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Use of artificial perches by birds in ecological restoration areas of the Cerrado and Atlantic Forest biomes in Brazil

Utilização de poleiros artificiais por aves em áreas de restauração ecológica dos biomas Cerrado e Mata Atlântica no Brasil

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Abstract

Artificial perches are widely used in ecological restoration projects; however, the results of these works are yet to be summarized in a review. The goal of the present study was to describe the taxonomic structure of birds that utilized artificial perches, as well as determine the species of birds that most frequently utilized the perches in restoration areas of the Cerrado and Atlantic Forest biomes. We used secondary data obtained from a systematic review of literature available on digital sources. A total of 17 studies were obtained for the two biomes, 15 of which were analyzed. From these studies, 126 bird species were recorded, averaging 19.26 ± 8.30 SD species per study. Five species were categorized as frequent users of artificial perches (*Pitangus sulphuratus*, *Tyrannus melancholicus*, *Mimus saturninus*, *Columbina talpacoti*, and *Tyrannus savana*). These birds are predominantly generalist species, which disperse seed under the perches and this feeding habit of this group has implications for the restoration process. The large number of species that utilize artificial perches highlights the importance of these structures in supporting bird diversity, in addition to the promotion of bird ecosystem services.

Keywords: nucleation, birdlife, ecosystem services, agroecosystems.

Resumo

Poleiros artificiais são amplamente utilizados em programas de restauração ecológica, mas ainda não há uma síntese sobre os principais resultados obtidos. Desse modo, objetivou-se descrever a estrutura taxonômica e diagnosticar quais espécies da avifauna usam mais frequentemente poleiros artificiais destinados à restauração nos biomas Cerrado e Mata Atlântica. Este trabalho utilizou dados secundários obtidos por meio de uma revisão sistemática em levantamentos previamente publicados em meio eletrônico. Foi obtido um total de 17 estudos para os dois biomas, sendo que 15 foram analisados, obtendo-se o registro de 126 espécies, com média de 18,50 ± 8,04 aves por estudo. Cinco espécies foram categorizadas como frequentes em poleiros artificiais (*Pitangus sulphuratus*, *Tyrannus melancholicus*, *Mimus saturninus*, *Columbina talpacoti* e *Tyrannus savana*). Essas espécies são generalistas, as quais dispersam sementes sob os poleiros, e esse hábito alimentar tem implicações no processo de restauração ecológica. O elevado número de espécies capazes de ocorrer em poleiros ressalta a importância dessas estruturas na manutenção da diversidade de aves, auxiliando na prestação de serviços ecossistêmicos.

Palavras-chave: nucleação, avifauna, serviços ecossistêmicos, agroecossistemas.

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Introduction

Artificial perches mimic bare trees that naturally occur in the landscape. The application of artificial perches in the restoration of degraded areas attempt to increase the seed rain of autochthonous and allochthones plant species because they attract birds via the provision of resting sites from which they might defecate or regurgitate seeds consumed from nearby forests (Marcuzzo *et al*., 2013). Dispersed seeds might germinate and establish into woody recruits, which in turn might facilitate the establishment and spread of new species. This ecological engineering process is known as nucleation and is one of the few techniques aimed to facilitate restoration in a degraded environment from an original patch of vegetation (Bechara *et al*., 2016).

Studies regarding artificial perches indicate that perches fail to achieve ecological restoration in degraded landscapes when seed-dispersing birds are absent. The fragmentation of a habitat plays a decisive role in determining the diversity of bird species. For example, in degraded landscapes the number of potential seed-dispersing birds tends to be low (Pillatt *et al*., 2010; Vicente *et al*., 2010). Ecological restoration can also be limited by a lack of seed deposition, which might occur when the fruiting phenology of vegetation is not synchronized with the presence of seed-dispersing bird species (Vogel *et al*., 2016).

An additional criticism offered towards the application of artificial perches is that whereas they might aid in the arrival of seeds, there is no guarantee that the seeds will germinate. This is attributed to factors such as hydric stress, secondary seed predation, herbivory, seedling defoliation, and so on (Reid and Holl, 2012; Silveira *et al*., 2015). Furthermore, the quality of the restoration provided by artificial perches might not be worth the cost (Graham and Page, 2012; Bento *et al*., 2013). One of the most positive aspects of perch utilization includes the promotion of increased environmental complexity (Melo *et al*., 2000). New evidence suggests that artificial perches promote structural complexity in the landscape and thereby increase local bird diversity (Horgan *et al*., 2016).

Artificial perches occur in various forms. The most common types are dry perches, which utilize the logs of trees or bamboo (Reis *et al*., 2003), whereas other designs utilize the available vegetation. For example, in a technique called "tower of lianas" fruiting vines are grown at the base of an artificial perch to attract birds, bats, and insects (Bechara *et al*., 2016). The aim of artificial perches is to attract seed-dispersing birds. However, frugivorous birds are rarely observed using perches and dispersal tends to be carried out only by generalist bird species (Vicente *et al*., 2010; Ferreira and Mello, 2016).

Birds make use of artificial perches for a variety of reasons, e.g., to hunt prey, watch reproductive sites, rest between movements in the landscape, or to monitor territories (Guedes *et al*., 1997; Bocchese *et al*., 2008a; Pillatt *et al*., 2010; Vicente *et al*., 2010; Ferreira and Mello, 2016; Vogel *et al*., 2016). However, to date, there is no summary of reasons as to why different bird families utilize artificial perches. In addition, there has been no analytical review of studies to determine which species of birds most frequently utilize artificial perches. Thus, the main goal of the present review study was to fill these gaps in knowledge with data from two of the most endangered biomes in Brazil, namely Cerrado and Atlantic Forest.

These two biomes are important global biodiversity hotspots (Myers *et al*., 2000). Cerrado is the second largest Brazilian biome, occupying 21% of the country territory (approximately 200 million hectares) and is characterized by several ecosystems including savannas, forests, fields, and riverine forests (Klink and Machado, 2005). The Cerrado is considered to be the last agricultural frontier in the world, with some projections warning that 40 to 60% of its area has already been deforested, with further projections indicating that the biome will become extinct by 2030 (Fernandes and Pessôa, 2011).

The Atlantic Forest is the second largest tropical forest on the American continent. This biome is thought to have an area of 1.5 million km², with 93% of the area into the Brazilian borders (Myers *et al*., 2000). This biome is composed of 15 ecoregions ranging from three degrees latitude south of Ecuador to ten degrees latitude south of the Tropic of Capricorn, where it borders the Pampa biome. In the Atlantic Forest there are ombrophilous and seasonal forests, as well as associated ecosystems that extend over 17 Brazilian states including sandbanks, mangroves, and highland fields (Lagos and Muller, 2007). Currently, only 7% to 8% of the original vegetation of the Atlantic Forest remains. Furthermore, 80% of these remnants are smaller than 50 ha (Ribeiro *et al*., 2009; Tabarelli *et al*., 2010).

Therefore, we aimed to (1) describe the taxonomic structure of bird assemblages that utilize artificial perches and (2) determine which species of birds most frequently utilize artificial perches. In addition to these two objectives we aimed to (3) review the recent literature regarding bird utilization of artificial perches to understand the role of perches in simulating the effect of bare trees in the landscape. Thus, the present review provides important guidelines for the utilization of birds as vectors of ecological restoration, particularly during the application of ecological engineering techniques such as artificial perches.

Material and methods

Data collection

Many of the studies pertaining to ecological restoration in the Cerrado and Atlantic Forest have been published in local scientific journals, doctoral and Master's theses, study papers from Bachelor and Licentiate degrees, and research reports. Thus, a search was performed to locate these types of studies using Google's advanced search tool (http://www.google.com.br/advanced_search).

A search was also conducted with Publish or Perish software that retrieves papers from Google Scholar (Harzing, 2012). This software is able to get information from various indexing databases including the Directory of Open Access Journals, Information Sciences Institute, Scientific Electronic Library Online, and Elsevier (Scopus). Considering our objectives, it was important to include articles from both local publications and large index databases.

The following terms were entered in the search engines: perches+artificial+birds (in Portuguese and English). The criteria to include data were (a) studies conducted in the Cerrado and Atlantic Forest biomes, (b) studies with details of the methodological procedures, and (c) studies containing eight or more bird species. Studies with less than eight species were disregarded to avoid creating bias in the MacKinnon analysis method (details about this method are described in the next section). The review of the data was conducted until September 30th, 2017.

Data analysis

Following synthesis of the papers, bird species lists from each study were sorted into chronological order, based particularly on the date of publication. Basic information about study sites was obtained from each publication including the location's geographic coordinates, altitude (meters above sea level), and type of land use prior to implementation of the artificial perches. This information was obtained via Google Earth when it wasn't available in the publication. By using this method, it was possible to categorize each of the study sites into the appropriate Brazilian biome as defined by the Brazilian Ministry of the Environment (Ministério do Meio Ambiente, 2007).

The data were then organized into a presence-absence matrix. The species not identified in our databases (from the original paper source of data) were suppressed from analysis.

Univariate statistics were obtained and a rarefaction curve to observe expected species richness attained. Each study was a sample and the rarefaction curve was obtained with the *Mao Tau* estimator. A predictive model was then created to determine maximum species richness. The model was fitted with a second-order polynomial function that calculated the rate of species accumulation. Species richness estimates were then obtained after simulating the sampling efforts via Bootstrap analysis (with and without replication). This method is most suited for binary data (Dias, 2004). Analyses were performed with PAST software (Hammer *et al*., 2001).

Following this, we analyzed the frequency of bird incidence in the samples (samples being studies containing artificial perches) utilizing the MacKinnon list technique (Ribon, 2010). This technique works similarly to the occurrence frequency index (Linsdale and Rodgers, 1937), where the total number of samples depends upon the number of times that the species is present in the study. Thus, the calculation of bird species frequency from each sample is random. The species were grouped into frequency classes based in Gimenes and Anjos (2000). These categories are: 1 – frequent (percentage of occurrence equal to or above 50%); 2 – occasional (between 25% and 50%), and 3 – accidental (below 25%). We then tested for significant differences between the proportions of frequency occurrence classes using a chi-square test (χ^2), where $\alpha = 0.05$. The taxonomic structure applied to distinguish bird families in the analysis was described according to Piacentini *et al*. (2015).

Results and discussion

We found a total of 17 studies (mean of 0.85 per year) during the last 20 years covered for analysis in the present review. However, only 15 of these studies were analyzed (Table 1). Of these, 53.3% were conducted in the Atlantic Forest, 20% in the Cerrado, and 26.7% in the ecotones between the Cerrado and Atlantic Forest biomes. In total, 126 (± 7.74 standard deviation [SD]) species were recorded. The estimated species richness was 153 species (Bootstrap analysis without replication). Using the Bootstrap analysis with replication, the estimated richness was 121.99 (± 13.71 SD) species. The second-order polynomial function determined the rate of species accumulation to be: $y = -0.3143x^2 + 12.277x + 10.546$; $R^2 = 0.99$. This model predicts the maximum richness to 130 species over the next four sample periods (or next four studies with artificial perches). In total, 16 orders of birds were recorded and the most represented order was Passeriformes (61.11%), followed by Piciformes (8.73%). The families most represented (Appendix 1) were Thraupidae (19.84%) and Tyrannidae (19.04%).

The total species richness was found to be higher than the estimated species richness. There was also a high percentage of rare species recorded that utilized artificial perches. Projections indicate that as the number of studies conducted increases, it is likely that the number of bird species using the perches will also increase. However, patterns in the data indicate that only a portion of the bird species occurring in the Cerrado and Atlantic Forest utilized artificial perches. Notably, the number of species utilizing artificial perches ranged from 2 to 36 species; however, only those works with 8 or more species were analyzed (priori criteria), resulting in an average of 19.26 (± 8.30 SD) taxa.

Table 1. Summary of studies on artificial perch utilization conducted in the Cerrado and Atlantic Forest, in Brazil. "LU" refers to the type of land use before the implementation of perches and "S" refers to bird species richness. The abbreviations of the states correspond to: MG = Minas Gerais, SP = São Paulo, PR = Paraná, MS = Mato Grosso do Sul, SC = Santa Catarina and RS = Rio Grande do Sul.

Reference	Latitude S	Longitude W	Elevation m.a.s.l	State: city, biome and LU	S
Melo (1997)	19°00'00"	43°30'00"	690	MG: Curvelo, Cerrado; forestry.	22
Bechara (2006)	21°35'14"	47°42'47"	680	SP: Santa Rita do Passa Quatro, Cerrado/Atlantic Forest; forestry.	16
Zwiener (2006)	25°25'15"	48°42'24"	10	PR: Antonina; Atlantic Forest; agriculture.	12
Gustman *et al.* (2007)	23°52'17"	51°57'59"	330	PR: Fênix, Atlantic Forest; agriculture.	18
Bocchese *et al.* (2008b)	20°25'41"	54°40'55"	560	MS: Campo Grande, Cerrado; pasture.	8
Brodt (2009)	29°51'22"	51°16'26"	40	RS: Nova Santa Rita, Atlantic Forest; agriculture.	8
Toppa and Serrano (2009)	24°00'08"	46°23'38"	160	SP: Praia Grande, Atlantic Forest; agriculture.	14
Vicente *et al.* (2010)	28°35'00"	49°25'00"	130	SC: Siderópolis, Atlantic Forest; mining.	14
Silva (2011)	22°45'55"	53°15'30"	240	PR: Porto Rico, Atlantic Forest; pasture.	36
Alves and Pinheiro (2013)	22°30'50"	45°27'15"	1140	MG: Piranguçu, Atlantic Forest; pasture.	19
Simei-Martins (2014)	20°19'37"	50°30'02"	440	SP: Jales, Cerrado/Atlantic Forest; pasture.	16
Athiê and Dias (2016)	21°49'00"	47°25'00"	590	SP: Porto Ferreira, Cerrado/Atlantic Forest; pasture.	22
Ferreira and Melo (2016)	18°55'00"	47°40'00"	920	MG: Araguari, Cerrado; forestry.	22
Vogel *et al.* (2016)	25°41'43"	53°06'12"	510	MG: Dois Vizinhos; Atlantic Forest; agriculture.	32
Teixeira and Carvalho de Castro (2017)	21°06'16"	44°14'58"	904	MG: São João del-Rei; Cerrado/Atlantic Forest; urbanization.	30

The mean number of species in each study (approximately 20) was similar to that found in studies from other regions. Data from Costa Rica, which is also in the Neotropical region, observed 11 species that utilized artificial perches (Holl, 1998). Similar results were observed in other biogeographical regions such as the Indo-Malaysian, where 5 species were recorded on artificial perches (Damanik, 2016) and in Australia where 30 species were recorded (McCarron, 2016). The data from these studies indicate that the general species richness of birds utilizing artificial perches is lower than the total assemblage of birds in that region, which is similar to Braga *et al*. (2015) where only two bird species were recorded on artificial perches on a sample of Cerrado in relation to the 20 species that occurred in that sample.

In the Cerrado, the proportion of bird species that were observed on artificial perches equated to 15.18% of the 830 total species found in that biome (Rosa, 2013). This corresponds to 3.93% of species if only those with an occurrence frequency over 25% are considered. In the Atlantic Forest, the total proportion of bird species recorded was 14.14% out of a total of 891 species found in that biome (Lima, 2013). This represents 0.56% of the total if only species with an occurrence frequency greater than 25% are considered. It should be noted that there are endemisms in each biome and that many species likely act as ecological substitutes in the geographical gradient between the biomes.

Only 5 species were categorized as frequent users of artificial perches, namely *Pitangus sulphuratus* (Linnaeus 1766) and *Tyrannus melancholicus* Vieillot 1819 with 80%, *Mimus saturninus* (Lichtenstein 1823) with 60%, *Columbina talpacoti* (Temminck 1810) with 53.3%, and *Tyrannus savana* Daudin 1802 both with 53.3%.

The occasional perch users included *Furnarius rufus* (Gmelin 1788) and *Zonotrichia capensis* (Statius Muller 1776) with 46.7%; *Sicalis flaveola* (Linnaeus 1766), *Rupornis magnirostris* (Gmelin 1788), and *Volatinia jacarina* (Linnaeus 1766) with 40%; *Crotophaga ani* Linnaeus 1758, *Stelgidopteryx ruficollis* (Vieillot 1817), *Turdus rufiventris* Vieillot 1818, and *Myodynastes maculatus* (Statius Muller 1776) with 33.3%; and *Sporophila caerulescens* Ridgway 1901, *Empidonomus varius* (Vieillot 1818), *Tangara sayaca* (Linnaeus 1766), *Elaenia fla-*

vogaster (Linnaeus 1766), *Zenaida auriculata* (Des Murs 1847), *Molothrus bonariensis* (Gmelin 1789), *Troglodytes musculus* Naumann 1823, *Colaptes melanochloros* (Gmelin 1788), *C. campestris* (Vieillot 1818), *Milvago chimachima* (Vieillot 1816), *Xolmis velatus* (Lichtenstein 1823), and *Cyanocorax cristatellus* (Temminck 1823) with 26.7%. The remaining species (100 taxa, 79.36%) were categorized as accidental perch users, the group with greatest number of species ($\chi^2 = 62$, gl = 2, $P < 0.01$). The occurrence frequencies of these and other bird species are listed in Appendix 1.

The data signify clear implications for ecological restoration processes. Seed dispersal was only carried out by a restricted group of birds, in which the most represented bird species were from the families Thraupidae and Tyrannidae. These birds are considered to be generalist species and secondary seed dispersers (Pillatt *et al*., 2010; Vogel *et al*., 2016).

Among the frequent users of artificial perches, *P. sulphuratus*, *T. melancholicus*, *M. saturninus*, and *T. savanna* are known to consume fruit and have demonstrated the ability to regurgitate viable seeds. These birds are characterized by their utilization of tall perches and occupation of a wide trophic niche (Martins-Oliveira *et al*., 2012). Thus, artificial perches inserted in the degraded landscape (principally at a height of five meters or more) will act as landing sites that naturally attract these species (Simei-Martins, 2014). These birds are of notable importance as they are the main seed dispersers in fragmented areas of the Atlantic Forest (Pizo, 2004).

In addition to seed-dispersal services, these bird species are useful in the control of herbivorous insects. Species of the family Tyrannidae are predominantly insectivorous and utilize perches to observe and hunt for prey (Gabriel and Pizo, 2005). *Pitangus sulphuratus* is the only species in this family that is considered a resident (frequency of occurrence > 50%) amongst the study sites, whereas the others are considered migratory. This species is the most frequent seed-disperser species to utilize artificial perches throughout the year and, therefore, this species is thought to be an important generalist seed disperser in degraded landscapes (Ramos-Robles *et al*., 2016; Vogel *et al*., 2016).

The family most represented in the data was Thraupidae (tanagers). This family is composed of omnivorous, granivorous, and frugivorous birds. From those within the family that have the ability to disperse seed, *T. sayaca* was found to have an occurrence frequency of 26.7% in the sample sites. This species is thought to be one of the most effective seed dispersers in degraded areas because it frequently consumes fruit and is commonly observed along forest edges and in open areas (Jacomassa, 2016). Other species in the family Thraupidae are more likely to occur in intact forests and, therefore, are rarely seen on artificial perches. This environmental association means that tanagers predominantly utilize artificial perches as resting areas while moving through the landscape, which means that the perches provide a similar function to that of a dead trees (Reis *et al*., 2007).

Despite being common in degraded areas, only four species from the family Hirundinidae (swallows) were usually observed in the study sites researched in the present review. This included *S. ruficollis*, *Progne tapera* (Vieillot 1817), *Pygochelidon cyanoleuca* (Vieillot 1817), and *Progne chalybea* (Gmelin 1789). This family consists of aerial insectivorous hunters and recent discussion indicates that these species have a tendency to avoid areas containing artificial perches. This behavior is likely the result of the perches presenting an obstacle in their course of flight (Horgan *et al*., 2016).

A greater proportion of birds in the family Thraupidae are now considered granivorous following the reclassification of this family to include several *Emberizidae* (sparrows). This taxonomic shift includes the species *S. flaveola*, *S. caerulescens*, *Coryphospingus cucullatus* (Statius Muller *1776*), and *Embernagra platensis* (Gmelin 1789) among others listed in Appendix 1. These birds have been observed utilizing artificial perches to vocalize (Vogel, H.F., personal observation). Generally talking, birds vocalize in central and strategic points of their territories (Tomaz and Alves, 2009). Recent data from Canadian prairies suggests that some bird species use artificial structures in the landscape (e.g., fences along gas wells) to vocalize and defend their territories from other birds. The structures, therefore, in some respects were able to influence local bird abundance (Rodgers and Koper, 2017). Artificial perches in degraded landscapes act in a similar manner to structures found on the prairies, i.e., they are the highest perching point in relation to the ground; however, they can also play an important role in the life history of bird species.

The occurrence frequency of granivorous birds on artificial perches is most likely associated with the type of vegetation present near the perches, in particular the presence of grasses and herbaceous vegetation (Vogel *et al*., 2015). Thus, the occurrence frequency can vary as vegetation changes from area to area. However, studies have commonly recorded granivorous birds using artificial perches (Guedes *et al*., 1997; Bocchese *et al*., 2008a). Prior to restoration, the land in the study sites in the present review was primarily used for agriculture and livestock purposes (Table 1). These practices introduce fodder species capable of supplying grains that attract granivorous birds, thereby influencing their population dynamics.

Picidae (7.93% of total richness) was also one of the most represented bird families. These birds have been known to utilize artificial perches to hunt for prey, specifically between the bark of the perch they were sitting on (Vogel, H.F., personal observation). This highlights the importance of artificial perches to improve the structural complexity in the landscape, replacing the bare trees that were removed during agriculture, pasture, livestock, forestry, and mining processes. The absence of bare trees is ideally compensated by structures that mimic them, including artificial perches constructed from eucalyptus and bamboo (Reis *et al*., 2003).

Perches constructed from natural materials can provide services additional to seed dispersal. Eucalyptus logs, for example, were observed providing cavities for Picidae nests (Pereira *et al*., 2015). When considering conservation strategies, perches could be designed to contain cavities, thereby supporting the reproduction of this bird family. The presence of Picidae during restoration should be encouraged as they consume fruit as part of their diet (Mickich, 2002). In addition, they are the likely ecological substitutes to specialized seed dispersers. However, their capacity to disperse seed is currently not well known.

Some species, while recorded on artificial perches, were not described in some studies in how they utilize the perches or their ability to facilitate seed dispersal. For example, birds of the family Tinamidae (3.2% of total richness) are largely sedentary birds that dwell on the ground and do not exhibit perching behavior. In the studies they were recorded in, it was likely that they were observed at the base of the perch given that these birds are granivorous and predate seed on the ground. These birds may consume post-dispersed seeds on the ground (Christianini and Galetti, 2007), thereby inducing negative effects on the restoration process.

Brazilian studies on artificial perches are characterized by a focus on seed-dispersal processes and, as a result, they primarily study bird species that perch during the day. This influences the species observed and, in the present review, there was only one nocturnal species recorded, which was the burrowing owl *Athene cunicularia* (Molina 1782). Other raptors, albeit diurnal, were also recorded from the families Accipitridae and Falconidae (5.5% total richness for both), namely *Falco femoralis* Temminck, 1822, *F. sparverius* Linnaeus 1758, *Heterospizias meridionalis* (Latham 1790), *M. chimachima* and *R. magnirostris*. Of these, *R. magnirostris* was the most frequently observed (40%). Raptors have been observed controlling invasive species, both vertebrates and invertebrates, via their utilization of artificial perches (Kay *et al*., 1994; Pias *et al*., 2012). Thus, they deserve greater attention for the ecosystem services they provide, including the reduction of pest species such as rodents that might compromise the seed bank (Askham, 1990).

Only three hummingbird species, *Thalurania furcata* (Gmelin 1788), *Chlorostilbon lucidus* (Shaw 1812), and *Colibri serrirostris* (Vieillot 1816), were recorded on artificial perches with a low occurrence frequency. Birds in the family Trochilidae are important pollinators and research on their use of artificial perches is significant (Rocca and Sazima, 2010; Lindell and Thurston, 2013). Researching the use of artificial perches by the Trochilidae family is important as these birds provide the ecosystem service of pollination. Natural perches are commonly utilized by hummingbirds for short rests while moving across the land, as well as for territorial defense. Recent research has suggested that some hummingbird species prefer perches less than 2 m in height and less than 4 mm in diameter (Lanna *et al*., 2016). The low richness and incidence of this family in the present review might be associated with the utilization of artificial perches outside the preferences of this group. For example, many perches tend to lose their fine branches over time and become disputed over by several competitors (Vogel *et al*., 2016).

Usually little importance is given to the bird orders that infrequently use artificial perches and do not perform seed-dispersal processes (e.g., Pelecaniformes, Galliformes, and Galbuliformes). However, the importance of the ecosystem roles these birds perform, including deposition of nutrients simply by defecating while using the perches, is poorly recognized. This important ecosystem service is usually associated with seabirds or aquatic birds (Sekercioglu, 2012); however, other bird species may exercise it to a lesser extent, contributing to the input of nutrients into degraded ecosystems (Tomassen *et al*., 2005).

Finally, in conclusion we recommend the use of artificial perches to not only promote seed supply but also restore ecological relationships that were once provided by bare trees in natural ecosystems. This latter role is underestimated in importance and further research is required to better understand its purpose in regeneration environments.

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Appendix 1. Species recorded utilizing artificial perches in the Cerrado and Atlantic Forest of Brazil, their frequency of occurrence and bibliographical source.

Order/ Family	Species	Melo (1997)	Bocchese *et al.* (2008)	Ferreira and Melo (2016)	Bechara (2006)	Zwiener (2006)	Gustman *et al.* (2008)	Serrano and Toppa (2008)	Brodt (2009)	Vicente *et al.* (2010)	Silva (2011)	Alves and Pinheiro (2013)	Simei-Martins (2014)	Athiê and Dias (2016)	Vogel *et al.* (2016)	Teixeira and Carvalho de Castro (2017)	Frequency of occurence (%)
Passeriformes/Tyrannidae	*Pitangus sulphuratus* (Linnaeus 1766)	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1	80.0
Passeriformes/Tyrannidae	*Tyrannus melancholicus* Vieillot 1819	1	0	1	1	1	1	0	1	1	1	0	1	1	1	1	80.0
Passeriformes/Mimidae	*Mimus saturninus* (Lichtenstein 1823)	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	60.0
Columbiformes/Columbidae	*Columbina talpacoti* Leach 1820	0	1	0	0	0	1	1	0	1	1	0	1	1	1	0	53.3
Passeriformes/Tyrannidae	*Tyrannus savana* Vieillot 1808	1	0	0	1	0	1	0	1	0	1	0	0	1	1	1	53.3
Passeriformes/Furnariidae	*Furnarius rufus* (Gmelin 1788)	0	0	0	0	1	1	0	1	0	1	0	1	1	1	0	46.7
Passeriformes/Passerellidae	*Zonotrichia capensis* (Statius Muller 1776)	1	0	1	0	0	1	1	1	1	0	0	0	1	0	0	46.7
Passeriformes/Thraupidae	*Sicalis flaveola* (Linnaeus 1766)	0	0	0	0	1	0	0	0	1	1	0	1	0	1	1	40.0
Accipitriformes/Accipitridae	*Rupornis magnirostris* (Gmelin 1788)	1	0	0	0	0	0	0	0	1	1	0	0	1	1	1	40.0
Passeriformes/Thraupidae	*Volatinia jacarina* (Linnaeus 1766)	1	1	0	0	0	1	0	0	0	0	0	0	1	1	1	40.0
Cuculiformes/Cuculidae	*Crotophaga ani* Linnaeus 1758	0	0	0	0	0	1	0	0	0	1	1	1	0	1	0	33.3
Passeriformes/Hirundinidae	*Stelgidopteryx ruficollis* (Vieillot 1817)	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	33.3
Passeriformes/Turdidae	*Turdus rufiventris* Vieillot 1818	0	0	0	1	0	0	1	0	1	0	1	0	0	1	0	33.3
Passeriformes/Tyrannidae	*Myodynastes maculatus* (Statius Muller 1776)	1	0	0	1	0	1	0	0	0	0	0	0	1	0	1	33.3
Passeriformes/Thraupidae	*Sporophila caerulescens* (Vieillot 1823)	0	0	0	0	0	1	1	0	1	0	0	0	0	1	0	26.7
Passeriformes/Tyrannidae	*Empidonomus varius* (Vieillot 1818)	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0	26.7
Passeriformes/Thraupidae	*Tangara sayaca* (Linnaeus 1766)	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0	26.7
Passeriformes/Tyrannidae	*cf Elaenia flavogaster* (Thunberg 1822)	0	0	0	1	0	0	1	0	0	1	0	0	0	1	0	26.7

Appendix 1. Continuation.

Cuculiformes/Cuculidae	*Zenaida auriculata* (Des Murs 1847)	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	26.7
Passeriformes/Icteridae	*Molothrus bonariensis* (Gmelin 1789)	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	26.7
Passeriformes/Troglodytidae	*Troglodytes musculus* Naumann 1823	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	26.7
Piciformes/Picidae	*Colaptes melanochloros* (Gmelin 1788)	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	26.7
Piciformes/Picidae	*Colaptes campestris* (Vieillot 1818)	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	26.7
Falconiformes/Falconidae	*Milvago chimachima* (Vieillot 1816)	1	0	1	0	0	0	0	0	0	0	1	0	0	0	1	26.7
Passeriformes/Corvidae	*Cyanocorax cristatellus* (Temminck 1823)	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	26.7
Passeriformes/Tyrannidae	*Xolmis velatus* (Lichtenstein 1823)	0	0	1	0	0	0	0	0	0	1	0	1	0	0	1	26.7
Cuculiformes/Cuculidae	*Guira guira* (Gmelin 1788)	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	20.0
Passeriformes/Turdidae	*Turdus amaurochalinus* Cabanis 1850	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	20.0
Passeriformes/Tyrannidae	*Megarynchus pitangua* (Linnaeus 1766)	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	20.0
Columbiformes/Columbidae	*Columbina picui* (Temminck 1813)	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	20.0
Passeriformes/Tyrannidae	*Myiarchus ferox* (Gmelin 1789)	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	20.0
Passeriformes/Thraupidae	*Tangara cayana* (Linnaeus 1766)	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	20.0
Columbiformes/Columbidae	*Patagioenas picazuro* (Temminck 1813)	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	20.0
Passeriformes/Tyrannidae	*Myiozetetes similis* (Spix 1825)	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	20.0
Passeriformes/Tyrannidae	*Machetornis rixosa* (Vieillot 1819)	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	20.0
Psittaciformes/Psittacidae	*Forpus xanthopterygius* (Spix 1824	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	20.0
Passeriformes/Thraupidae	*Embernagra platensis* (Gmelin 1789)	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13.3
Passeriformes/Tyrannidae	*Xolmis cinereus* (Vieillot 1816)	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	13.3
Galbuliforme/Bucconidae	*Nystalus chacuru* (Vieillot 1816)	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	13.3
Passeriformes/Thraupidae	*Coryphospingus cucullatus* (Statius Muller 1776)	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	13.3
Passeriformes/Thraupidae	*Tangara palmarum* (Wied 1823)	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	13.3
Passeriformes/Tyrannidae	*Satrapa icterophrys* (Vieillot 1818)	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	13.3
Piciformes/Picidae	*Dryocopus lineatus* Linnaeus 1766	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	13.3
Cuculiformes/Cuculidae	*Piaya cayana* (Linnaeus 1766)	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	13.3
Passeriformes/Thraupidae	*Sicalis luteola* (Sparrman 1789)	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	13.3
Passeriformes/Icteridae	*Sturnella superciliaris* (Bonaparte 1850)	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	13.3
Passeriformes/Passerellidae	*Ammodramus humeralis* (Bosc 1792)	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	13.3
Pelecaniformes/Ardeidae	*Syrigma sibilatrix* (Temminck 1824)	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	13.3

Appendix 1. Continuation.

Falconiformes/Falconidae	*Herpetotheres cachinnans* (Linnaeus 1758)	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	13.3
Passeriformes/Tyrannidae	*Knipolegus lophotes* Boie 1828	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	13.3
Passeriformes/Hirundinidae	*Pygochelidon cyanoleuca* (Vieillot 1817)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	13.3
Passeriformes/Passeridae	*Passer domesticus* (Linnaeus 1758)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	13.3
Cathartiformes/Cathartidae	*Coragyps atratus* (Bechstein 1793)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	13.3
Piciformes/Picidae	*Picumnus cirratus* Temminck 1825	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	13.3
Pelecaniformes/Corvidae	*Cyanocorax chrysops* (Vieillot 1818)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	13.3
Passeriformes/Icteridae	*Pseudoleistes guirahuro* (Vieillot 1819)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	13.3
Apodiformes/Trochilidae	*Eupetomena macroura* (Gmelin 1788)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Passeriformes/Fringillidae	*Euphonia chlorotica* (Gmelin 1788)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	6.7
Apodiformes/Trochilidae	*Chlorostilbon lucidus* (Shaw 1812)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6.7
Accipitriformes/Accipitridae	*Elanus leucurus* (Vieillot 1818)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6.7
Passeriformes/Parulidae	*Geothlypis aequinoctialis* (Gmelin 1789)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6.7
Passeriformes/Icteriidae	*Agelaioides badius* (Vieillot 1819)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6.7
Anseriformes/Anatidae	*Amazonetta brasiliensis* (Gmelin 1789)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Columbiformes/Columbidae	*Columbina squammata* (Lesson 1831)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Falconiformes/Falconidae	*Falco sparverius* Linnaeus 1758	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Passeriformes/Hirundinidae	*Progne tapera* (Linnaeus 1766)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Passeriformes/Icteridae	*Gnorimopsar chopi* (Vieillot 1819)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Strigiformes/Strigidae	*Athene cunicularia* (Molina 1782)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Sicalis citrina* (Temminck 1815)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Sporophila plumbea* (zu Wied-Neuwied 1830)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Coryphospingus pileatus* (zu Wied-Neuwied 1821)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Estrildidae	*Estrilda astrild* (Linnaeus 1758)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6.7
Passeriformes/Tyrannidae	*Fluvicola nengeta* (Linnaeus1766)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6.7
Passeriformes/Hirundinidae	*Progne chalybea* (Gmelin 1789)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6.7
Passeriformes/Tyrannidae	*Arundinicola leucocephala* (Linnaeus 1764)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Passerellidae	*Ammodramus humeralis* (Bosc 1792)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Conirostrum speciosum* Cabanis 1847	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6.7
Passeriformes/Thraupidae	Saltator similis d'Orbigny and Lafresnaye 1837	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6.7

Appendix 1. Continuation.

Psittaciformes/Psittaciidae	*Psittacara leucophthalmus* (Statius Muller 1776)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Piciformes/Picidae	*Melanerpes candidus* (Otto 1796)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Piciformes/Picidae	*Melanerpes flavifrons* (Vieillot 1818)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Passeriformes/Tyrannidae	*Camptostoma obsoletum* (Temminck 1824)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Tyrannidae	*Muscipipra vetula* (Lichtenstein 1823)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Vireonidae	*Cyclarhis gujanensis* (Lichtenstein 1823)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Vireonidae	*Vireo cf. olivaceus* (Linnaeus 1766)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Tyrannidae	*Tyrannus albogularis* Burmeister 1856	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Trichothraupis melanops* (Vieillot 1818)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6.7
Caprimulgiformes/Caprimulgidae	*Hydropsalis albicollis* (Gmelin 1789)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Dacnis cayana* (Linnaeus 1766)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6.7
Tinamiformes/Tinamidae	*Crypturellus tataupa* (Temminck 1815)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6.7
Tinamiformes/Tinamidae	*Crypturellus parvirostris* (Wagler 1827)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6.7
Piciformes/Picidae	*Campephilus melanoleucos* (Gmelin1788)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6.7
Pelecaniformes/Corvidae	*Cyanocorax caeruleus* (Vieillot 1818)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6.7
Piciformes/Picidae	*Pteroglossus castanotis* Gould 1834	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Piciformes/Picidae	*Campephilus robustus* (Lichtenstein 1818)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6.7
Passeriformes/Turdidae	*Turdus albicollis* (Vieillot 1819)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	6.7
Tinamiformes/Tinamidae	*Tinamus solitarius* (Vieillot 1819)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Tyrannidae	*Conopias trivirgatus* (zu Wied-Neuwied 1831)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Ramphocelus bresilius* (Linnaeus 1766)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6.7
Tinamiformes/Tinamidae	*Crypturellus obsoletus* (Temminck 1815)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6.7
Psittaciformes/Psittaciformes	*Pionus maximiliani* (Kuhl 1820)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6.7
Galliformes/Cracidae	*Penelope ochrogaster* Pelzeln 1870	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6.7
Passeriformes/Thraupidae	*Tangara cyanocephala* (Statius Müller 1776)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Tangara seledon* (Statius Müller 1776)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6.7
Pelecaniformes/Dendrocolaptidae	*Lepidocolaptes angustirostris* (Vieillot 1818)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	6.7
Pelecaniformes/Threskiornithidae	*Phimosus infuscatus* (Lichtenstein 1823)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	6.7
Accipitriformes/Accipitridae	*Heterospizias meridionalis* (Latham 1790)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	6.7
Pelecaniformes/Threskiornithidae	*Theristicus caudatus* (Boddaert 1783)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7

Appendix 1. Continuation.

Falconiformes/Falconidae	*Falco femoralis* Temminck 1822	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Piciformes/Ramphastidae	*Ramphastos toco* Statius Muller 1776	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Apodiformes/Trochilidae	*Thalurania furcata* (Gmelin 1788)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Piciformes/Picidae	*Campephilus melanoleucos* (Gmelin 1788)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Tyrannidae:	*Tyrannus albogularis* Burmeister 1856	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Neothraupis fasciata* Cabanis 1847	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Saltatricula atricollis* (Vieillot 1817)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Emberizoides herbicola* (Vieillot 1817)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Sporophila nigricollis* (Vieillot 1823)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Thraupidae	*Sporophila plumbea* (Wied 1830)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.7
Passeriformes/Tyrannidae	*Gubernetes yetapa* (Vieillot 1818)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	6.7
Passeriformes/Fringillidae	*Spinus magellanicus* (Vieillot 1805)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6.7
Apodiformes/Trochilidae	*Colibri serrirostris* (Vieillot 1816)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6.7
Passeriformes/Furnariidae	*Anumbius annumbi* (Vieillot 1817)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6.7
Passeriformes/Tyrannidae	*Hirundinea ferruginea* (Gmelin 1788)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6.7
Passeriformes/Tyrannidae	*Myiarchus swainsoni* Cabanis & Heine 1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6.7
Passeriformes/Thraupidae	*Nemosia pileata* (Boddaert 178)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6.7
Passeriformes/Turdidae	*Turdus leucomelas* Vieillot 1818	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6.7