ZOOLOGIA 27 (1): 99–105, February, 2010

Small mammal community structure and microhabitat use in the austral boundary of the Atlantic Forest, Brazil

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ABSTRACT. We investigated the richness, composition, and species relative abundance of a terrestrial small mammal community in a Deciduous Forest area in the austral boundary of the Atlantic Forest. The microhabitat use of the most common species was also investigated. Six rodents – *Akodon montensis* (Thomas, 1913), *Oligoryzomys nigripes* (Olfers, 1818), *Sooretamys angouya* (Thomas, 1913), *Thaptomys nigrita* (Lichtenstein, 1829), *Mus musculus* (Linnaeus, 1758) and *Juliomys* sp. – and one marsupial – *Didelphis albiventris* (Lund, 1840) – were captured. *Thaptomys nigrita* is recorded in the state of Rio Grande do Sul for the first time. Species richness was poor when compared with communities in the central portions of the Atlantic Forest, but equivalent to that found in the *Araucaria* and Dense Ombrophilous forests of southern Brazil. The species most often captured in our study, *A. montensis* and *O. nigripes*, are also the most common in the majority of faunistic studies carried out in the Atlantic Forest. *Akodon montensis* and *S. angouya* used places with high abundance of bamboo, possibly to avoid predators. *Oligorizomys nigripes* used areas with a high density of scrubs, what could facilitate aboveground movements, and was negatively correlated to mature forest indicators, which reinforce the idea that this species has opportunistic habits.

KEY WORDS. *Akodon montensis*; Decidual Forest; *Oligoryzomys nigripes*; *Sooretamys angouya*.

The Atlantic Forest, one of the most threatened biomes in the world, has a high mammalian diversity and endemism (Myers *et al.* 2000). Even though remnants of the Atlantic Forest span from the state of Rio Grande do Norte, northeastern Brazil, to as far South as southern Rio Grande do Sul (Collins 1990), most faunistic studies have been carried out in the central portion of the biome, southeastern Brazil, (*e.g.,* Bonvicino *et al.* 2002, Geise *et al.* 2004, Pardini 2004, Umetsu *et al.* 2006, Püttker *et al.* 2008). Information on the austral regions of the forest is still scarce. The majority of studies that deal with the mammalian fauna of the southern portions of the Atlantic Forest are faunal surveys (Cademartori *et al.* 2002, Cáceres 2004, Cherem 2005, Scheibler & Christoff 2007). In addition, there are few studies on the demographic patterns of small mammals inhabiting the Dense Ombrophilous Forest (Graipel *et al.* 2006, Antunes *et al.* 2009) and studies on the abundance patterns (Cademartori *et al.* 2004) and microhabitat selection (Dalmagro & Vieira 2005) of mammals dispersed in the *Araucaria* Forest.

Most studies carried out in the austral Atlantic Forest have recorded four to 10 species of small mammals (Cademartori *et al.* 2002, Cáceres 2004, Cherem 2005, Dalmagro & Vieira 2005). In an austral Deciduous Atlantic Forest region, Scheibler & Christoff (2007) found an unexpectedly high species richness (15 species) particularly in abandoned agricultural fields (locally named *capoeira*), while in forest fragments only four species were recorded. By contrast, the central portions of the Atlantic Forest harbor up to 20 small mammal species per locality (Bergallo 1994, Bonvicino *et al.* 2002, Pardini & Umetsu 2006, Umetsu *et al.* 2006).

In addition to species richness, information on species composition and relative species abundance are the most basic and important data to gather on small mammal communities. Most areas of the Atlantic Forest have a few generalist species that are common and easy to capture, and a large number of species that are rare and difficult to capture (*e.g.* Bonvicino *et al.* 2002, Dalmagro & Vieira 2005, Pardini & Umetsu 2006, Scheibler & Christoff 2007). This pattern is responsible for a sampling bias that results in generalist species being recorded from almost anywhere, whereas the recorded distribution of rarer species has many gaps.

Another important ecological approach to the study of a small mammal community is the investigation of microhabitat use, a key factor in their structure (Schoener 1974). Studies on small mammals in many regions over the world have considered microhabitat use crucial in niche segregation (Dueser & Shugart 1978, Yahner 1982, Seagle 1985, Fa *et al.* 1992, Brannon 2000). In an area of Dense Ombrophilous Forest, Püttker *et al.* (2008) indicated the importance of micro-scale variation in the vegetation structure for the distribution of small mammal species in secondary forest fragments. In the *Araucaria* Forest, Dalmagro & Vieira (2005) also found significant effects of microhabitat variables on species occurrence.

In this study we investigated the richness, species composition and abundance of a terrestrial small mammal community in a Deciduous Forest located in the austral boundary of the Atlantic Forest domain, and the microhabitat use of the most common species. We focused on two main questions. (1) Are the parameters richness, species composition and species relative abundance in this community similar to those found in other communities in the Atlantic Forest? (2) Are microhabitat characteristics correlated with the occurrence of small mammal species?

MATERIAL AND METHODS

The austral Atlantic Forest consists of four main formations: the Dense Ombrophilous Forest; the Mixed Ombrophilous forest (also known as *Araucaria* Forest), dominated by *Araucaria angustifolia* (Bertol.) Kuntze pines (Araucariaceae); the Coastal Forest on marine sandy soils (Restinga Forest) and the Deciduous Forest. These forest formations bound grassland vegetation with scattered forest patches known as Campos Sulinos (Quadros & Pillar 2002).

This study was carried out in a fragment of Deciduous Forest (about 400 ha) connected to others forest areas and composed by primary and secondary forests. The study area is called Morro do Elefante by the local people. It is located 2 km away from an urban area and is used by the local population for trekking. This forest fragment is located on the hillside of the Serra Geral hills, municipality of Santa Maria, state of Rio Grande do Sul, Brazil (29°40'S, 53°43'W, Fig. 1). These hills are covered by one of the southernmost parts of the Atlantic Forest. At the base of these hills the forest is replaced by the *Campos Sulinos* grasslands. According to Machado & Longhi (1989), the arboreal vegetation of the study area is composed mainly by Leguminosae, Lauraceae, Myrtaceae and Meliaceae species.

The local climate is markedly seasonal, Cfa type, humid and subtropical, according to the Köppen classification (Moreno 1961). The mean annual temperature is 19.9ºC and the annual rainfall averages 1520 mm (Departamento de Fitotecnia; Universidade Federal de Santa Maria), according to data from a Climatic Station located at 138 m a.s.l. and 4 km from the study area. Monthly average temperatures vary between 25.9ºC in January to 14.1ºC in July, and the annual rainfall is well distributed throughout the year.

Two trapping grids (1.35 ha each) were established inside the forest at 260 and 460 m above sea level. Each grid was sampled four times (March, May, July and October 2005) during seven consecutive nights each month. Inside each grid 30 pitfall traps and 40 wire-mesh live traps were placed. For pitfalls traps, 20 buckets of 20 liters and 10 buckets of 30 liters were used. The pitfalls were set up with plastic drift fences of 6 m length, disposed as a simple line with the bucket in the center. The wire-mesh live traps, of different sizes (12x12x34, 12x11.5x24, 16.5x16.5x44 cm), were placed on the ground. The traps in each grid were arranged on seven transect lines – four transect lines with live traps interspersed by three transect lines with pitfalls. Each transect, with pitfalls or live traps, had 10 traps spaced out 10 m from each other. Traps with different sizes were disposed randomly. The distance between the transect lines was 25 m. Traps were alternately baited with bacon or pumpkin with sardine. The use of pitfalls makes possible to record species that are rarely captured with standard trapping, such as some fossorial small mammal species. The combination of the two methods is currently considered one of the best sampling approaches for studies of small mammal communities (Williams & Braun 1983, Lyra-Jorge & Pivello 2001, Umetsu *et al.* 2006).

Undetermined individuals were collected and sent to specialists for karyotypic analyses and skull and skin comparisons. Individuals that could be identified in the field were measured, marked and released in the same capture station. Voucher specimens were deposited in the Fundação Zoobotânica do Rio Grande do Sul science museum (numbers 3085 to 3188), Porto Alegre, Rio Grande do Sul, Brazil.

To investigate microhabitat use, 14 variables were measured at each trapping station. These variables were chosen to gauge forest age and conservation status, forest structure and regeneration ratio and availability of nesting and hiding sites. The variables measured were the following: average canopy height above trapping station (visually estimated by comparison with an object of known height); canopy cover above trapping station (measured with a small mirror divided in 37 squares of 1 cm^2 placed at 1.5 m height); number of trees between 10 and 20 cm of perimeter at breast height (PBH) in a 3 m radius from the center of the trapping station; number of trees between 20 and 30 cm, 30 and 50 cm and larger than 50 cm of PBH in a 3 m radius of the trapping station; number of scrubs in a transect of 6 x 2 m positioned at the center of the trapping station in an east-west orientation; number of saplings in a transect of 6 x 2 m positioned at the center of the trapping station in an east-west orientation; classes of abundance of bamboos in a 3 m radius (0 = absent, 1 = few individuals and 2 = abundant); classes of abundance of ferns in a 3 m radius (0 = absent, 1 = few individuals and 2 = abundant); sum of largest width of exposed rocks within a 3 m radius of the trapping station; sum of lengths of fallen logs with diameter >10 cm in a 3 m radius of the trapping station; weight of dry litter, collected at each trapping station in an area of 0.2 m^2; and classes of land inclination (0 = 0 to 5º, 1 = 5 to 30º and 2 = higher than 30º) measured at the trapping station.

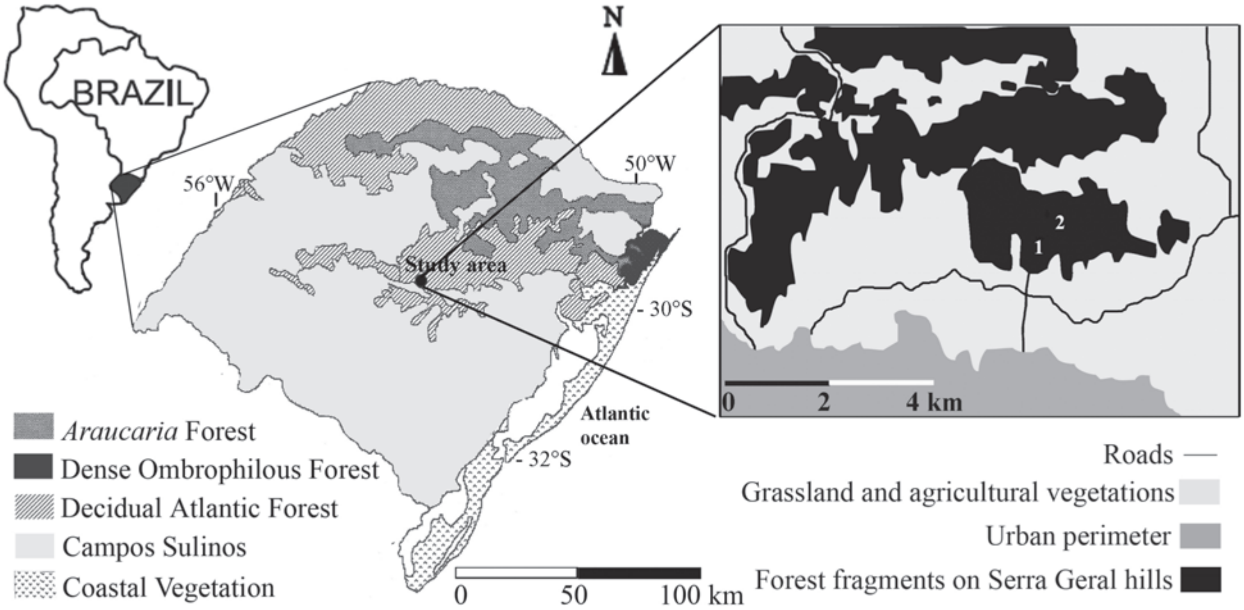

Figure 1. Location of study area in South America and in the state of Rio Grande do Sul, Brazil. The number 1 and 2 are references to the position of each trapping grid in the forest fragment studied, locally named *Morro do Elefante*.

We used the number of individuals captured for each species as a proxy of species abundance. The number of captures was also used to analyze microhabitat use by he three most frequent species (based on the first captures only, to ensure data independency). We used the number of captures of each rodent species in each trapping station instead of merely presence/absence. The correlation between animal captures in each trapping station with habitat measures in the same station was evaluated by principal component analysis (PCA), using the captures of rodents as a supplementary variable (VALENTIN 2000).

PCA aims to optimally represent objects in a new space of uncorrelated axes which are linear combinations of a set of object measures. The scores of the measures in the factorial axes express their importance for each axis and similarity in these scores can be directly interpreted in terms of correlations between variables. Supplementary variables (*e.g.* rodent captures) can be also represented with the environmental variables in the ordination space. They do not participate in the computation of the PCA and enable the characterization of supplementary variables according to their locations with respect to the main variables in the analysis. Consequently, PCA enables the comparison of a reference population (microhabitat variables) with a tested one (rodent captures).

The PCA assumes linear relationships between all variables, an assumption that is not suitable for data with a large range of variation. However the environmental variations found in this study were low, making it possible to assume linearity between the number of captures and environmental variations.

RESULTS

As a result of a total effort of 3,920 trap-nights, 142 individuals of seven species were captured: six rodents and one species of marsupial (Tab. I), corresponding to a trapping success of 3.6%. Trapping successes of pitfall and live traps were 4.05% and 3.26%, respectively. One exotic species was captured, the house mouse *Mus musculus* (Linnaeus, 1758). *Akodon montensis* (Thomas, 1913) was the most frequent species in our samples, followed by *Oligorizomys nigripes* (Olfers, 1818) and *Sooretamys angouya* (Thomas, 1913). *Thaptomys nigrita* (Lichtenstein, 1829)

Table I. Small mammal species sampled and the number of captures in live traps and pitfall traps in the Morro do Elefante, municipality of Santa Maria, southern Brazil.

Species	Live trap	Pitfall
Cricetidae		
Akodon montensis	55	36
Oligoryzomys nigripes	6	21
Sooretamys angouya	8	5
Thaptomys nigrita	–	6
Juliomys sp.	–	1
Muridae		
Mus musculus	1	1
Didelphidae		
Didelphis albiventris	2	–

is recorded in the state of Rio Grande do Sul for the first time in this study.

The first axis in the PCA ordination explained 20% of the data variance. Greater values in this axis are indicative of a forest in the mature stage, with a large number of trees, great canopy cover and abundance of litter. The amount of exposed rock was also correlated with higher values in the first axis. In the opposite direction there were land inclination and abundance of ferns. The second axis explained 14% of the data variance. Greater values for this second axis represent great abundance of saplings and scrubs and a high forest canopy. The other extremity of this axis represents abundance of bamboos and ferns. *Akodon montensis* was correlated only with the second axis, mainly associated with the abundance of bamboos. *Oligoryzomys nigripes* was also correlated with the second axis, however in the opposite direction, positively correlated with the number of scrubs. Regarding the first axis, *O. nigripes* was negatively correlated with the mature forest indicators. *Sooretamys angouya* had similar scores on PCA axes to *A. montensis*, being negatively correlated with the second axis. However, *S. angouya* had a weaker correlation with the both axes and was positioned closer to the center of the ordination space (Fig. 2).

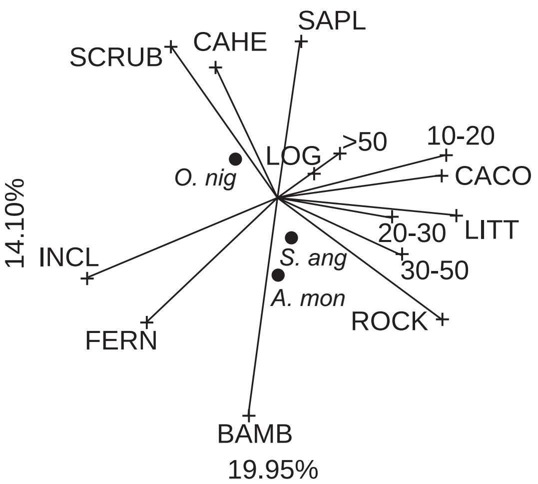

Figure 2. Principal component analysis of microhabitat variables (active variables, represented by crosses) and abundances of the three most common rodents (supplementary variables, represented by filled circles).Variable abbreviations: (10-20) number of trees between 10 and 20 cm of perimeter at breast height (PBH); (20-30) number of trees between 20 and 30 cm of PBH; (30-50) number of trees between 30 and 50 cm of PBH; (>50) number of trees larger than 50 cm of PBH; (CACO) canopy cover above trapping station; (CAHE) canopy height above trapping station; (LOG) fallen logs; (BAMB) abundance of bamboos; (FERN) abundance of ferns; (SAPL) number of saplings; (SCRU) number of scrubs; (INCL) land inclination;(LITT) dry litter; (ROCK) exposed rocks. For rodents: (*A. mon*) *A. montensis*; (*O. nig*) *O. nigripes*; and (*S. ang*) *S. angouya*.

DISCUSSION

The small mammal's species richness found in this study can be considered low for the Atlantic Forest, especially when compared with similar studies carried out in the central, northern portion of the biome (Bergallo 1994, Bonvicino *et al.* 2002, Pardini & Umetsu 2006). Our results, however, are consistent with findings for other small mammal communities in the *Araucaria* Forest (Cademartori *et al.* 2004, Dalmagro & Vieira 2005) and in the Dense Ombrophilous Forest of southern Brazil (Cáceres 2004, Cherem 2005), where four to 10 species have been recorded. A higher number of species (18 species) was reported by Scheibler & Christoff (2007) for an area of the austral Deciduous Atlantic Forest. However, since their study included a wider diversity of habitats (including cultivated and uncultivated agricultural fields), their overall results cannot be compared with surveys carried out on forest habitats alone. In forest fragments, however, the authors found only four species, a result consistent with our findings. A comparison of similar species inventories carried out in the Atlantic Forest reveals that small mammal's richness decreases along the latitudinal gradient, a pattern that has been reported for many different taxa (Stevens 1989, Kaufman & Willig 1998, Willig & Lyons 1998, Willig *et al.* 2003, Hillebrand 2004).

The native rodents with small number of captures in our data are endemic to the Atlantic Forest: *S. angouya*, *T. nigrita* and *Juliomys* sp. The first species occurs in the central (Bonvicino *et al.* 2002, Geise *et al.* 2004, Umetsu *et al.* 2006) and austral portions of the Atlantic Forest (Cáceres 2004, Cademartori *et al.* 2004, Scheibler & Christoff 2007). *Thaptomys nigrita* was recorded a few times in the central Atlantic Forest (Bonvicino *et al.* 2002, Geise *et al.* 2004, Pardini 2004, Umetsu *et al.* 2006) and in the austral Atlantic Forest (Cáceres 2004). By contrast, rodents with the greater number of captures in our study area, *A. montensis* and *O. nigripes,* occur in several biomes. Both are common species in the central and austral Atlantic Forest (Bonvicino *et al.* 2002, Geise *et al.* 2004, Dalmagro & Vieira 2005, Pardini & Umetsu 2006) and in the Cerrado biome (Lyra-Jorge & Pivello 2001). *Oligoryzomys nigripes* also occurs in the Pampas biome (Trott *et al.* 2007). Our results on number of captures corroborate the hypothesis that a positive relationship exists between species abundance and distribution range. According to this hypothesis, within a taxonomic group, locally abundant species tend to have wide ranges, whereas locally rare species tend to have restricted distribution (Brown 1984, Gaston 1996, Johnson 1998).

The relative abundance of each species expressed by the number of captures in our data is in agreement with the abundance patterns found for the same species in the central portions of the Atlantic Forest and in the *Araucaria* Forest. Bonvicino *et al.* (2002), studying areas of the central Atlantic Forest, considered *A. montensis* and *O. nigripes* as common and abundant; *S. angouya* as common but not abundant, and *T. nigrita* as both rare and not abundant. The first two species were also the most captured species in the *Araucaria* Forest (Cademartori *et al.* 2004, Dalmagro & Vieira 2005). In a Deciduous Forest area, Scheibler & Christoff (2007) also found a similar pattern, with *O. nigripes* being the most frequent species in captures, while *S. angouya* was particularly rare. In that study, *A. montensis* was not recorded, but a congeneric species, *A. paranaensis*, was the most captured. The scarcity of *Juliomys* sp.in our sampling may be due to the fact that all species of the genus are apparently rare in small mammal communities (Costa *et al.* 2007, Pardiñas *et al.* 2008). However, it is important to emphasize that sampling with small buckets and the sampling only on the ground can underestimate the abundance of certain species. Larger and/or the scansorial species may be able to jump from the bucket floor, and trapping on the ground level using standard live traps may limit the captures of scansorial species.

This study supplies the first record of *Thaptomys nigrita* in the state of Rio Grande do Sul, broadening the distributional range of this species to 650 km southwest of its previous record (Cáceres 2004). It also provides the second record of *Juliomys* (González, 2000) (first recorded in Rio Grande do Sul by Paresque *et al.* 2009) in the state. Unfortunately, it was not possible to identify the *Juliomys* specimen captured by us beyond genus. It is possible that it represents a new species, as suggested by Paresque *et al.* (2009) for three individuals captured at Aparados da Serra National Park, Rio Grande do Sul. To our knowledge, our records represent the southernmost know distribution points for *Juliomys* sp. and also for *T. nigrita*. These findings may be a function of the trapping methods we have used. These two rodents were present only in pitfall traps, which have been increasingly acknowledged as an efficient trapping method (Williams & Braun 1983, Lyra-Jorge & Pivello 2001, Umetsu *et al.* 2006) that has been rarely used in southern Brazil. Our results highlight the importance of using pitfall traps in small mammal surveys, even if small buckets are used.

Oligoryzomys nigripes and *D. albiventris* are the only species captured in our study that are known from the Pampa biome (Cerqueira 1985, Cáceres *et al.* 2007, Trott *et al.* 2007), which is further south of our sampling area. All the others small mammal species recorded here are probably near to their austral distribution limits. However, we need to be weary of drawing conclusions until we have extensive surveys in the boundaries between Pampa and Atlantic Forest.

The number of captures of *A. montensis* was positively correlated with the abundance of bamboo. In the *Araucaria* Forest, Dalmagro & Vieira (2005) had found a relationship between the abundance of this species and higher percentages of canopy cover. Since both abundance of bamboo and canopy cover tend to decrease the probability that a predator will see a small rodent, the positive association between *A. montensis* and these two parameters may be a function of predator avoidance. In Chilean temperate forests, *Akodon olivaceus* (Waterhouse, 1835) (Cricetidae) was found to be more abundant when canopy cover was dense (Múrua & González 1982), and in the central Atlantic Forest, *A. cursor* (Winge, 1887) (Cricetidae) was found more often in places with high herbaceous density near to the ground and high litter density (Gentile & Fernandez 1999). Similar results were found for other terrestrial species of rodents in different regions (Vieira *et al.* 2005, Corbalán *et al.* 2006). These studies suggest that escape from predation is an important aspect of microhabitat selection by small mammals, particularly the most terrestrial ones.

Oligoryzomys nigripes used places with high abundance of scrubs. Considering its scansorial behavior (Vieira & Monteiro-Filho 2003), it would be expected that this rodent favors places with dense understory cover, which is provided mainly by scrubs in the study area. Likewise, this species was positively correlated with vegetation density at 1 m above ground in the *Araucaria* Forest (Dalmagro & Vieira 2005) and places with dense understory in secondary Atlantic Forest remnants in southeastern Brazil (Püttker *et al.* 2008). In the same way, the scansorial rodent *Oligoryzomys longicaudatus* (Bennett, 1832) (Cricetidae), was found to favor high foliage density provided by dense understory in Chilean temperate forests (Múrua & González 1982). Another important issue is that *O. nigripes* was negatively correlated with variables that were indicators of a mature forest. This result corroborates Püttker *et al.* (2008), who found this species occurring mainly at locations with vegetation characteristic of a disturbed forest. Püttker *et al.* (2008) suggested that microhabitat preferences may be an important factor influencing the capacity of small mammals to occupy altered habitats.

Sooretamys angouya, in our data, had PCA scores very close to *A. montensis*, mainly in relation to bamboos. This is an indication that these two species use similar microhabitats. Since microhabitat does not seem to be a niche dimension in which these two species segregate, it seems reasonable to assume that there are other dimensions of niche segregation between these two species, such as diet and use of the forest strata. Species of *Akodon* are omnivorous-insetivorous (Fonseca *et al.* 1996, Campos *et al.* 2001, Giannoni *et al.* 2005, Casella & Cáceres 2006) while the rodents of "*Oryzomys*" group are omnivorous-granivorous (Fonseca *et al.* 1996, Emmons & Feer 1997). The two rodents also differ in the use of the vertical forest strata: species of *Akodon* are strictly terrestrial (Emmons & Feer 1997, Vieira & Monteiro-Filho 2003), whereas *S. angouya* is mainly scansorial (Cademartori *et al.* 2002). The small overlap in their diet and in their use of different vertical strata allows a larger overlap in microhabitat use without competitive exclusion.

In summary, relatively poor small mammal richness, when compared with the southeastern Dense Ombrophilous Forest, was documented for the area of the austral Deciduous Forest surveyed in this study. This result is consistent with data obtained for other austral communities in the *Araucaria* Forest and the Dense Ombrophilous Forest. All species recorded in our study also occur in regions of the Atlantic Forest north of the area surveyed. The most common species in our study, *A. montensis* and *O. nigripes,* were also the most common or abundant in the majority of faunistic surveys of the Atlantic Forest, and have a wider geographical range. Captures of *A. montensis* and *S. angouya* were correlated with places having an abundance of bamboo. Conversely, *O. nigripes* used areas with high density of scrubs. The two most abundant species used very different microhabitats, highlighting the importance of microhabitat use in this community. However, considering the relationship between *A. montensis* and *S. angouya* the microhabitat use does not seem to be the only factor responsible for the structure of this small mammal community.

ACKNOWLEDGEMENTS

We are indebted to our friends from the Laboratório de Ecologia de Mamíferos e Aves at UFSM for helping with fieldwork and for many useful discussions, especially Jeferson S. Arruda and Marcelo M. Weber. Alexandre U. Christoff, João A. de Oliveira and Pedro Estrela helped with the rodent identifications. Eduardo H. Giehl and Jean L. Valentin gave essential suggestions in the statistical analyses. Diogo Loretto, Jayme A. Prevedello, Pamela C. Antunes, Sandra M. Hartz and two anonymous referees provided constructive criticism which was essential to improving the manuscript. Personal grants were given by PET/SESu/MEC – Programa de Educação Tutorial for the first two authors and by Fundo de Amparo à Pesquisa do Rio Grande do Sul for VLC. NCC is CNPq's research fellow. IBAMA authorized the fieldwork under process number 021/05.

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Submitted: 24.I.2009; Accepted: 16.I.2010.
Editorial responsibility: Paulo Inácio López de Prado