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SEASONAL VARIATION IN A SMALL-MAMMAL ASSEMBLAGE IN A PRIORITY SITE FOR CONSERVATION IN SOUTH-CENTRAL CHILE

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Seasonal Variation in a Small-Mammal Assemblage in a Priority Site for Conservation in South-Central Chile. Zúñiga, A. H., Andrés Muñoz-Pedreros, A., Quintana, V. — Diversity of rodents were compared in a priority site of conservation in southern-central Chile through two seasons (winter and spring). Through the use of Sherman traps, the richness and abundance of species present in both the priority site (native forest) and its adjacent habitat (commercial plantation of *Eucalyptus globulus*) was assessed. There were significant differences in terms of diversity between both habitats, the composition was significant only for the case of the native forest; however, the seasonal effect was only significant in this same habitat. The ecological aspects linked in this pattern are discussed, which involved both the particularities of the recorded species and microhabitat features in both habitats.

Key words: Forest, seasonality, trophic guild, plantation, vegetation cover.

Introduction

The change in land use, and consequently the loss of habitat, is one of the main causes of the loss of biological diversity (Vitousek et al., 1997). In Chile, replacement of the original forest cover by agroecosystems, and especially by forest plantations with exotic species (e. g., *Pinus radiata* and *Eucalyptus* spp.), has generated a great fragmentation of these ecosystems (Echeverría et al., 2006, Echeverría et al., 2008), affecting biological diversity, partially documented in some native fauna taxa (for insects, Sáiz & Salazar, 1981, Fierro et al., 2017; for small mammals, Muñoz-Pedreros & Murúa, 1989; Kelt 2001; for birds, Estades & Temple, 1999). In this way, fragmentation is the transformation of a continuous area of habitat (i. e., forests) in an anthropized landscape, which maintains “islands of original habitat” (Saunders et al., 1991; Bustamante et al., 2003), and in southern Chile, forestry expansion has been the main cause of the loss of native forests in recent decades (Echeverría et al., 2007; Aguayo et al., 2009; Lara et al., 2012).

To analyze the effect of land use change on the rodent assemblage, two aspects must be considered: (a) partitioning of resources, and (b) seasonal availability of food. Partitioning of resources implies the existence of mechanisms that prevent interspecific competition among sympatric species (Grant, 1972), for example the differentiation in the use of food and space (Price, 1978). Space plays an important role in this coexistence, where the diversity of strata in forest ecosystems allows the diversification of niches (August, 1983). For example,

sympatry between cursorial, scansorial and arboreal species has been documented in the Northern Hemisphere by various authors (e. g., M'Closkey, 1978, Jones et al., 2001). Food supply would be modulated by seasonal environmental variations, which affect the availability of plants (Rathcke & Placey, 1985) and animals (Borror et al., 1989). Therefore, a change in the niche relationships between species is expected, a situation that would be different in native forests versus forest plantations.

For the assemblage of rodents in southern Chile, the replacement of the native forest by forest plantations and agroecosystems has resulted in a structural modification of the habitat, with a compressed vegetation foliage profile and a diversity of strata concentrated in the shrub (Muñoz-Pedreros & Murúa, 1989), also altering the food supply (Muñoz-Pedreros et al., 1990; Muñoz-Pedreros, 1992). However, the aforementioned studies compare degraded native vegetation (not forests) with plantations, therefore there are very few studies in Chile that compare the diversity of rodents between native forests and plantations, contrasting it with habitat variables such as the vegetation structure (Moreira-Arce et al., 2015). The objective of this study is to determine seasonal variations (diversity and abundance) of the assemblage of rodents in native forest versus forest plantation, relating them to the diversity of strata.

Material and methods

This study was carried out in two sites: (a) Predio Rucamanque (38° 39' S, 72° 36' W), a patch of native forest, located northwest of the city of Temuco, in south-central Chile (fig. 1). It has a size of 438 ha, and it is located in the Huimpil-Nielol mountain range. Its vegetation is characterized by being of the evergreen humid forest type, which includes associations of olivillo (*Lapagerio-Aextoxiconetum punctatii*) and roble-laurelingue (*Nothofago-Perseetum*) (Ramírez et al., 1989), also finding various alien species. (b) A forestal plantation of *Eucalyptus globulus*, with seven years old and located contiguously and south of the Rucamanque forest.

During the months of June to December 2017 (winter and spring of the southern southern hemisphere), 80 collapsible medium Sherman traps baited with crushed oats were installed in both study areas, which were checked every morning. In each site (forest and *Eucalyptus* plantations), two transects of 20 traps each separated by 500 meters were arranged, which allowed the independence of records considering the home range of these target species (< 3.700 m²; Muñoz-Pedreros, 1992), and that they acted as replicas. The spatial arrangement of the traps in the form of lines allows a high perimeter / area ratio, facilitating catches (Pearson & Ruggiero, 2003).

The catch rate index was calculated (Calhoun, 1959), which considers the number of catches per species as a function of the sampling effort (number of traps/night). This index is an indicator of the abundance of the components of the small mammal assemblage. The structure of this assemblage, in each environment and season, was characterized by α (intra-environment) diversity, measured as species richness (S), and Shannon-Wiener index (Shannon, 1948), which quantifies the total diversity of a sample influenced by two basic components, species richness and evenness. The formula for this function is $H' = - \sum (p_i \times \log_2 p_i)$, where p_i is the proportion of the total number of individuals in the sample corresponding to the species. The values fluctuate between zero, when there was only one species, and the maximum (Hmax) corresponding to $\log_2 S$. Pielou

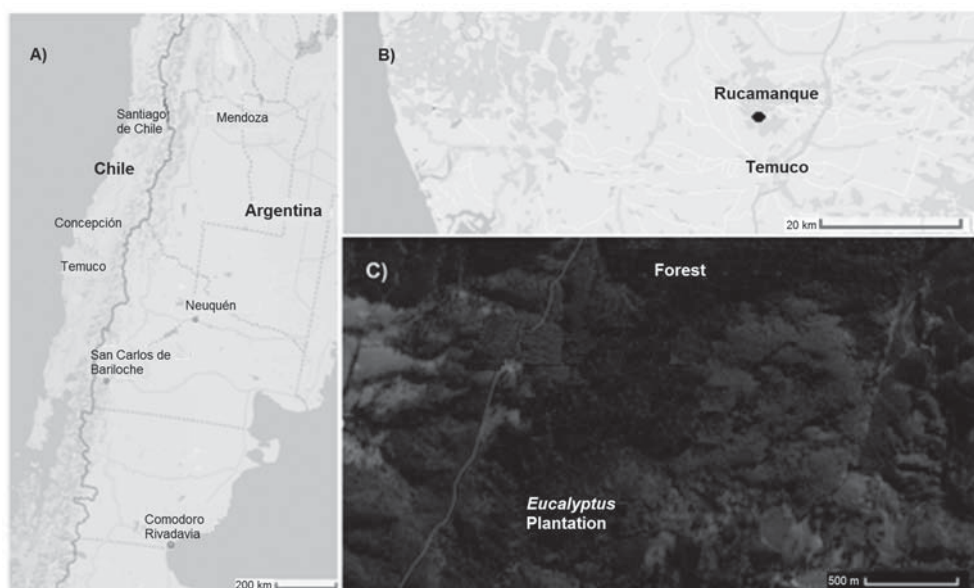


Fig. 1. Study area.

index (J') was calculated according to the equation $J = H'/H$. This index describes the evenness of a community, through the proportion of the diversity observed (H') in relation to the maximum expected diversity (H_{max}). This value fluctuates between zero (minimum heterogeneity), and one (maximum heterogeneity), where species are equally abundant (Morin, 2011). To test the null hypothesis that the H' diversity in the two environments in the two seasons of the year are equal, the Hutcheson procedure was performed (Hutcheson, 1970) described in Zar (Zar, 1996), consisting of a t test calculating the weighted diversity index $H_p = (N \log N) - (\sum f_i \log f_i) / N$, including the calculation of its variance for each environment according to $SH'^2 = [\sum f_i \log^2 f_i - (\sum f_i \log f_i)^2 / N] / N^2$. The distribution pattern of the species in each habitat and season was obtained by comparing the capture frequencies through a goodness-of-fit test (Ojeda, 1989; Sokal & Rohlf, 1995). To determine the existence of differences at the microhabitat level between the forest and the *Eucalyptus* plantation, canopy cover, herbaceous vegetation, shrub vegetation, litter and dead wood were compared, selecting 40 random points in the two habitats with a radius of 100 m², and estimating them as a percentage (Quinn & Keough, 2002). These values were compared with the frequency of rodent records obtained in winter and spring through correlation analysis (Quinn & Keough, 2002), in order to determine the variables of greatest association with the occurrence of these species.

Results

With a total sampling effort of 1600 traps / night, 62 specimens were captured (3.9 % of trapping success), with five species: three of the Cricetidae family: long-tailed mouse *Oligoryzomys longicaudatus* (Bennett, 1832), long-haired mouse *Abrothrix longipilis* (Waterhouse, 1837), olive mouse *Abrothrix olivaceus* (Waterhouse, 1837), plus two exotic and invasive species of the family Muridae, black rat *Rattus rattus* (Linne, 1758), and brown rat *Rattus norvegicus* (Berkenhout, 1769).

In winter, with a sampling effort of 800 traps / night, 37 specimens were recorded, the five species (4.6 % of capture success), of which 31 specimens were captured in native forest and six in forest plantation (two species). In spring, with the same sampling effort, 25 specimens were recorded (3.1 % of capture success), of five species, of which 20 were captured in native forest and five in forest plantations (table 1).

Oligoryzomys longicaudatus was the only native rodent in commercial plantations, where this species had a lower capture frequency in relation to the native forest. *O. longicaudatus* presented the highest representation of captures in relation to the rest of the native species in both seasons (fig. 2). *R. rattus* presented the second highest representation than in the rest of the species in winter in both habitats. In spring, this situation changed, being the frequency of captures of native species in the forest higher than the exotic rodents (fig. 2). The distribution pattern of the species presented a non-random character in the forest ($\chi^2 = 21.74$, $p = 0.0002$; $\chi^2 = 12.50$, $p = 0.0140$ for winter and forest, respectively; g.l. = 4 in both cases), while in the plantation the opposite pattern was obtained ($\chi^2 = 1.50$, $p = 0.2207$, g.l. = 1; $\chi^2 = 0.40$, $p = 0.8187$, g.l. = 2 for winter and spring, respectively).

Regarding diversity, forest presented significant differences in relation to the plantation both in winter ($T = 6.78$; $t_{0.05(2)9} = 1.83$; $p < 0.0001$) and spring ($T = 6.81$; $t_{0.05(2)214} = 1.76$; $p < 0.0001$), situation that was also appreciated when comparing the forest in both seasons ($T = 2.66$; $t_{0.05(2)45} = 1.76$; $p = 0.0108$). However, the plantation did not show differences between seasons ($T = 0.09$; $t_{0.05(2)4} = 2.13$; $p = 0.9281$).

When comparing the frequency of capture of species based on habitat, only *O. longicaudatus* presented a statistical significance, while the rest of the species did not present the same pattern. This fact was observed both in winter (Mann-Whitney test, $U = 78.50$, $p < 0.0001$; $U = 49.50$, $p = 0.145$; $U = 54$, $p = 0.066$; $U = 51$, $p = 0.290$ for *O. longicaudatus*, *A. olivaceus*, *A. longipilis*, and *R. rattus* respectively; *R. norvegicus* only had a capture in the plantation), both in spring ($U = 64.50$, $p = 0.015$; $U = 54$, $p = 0.065$; $U = 49.50$, $p = 0.145$; $U = 36$, $p = 0.539$; $U = 40$, $p = 1$ for *O. longicaudatus*, *A. olivaceus*, *A. longipilis*, *R. rattus* and *R. norvegicus*, respectively). On the other hand, it was observed that no species exhibited significant differences (in the sampling seasons, winter and spring) when comparing their frequency of records in both habitats independently.

Table 1. Number of catches per species, Diversity (H'), Maximum diversity (H_{max}) and evenness (J'), for the habitats examined in the study area in two seasons

Habitat	Forest		Plantation	
	Winter	Spring	Winter	Spring
<i>Oligoryzomys longicaudatus</i>	16	10	1	2
<i>Abrothrix longipilis</i>	5	4	0	0
<i>Abrothrix olivaceus</i>	3	3	0	0
<i>Rattus rattus</i>	6	2	5	2
<i>Rattus norvegicus</i>	1	1	0	1
Number of specimens	31	20	6	5
Richness of species	5	5	2	3
H'	1.86	1.92	0.65	1.52
H_{max}	2.32	2.32	1.00	1.58
J'	0.80	0.91	0.65	0.96

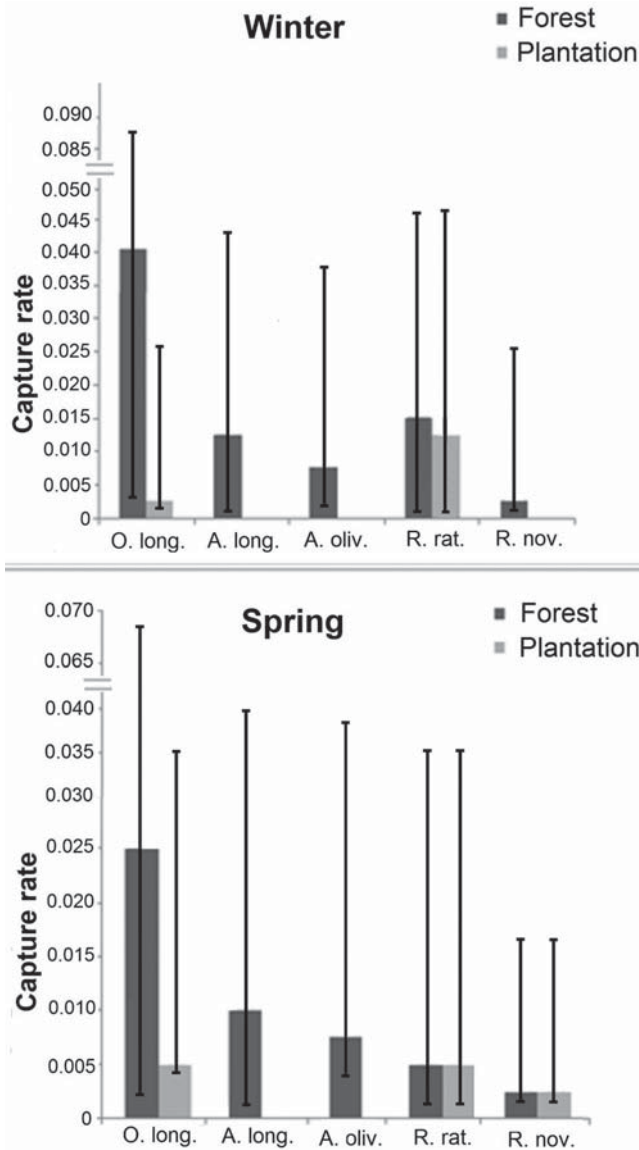


Fig. 2. Rodent capture rate (plus standard deviations) in the study area in a) winter, and b) spring: *O. long.* — *Oligoryzomys longicaudatus*; *A. long.* — *Abrothrix longipilis*; *A. oliv.* — *Abrothrix olivaceus*; *R. rat.* — *Rattus rattus*; *R. nov.* — *Rattus norvegicus*.

Regarding the structure of the existing microhabitat both in forest and plantations, significant differences were only observed in the canopy, herbaceous vegetation and litter. (Mann-Whitney test, $p < 0,0001$ in all cases; table 2). When these covers were associated with the frequency of rodent records, low correlation values were observed in general terms (table 3), highlighting the statistical significance in winter of *O. longicaudatus* for canopy ($p = 0.012$), herb ($p = 0.002$), litter ($p = 0.004$) and dead wood ($p = 0.019$), and *A. olivaceus* for canopy ($p = 0.007$). For spring, this differentiation was only observed in *A. longipilis* for canopy ($p = 0.038$), and *A. olivaceus* for shrub cover and litter ($p = 0.038$ and $p = 0.008$, respectively).

Discussion

The pattern of diversity observed in the forest is lower than that reported in other sites in the region (Muñoz-Pedrerros et al., 1990; Kelt, 2000). However, there is a contrast with *Eucalyptus* plantation, where exotic species predominated. This fact suggests a limitation on the part of *Eucalyptus* plantations to sustain the requirements of

Table 2. Mean (% + standard deviation) of the covers of the vegetation strata in the habitats sampled in the study area

Variable	Forest	Plantation
Canopy	52.57 (17.25)	12 (3.80)
Herb	3.67 (9.49)	39.60 (8.89)
Shrub	12.47 (5.08)	13.02 (2.99)
Litter	52.25 (10.73)	30.62 (8.38)
Dead wood	7.35 (2.65)	6.55 (2.35)

Table 3. Spearman correlations (ρ) obtained for the species in the area in the study, in relation to the vegetation cover

Vegetation cover	<i>O. long.*</i>		<i>A. long.**</i>		<i>A. oliv.***</i>		<i>R. rat.****</i>		<i>R. nor.*****</i>	
	W	S	W	S	W	S	W	S	W	S
Canopy	0.291	0.083	0.177	0.330	0.309	0.204	0,281	-0.158	0.033	-0.176
Herbs	-0.359	-0.131	-0.226	-0.116	-0.117	-0,214	-0,188	-0.044	-0.150	0.037
Shrub	0.032	0.039	0.131	-0.242	-0.185	0.010	-0,083	0.102	-0.022	-0.004
Litter	0.327	0.032	0.209	0.139	0.114	0.306	0,201	-0.214	0.168	-0.087
Dead wood	0.272	-0.041	0.055	0.001	-0.205	0.170	-0,026	-0.106	0.097	0.046

Note. Significant correlations are highlighted in bold characters.

O. long.* — *Oligoryzomys longicaudatus*; *A. long.* — *Abrothrix longipilis*; ****A. oliv.* — *Abrothrix olivaceus*; *****R. rat.* — *Rattus rattus*; ******R. nor.* — *Rattus norvegicus*. W — Winter; S — Spring.

rodents, due to the low diversity of plant species that the plantations harbored (Wang et al., 2011), thus resulting in a limited food supply for rodents. This situation also applies to insects, where there is information about the decrease in their diversity in *Eucalyptus* plantations (Fierro et al., 2017), which would reinforce the hypothesis of resource limitation in homogeneous environments for the case of these species. It is noteworthy the absence of in the study area the climbing mouse *Irenomys tarsalis*, and the marsupial *Dromiciops gliroides*, which has been previously detected as prey by local carnivores (Zúñiga et al., 2005; Zúñiga et al., 2008). This fact would be explained by their spatial habits, which are mainly arboreal (Kelt, 1993; Fontúrbel et al., 2010), limiting the chance of successful capture (Rau et al., 1995), because the Sherman traps, being located at ground level, would be limited in terms of the delectability of species in the other strata. However, considering that this cricetid has also been detected in other studies with this same technique (Zúñiga et al., 2021), it is necessary to consider its situation in the study area with caution, where its absence of records could be due to small population sizes.

The dominance of the assemblage in the forest by *O. longicaudatus* can be explained by its flexibility to use different microhabitats, mainly in the vertical layer of this habitat (Murúa, 1982), situation that is favored by the extensive tree cover present (Salas, 2001). Likewise, the herbivorous habits of this species are favored by the high richness of available plant species (Meserve et al., 1988; Ramírez et al., 1989; González et al. 1989), thus contributing to the selection of this habitat. On the other hand, the incursion into the plantations by this cricetid is due to sporadic forays in search of food (Murúa et al., 1986), those that would not obey some pattern of selectivity for resources. In contrast, the two recorded species of *Abrothrix* (*A. longipilis* and *A. olivaceus*), had a lower frequency of recordings in the two seasons, which is explained by their preference for open environments (Glantz, 1984), which would be mainly associated with the clearings present in the forest. The trophic generalism of these species would allow them to differentiate from *O. longicaudatus*, which food habits is based mainly on arthropods (Meserve et al., 1988; Silva, 2005), a group that is available in the forest (Fierro et al., 2011). Its absence in the *Eucalyptus* plantation contrasts with what was previously observed in *Pinus radiata* plantations (Muñoz & Murúa, 1989), where they could take advantage of the plant resources available mainly through scrubs. In this sense, the opportunistic condition that *Abrothrix olivaceus* establishes when feeding on fungi linked to *Pinus radiata* plantations is remarkable (Bozinovic & Muñoz-Pedrerros, 1995). However, this situation has not been detected in the studied plantations. In this way,

the homogeneous disposition of these resources in the case of *Eucalyptus* plantations means that their records may be of very low frequency, despite the vagility of rodents (Muñoz & Murúa, 1989).

The dominance in *Eucalyptus* plantations of *Rattus rattus*, one of the registered exotic species, would be explained by its ecological versatility, since it can be found in high population sizes in different habitats (King et al., 1996). Although this rodent can use environments with low tree cover, it could eventually make use of sites with wide vegetation cover, such as the forest, to minimize the risk of predation (King et al., 1996). Similarly, *R. norvegicus* is found both in the forest and on plantations, although in a lower proportion than *R. rattus*. This fact supposes a lower suitability to use this habitat, which refers to its greater affinity with anthropized environments (Fernández & Simonetti, 2013). Notwithstanding the above, its proximity to watercourse sites suggests that this would be a key resource for its persistence in certain habitats, so its presence in the study area would be more restricted. In general terms, it has been observed that exotic species have a high potential for invasiveness of novel environments in Chile, where native species have little affinity given their coverage requirements (Simonetti, 1989), which in contrast, has allowed exotic species to dominate these habitats progressively (Jaksic et al., 2002).

Although the species of the assemblage present relatively different food habits (Meserve et al., 1988), there may be a degree of ecological flexibility depending on the availability of the food, which suggests a greater trophic overlap in a context of scarcity. This scenario assumes that the differentiation in the use of the micro-habitats, where the morphological particularities of the species are essential for their coexistence (Vásquez, 1996). In this way, it is assumed that species such as *O. longicaudatus* partially use the tree canopy in their movements (Murúa et al., 1986), contrasting with the rest of the species observed, which are essentially cursorials. Despite this, the lack of correlation between their abundance and canopy cover could be explained by the low frequency of recordings in the *Eucalyptus* plantations. By other hand, both species of *Abrothrix* tend to occupy sites with different levels of vegetation cover, which would favor a low likelihood of interaction among them (Glantz, 1984).

In general terms, the low association of vegetation cover with the frequency of species records would be explained by the interaction of these variables, which would affect their space requirements. However, the statistical significance resulting from the comparison of three of the five covers, allows to establish the structural difference between both habitats. One aspect to consider in the selection of native forest by rodents is the use of vegetation cover as a visual obstacle against predators (Simonetti, 1989), situation that acquires relevance in the face of evidence of predation in the study area (Zúñiga et al., 2005). This fact shows a constant threat from local carnivores, as well as a selective pressure that urges rodents to use anti-predation behaviors, which would lead to the use of sites with high vegetation cover. A similar pattern has been observed in the northern hemisphere, where there is a positive relationship between the cover of shrub vegetation and the abundance of individuals (Carrilho et al., 2017), which suggests its suitability to support rodent populations. Despite the absence of statistical significance observed around the shrub cover between both habitats, the higher standard deviation of this variable in forest suggests a condition of greater heterogeneity in this habitat, where larger patches would be those that would provide greater protection against predators. This fact has been observed in *Pinus radiata* plantations in Argentine Patagonia, where the richness of shrub vegetation partially explained the abundance of local rodents (Lantschner et al., 2011).

The importance of litter as a predictor of the occupation of rodents in the forest could be explained by its use as a facilitator in the formation of nesting sites (Clark & Kaufman, 1991), where significant differences observed between both habitats would allow part of the selectivity of the species for the forest. However, the significant association of this variable

with two of the recorded species (*O. longicaudatus* and *A. olivaceus*) reports on the link between this species and the forest microhabitat, as well as its spatial habits associated with the horizontal profile of the ground (Glantz, 1984).

There are reports of the importance of dead wood as a resource facilitator for rodents due to its association with epigeal fauna, with which it is positively associated (Loeb, 1999, Ulyshen, 2016). This fact contrasts with the absence of statistical significance observed for both habitats, which would be attributable to chemical properties of dead wood from *Eucalyptus* plantations, limiting the degradation processes of organic matter (Graça et al., 2002). This situation has been reported for *Pinus radiata* plantations (Husk et al., 2001), which would partially explain its effect on plantations in the study area. However, this would constitute a hypothesis that should be tested. Being *O. longicaudatus* the only rodent with a significant association of this variable (in winter), its trophic flexibility could be considered to explain part of this pattern (Meserve et al., 1988). Thus, the changes in the availability of resources promoted by seasonality (spring) would allow a change in their interaction with the habitat, affecting their use of space.

The differences observed in the capture frequency of rodents between seasons would be explained mainly by the particularities of their reproductive dynamics (González & Murúa, 1983), which present differences throughout the year. The higher frequency of captures obtained in winter would be due to a surplus of individuals from the previous season (fall), with a remaining population of adults. This fact acquires consistency with the record in the traps of juvenile *A. longilipis* individuals in spring (Zúñiga, personal observation). However, seasonal differences in the abundance of records observed in *O. longicaudatus* could be explained by interannual patterns of great variation recorded for this rodent (Murúa et al., 1986), where the availability of resources has a strong effect. In this way, and given the restricted time horizon of field sampling, it is necessary to carry out long-term monitoring to determine the scope of these fluctuations in the study area.

As a conclusion, it was obtained that forest harbored more diversity than the *Eucalyptus* plantation throughout the two sampled seasons. Differences observed were manifested both in the number of native species (being greater in the case of the forest), and the type of dominance (by an exotic species in the plantation, however in less abundance in relation to the forest). The evaluation of its variation in a broader time frame, as well as its relationship with the availability of resources for each species is pending.

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