

Small mammal diversity in Semi-deciduous Seasonal Forest of the southernmost Brazilian Pampa: the importance of owl pellets for rapid inventories in human-changing ecosystems

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Abstract. The Pampa biogeographic province covers a mere 2% of the Brazilian territory (176,496 km²). However, it stands out as a complex and diverse ecosystem, although its mammal communities are still scarcely understood. Human activities are transforming the territory into a mosaic of agroecosystems, native and exotic forest fragments, and grasslands. Here we conducted the first investigation to determine the richness of small mammal assemblages in the region based on extensive analyses of owl pellets (*Tyto furcata*). Craniodental remains were studied from samples collected from 12 Semi-deciduous Seasonal Forest sites in the municipality of São Lourenço do Sul, State of Rio Grande do Sul, Southern Brazil. A total of 2,617 individuals belonging to 18 taxa were recorded, including 2 marsupials (Didelphidae; 0.42%), 2 chiropterans (Molossidae, Phyllostomidae; 0.12%), and 14 rodents (Cricetidae, Muridae, Caviidae; 99.46%). The rodent genera *Oligoryzomys*, *Mus*, *Calomys*, and *Akodon* were the most common taxa. Large samples also included poorly known taxa, such as the cricetids *Bibimys*, *Juliomys* (recording here its southernmost occurrence), *Lundomys*, and *Wilfredomys*. From a biogeographical point of view, the recorded assemblage embraces a mixture of Platan, Pampean, and Atlantic Forest elements, highlighting the role of the southernmost Brazilian hills as a wedge favoring the penetration of forest micromammals to higher latitudes. Our findings testify to the great diversity of the Pampa, but also point to a growing homogeneity and dominance of rodent species that are widespread in agroecosystems. Rapid inventories based on owl pellets emerge as a suitable, economic, non-invasive tool to document these community changes.

Key-Words. *Bibimys*; *Juliomys*; *Lundomys*; *Tyto furcata*; *Wilfredomys*.

INTRODUCTION

The Pampa biogeographic province extends from the southern half of the State of Rio Grande do Sul (RS, hereafter) in Brazil across the whole of Uruguay to Central Argentina (Morrone, 2001). In Brazil, the Pampa is one of the smallest biomes, covering an area of 176,496 km², which corresponds to 2.07% of the national territory (IBGE, 2004a). Although dominated by grasslands and largely treated as a non-forest ecosystem (Overbeck *et al.*, 2015), the Brazilian Pampa also encompasses the southernmost expression of Semi-deciduous Seasonal Forest (Belton, 1984). The latter is ar-

ranged into two blocks: The larger Southern Block (10,137.73 km²) is located on the eastern slope of the Serra do Sudeste, flanking the Patos lagoon, and the Northern Block (3,159.03 km²) is located on the southeastern Meridional Plateau. These forest environments have been almost totally converted to agroecosystems (IBGE, 2004b; Cordeiro & Hasenack, 2009). Today, the general landscape is constituted by myriad small patches of native and exotic forests and cleared areas supporting pastures or grasslands (Cordeiro & Hasenack, 2009). The few, but important, efforts directed at exploring the non-volant small mammals in these grassland-forest ecotones have revealed diverse

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communities of rodents and marsupials, while also finding disturbed habitats harbor simplified species assemblages (Luza et al., 2016).

The analysis of owl pellet samples has been considered a useful tool to inventory small mammals (e.g., Taylor, 1994; Bonvicino & Bezerra, 2003; Torre et al., 2004; Pardiñas et al., 2005; Teta et al., 2010; Meek et al., 2012; Baglan & Catzeflis, 2016; Mancini et al., 2018). In addition, it is a relatively easy and low-cost method that generates estimates of species richness that are identical or higher than those obtained by expensive traditional methods (e.g., trapping; Torre et al., 2004). Indeed, the fauna contained in owl pellets has been considered a better representation of the composition of small mammal communities on a broader spatiotemporal scale (Formoso et al., 2016; Heisler et al., 2016). In southern Brazil, few studies have utilized *Tyto furcata* (Temminck, 1827) pellets. Nonetheless, the potential of the pellets to record small mammal communities has been corroborated by the variety of species recorded and the reports of rare taxa (e.g., González et al., 1999; Scheibler & Christoff, 2007; Peters et al., 2010; Cherem et al., 2018).

Here, we studied a large sample of cranial and mandibular fragments of small mammals derived from *Tyto furcata* pellets representing Semi-deciduous Seasonal Forest faunas in the southern Pampa Biome. Our survey focused on the municipality of São Lourenço do Sul in RS, Brazil. This administrative unit is of particular relevance

because it encompasses several mammal type-localities (e.g., *Wilfredomys oenax* (Thomas, 1928), *Lutreolina crassicaudata lutrilla* Thomas, 1923, *Lasiurus enslenii* Lima, 1926) (Avila-Pires, 1994). In addition, it represents the southernmost expression of forest elements and, as such, the potential limit between the Brazilian and Patagonian mammalian subregions (Hershkovitz, 1958). Our aim is thus to contribute to the knowledge of current Pampa small mammal assemblages, including the record of poorly known taxa. In addition, we emphasize the necessity to conduct extensive and low-cost surveys as a way to explore small mammal assemblages in rapidly changing anthropogenic environments.

MATERIAL AND METHODS

The municipality of São Lourenço do Sul (SLS, hereafter) is located on the eastern slope of the Serra do Sudeste, near the coastal region of RS (Brazil). The climate is mild mesothermal, with average temperatures between 10 and 15°C, super humid, and without periods of drought (IBGE, 1978). On the 2nd and 3rd July 2018, owl pellet samples were collected from inside buildings (sheds, churches, and abandoned houses) that were used as shelters by the owl *Tyto furcata*, totaling 12 sampling sites in SLS (Fig. 1). The sites are located at altitudes of between 70 and 280 m and are within the phytoeco-

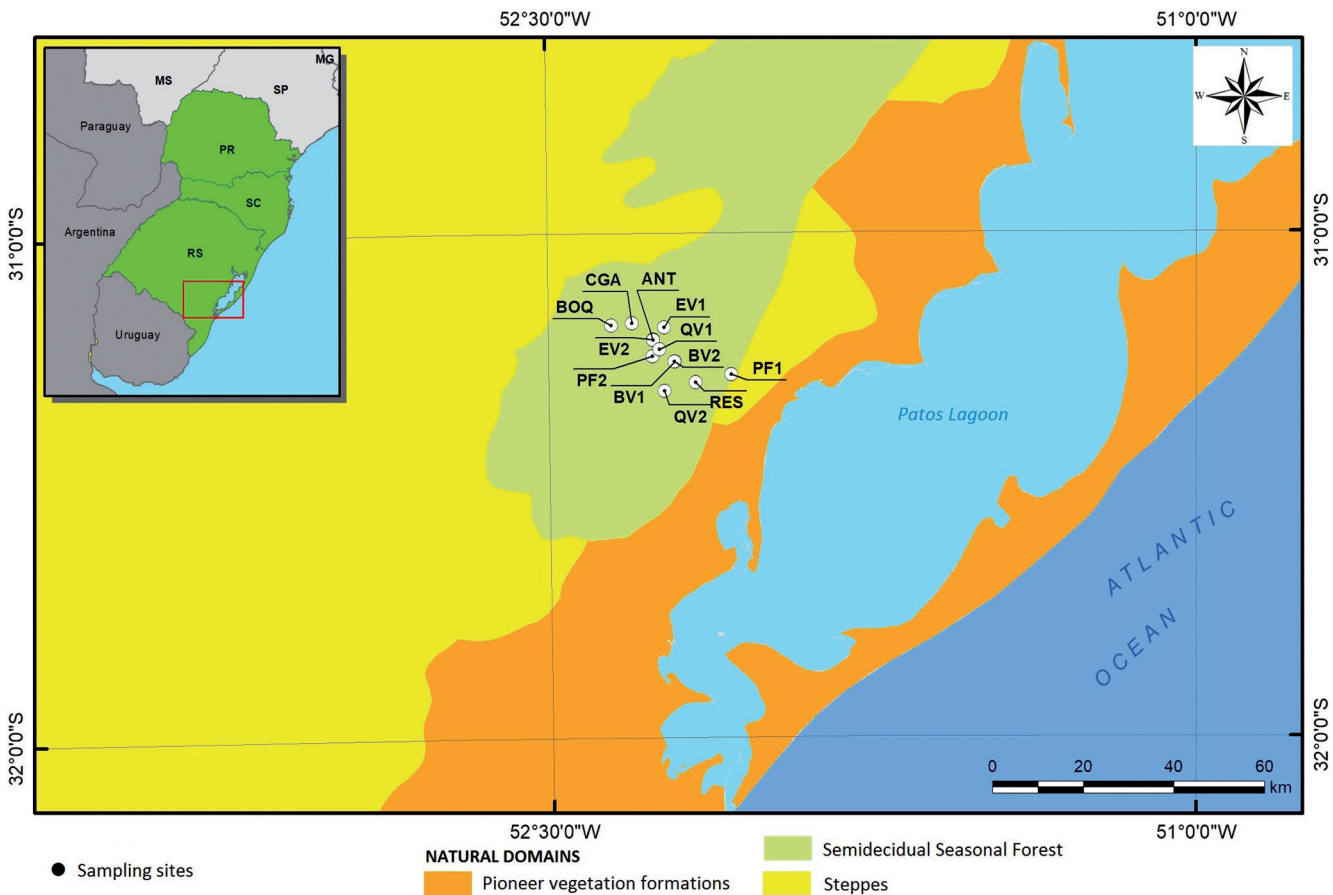


Figure 1. Location of the sampling sites of the *Tyto furcata* pellets at the Municipality of São Lourenço do Sul, State of Rio Grande do Sul, Southern Brazil. BV1 = Boa Vista I; BV2 = Boa Vista II; BOQ = Boqueirão; CGA = Canta Galo; EV1 = Evaristo I; EV2 = Evaristo II; ANT = Picada das Antas; PF1 = Picada Feliz I; PF2 = Picada Feliz II; QV1 = Quevedos I; QV2 = Quevedos II; RES = Reserva. Map modified from MMA (1992).

Table 1. Sampling sites of *Tyto furcata* pellets at the municipality of São Lourenço do Sul, State of Rio Grande do Sul, Southern Brazil. UFSC-CF = Coleção de Fragmentos Ósseos do Laboratório de Paleontologia, Universidade Federal de Santa Catarina.

Sampling Site	Abbreviation	Coordinates (WGS 84)	Catalog number
Boa Vista I	BV1	31°15'17"S, 52°12'31"W	UFSC-CF 38
Boa Vista II	BV2	31°15'18"S, 52°12'34"W	UFSC-CF 39
Boqueirão	BOQ	31°16'55"S, 52°04'39"W	UFSC-CF 35
Canta Galo	CGA	31°10'58"S, 52°21'19"W	UFSC-CF 41
Evaristo I	EV1	31°11'13"S, 52°13'58"W	UFSC-CF 40
Evaristo II	EV2	31°10'43"S, 52°18'25"W	UFSC-CF 42
Picada das Antas	ANT	31°18'48"S, 52°13'58"W	UFSC-CF 37
Picada Feliz I	PF1	31°12'39"S, 52°15'29"W	UFSC-CF 32
Picada Feliz II	PF2	31°12'46"S, 52°15'29"W	UFSC-CF 33
Quevedos I	QV1	31°14'41"S, 52°15'35"W	UFSC-CF 34
Quevedos II	QV2	31°13'51"S, 52°14'37"W	UFSC-CF 43
Reserva	RES	31°17'47"S, 52°09'38"W	UFSC-CF 36

logical region of Semi-deciduous Seasonal Forest, Pampa Biome (Leite, 2002).

The owl pellet preparation included maceration in hot water with NaClO 2% (3 ml per liter of water) over 24 hours, followed by washing with running water to remove bristles and then handpicking of the bones. The craniodental material was deposited in the Coleção de Fragmentos Ósseos do Laboratório de Paleontologia, Universidade Federal de Santa Catarina, Florianópolis (UFSC-CF), State of Santa Catarina, Brazil (Table 1). The taxonomic identification of the small mammals was made by comparison with specimens deposited in the Coleção de Mamíferos do Departamento de Ecologia e Zoologia, Universidade Federal de Santa Catarina, Florianópolis (UFSC) (see Appendix 1) and specific literature (Barquez et al., 1999; Gonçalves et al., 2007; Patton et al., 2015; Hadler et al., 2016; Stutz et al., 2017, 2018; Cherem et al., 2018). The taxonomy employed here follows Gardner (2008) for Didelphimorphia and Chiroptera, Wilson & Reeder (2005) for Muridae, and Patton et al. (2015) for the other rodents; taxonomic ordination follows Wilson & Reeder (2005). Threatened species at global (IUCN, 2019), national (ICMBio, 2018), and state (Rio Grande do Sul, 2014) levels are indicated, as are exotic invasive species (Rio Grande do Sul, 2013). The minimum number of individuals (MNI) per species and per sampling site was determined by considering the greatest number of right or left mandibles or maxillaries (Beisaw, 2013). The length of the upper molar series (LM1-M3) of the sigmodontine rodents was measured with a manual caliper with a precision of 0.02 mm. Molar abbreviations are: M1, first upper molar; m1, first lower molar; M2, second upper molar; m2, second lower molar; M3, third upper molar; m3, third lower molar.

RESULTS

The *Tyto furcata* pellets from 12 sites in SLS contained 2,617 individuals belonging to 19 small mammal taxa, including two didelphimorphian species

(Didelphidae) (Fig. 2), two chiropterans (Molossidae and Phyllostomidae) (Fig. 3), and 15 rodents (Cricetidae, Muridae, and Caviidae) (Figs. 4, 5, and 6) (Table 2). The

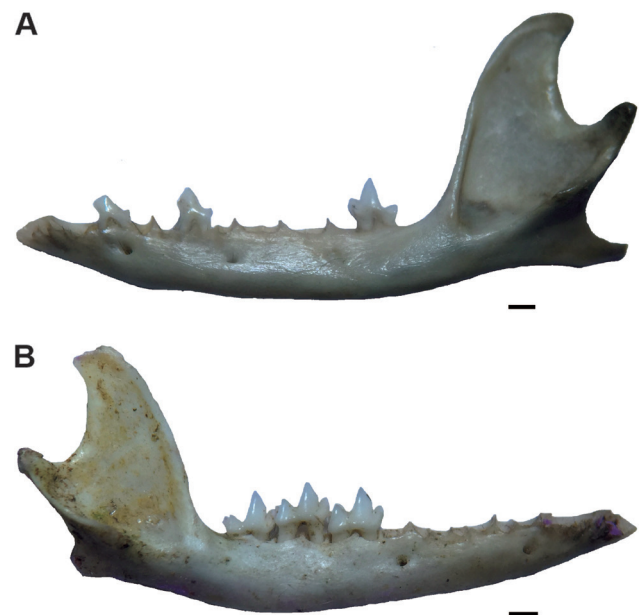


Figure 2. Didelphimorphia specimens from the *Tyto furcata* pellets from the Municipality of São Lourenço do Sul, State of Rio Grande do Sul, Brazil. (A) = labial view of the left dentary of *Cryptonanus guahybae*, UFSC-CF 32-2-1. (B) = labial view of the right dentary of *Gracilinanus microtarsus*, UFSC-CF 42-10-1. Scale bars: 1 mm.

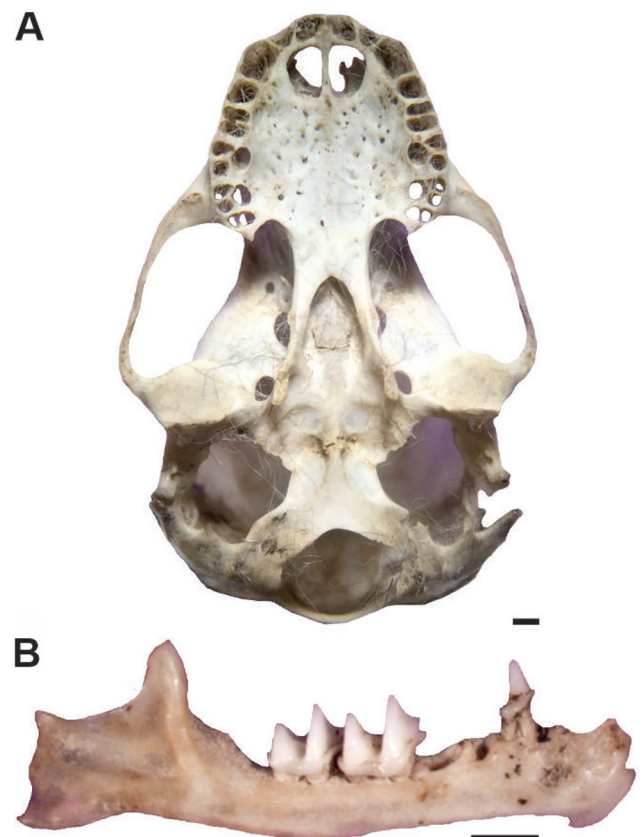


Figure 3. Chiroptera specimens from the *Tyto furcata* pellets from the Municipality of São Lourenço do Sul, State of Rio Grande do Sul, Brazil. (A) = ventral view of the skull of *Sturnira lilium*, UFSC-CF 40-5-1. (B) = labial view of the right dentary of *Tadarida brasiliensis*, UFSC-CF 42-11-1. Scale bars: 1 mm.

rodents were dominant in the samples (78.95% of the taxa and 99.46% of the individuals) and, among them, the cricetids prevailed (63.16% and 71.23%, respectively). Marsupials and chiropterans were represented by two taxa each, composing 0.42% and 0.12% of the total individuals, respectively. The greatest number of taxa

was registered at site Picada Feliz I (16 taxa), followed by Evaristo II (11 taxa), Boqueirão (9 taxa), and Quevedos II (8 taxa) (Table 2).

Mus musculus, an exotic invasive murine, was registered in all of the sites. Moreover, *Akodon* spp., *Calomys* sp., and *Oligoryzomys* sp. were registered in 11



Figure 4. Occlusal view of the upper molars of the Sigmodontine rodents from the *Tyto furcata* pellets from the Municipality of São Lourenço do Sul, State of Rio Grande do Sul, Brazil. (A) = *Akodon azarae*, UFSC-CF 43-2-1, left M1-M3. (B) = *Akodon* sp., UFSC-CF 32-4-1, left M1-M3. (C) = *Bibimys* sp., UFSC-CF 32-5-1, left M1-M3. (D) = *Calomys* sp., UFSC-CF 32-6-1, left M1-M3. (E) = *Juliomys* sp., UFSC-CF 32-7-1, left M1-M3. (F) = *Holochilus* sp., UFSC-CF 43-4-1, left M1-M3. (G) = *Oligoryzomys* sp., UFSC-CF 32-11-1, left M1-M3. (H) = *Oxymycterus* sp., UFSC-CF 32-12-1, left M1-M3. (I) = *Sooretamys angouya*, UFSC-CF 32-13-1, right M1-M3. (J) = *Wilfredomys oenax*, UFSC-CF 32-14-1, left M1-M3. Scale bars: C = 200 μ m; A, B, D, E, F, G, H, I, J = 500 μ m.

sites, being absent only in the smaller sample (Reserva). Five taxa (*Tadarida brasiliensis*, *Sturnira lilium*, *Akodon azarae*, *Juliomys* sp., and *Lundomys molitor*) occurred only in one site. *Oligoryzomys* sp. represented 52.5% of the recorded individuals, being the most frequent taxon in ten of the 12 studied sites, followed by *M. musculus* (28.28%; most frequent in Picada das Antas), *Calomys* sp. (7.64%), and *Akodon* spp. (6.07%). The other 12 taxa together represented 5.46% of the individuals. *Wilfredomys oenax*, a threatened species (“endangered” at the global level and “critically endangered” at the national and state levels), was reported for three sites (Evaristo II, Picada Feliz I, and Quevedos I).

Akodon azarae, one of the smallest Brazilian species of *Akodon*, was present in the SLS pellets, represented by a skull, one isolated maxillary, and six dentaries from the site Quevedos II. The skull possesses complete upper molar rows, measuring LM1-M3 = 3.98 mm. In addition, the specimens present an alveolar LM1-M3 = 4.04 to 4.1 mm (n = 2) and very deep anteromedian flexi/flexids, allowing their attribution to *A. azarae* following Hershkovitz (1990). The other specimens were treated as *Akodon* spp. They included maxillae with longer molar series (n = 53, LM1-M3 = 4.2 to 4.82 mm), which could be referred to *A. montensis* Thomas, 1913 (relatively shorter molar series) or *A. paranaensis* Christoff et al., 2000 or *A. reigi*

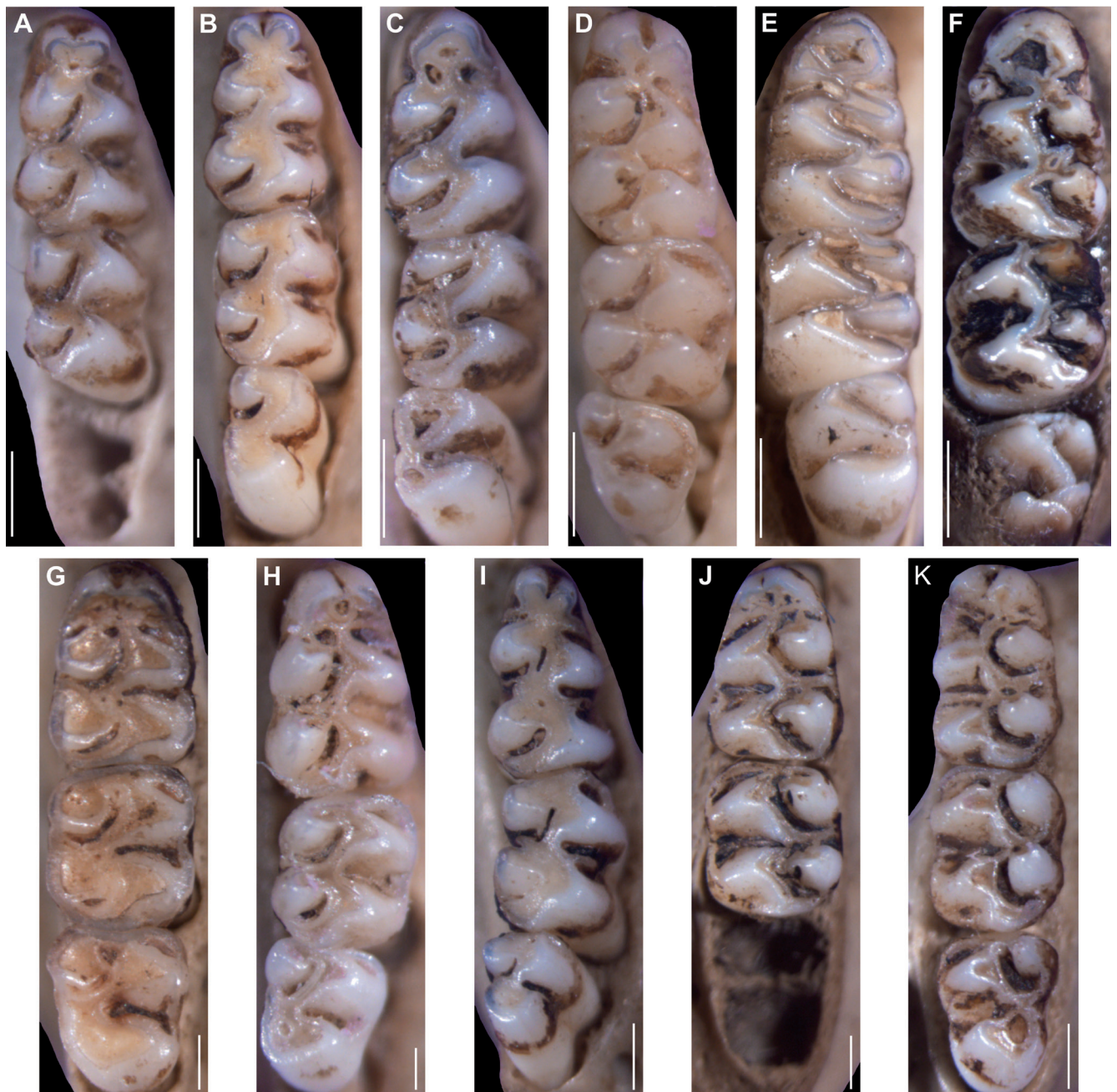


Figure 5. Occlusal view of the lower molars of the Sigmodontine rodents from *Tyto furcata* pellets from the Municipality of São Lourenço do Sul, State of Rio Grande do Sul, Brazil. (A) = *Akodon azarae*, UFSC-CF 43-2-2, right m1-m2. (B) = *Akodon* sp., UFSC-CF 32-4-2, right m1-m3; (C) = *Bibimys* sp., UFSC-CF 32-5-2, right m1-m3. (D) = *Calomys* sp., UFSC-CF 32-6-2, right m1-m3. (E) = *Holochilus* sp., UFSC-CF 43-4-2, left m1-m3. (F) = *Lundomys molitor*, UFSC-CF 32-9-1, left m1-m3. (G) = *Nectomys squamipes*, UFSC-CF 32-10-1, right m1-m3. (H) = *Oligoryzomys* sp., UFSC-CF 32-11-2, right m1-m3. (I) = *Oxymycterus* sp., UFSC-CF 32-12-2, right m1-m3. (J) = *Sooretamys angouya*, UFSC-CF 32-13-2, left m1-m2. (K) = *Wilfredomys oenax*, UFSC-CF 32-14-2, left m1-m3. Scale bars: H = 200 μ m; A, B, C, D, G, I, J, K = 500 μ m; E, F = 1 mm.

Table 2. Minimum number of individuals per taxon of small mammals registered in *Tyto furcata* pellets from the municipality of São Lourenço do Sul, State of Rio Grande do Sul, Brazil. The sites abbreviations follow Table 1.

Taxon	BV1	BV2	BOQ	CGA	EV1	EV2	ANT	PF1	PF2	QV1	QV2	RES	Total	%
Didelphimorphia														
Didelphidae														
<i>Cryptonanus guahybae</i> (Tate, 1931)			1			1		7					9	0,34
<i>Gracilinanus microtarsus</i> (Wagner, 1842)						1		1					2	0,08
Chiroptera														
Molossidae														
<i>Tadarida brasiliensis</i> (L. Geoffroy, 1824)						1							1	0,04
Phyllostomidae														
<i>Sturnira lilium</i> (E. Geoffroy, 1810)					2								2	0,08
Rodentia														
Cricetidae														
<i>Akodon azarae</i> (J. Fischer, 1829)											3		3	0,11
<i>Akodon</i> spp.	9	4	9	2	4	15	2	104	4	3	3		159	6,08
<i>Bibimys</i> sp.						2		10	1				13	0,50
<i>Calomys</i> sp.	5	5	3	5	13	21	10	122	3	3	10		200	7,64
<i>Juliomys</i> sp.								1					1	0,04
<i>Holochilus</i> sp.			1					3			3		7	0,27
<i>Lundomys molitor</i> (Winge, 1887)								1					1	0,04
<i>Nectomys squamipes</i> (Brants, 1827)						1		1					2	0,08
<i>Oligoryzomys</i> sp.	41	21	42	26	26	145	23	949	38	13	50		1374	52,5
<i>Oxymycterus nasutus</i> (Waterhouse, 1837)	1	1	4	1		4	3	51			8	1	74	2,83
<i>Sooretamys angouya</i> (G. Fischer, 1814)		1	1	1			1	3				2	9	0,34
<i>Wilfredomys oenax</i> (Thomas, 1928)						3		7		1			11	0,42
Muridae														
<i>Mus musculus</i> Linnaeus, 1758	15	20	32	4	9	22	33	564	12	2	26	1	740	28,28
<i>Rattus rattus</i> (Linnaeus, 1758)			2					5					7	0,27
Caviidae														
<i>Cavia aperea</i> Erxleben, 1777								1			1		2	0,08
MNI	71	52	95	39	54	216	72	1830	58	22	104	4	2617	100,00
Richness (small mammals total)	5	6	9	6	5	11	6	16	5	5	8	3	19	

González *et al.*, 1998 (relatively longer molar series), following Gonçalves *et al.* (2007). However, the absence of clear diagnostic characters and the fragmentary nature of the studied specimens prevent species determination.

The genus *Bibimys* was represented by a MNI = 13 in three SLS samples (Evaristo II, Picada Feliz I and II). The uncertain taxonomic status and subtle cranial traits of the three species recognized for this genus preclude reliably assigning these specimens to one particular species (Pardiñas *et al.*, 2015a, 2017a). Populations recorded in RS are referred to *B. labiosus* (Winge, 1887) (*e.g.*, Pardiñas *et al.*, 2015a; Machado *et al.*, 2016), which is a plausible hypothesis for the SLS specimens pending a revision of a more extensive set of traits (*e.g.*, molecular data).

Two species of *Calomys* are mentioned for RS: *C. tener* (Winge, 1887) and *C. laucha* (G. Fischer, 1814) (Haag *et al.*, 2007; Quintela *et al.*, 2014; González-Iltig *et al.*, 2019). The SLS specimens belonging to this genus possess a distinctively prominent supraorbital margin, large sphenopalatine vacuities, and a generally conspicuous capsular projection. These features are commonly attributed to *C. tener*. Nevertheless, the studied material also presents an M3 with a shallow hypoflexus and a "W-shaped" m3, which are reported as characteristics of *C. laucha* (Salazar-Bravo, 2015). Thus, the specific assignment of the studied material was not possible.

One specimen of the arboreal mouse *Juliomys* was registered in the Picada Feliz I sample. The generic attribution is supported by its short and broad palate and the complex morphology of the brachyodont molars, which possess a broad procingulum, well-developed antero-medial flexus, mesoloph, and developed enteroloph in M1; and an anterostyle in M2. The features preserved in this specimen do not allow its assignment to one of the three species recorded in RS, *J. ossitenuis* Costa *et al.*, 2007, *J. pictipes* (Osgood, 1933), and *J. ximenezi* Christoff *et al.*, 2016.

Holochilus and *Lundomys* are semiaquatic rats, and are also present in the SLS pellets, the former registering in three sites (Boqueirão, Picada Feliz I, and Quevedos II) and the latter in only one site (Picada Feliz I). Two species of *Holochilus* occur currently in RS, *H. brasiliensis* (Desmarest, 1819) and *H. vulpinus* (Brants, 1827), both belonging to the *H. brasiliensis* group (Pardiñas *et al.*, 2013; D'Elía *et al.*, 2015). Dental differences between these species are poorly addressed, precluding the specific assignment of the fragmentary material. The identification of *Lundomys* was based on the following features: a low coronoid process; poorly developed capsular projection (compared to *Holochilus*); masseteric crests which do not join together and which extend farther from the mentonian process than in *Holochilus*; flexi and flexids shallow-

er than in *Holochilus* and non-interpenetrating; an M1/m1 and M2/m2 with a small and distinct mesoloph/mesolophid; a procingulum divided by a small anteromedian flexus, which is absent in *Holochilus*; and an M2 with a protoflexus (Voss & Carleton, 1993).

The genus *Oligoryzomys* comprises two species in Southern Brazil, *O. flavescens* (Waterhouse, 1837) and *O. nigripes* (Olfers, 1818), which are reported as being very similar in metrics and cranial morphology (Pardiñas *et al.*, 2017b). Some characters, such as the length of the upper molar series, the length of the incisive foramen, the position of the frontal (or suprafrontal) foramen, and the development of the capsular projection on the dentary, have already been considered diagnostic for these two species (Langguth, 1963; Machado *et al.*, 2011;

Boroni *et al.*, 2015). Nevertheless, these features showed some variation in the material used for comparison (see the discussion in Cherem *et al.*, 2018). Thus, the SLS specimens were identified only as *Oligoryzomys* sp.

DISCUSSION

Semi-deciduous Seasonal Forests in the Brazilian Pampa: small mammal taxonomy

Although we uncritically referred the studied *Lundomys* material to the single species today recognized for the genus, *L. molitor* (Winge, 1887), it is important to note that the species has its type locality in Lagoa Santa, Minas Gerais, about 1,500 km northeast of SLS, where it became extinct (Voss & Carleton, 1993; Pardiñas & Teta, 2013). Today, *L. molitor* is mostly known from populations in the Uruguayan territory and three adjacent Brazilian localities (Silveira *et al.*, 2011; Voss, 2015; Brandão & Fegies, 2017). In addition, differences in molar morphology have been highlighted between the Lagoa Santa material and living samples (Pardiñas & Teta, 2011). More important to the focus of the present study, Brandão & Fegies (2017) reported subtle differential traits between individuals from SLS and Uruguay. In this context, the nominal form *Holochilus magnus*, erected by Hershkovitz (1955) with a type locality in eastern Uruguay, deserves attention for its potential value in a much needed revision of *Lundomys*.

The case of the arboreal cricetid *Wilfredomys* seems to have some parallelism with that described above for *Lundomys*. *Wilfredomys oenax*, the type and single species recognized for the genus, was described based on material collected in SLS (Thomas, 1928). This rat has a large geographic range, including most of the Uruguayan territory and also isolated enclaves in the Brazilian states of Paraná and São Paulo (González *et al.*, 2015). Vaz Ferreira (1960) highlighted differences between the type material and one specimen from Uruguay, and Pine (1980: 198) expanded these comparisons and concluded "further study may show that the Brazilian and Uruguayan populations are worthy of subspecific designation." Our knowledge about the alpha taxonomy of *Wilfredomys* is poor (Machado *et al.*, 2015), and specimens available for study are so scarce and fragmentary (Brandão, 2015) that non-geographic variation is difficult to assess (González *et al.*, 2015: 106). However, taking into account that *W. oenax* comes from the hilly surroundings of SLS, despite its geographic proximity to Uruguayan localities, environmental differences could be associated with the reported variability.

The alpha taxonomy of *Juliomys*, a small forest dweller, deserves attention, especially regarding its southernmost expressions. With the recent description of *J. ximenezi*, a new species was added to the pool of *Juliomys* species reported for the southern portion of the Atlantic Forest, totaling three forms including *J. pictipes* and *J. ossitenuis* (Christoff *et al.*, 2016). This is a striking case of sympatry because they are phenotypically very



Figure 6. Occlusal view of the upper and lower molars of the Muridae and Caviidae rodents from *Tyto furcata* pellets from the Municipality of São Lourenço do Sul, State of Rio Grande do Sul, Brazil. (A) = *Mus musculus*, UFSC-CF 32-15-1, left M1-M3. (B) = *Rattus rattus*, UFSC-CF 35-9-1, right M1-M3. (C) = *Cavia aperea*, UFSC-CF 43-8-1, left P4-M3. (D) = *M. musculus*, UFSC-CF 32-15-2, right m1-m3. (E) = *R. rattus*, UFSC-CF 35-9-2, right m1-m3. (F) = *C. aperea*, UFSC-CF 43-8-2, right p4-m3. Scale bars A, D = 200 μ m; B, C, E, F = 1 mm.

similar (Pavan & Leite, 2011), suggesting no major niche differences among them. If the diversity of the assemblage is not artifactual (*i.e.*, misidentifications), clearly a working hypothesis is needed to explain the recorded sympatry. In sharp contrast, populations of *Juliomys* in Misiones Province, Argentina, are exclusively attributed to a single species, *J. pictipes* (Pardiñas *et al.*, 2008). The material recovered in SLS, extending the southern limit of the distribution of this genus by around 250 km, could represent an important piece of information to clarify the taxonomy of *Juliomys* in its southern range. Since most of the current understanding of the alpha taxonomy of *Juliomys* is based on genetic data, the growing possibility of extracting DNA from remains retrieved from owl pellets is exciting.

The current alpha taxonomy of the rare akodontine *Bibimys*, which includes three species, is mostly based on subtle cranial and genetic differences (D'Elia *et al.*, 2005; Gonçalves *et al.*, 2005; Pardiñas *et al.*, 2015a). The Brazilian samples are traditionally referred to *B. labiosus* (see Grazzini *et al.*, 2015; Pardiñas *et al.*, 2015a), but the populations from the grasslands of southern Misiones Province (Argentina), not far from SLS, are referred to *B. chacoensis* (Pardiñas *et al.*, 2017a). The SLS record enlarges the known distribution of this genus by about 450 km to the south in Brazil, but its specific assignment needs to be strengthened; again, the possibility to extract DNA from owl pellet material seems a plausible way to do that. In addition, since SLS is about 200 km from the Uruguayan border, a future record of *Bibimys* in that country is not unlikely, taking into account the environmental continuity between southernmost RS and the Cerro Largo department (Brazeiro *et al.*, 2008).

Semi-deciduous Seasonal Forests in the Brazilian Pampa: small mammal biogeography

The SLS small mammal assemblage as revealed by the owl pellet samples studied here is composed of a mixture of species with different ecological affinities. The perceptible dominance of *Oligoryzomys* (possibly including *O. flavescens* and *O. nigripes*) reflects disturbed environments, since this genus includes opportunistic invasive species in cleared areas of the Atlantic Forest (Fonseca & Kierluff, 1989; Pardini & Umetsu, 2006; Melo *et al.*, 2011). The moderate abundance of *Calomys* (possibly including *C. laucha* and *C. tener*), typically a grassland phyllotine, seems in line with the extensive implementation of agroecosystems (Bilenca *et al.*, 1992; Courtalon *et al.*, 2003; Castellarini *et al.*, 2011). The occurrence of Pampean and high-elevation grassland elements, such as *Akodon azarae* and *Oxymycterus nasutus* (Bilenca *et al.*, 1992; Paise & Vieira, 2006; Sponchiado *et al.*, 2012; Oliveira & Gonçalves, 2015), reinforces the notion that these species are intruders favored by forest clearance. However, a small group of primarily sylvan (*e.g.*, *Gracilinanus microtarsus*, *Juliomys* sp., *Sooretamys angouya*) or scrub and perisylvan grass-associated (*e.g.*, *Bibimys* sp., *Wilfredomys*

oenax) species (Pardini & Umetsu, 2006; González *et al.*, 2015) probably represent the original core of the SLS assemblage. Fragmented populations of these mammals surely survive favored by gallery forests which normally bordered watercourses coupled with occasional patches of forest and scattered trees that covered the top of the hills. Clearly, these marsupials and rodents are penetrating into the area from more densely forested areas in the northeastern part of RS, and some of them reach their southernmost occurrences in or close to SLS (*Juliomys*, *Nectomys*, *Sooretamys*).

The SLS small mammal assemblage reflects a biogeographical mixture. Hershkovitz (1958), in his seminal contribution exploring mammal units within the Neotropics, crossed southernmost RS with the limit between Brazilian (to the east) and Patagonian (to the west) subregions. In a more focused geographical approach, González (2000) argued for the displacement of this boundary to the south, dissecting Uruguay centrally. The latter author also recognized an assemblage of Platan mammals (alluding to the Río de la Plata fluvial system), in which he included several of the rodents recorded in SLS, such as *A. azarae*, *Lundomys*, and *Wilfredomys* (González, 2000: fig. 1). In this context, the SLS assemblage could be interpreted as a mixed fauna composed of Pampean and Platan elements interpenetrated by Atlantic Forest invasive species. One of the most comprehensive studies to explore the biogeography of the Atlantic Forest was conducted by Pires *et al.* (2000) based on a cladistic analysis of the distribution of marsupials, rodents, and primates. According to their results, the southern portion of this biome is retrieved in a polytomy, revealing a poor community structure in sharp contrast to the central and northern portions. These findings suggest that these regions, where SLS and the Semi-deciduous Seasonal Forest of southwestern RS are included, support mixed ecotonal micromammal assemblages mostly infiltrated by those Atlantic Forest elements with greater ecological lability. Corroborating this, *Juliomys* sp., *Nectomys squamipes*, and *Sooretamys angouya*, and perhaps *Akodon montensis*, were recorded in SLS. *Juliomys* and *Sooretamys* were genera hitherto considered endemic to the Atlantic Forest Biome (Paglia *et al.*, 2012), while *N. squamipes*, a semiaquatic rodent, is strongly associated with this biome and the adjacent Cerrado gallery forests (Bonvicino & Weksler, 2015). *Akodon montensis* has a wider distribution, from eastern Paraguay and northeastern Argentina to the coast of Brazil (Pardiñas *et al.*, 2015b), but has been associated with a closed and dense microhabitat (*e.g.*, a higher percentage of canopy cover or abundance of bamboo) in the Brazilian Atlantic Forest Biome (Geise *et al.*, 2004; Dalmagro & Vieira, 2005; Lima *et al.*, 2010). Thus, the southeastern extension of the range of these species, penetrating into the Pampa Biome, is due to presence of the Semi-deciduous Seasonal Forest at high latitudes. A similar pattern was reported by Lima *et al.* (2010), who recorded *A. montensis*, *Juliomys* sp., and *S. angouya* in a deciduous forest area on the austral boundary of the Atlantic Forest in central RS.

Rapid inventories in human-changing ecosystems: owl pellet value

Several studies have stressed the importance of owl pellet analysis in small mammal surveys (e.g., Bonvicino & Bezerra, 2003; Formoso et al., 2016; Mancini et al., 2018), and this was also corroborated by the present work. The data obtained in SLS reveal a rich small mammal community occurring in a forested portion of the Pampa Biome in Southern Brazil, including at least 17 taxa of non-volant small mammals and two chiropterans. This is the richest owl pellet sample studied in RS to date (Cherem et al., 2018, 10 taxa; González et al., 1999, 11 taxa; Peters et al., 2010, 13 taxa; Scheibler & Christoff, 2007, 16 taxa), and one of the richest reported in South America (e.g., Baglan & Catzefflis, 2016, 12 species in coastal savannas in French Guiana; Fernández et al., 2012, 13 species in Quiñihual, Argentinean Pampa; Massoia et al., 1990, 14 species in Desaguadero, Argentinean wetlands; Brito et al., 2015, 14 species in Los Santiagos, Ecuador; Bonvicino & Bezerra, 2003, 16 species in Brazilian Cerrado; Lemos et al., 2015, 17 species in coastal Rio de Janeiro, Brazil; Mancini et al., 2018, 26 species in caves of the Caatinga, Northeastern Brazil).

Therefore, we highly recommend the analysis of owl pellet samples as an efficient, non-invasive and low-cost method to record small mammals in vast and poorly known Neotropical territories. Despite the material being fragmentary, it is possible to achieve great taxonomic resolution through comparison with specimens housed in scientific collections and the literature. Furthermore, molecular analysis could also be used to elucidate the taxonomic identity of several taxa with poorly resolved taxonomies (Buś et al., 2014; Rocha et al., 2015). An increase in morphological studies is desirable to help in the identification of the material retrieved from owl pellets.

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APPENDIX 1

List of the specimens deposited in the Coleção de Mamíferos do Departamento de Ecologia e Zoologia da Universidade Federal de Santa Catarina (UFSC) which were used for comparison with the SLS owl pellet specimens:

Cryptonanus guahybae: UFSC 4465, 4589, 4854, 5197, 5234, 5434. *Gracilinanus microtarsus*: UFSC 3851, 4857, 5951, 5893. *Marmosa paraguayana*: UFSC 4048, 4374. *Monodelphis dimidiata*: UFSC 3778, 4823, 4861, 5740. *Monodelphis iheringi*: UFSC 3797, 4585, 4607, 5436. *Monodelphis scalops*: UFSC 3780, 3915, 4056. *Akodon montensis*: UFSC 222, 288. *Akodon paranaensis*: UFSC 3628, 3631. *Brucepattersonius iheringi*: UFSC 3425, 4925. *Brucepattersonius soricinus*: UFSC 4692, 4810. *Calomys tener*: UFSC 5166, 5490. *Euryoryzomys russatus*: UFSC 4960, 4961. *Juliomys ossitenuis*: UFSC 950, 4812. *Juliomys pictipes*: UFSC 2960, 2963. *Necomys lasiurus*: UFSC 3599, 3600, 3876, 4714. *Nectomys squamipes*: UFSC 5078, 5494. *Oligoryzomys flavescens*: UFSC 3643, 4400, 4548, 4694. *Oligoryzomys nigripes*: UFSC 498, 501, 3638, 4544. *Oxymycterus dasythrichus*: UFSC 2084, 2085, 2086. *Oxymycterus nasutus*: UFSC 955, 5892, 5934. *Oxymycterus quaestor*: UFSC 4817, 5645, 5787. *Scapteromys meridionalis*: UFSC 2662, 2671, 3597, 3819. *Sooretamys angouya*: UFSC 5927, 6031. *Rattus norvegicus*: UFSC 428, 5456. *Rattus rattus*: UFSC 5565, 5749.

Erratum

In the article “**Small mammal diversity in Semi-deciduous Seasonal Forest of the southernmost Brazilian Pampa: the importance of owl pellets for rapid inventories in human-changing ecosystems**”, <http://doi.org/10.11606/1807-0205/2020.60.25>, published in the Journal **Papéis Avulsos de Zoologia**, Volume 60: 1-12, the material attributed to *Nectomys squamipes* was misidentified. The material in fact is quite large specimens of *Sooretamys angouya*. So,

In the Abstract:

Where you read:

... individuals belonging to 19 taxa were recorded,

Read it:

... individuals belonging to 18 taxa were recorded,

Where you read:

... and 15 rodents (Cricetidae, Muridae, Caviidae; 99.46%).

Read it:

... and 14 rodents (Cricetidae, Muridae, Caviidae; 99.46%).

In page 3:

Where you read:

... 2,617 individuals belonging to 19 small mammal taxa, including two didelphimorphian species (Didelphidae) (Fig. 2), two chiropterans (Molossidae and Phyllostomidae) (Fig. 3), and 15 rodents (Cricetidae, Muridae, and Caviidae)...

Read it:

... 2,617 individuals belonging to 18 small mammal taxa, including two didelphimorphian species (Didelphidae) (Fig. 2), two chiropterans (Molossidae and Phyllostomidae) (Fig. 3), and 14 rodents (Cricetidae, Muridae, and Caviidae)...

In page 5:

Where you read:

The other 12 taxa together represented 5.46% of the individuals.

Read it:

The other 14 taxa together represented 5.51% of the individuals.

Where you read:

(G) = *Nectomys squamipes*, UFSC-CF 32-10-1, right m1-m3.

Read it:

(G) = *Sooretamys angouya*, UFSC-CF 32-10-1, right m1-m3.

In page 6:

The correct Table 2 is shown below:

Pap. Avulsos Zool., 2020; v.60: e20206038

<http://doi.org/10.11606/1807-0205/2020.60.38>

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Table 2. Minimum number of individuals per taxon of small mammals registered in *Tyto furcata* pellets from the municipality of São Lourenço do Sul, State of Rio Grande do Sul, Brazil. The sites abbreviations follow Table 1.

Taxon	BV1	BV2	BOQ	CGA	EV1	EV2	ANT	PF1	PF2	QV1	QV2	RES	Total	%
Didelphimorphia														
Didelphidae														
<i>Cryptonanus guahybae</i> (Tate, 1931)			1			1		7					9	0,34
<i>Gracilinanus microtarsus</i> (Wagner, 1842)						1		1					2	0,08
Chiroptera														
Molossidae														
<i>Tadarida brasiliensis</i> (L. Geoffroy, 1824)						1							1	0,04
Phyllostomidae														
<i>Sturnira lilium</i> (E. Geoffroy, 1810)					2								2	0,08
Rodentia														
Cricetidae														
<i>Akodon azarae</i> (J. Fischer, 1829)											3		3	0,11
<i>Akodon</i> spp.	9	4	9	2	4	15	2	104	4	3	3		159	6,07
<i>Bibimys</i> sp.						2		10	1				13	0,50
<i>Calomys</i> sp.	5	5	3	5	13	21	10	122	3	3	10		200	7,64
<i>Juliomys</i> sp.								1					1	0,04
<i>Holochilus</i> sp.			1					3			3		7	0,27
<i>Lundomys molitor</i> (Winge, 1887)								1					1	0,04
<i>Oligoryzomys</i> sp.	41	21	42	26	26	145	23	949	38	13	50		1374	52,5
<i>Oxymycterus nasutus</i> (Waterhouse, 1837)	1	1	4	1		4	3	51			8	1	74	2,82
<i>Sooretamys angouya</i> (G. Fischer, 1814)		1	1	1		1	1	4				2	11	0,42
<i>Wilfredomys oenax</i> (Thomas, 1928)						3		7		1			11	0,42
Muridae														
<i>Mus musculus</i> Linnaeus, 1758	15	20	32	4	9	22	33	564	12	2	26	1	740	28,28
<i>Rattus rattus</i> (Linnaeus, 1758)			2					5					7	0,27
Caviidae														
<i>Cavia aperea</i> Erxleben, 1777								1			1		2	0,08
MNI	71	52	95	39	54	216	72	1830	58	22	104	4	2617	100,00
Richness (small mammals total)	5	6	9	6	5	11	6	15	5	5	8	3	18	

In page 8:

Where you read:

... (*Juliomys*, *Nectomys*, *Sooretamys*).

Read it:

... (*Juliomys*, *Sooretamys*).

Where you read:

Corroborating this, *Juliomys* sp., *Nectomys squamipes*, and *Sooretamys angouya*,

Read it:

Corroborating this, *Juliomys* sp., and *Sooretamys angouya*,

Where you read:

... (Paglia *et al.*, 2012), while *N. squamipes*, a semiaquatic rodent, is strongly associated with this biome and the adjacent Cerrado gallery forests (Bonvicino & Weksler, 2015).

Read it:

... (Paglia *et al.*, 2012).

In page 9:

Where you read:

... including at least 17 taxa of non-volant small mammals...

Read it:

... including at least 16 taxa of non-volant small mammals...