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Seasonal dynamics of bird assemblages in commercial plantations of *Pinus radiata* in southern-central Chile

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Abstract Forest plantations are a relatively new environment in Chile, with impacts of different magnitude on different taxa. Birds are one of the taxa mostly used as ecological indicators to evaluate the effect of different types of disturbances, due to their level of specialization in the use of different microhabitats. We assessed the effect of the age of *Pinus radiata* plantations (2 sites of 8 and 12 years, respectively) and seasonal (three seasons) on the diversity of bird assemblages. The abundance of species from both sites was assessed through acoustic and visual survey records, which were also compared at trophic guild level. Differences were observed at both sites, with higher diversity calculated for Cerro Ñielol (8 years) compared to Rucamanque (12 years). In seasonal terms, diversity was not affected in Cerro Ñielol, while in Rucamanque significant differences were observed during fall. Guild composition of both localities also showed differences, resulting in higher diversity for Cerro Ñielol in most cases. Despite the fact that the younger plantation presented the highest diversity, elements associated with the landscape are discussed, as well as particularities in the use of space by the species.

Keywords: diversity, ecological matrix, guilds, seasonality, vegetation cover

Összefoglalás Az ültetvény-erdők viszonylag új környezetet jelentenek Chilében, és eltérő hatást gyakorolnak a különböző taxonokra. A madarak az egyik olyan csoport, melyeket gyakran használnak ökológiai indikátorként a különböző típusú zavarások hatásának értékelésére, mivel eltérő mikrohabitatok használatára specializálódtak. Felmérték a Monterey-fenyő *(Pinus radiata)* ültetvények kora (két terület, 8, illetve 12 éves állományok) és a szezonalitás (3 évszak) hatását a madárközösségek diverzitására. A fajok abundanciáját mindkét területen akusztikus és vizuális felméréssel vizsgálták, melyeket a trofikus guildek szintjén is összehasonlították. A két terület között eltéréseket figyeltek meg: Cerro Ñielol (8 év) esetén magasabb diverzitást számoltak, mint Rucamanque (12 év) esetén. A szezonalitást figyelembe véve Cerro Ñielolban nem tapasztaltak változást, míg Rucamanqueban jelentős különbségeket figyeltek meg az őszi időszakban. Mindkét terület guild összetétele is eltéréseket mutatott, ami a legtöbb esetben Cerro Ñielolban eredményezett magasabb diverzitást. Annak ellenére, hogy a fiatalabb ültetvény mutatta a legmagasabb diverzitást, vizsgálták a tájképi elemeket és a fajok térhasználatának sajátosságait is.

Kulcsszavak: diverzitás, ökológiai mátrix, guildek, szezonalitás, növénytakaró

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Introduction

The loss and transformation of habitats are among the main threats to biodiversity (Caughley 1994). The replacement of native forest cover by monoculture plantations is a relatively recent phenomenon in Chile (Donoso & Lara 1996), where the Monterrey pine *(Pinus radiata)* is one of the most widely used for this conversion (Lavery & Mead 1998). This fact is presented through significant effects at the landscape level (Echeverría *et al.* 2008), where the original habitat has been reduced to scattered fragments with different degrees of connectivity. In this context, the local fauna must adapt to this new ecological scenario in order to persist. Despite the recognition of plantations as "green deserts" due to the low diversity, there is evidence that they could support various taxa (Bremen & Farley 2010, Estades *et al.* 2012), depending on the presence of specific environmental conditions suitable for certain species. However, the high degree of specialism in some species can significantly limit their occupation (Newbold *et al.* 2008) affecting the community composition and the functionality performed locally (Lindenmayer *et al.* 2005). In this way, the resulting community structure would allow to improve the understanding of the interactions between species with different resource requirements, under the spatial context that the plantations can provide (Devictor *et al.* 2008).

Bird communities in South America comprise a mosaic of groups with different places of origin and times of speciation (Jaksic & Feinsinger 1991). This heterogeneous origin is reflected in its community organization throughout the Chilean territory (Gantz *et al.* 2009, Zúñiga 2014), differentiated through space and food use (Rozzi *et al.* 1996, Díaz *et al.* 2005). The belonging of these species to specific groups delimited by specific uses of resources, called guilds, allows them to limit actions associated with competition, which enables their coexistence (Root 1967, Jaksic 2002). However, the conversion of native forest into plantations can result in the decrease of species richness whose habitat preferences are associated with the resources lost with changes derived from human disturbances (Arriaga-Weiss *et al.* 2008). Additionally, seasonal variations represent changes in the availability of resources, as a consequence of phenological processes in plants (Ratchke & Placey 1985), and invertebrate development (Borror *et al. 1*992), which affect the spatial dynamics of bird species. This situation implies additional changes in the composition of bird communities in the plantations, as the resources vary in response to seasonality.

Although the problem of the effect of *Pinus radiata* plantations and bird assemblages has been addressed in central and south-central Chile (Estades 1994, Estades & Temple 1999, Pérez 2004), there are information gaps regarding their composition in seasonal terms, which is of interest regarding species interaction and their impact on the environment. Another issue of particular importance is associated with the age of the plantation, since the development of the vegetation cover could result in niches available for these species (Macarthur & Macarthur 1962). This is supported by the fact that *Pinus radiata* plantations present variations in the accompanying vegetation as their age increases (Brockerhorff *et al.* 2003), by which a change in the associated animal communities is expected (Hernández *et al.* 2013, Rodríguez-Pérez *et al.* 2018).

The objective of this study is to examine the avifauna present in two sites with different age of *Pinus radiata* plantations in south-central Chile in a seasonal context. The hypothesis to be tested is about the dissimilarity of bird assemblages at both sites according to the age of plantations, which could be reflected both at the level of diversity of the whole diversity and guild composition. Likewise, variations of assemblages through seasons would also be expected.

Material and Methods

The two study sites were located around two protected areas. The first is near Cerro Ñielol (hereinafter Cerro Ñielol; 38º43'S, 72º35'W), a protected area that is close to the city of Temuco, in south-central Chile *(Figure 1)*. It is characterized by deciduous forests, represented mainly by the roble-laurel-lingue formation (*Nothofago-Perseetum*; Oberdorfer 1960). The present *Pinus radiata* plantation is eight years old. Its contiguous location with the city of Temuco gives it the presence of an urban matrix. The other plantation is 12 years old, and is close to the Predio Rucamanque (hereinafter Rucamanque; 38º39'S, 72º36'W), which is a private protected area characterized by evergreen forest formations, with olivillo *(Lapagerio-Aextoxiconetum punctatii)* and roble-laurel-lingue *(Nothofago-Perseetum)* associations (Ramírez 1989). In its environment there is a matrix associated with grasslands and scrub, as well as the occurrence of small-scale crops (Zúñiga *et al.* 2020). A preliminary comparison of vegetation of both sites allowed to establish that Rucamanque has a greater canopy cover (Mann-Whitney test, U=65, P=0.001), shrub

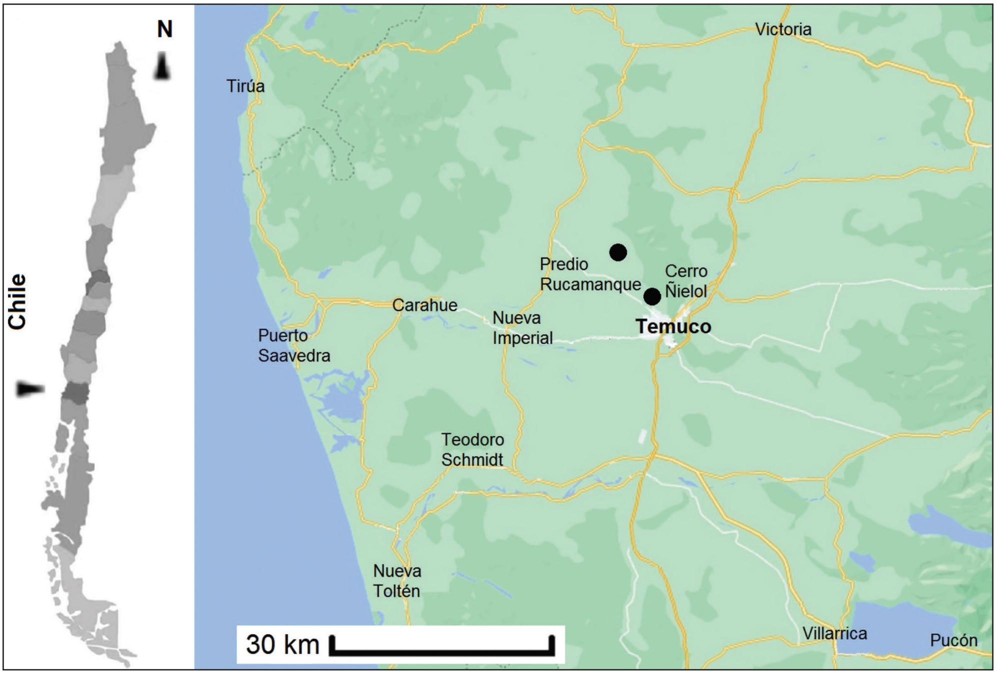

Figure 1. Study area. Sampling sites are highlighted with black dots
1. ábra A vizsgálati terület. A mintavételi helyeket fekete pontok jelölik

cover (U=255,48, P=0.028), litter (U=0, P<0.0001) and dead wood (U=107, P=0.026). However, the two sites did not show significant differences with respect to herbaceous vegetation cover (U=226, P=0.170).

During the period from April to December 2018 (fall, winter and spring in the southern hemisphere), point count method with a fixed radius of 50 m were carried out at both sites (Bibby *et al.* 1992), consisting of counting individuals of the different species through listening and observation stations in 50 m wide. These counts were performed fortnightly during the mornings (07:00 to 13:00 hrs.) and carried out within 4 minutes, after a waiting period of 3 minutes. Four recording stations were considered for each site. The acoustic identification of the birds was based on Egli (2006), and the nomenclature established by Jaramillo (2005).

The data for each site were expressed as the percentage representation of each species by site and season (Estades 1994, Zúñiga 2014), which allows to establish dominance for each case. The diversity at each site was calculated with the Shannon index (Shannon 1948), maximum diversity (Morin 2011) and evenness (Pielou 1966) for each season. To compare the diversity between stations in each locality, the procedure of Hutchenson (1970) was used, which was also applied to compare the effect of each station between both localities. To avoid the occurrence of type I error as a consequence of multiple comparisons, the Bonferroni procedure (Holm 1979) was performed. At each site, to evaluate the effect of seasonality on species abundance, the Kruskal-Wallis test was used (Quinn & Keough 2002). The effect of site at each season was examined using Mann-Whitney tests (Quinn & Keough 2002). Additionally, the community similarity was assessed in each season using the Bray-Curtis index (Odum 1950), which where performed with Biodiversity Profesional beta software (Mc Aleece *et al.* 1997).

To determine the effect of seasonality on trophic guilds, the composition of each group was compared across these periods. In this way, each registered species was represented within a particular guild, which is comprised of insectivores, granivores, omnivores and carnivores (Estades 1994, Rozzi *et al.* 1996). The importance of each guild in the different seasons was estimated using the Levins index (Levins 1968, Zúñiga *et al.* 2020), and its standardization was obtained through the index by Colwell and Futuyma (1971), due to the eventual inequality in the representation of species through the seasons. This index varies between 0 and 1, according to homogeneity in species composition. Their comparison was made using the Hutchenson procedure (Hutchenson 1970). All analyses (except Bray-Curtis index) were performed with XLSTAT trial version.

Results

During the total sampling effort of 672 minutes, a total of 28 species were observed, of which 27 were registered in Cerro Ñielol and 20 in Rucamanque (57.14% of shared species), with different representation through seasons (Kruskal-Wallis test) (*Table 1)*. It is highlighted that in Cerro Ñielol 11 species presented significant differences in their abundances among the sampled seasons, compared to the 9 in Rucamanque *(Table 1)*. However, when seasonality was compared between sites, 9, 6 and 10 species were obtained with significant

Table 1. Percentage representation of bird species in different stations in the two sampled locations (F: fall; W: winter; S: Spring). Statistic values of Kruskal-Wallis tests (H) is indicated, the statistical significance (p), and the guild to which each species belongs. In bold, the cases where there was statistical significance are indicated. C: carnivorous; G: granivorous; I: insectivorous; O: omnivorous

1. táblázat A madárfajok százalékos aránya a különböző területeken a két mintavételi helyen (F: ősz; Ny: tél; S: tavasz). A Kruskal-Wallis tesztek statisztikai értékeit (H), a statisztikai szignifikanciát (p) és a guildet is jeleztük, amelyhez az egyes fajok tartoznak. Félkövéren szedve azokat az eseteket tüntettük fel, ahol statisztikailag szignifikáns eredményt kaptunk. C: ragadozó; G: magevő; I: rovarevő; O: mindenevő

Site	Cerro Ñielol					Rucamanque				
Sspecies	F	W	S	H	p	F	W	S	H	p
	%	%	%			%	%	%		
Anairetes parulus (I)	–	–	1.38	4.50	0.105	–	–	–	–	–
Aphrastura spinicauda (I)	2.89	2.66	6.94	0.42	0.807	3.05	5	3.44	6.03	**0.048**
Caracaras chimango (C)	0.72	2.66	–	6.33	**0.042**	–	–	–	–	–
Cinclodes patagonicus (I)	0.72	1.33	0.69	7.62	**0.027**	3.05	2	–	4.75	0.093
Colaptes pitius (I)	0.72	4	–	6.72	**0.035**	–	1	–	7.71	**0.021**
Columba araucana (G)	2.17	6	2.77	6.06	**0.048**	1.52	–	6.03	7.71	**0.021**
Curaeus curaeus (O)	–	0.66	–	4.50	0.105	–	–	2.58	–	–
Diuca diuca (G)	5.07	5.33	1.38	5.74	0.057	1.52	–	10.34	7.714	**0.021**
Elaenia albiceps (O)	–	–	2.08	4.50	0.105	–	–	4.31	7.714	**0.021**
Eugralla paradoxa (O)	6.52	4.66	–	6.72	**0.035**	1.52	10.99	6.03	5.992	**0.050***
Glaucidium nana (C)	–	2.66	2.08	2.93	0.230	0.76	6	1.72	1.556	0.459
Lepthastenura aegithaloides (I)	–	–	–	3.20	–	–	0.99	–	3	0.223
Mimus thenca (O)	–	–	1.38	4.50	0.105	–	–	–	–	–
Nothoprocta perdicaria (O)	–	2	3.47	4.13	0.127	–	–	–	–	–
Pteroptochos tarnii (O)	6.52	10.66	0.69	4.90	0.086	15.28	6.99	12.06	3.342	0.188
Scelorchilus rubecula (O)	7.97	3.33	6.94	5.83	0.054	22.92	13.01	7.75	0.957	0.620
Sicalis luteola (G)	5.07	–	1.38	6.33	**0.042**	–	–	–	–	–
Sporagra barbatus (G)	12.31	6	9.02	7.26	**0.027**	–	–	6.03	6.82	**0.033**
Syctalopus magellanicus (O)	7.97	7.33	–	6.47	**0.039**	26.65	14	7.75	4.118	0.128
Sylviorthorhynchus desmursii (I)	–	–	–	–	–	1.52	1	–	4.935	0.085
Sturnella loyca (O)	1.44	1.33	1.38	5.54	0.063	2.29	–	–	4.571	0.102
Tachycineta leucopyga (I)	3.62	4	6.94	4.14	0.126	–	3	3.44	5.534	0.063
Troglodytes aedon (I)	5.79	7.33	13.19	5.88	0.053	1.52	11	14.65	5.907	0.052
Theristicus caudatus (C)	5.79	1.33	8.33	6.77	**0.034**	–	–	–	–	–
Turdus falcklandii (Om)	2.89	6	11.80	5.69	0.058	9.16	10	12.06	6.167	**0.046**
Vanellus chilensis (O)	5.79	6.66	–	4.18	0.123	–	–	–	–	–
Xolmis pyrope (I)	6.52	6	0.69	6.00	**0.050**	7.64	11	1.72	4.068	0.131
Zonotrichia capensis (G)	9.42	8	17.36	7.20	**0.027**	1.52	3.99	6.03	6.085	**0.048**

Table 2. Effect of seasonality over the abundance of species at each site. Statistical values of Mann-Whitney tests (U) and statistical significance (p) are indicated. Significant differences are marked in bold

2. táblázat A szezonalitás hatása a fajok egyedszámára az egyes helyszíneken. A Mann-Whitney tesztek statisztikai értékeit (U) és a statisztikai szignifikanciát (p) tüntettük fel. A jelentős eltéréseket félkövérrel jelöltük

Species	Fall		Winter		Spring	
	U	p	U	p	U	p
Anairetes parulus	–	–	–	–	1.50	0.121
Aphrastura spinicauda	3	0.487	7	0.275	4	0.827
Caracaras chimango	0	0.053	9	**0.037**	–	–
Cinclodes patagonicus	0	**0.034**	3.50	0.653	7.50	0.121
Colaptes pitius	3	0.317	1	0.105	–	–
Columba araucana	5.50	0.637	1.50	0.121	0	**0.046**
Curaeus curaeus	–	–	7.50	0.121	–	–
Diuca diuca	0	**0.046**	9	**0.037**	9	**0.043**
Elaenia albiceps	–	–	–	–	5.50	0.658
Eugralla paradoxa	5	0.796	5.50	0.658	9	**0.037**
Glaucidium nana	6	0.317	7	0.246	7.50	0.114
Lepthastenura aegithaloides	–	–	7.50	0.121	–	–
Mimus thenca	–	–	–	–	7.50	0.121
Nothoprocta perdicaria	–	–	7.50	0.121	3	0.317
Pteroptochos tarnii	8.50	0.077	8	0.105	9	**0.046**
Scelorchilus rubecula	9	**0.046**	6.50	0.369	9	**0.046**
Sicalis luteola	9	**0.037**	–	–	1.50	0.121
Sporagra barbatus	9	**0.037**	0	**0.046**	9	**0.046**
Syctalopus magellanicus	9	**0.050**	9	**0.046**	9	**0.043**
Sylviorthorhynchus desmursii	6	0.317	9	**0.034**	–	–
Sturnella loyca	1	0.105	6	0.317	0	**0.034**
Tachycineta leucopyga	0	**0.037**	2	0.197	1	0.105
Troglodytes aedon	0	**0.043**	4.50	1	8.50	0.072
Theristicus caudatus	9	**0.037**	9	**0.034**	0	**0.034**
Turdus falcklandii	6.50	0.369	7	0.246	6	0.487
Vanellus chilensis	7.50	0.121	9	0.034	–	–
Xolmis pyrope	1	0.105	6	0.507	5.50	0.637
Zonotrichia capensis	0.50	0.072	0.50	0.072	0	**0.046**

differences for fall, winter and spring, respectively *(Table 2)*. Regarding the similarity in the conformation of species through seasons, the highest values were obtained between fall and winter at both sites *(Table 3)*. In contrast, spring communities showed low similarities with those of the other seasons.

In general terms, a greater diversity, as well as a higher value of maximum diversity were observed in Cerro Ñielol than in Rucamanque *(Table 4)*. However, in the case of community evenness, its value was higher in Rucamanque than Cerro Ñielol in only one season (spring). In this way, significant differences in diversity were observed when comparing the sites in all seasons (Hutchenson test, t=3.14, P=0.0019; t=4.71, P<0.0001; t=3.63, P=0.0003 for fall, winter, and spring, respectively). When the effect of the seasons on the diversity of each site was independently compared, a variety of responses were obtained. In Cerro Ñielol, no significant differences in diversity were observed among these seasons, while in Rucamanque, differences were found in two cases, when fall vs. winter and fall vs. spring were compared (Hutchenson t-test, t=8.43, t=9.11, respectively; P<0.0001 in both cases).

Table 3. Bray-Curtis similarity at both sites through the seasons sampled
3. táblázat Bray-Curtis hasonlóság mindkét területen a mintavételi évszakok során

Season	**Winter**		**Spring**	
	Cerro Ñielol	**Rucamanque**	**Cerro Ñielol**	**Rucamanque**
Fall	72.11	61.93	57.74	53.41
Winter	–	–	54.56	56.11

Table 4. Diversity (H´), maximum diversity (Hmax) and evenness (J´) of the bird assemblages in the examined seasons
4. táblázat A madárközösségek diverzitása (H´), maximális diverzitása (Hmax) és egyenletessége (J´) a vizsgált évszakokban

	H´		**Hmax**		**J´**	
	Cerro Ñielol	**Rucamanque**	**Cerro Ñielol**	**Rucamanque**	**Cerro Ñielol**	**Rucamanque**
Fall	2.70	2.18	2.94	2.70	0.91	0.80
Winter	2.82	2.43	3.04	2.77	0.93	0.87
Spring	2.58	2.55	2.99	2.70	0.86	0.94

Table 5. Diversity of the different guilds (plus standardized index) in the two study sites, through the sampled seasons.
5. táblázat A különböző guildek sokfélesége (plusz standardizált index) a két vizsgálati helyszínen, a mintavételi évszakokban

Guilds	**Fall**		**Winter**		**Spring**	
	Cerro Ñielol	**Rucamanque**	**Cerro Ñielol**	**Rucamanque**	**Cerro Ñielol**	**Rucamanque**
Insectivores	4.88 (0.76)	3.55 (0.61)	4.90 (0.78)	4.32 (0.47)	3.26 (0.45)	2.24 (0.41)
Granivores	3.73 (0.68)	2.66 (0.83)	3.90 (0.96)	1.47 (0.47)	2.58 (0.39)	3.79 (0.93)
Omnivores	5.03 (0.60)	3.87 (0.57)	6.33 (0.66)	4.76 (0.94)	3.69 (0.44)	4.86 (0.77)
Carnivores	1.24 (0.24)	1 (0)	2.77 (0.88)	1 (0)	1.47 (0.47)	1 (0)

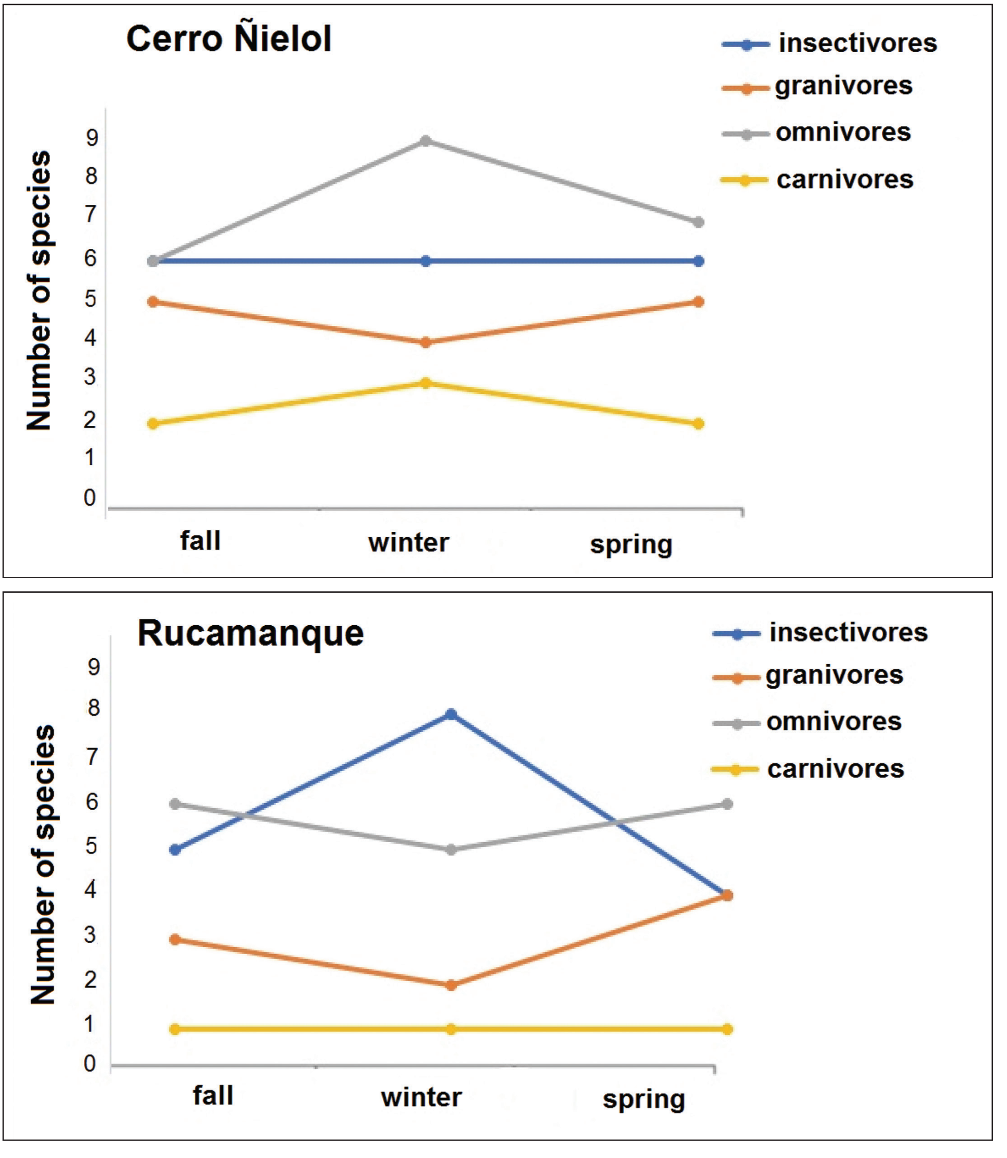

Figure 2. Variation of guilds across sampled seasons in the studied sites
2. ábra A guildek változása a mintavételi évszakok során a vizsgált területeken

Regarding the guild composition, four groups (insectivores, granivores, omnivores and carnivores) were observed, with a predominance of omnivores, followed by insectivores and granivores, respectively *(Figure 2)*. A variation in their diversity was also observed at both sites *(Table 5)*, which was reflected both locally and seasonally. Thus, a decrease in the number of granivorous species was observed in winter in both localities, with a simultaneous increase in omnivores, subsequently increasing the general species richness in spring. In Cerro Ñielol, Hutchenson's t-test yielded significant differences in the case of insectivores (fall vs. spring, t=2.55, P=0.0124), granivores (fall vs. spring, t=4.13, P<0.0001), and omnivores (fall vs. spring, winter vs. spring, t=37.00, t=4.20, respectively; P<0.0001 in both cases). In Rucamanque, significant differences were obtained for insectivores (fall vs. winter, fall vs. spring, t=44.34, t=6.56, respectively; P<0.0001 in both cases), granivores (fall vs. spring and winter vs. spring; t=10.99, t=10.30, respectively; P<0.0001 in both cases), and omnivores (fall vs. winter and winter vs. spring; t=3.73, p=0.0009; t=3.70, P=0.0003, respectively). When both localities were compared, differences were observed for insectivores (fall vs. winter, t=4.48, P<0.0001), granivores (fall vs. winter, fall vs. spring, winter vs. spring; t=10.33, t=8.58, t =5.13, respectively; P<0.0001 in both cases), omnivores (fall vs. winter and winter vs. spring; t=6.07, t=6.69, respectively; P<0.0001 in both cases) and carnivores (t=5.42, P=0.0016 for spring).

Discussion

The species richness of the assemblages at both sites was lower than that observed in forested habitats at the same latitude (Zúñiga *et al.* 2020), which reflects the restriction of plantations for their use by birds. This finding is consistent with that reported in other ecosystems (Volpato *et al.* 2010), where the community species richness and diversity in plantations are only fractions of what is experienced in the natural habitats. A remarkable fact is the predominance of generalist habitat species at both sites, whose ability to use different strata of vegetation would allow them to occupy the plantations for activities related to foraging and resting (Díaz *et al.* 2005). In this way, species with higher habitat requirements were found in low abundance, as well as in the limits of the points where the sampling was carried out, which shows that they would use the plantations in a marginal way. Despite the above, at both sites, the species richness was higher than reported in *Pinus radiata* plantations of similar age (Estades 1994), whose management involved significant removal of the shrub cover. This coverage would facilitate the expansion of niches for birds, reported in other locations (Friend 1982, Luck & Korodaj 2008). Moreover, nesting peculiarities of some species demonstrate the existence of requirements associated with both the structural complexity of the vegetation and the floristic diversity (Laiolo 2002), a situation that in the case of plantations is restricted. Despite the nesting records of some species in this type of environment (Estades 1999), it is necessary to assess this situation at both sites to determine if these plantations are suitable to carry out this process.

An aspect of special consideration at both sites is the matrix effect, which could explain some part of the variation in species richness (Dunford & Freemark 2005). This fact has been observed in *Pinus ponderosa* plantations in Patagonia Argentina, where the composition of bird communities would respond to the interaction of this environment with native vegetation through the landscape (Lantschner *et al.* 2008). In this sense, the greater proximity of Cerro Ñielol with the urban environment allowed the interaction of species with a greater degree of spatial and trophic flexibility (Díaz *et al.* 2005), which would increase the diversity of the assemblage. In contrast, Rucamanque is a site essentially surrounded by native forest, more linked to forest specialist birds (Díaz *et al.* 2005). Scattered shrub vegetation would be a facilitating element for this occurrence (Tomasevic & Estades 2008), which is should be considered in management plans.

The variation in the guild composition at both sites presents similarities with reports in other plantations, where winter would be the most critical season (Zúñiga *et al.* 2020), with omnivores being the least affected group. This fact would be explained by the ability of this group to use a wide spectrum of resources (Chubaty *et al.* 2013), which will add the spatial flexibility of these species by using nearby patches of habitat. The variation in the composition of insectivores at the seasonal level contrasts with that observed in other habitats of the same latitude, including plantations of *Eucalyptus* sp. (Zúñiga *et al.* 2020), where decreases in the diversity of this guild have been observed in winter. An explanation for this phenomenon would be the structural complexity resulting from its surroundings, given the age of both sites. This condition would favor the occurrence of insects through the vertical profile, thus enabling their use by birds of this guild (Poch & Simonetti 2013). One aspect to highlight is that although species with a high degree of specialization in habitat use were detected, such as *Aphrastura spinicauda* and *Lepthastenura aegithaloides* (Díaz *et al.* 2005), they only presented occasional records, which suggests a note of caution regarding their use about their preference as habitat.

The low presence of granivores at both sites is consistent with what was observed in *Eucalyptus* plantations (Zúñiga *et al.* 2020), which would be explained by the low richness of plant species that can provide seeds (Becerra & Simonetti 2020). Likewise, the low representation of carnivores in the study area could be the consequence of a sampling artifact, which minimizes their detection (Márquez *et al.* 2004). However, the high degree of vegetation closure resulted in a restriction for their occurrence due to the need for open environments for hunting activities (Pavez 2004). An aspect of special consideration in Cerro Ñielol is associated with its condition as a peri-urban site, which favors the presence of dogs. There are reports that dogs decrease the diversity of birds through predation (Banks & Bryant 2007), which would generate evasive behaviors in species, thus limiting their detection. In contrast, in Rucamanque there are no dogs around the plantations, which would partially restrict this process at this site. Although dogs have been detected around Rucamanque, they have a very low frequency of occurrence, for which they would not significantly affect the population dynamics of local bird species.

In conclusion, although differences were found in the diversity of birds at both sites, the older plantation did not present the highest species richness, limiting the applicability of the hypothesis of environmental heterogeneity as a promoter of diversity. Effects associated with the spatial context, mainly around the ecological matrix, would explain part of the variation of this pattern. In this way, it is necessary to extend the study on bird assemblages on a larger spatial scale, which would allow determining the exchange of species between both environments. Furthermore, seasonality had an important effect on the configuration of the assemblage composition on a temporal scale. The quantification of the plantation resources during their productive cycle is of special relevance, as to establish effective management measures for the management of microhabitats thus facilitating the occurrence of local wildlife.

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