} = 0.679$, $p = 0.581$). Principal component analysis (PCA), that was carried out to detect similarities of plant species and selected perches, showed a correlation between species and perches in three main groups (Fig. 6). The first group (perches 8, 9, 11, and 12) is represented by perches with the highest distance from the forest remnant and from the riparian vegetation which limits the perch placement area on the West side. The second group (perches 3, 4, and 6) is composed by perches placed nearby the forest remnant, and the third group (perches 2 and 5) is represented by perches located close to the riparian vegetation or to the forest remnant. Two out of twelve perches (7 and 10) were located far from the other groups. Despite the lack of a statistically significant difference between the distance from the seed source and the number of seeds deposited in the collectors revealed by ANOVA, PCA analysis demonstrated a separation of species dispersed in perches at different distances from the forest remnant and from the riparian vegetation.

In a period of 96 hours, a total of 14 bird species were observed resting on the artificial perches (Table 3). Ten of these 14 species were not considered seed dispersers due to their carnivore or granivore habits, with the latter being considered seed predator. A total of 137 visits from the 14 species was recorded in the perches. *T. melancholicus* was the species with the highest frequency of visits, with 27%, followed by *P. cyanoleuca* with 17%, *P. sulphuratus* with 11%, and *T. rufiventris* with 9% of the total visits. These four species were considered potential dispersers in the area due to their food habits (they have fruit as part of their diet) and to the frequency they visited the perches.

Table 3. Bird species recorded on the artificial perches during 96 hours of observation in the study area, in Siderópolis, SC. Species were arranged following SICK (1997) with modifications suggested by the Brazilian Committee of Ornithological Records (2006). (C = carnivore; F = frugivore; G = granivore; I = insectivore).

Taxon	Common name	Food Guild	N° of visits
Accipitridae Vigors, 1824			
Rupornis magnirostris (Gmelin, 1788)	Roadside Hawk	C	2
Columbidae Leach, 1820			
Columbina talpacoti (Temminck, 1811)	Ruddy Ground-Dove	G	15
Columbina picui (Temminck, 1813)	Picui Ground-Dove	G	10
Bucconidae Horsfild, 1821			
Nystalus chacura (Vieillot, 1856)	White-eared Puffbird	I	1
Tyrannidae Vigors, 1825			
Pitangus sulphuratus (Linnaeus, 1766)	Great Kiskadee	I/F	15
Tyrannus melancholicus Vieillot, 1819	Tropical Kingbird	I/F	37
Hirundinidae Rafinesque, 1815			
Pygochelidon cyanoleuca (Vieillot, 1817)	Blue-and-white Swallow	I	23
Stelgidopteryx ruficollis (Vieillot, 1817)	Southern Rough-Winged Swallow	I	8
Turdidae Rafinesque, 1815			
Turdus rufiventris Vieillot, 1818	Rufous-bellied Thrush	F/I	12
Turdus albicollis Vieillot, 1818	White-necked Thrush	F/I	3
Mimidae Bonaparte, 1853			
Mimus saturninus (Lichtenstein, 1823)	Chalk-browed Mockingbird	F/I	2
Emberizidae Vigors, 1825			
Zonotrichia capensis (Statius Muller, 1776)	Rufous-collard Sparrow	G	1
Sicalis flaveola (Linnaeus, 1766)	Saffron Finch	G	7
Sporophila caerulescens (Vieillot, 1823)	Doublé-collared Seedeater	G	1

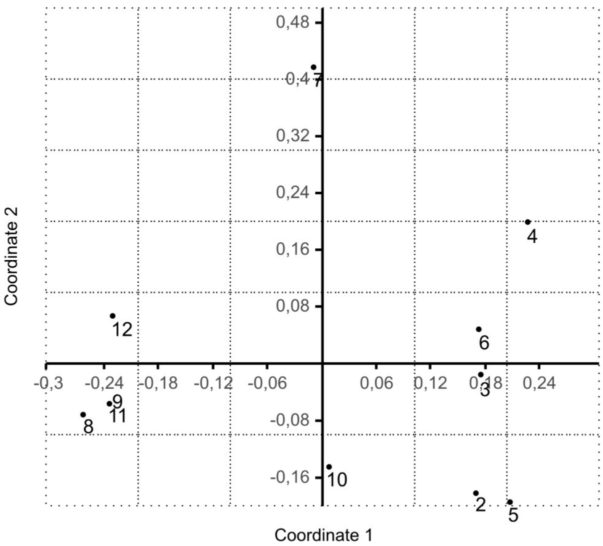

Figure 6. Groups of artificial perches found in the principal component analysis (PCA) for plant species recorded in the collectors during the study period, in Siderópolis, SC. Numbers 2 to 12 refer to the perch number assigned during their placement in the study area.

DISCUSSION

Seed rain on the artificial perches

The presence of perches for one year in the study area resulted in the dispersal of 23 species. This number could be considered relatively high, when compared to the numbers obtained by Holl (1998), and Shiels &Walker (2003) that found 15 and 16 species, respectively, with the same number of perches. However, Melo *et al.* (2000) found a higher richness of species dispersed with perches, 10 species and 40 morphospecies recorded.

In relation to the number of dispersed seeds using 12 perches in an area of approximately one hectare, a mean of 181 seeds $m^{-2}.yr^{-1}$ was observed, supporting the data obtained by Holl (1998) and McClanahan &Wolfe (1987) that found 164 seeds $m^{-2}yr^{-1}$ and 205 seeds $m^{-2}.yr^{-1}$, respectively. Shiels &Walker (2003) recording 50 seeds $m^{-2}.yr^{-1}$ and Zanini &Ganade (2005) with a record of 10 seeds $m^{-2}.yr^{-1}$ obtained a low density under the perches, considering that the latter used 40 perches in the study.

These differences in the number of species and seeds found under the perches in different regions are probably related to the complex structure of the vegetation that directly influences flight and grazing pattern of the birds (McDonnel & Stiles 1983). For example, Melo *et al.* (2000) obtained a higher number of species and seeds deposited under the perches in comparison with the present work, with the placement of the perches in eucalyptus plantations, and in areas of native and riparian vegetation that present a higher structural development of the vegetation than the observed in the present study. Apparently, the areas studied by these researchers attracted a higher diversity and abundance of frugivore birds, enhancing the seed arrival (McClanahan & Wolfe 1987). Moreover, the differences found indicate that there is a limitation of dispersers, perhaps due to the low permeability of the matrix for birds in areas with a very low number of seeds found in the collectors (Brunet & Von Oheimb 1998).

The high number of seeds found in the collectors of artificial perches suggests that perches could accelerate plant succession in the reclaimed areas of the region. These areas, for long periods, lack a sufficiently high vegetation to attract the majority of bird species. This result supports the results obtained in tropical and subtropical regions that demonstrated an increase in the seed rain in impacted environments using artificial perches (Holl 1998, Melo *et al.* 2000, Shiels & Walker 2003, Zanini & Ganade 2005). In contrast to the results reported by the authors mentioned above, we could not find seeds dispersed by frugivores in the witness collectors. Only anemochoric seeds were observed in these collectors. Probably, the arrival of zoochoric seeds under the perches and the lack of these seeds in the witness collectors are related to the bird behavior of defecate and regurgitate the seeds during landing and not during flight (McDonnel & Stiles 1993).

Due to the proximity of the perches with the forest remnant, we would expect a high number of seeds of forest species in the collectors. This is supported by the record of 135 plant species with zoochoric dispersion in the forest remnants close to the study area. However, only 16.4% of forest seeds were dispersed by birds in the open area with perches. Also, it is important to highlight that among the zoochoric species found in the forest, it was not possible to detect which ones are dispersed by birds due to a lack of information in the literature.

In all collectors with perches, few seeds of forest species of successional climax stage were found, with the majority of seeds coming from pioneer and early secondary species. This result is in agreement with the results obtained by Devlaeminck *et al.* (2005), who analyzed seed dispersion from the forest to agricultural areas in Belgium. Guevara & Laborde (1993) who studied the seed rain on the *Ficus* spp. trees also reported similar observations, as well as McClanahan & Wolfe (1987) who carried out a study in pasture areas in Florida. The result found in the present study differs from that of Shiels & Walker (2003), who verified a high abundance of seeds of late secondary and climax species. These data probably reflect the patterns of flight and foraging of the birds considered potential seed dispersers in the study area. These frugivores belong to the families Thyrannidae and Turdidae which are considered generalist species. They were observed feeding in the forest and/or on the border of the forest and dislocating in the open areas and used the perches to rest. Apparently, birds that fed inside the forest used the vegetation on the border as a landing area where they defecate or regurgitate seeds from the forest. Moreover, they also feed on seeds from the vegetation on the border of the forest which is constituted by pioneer and early secondary species. When they fly to open areas and land on perches, they disperse seeds, especially those of species in early successional stages. The fact that 63.6% of pioneer species and 21.4% of early secondary species were found in the collectors with perches supports this hypothesis. Pioneer species attract a high number of frugivore birds (Argel-de-Oliveira *et al.* 1996, Zimmermann 2001), making these birds important for the recruitment of seeds in the early stages of recovery of degraded areas lacking vegetation, the situation of areas recovered after coal extraction in Siderópolis municipality.

The seed rain originated from the forest remnants occurred during the whole year, with the highest intensity between October and January. In these months, 81.6% of the dispersed seeds were recorded in the collectors. Thus, the results demonstrate that the perches were important for the income of seeds in the area throughout the year. This would contribute with plant diversity in a sequential phenological pattern essential to the maintenance of the fauna in the area (Espindola 2005). Only in July and August, when the amount of seeds and the quality of fruit species were too low, the placement of the perches was less efficient.

Four species of the pioneer and early secondary successional categories were important food sources for the birds present in the study area, especially during food shortage. These species were *Cecropia glaziovii*, *Miconia cabucu*, *Myrsine coriacea*, and *Trema micrantha* which produced fruits between seven and ten months, expanding their fruiting period to the winter months. The presence of these plant species is extremely important for the maintenance of the fauna, and also to assure the permanence and survivorship of bird species found in the study area.

Influence of distance in the source of seed rain

Similar to what Wegner & Merriam (1979) found for temperate regions, we observed that the movement of frugivore birds to open areas is governed by the presence and organization of the closest forest element, such as riparian corridors and forest remnants. This is reflected in the formation of three distinct groups of species dispersed in the perches with different distances from the forest remnant or the riparian vegetation, demonstrated by the analysis of principal components (PCA). This could partially explain why there was no statistically significant difference between the number of species and seeds deposited under artificial perches, and the distance from the seed source (the closest forest remnant or the riparian vegetation close to Fiorita river at West side of the area of perch placement). Moreover, this result reflects the generalist behavior of the birds that used the perches: adapted to open areas and moving great distances from the border of the forests to those open areas. Consequently, the seeds dispersed by these birds reached distant perches and presented density and richness similar to the ones recorded in the perches close to the forest remnants. The results indicate that the distance of the perches from the seed source could be enhanced without diminishing the income of seeds.

Guevara & Laborde (1993) observed that some bird species dispersed seeds of species present in a distance longer than 300 m from the trees, when they studied seed rain under isolated trees in a pasture area. Holl (1998) also did not find a significant effect of distance from the source in the number of seeds, and analyzing the list with bird species that visited the perches in her work, it is possible to realize that seven out of ten species are commonly found in open areas, rarely foraging inside a forest. By contrast, in the majority of studies focusing on the dispersion of seeds related to the distance from the seed source it was observed a significant decrease in the seed number with an increase in the distance from the source (MacClanahan & Wolfe 1993, Wilson & Aebischer 1995, Melo et al. 2000, Devlaeminck *et al.* 2005). According to these authors, this result shows the importance of the proximity of degraded areas with intact forests to assure the seed rain and to accelerate plant recovery in those areas.

Our results demonstrate the importance of the presence of seed sources nearby degraded areas, and also the importance of the presence of generalist birds capable of flying long distances to open areas, assuring high dispersion of seeds. Thus, we conclude that bird diversity and the proximity of perches to forest remnants influence the seed dispersion in degraded areas.

Efficiency of artificial perches in degraded areas for natural regeneration

Considering that the presence of pioneer vegetation facilitates the establishment and survivorship of the more advanced species in the succession (Connell & Slatyer 1977), our results indicate a high efficiency of the artificial perches in the arrival of pioneer species in areas with poor vegetal covering. These pioneer species will constitute vegetation that will open the way for the establishment of late secondary and climax species which, in turn, will have their seeds dispersed by birds that feed on established species.

However, to make the artificial perches to work in an efficient way, it is important that the deposited seeds find good conditions for germination and establishment. The few studies that took into account the effect of perches in the establishment of seedlings, demonstrated that there was no significant increase in the number of established seedlings from seeds dispersed by animals under perches in comparison with control areas without perches (Holl 1998, MacClanahan & Wolfe 1993, Miriti 1997, Zanini & Ganade 2005). The lack of increase in the number of established seedlings in areas with perches could be a result of high predation rates that increased with an increase in seed density (Janzen 1971). It also could be a result of the competition between seedlings and grass that colonized these areas (Sun & Dickinson 1996). Ferguson (1995) and Miriti (1997) observed that the establishment of seedlings of species dispersed by birds under perches was higher when grass was eliminated. Other factors that may influence the establishment of the seedlings are the nutrient limitation, soil texture, and microclimate conditions (Uhl 1987, Nepstad *et al.* 1991, Aide & Cavelier 1994). In the study area, the establishment of seedlings is difficult due to the dense vegetal covering composed by *Melinis minutiflora*, an exotic grass species that was introduced after reclamation. An alternative to solve this problem is to remove the grass under the perches and to control the growth of the vegetation.

The data presented here are preliminary for the region and new studies should be developed using several kinds of perches. Moreover, comparative studies encompassing rain seed, the establishment and recruitment of plants under perches related to the vegetal covering and to the quality of the soil will be important to evaluate effectively the role of the perches in the recovery of areas following coal extraction.

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