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6 Barn owl pellets collected in coastal savannas yield two additional species of small mammals  
7 for French Guiana.

8

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16

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19

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22

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27 Abstract:

28 A sample of 251 pellets regurgitated by the Barn owl in an old building located in Sinnamary  
29 (French Guiana) provided a rare opportunity to get a preliminary inventory of small rodents  
30 and opossums living in grassy savannas along the coastal non-forested landscapes of this  
31 Guianan region.

32 From a total of 329 specimens of vertebrate remains, we focused on 259 small rodents and  
33 opossums which could be positively identified. Two species previously unknown in French  
34 Guiana were evidenced: a very small opossum of the genus *Cryptonanus* and the medium-  
35 sized terrestrial rodent *Sigmodon alstoni*. Whereas *Cryptonanus* was an unexpected finding so  
36 far away from its Amazonian distribution area, the presence of *Sigmodon* in French Guiana  
37 fills a gap between Suriname and Brazilian Amapa where this species is typical of grassy  
38 savannas.

39 The species of small mammals most commonly preyed upon by the Barn owls of Sinnamary  
40 was a large semi-aquatic rodent, *Holochilus sciureus*, followed in decreasing order by two  
41 sigmodontines typical of non-forested ecosystems: *Oligoryzomys fulvescens* and  
42 *Zygodontomys brevicauda*.

43

44

45

46 Keywords:

47 *Cryptonanus*; *Holochilus sciureus*, *Sigmodon alstoni*; Coastal savannas; Amazonia

48

49

50 TEXT

51 The analysis of owl pellets contents is a useful tool for providing an inventory of small  
52 mammal communities especially in open habitats such as agricultural landscapes or in  
53 cerrado-like biotopes (caatinga, savannas, llanos, grassy marshes, ...) in the Neotropics  
54 (Rocha et al. 2011; Scheibler and Christoff 2007). The Barn owl (*Tyto alba* (Scopoli, 1769))  
55 is a specialized predator and most of its preys are small non-volant mammals weighting from  
56 15 to 250 grams. Several recent investigations of Barn owl pellets in Brazil and elsewhere in  
57 South America have evidenced the presence of some species of small rodents and opossums  
58 which otherwise were very rarely caught by standard trapping methods using live- or snap-  
59 traps.

60 For example, Souza et al. (2010) found two rare dwarf opossums (*Gracilinanus agilis*  
61 Burmeister, 1854; *Cryptonanus agricolai* (Moojen, 1943)) among 162 pellets collected in the  
62 Northeastern Atlantic Forest realm, and those records were new for the coastal region of  
63 Pernambuco state. Similarly, Bonvicino and Bezerra (2003) found three rare species (2 small  
64 opossums, 1 cerrado mouse) in Barn owl pellets which could not be collected with traps,  
65 suggesting that trapping “was either inefficient or was not performed near their specific  
66 microhabitats”.

67

68 This study reports on Barn owl pellets which were collected in an old water-tower in  
69 downtown Sinnamary, French Guiana (05°23' N; 52°57'W) in march 2011 ( 120 pellets) and  
70 in september 2013 (131 pellets). Sinnamary is a small city (3100 inhabitants in 2013) at ca.  
71 100 km north-west from Cayenne; it is located within the coastal northern strip of the country,  
72 where non-forested areas, such as agricultural lands, grass and bush savannas, small thickets  
73 of trees, grassy swamps and marshes, predominate. The nearest large area of well-drained  
74 tropical rainforest starts at 3-4 km south-west from the village, and extends for dozens of km  
75 towards the south (the forest locality of Paracou studied by Voss et al. (2001) is only 12 km  
76 from the Barn owl breeding site of Sinnamary). Within a radius of 3 km from the Barn owl's

77 nest, swamp areas and pastures with draining canals constitute most of the area to the north-  
78 east, whereas grass and bush savannas intermingled with small thickets dominate to the south-  
79 east. The western sides of the water-tower are a mixture of highly degraded secondary forests  
80 and of agricultural openings for pastures and various abandoned crops.

81

82 The 251 pellets were individually examined for their bony content and a total of 329  
83 vertebrate specimens were isolated. Besides birds (46 individuals), bats (3 skulls of  
84 Molossidae) and unidentified murids (21 individuals), the pellets yielded 259 small rodents  
85 and opossums which could be identified to species level in most cases. For securing the  
86 identification, we relied on comparisons with cleaned skulls of reference specimens (vouchers  
87 deposited at Paris MNHN and Geneva MHNG museums) and descriptions and drawings  
88 found in Husson (1978), Voss et al. (2001), and Voss and Jansa (2009). All skull and  
89 mandibles materials from the owl's pellets have been kept and are available for examination  
90 upon writing to the senior author. The following craniodental variables were used and are  
91 illustrated and/or defined in Voss et al. (2001) and in Carleton and Musser (1989): BR =  
92 Breadth of Rostrum; BZP = Breadth of Zygomatic Plate; LBP = Length of Bony Palate; LIB  
93 = Least Interorbital Breadth; LIF = Length of Incisive Foramen;  $M^1$ ,  $M^1M^2$ ,  $M^1M^3$  : lengths of  
94 upper molars; ZB = Zygomatic Breadth.

95 Craniodental measurements were taken with digital callipers and recorded to the nearest 0.01  
96 mm, but values reported herein are rounded to the nearest 0.1 mm. Univariate statistical tests  
97 for comparing measurements between groups included Mann–Whitney nonparametric test, as  
98 implemented by the software PAleontological STatistics (PAST: Hammer et al. 2011).

99

100 The following taxa were found in the pellets collected at Sinnamary:

101 - *Cryptonanus* sp Voss et al. 2005: 10 individuals of that very tiny opossum bring an

102 additional taxon to the mammalian fauna of French Guiana. The identification of these

103 remains (mandibles were almost complete, whereas skulls were highly damaged and resumed

104 to the maxillary, palatine and jugal bones) was kindly established by Robert S. Voss (AMNH,  
105 New York).

106 The upper molars measurements for 7 adult (all 4 upper molars definitive and erupted)  
107 individuals are (mean, minimum, maximum) :  $M^1$  1.5 (1.3 to 1.5);  $M^1M^2$  2.8 (2.8 to 3.0);  
108  $M^1M^3$  4.2 (4.1 to 4.4);  $M^1M^4$  4.8 (4.6 to 4.8); width of  $M^4$  (measured as in Voss and Jansa  
109 2009) 1.9 (1.7 to 2.0).

110 The Sinnamary specimens of *Cryptonanus* appear smaller than *C. agricolai*, as judged by  
111 comparing  $M^1M^3$  and  $M^1M^4$  lengths values detailed in Voss et al. (2005: Table 5).

112 We refrain from naming to species level our pellets-derived materials of *Cryptonanus* sp.,  
113 pending future analysis on complete vouchered animals that has been recently acquired (two  
114 adults weighing 14.5 and 15.5 g: unpublished data).

115

116 - *Marmosa murina* (Linnaeus, 1758): 7 individuals, whose upper molars measurements are as  
117 follows:  $M^1M^2$  3.7 (3.5 to 4.0);  $M^1M^3$  5.6 (5.1 to 6.0);  $M^1M^4$  6.6 (6.3 to 7.1). Adult *M. murina*  
118 weigh ca 41 g (average of 39 individuals caught in French Guiana – unpublished materials).

119

120 - *Philander opossum* (Linnaeus, 1758): 1 juvenile (only 1. and 2. upper molars erupted) :  $M^1$   
121 = 3.8;  $M^1M^2$  = 7.8; *P. opossum* weighs ca. 220 g at that age (unpublished data).

122

123 - *Holochilus sciureus* Wagner, 1842: this large (adult animals of Guyana average 157 g:  
124 Twigg 1965) sigmodontine rodent was the most frequent prey of *Tyto alba* at Sinnamary, with  
125 106 individuals (41 % of all 259 rodents and opossums), most of them being adults (as  
126 defined by having three fully erupted molars). The recognition of skull remains of *Holochilus*  
127 *sciureus* from similar-sized *Nectomys rattus* (Pelzeln, 1883) is straightforward if molars are  
128 still present, as their dental pattern is quite different (see page “A Sampler of Sigmodontine  
129 molars” in Myers et al. 2014). When upper molars are lacking (as was the case in 12 skulls),  
130 the recognition of *Holochilus* from *Nectomys* can be easily reached by measuring the Least

131 Interorbital Breadth (LIB), as already shown by Husson (1978) for Surinamese animals. In  
132 French Guiana, *Holochilus sciureus* have LIB values smaller than 5.4 mm whereas *Nectomys*  
133 *rattus* skulls are larger than 6.1 mm for that measurement (Table 1).

134

135 - *Nectomys rattus*: this large (average weight of 177 g for 23 adults in French Guiana:  
136 Catzefflis 2012) terrestrial rodent was represented by 26 individuals (10 %) and was ranked  
137 second after *Holochilus* when biomass was considered. See above for *Holochilus* concerning  
138 the identification of *Nectomys*.

139

140 - *Oligoryzomys fulvescens* (Saussure, 1860) was ranked second for its occurrence (59  
141 individuals, or 23 %) but its contribution to the diet of *Tyto alba* was less than 4% of the total  
142 biomass, as this terrestrial oryzomyine weighs ca 17 g (average for 7 adults caught in French  
143 Guiana). The identification of this taxon was based upon dental and skull characters described  
144 and illustrated in Carleton and Musser (1989). We also compared the values of some selected  
145 craniodental measurements (Table 2) in Sinnamary pellets with those measured in vouchered  
146 specimens from French Guiana (housed at MNHN and MHNG museums).

147

148 - *Sigmodon alstoni* (Thomas, 1881): two individuals of this terrestrial sigmodontine bring an  
149 additional taxon to the mammalian fauna of French Guiana. The identification of this  
150 medium-sized (average weight is 61.5 g in Venezuela: Vivas 1986) species is straightforward  
151 due to its peculiar upper incisives which are broad and deeply grooved. Voss (1992) provides  
152 an excellent description together with detailed figures for the different species of *Sigmodon*,  
153 of which *S. alstoni* is the one already known in Suriname and Brazilian Amapa.

154 The following craniodental measurements characterize the 2 *S. alstoni* from Sinnamary owl's  
155 pellets: LIB 5.0 & 5.2; M<sup>1</sup>M<sup>2</sup> 4.1 & 3.9; M<sup>1</sup>M<sup>3</sup> 6.0 & 5.5; ZB 18.9 & 17.8.

156

157 - *Zygodontomys brevicauda* (J.A. Allen and Chapman, 1893): 38 individuals of this terrestrial  
158 sigmodontine were identified by comparison with reference materials of French Guianan  
159 vouchers, together with the descriptions and drawings available in Voss (1991).

160 *Zygodontomys* weigh ca 58 g (average for 52 adult specimens caught in French Guiana),  
161 therefore this species ranked third by its biomass in the diet of *Tyto alba* at Sinnamary. The  
162 following craniodental measurements are derived from 22 skull-remains : LIB  $4.9 \pm 0.3$  (4.4  
163 to 5.4) ; LIF  $6.4 \pm 0.6$  (4.7 to 7.1);  $M^1M^2$   $3.3 \pm 0.1$  (3.0 to 3.5);  $M^1M^3$   $4.2 \pm 0.1$  (4.0 to 4.4);

164

165 - *Mus musculus* Linnaeus, 1758: one single damaged skull was identified through the unique  
166 murine pattern of the upper molars, and had the following measures: LIB 3.4;  $M^1M^2$  2.7;  
167  $M^1M^3$  3.2; LIF 5.0. *Mus musculus* caught in French Guiana have an average weight of 14.0 g  
168 (average for 23 adults: unpublished data).

169

170 - *Rattus norvegicus* (Berkenhout, 1769): 6 individuals were identified through qualitative  
171 craniodental characters, and selected measurements confirmed their belonging to *R.*  
172 *norvegicus* (see pp. 382-420 in Niethammer and Krapp 1978). Average (N from 4 to 6  
173 individuals) and range of values for Sinnamary's materials are: LIB 6.5 (6.2 to 7.2);  $M^1M^2$  5.4  
174 (5.3 to 5.5);  $M^1M^3$  7.1 (7.0 to 7.2); BZP 4.5 (4.0 to 4.9). We assume that those *R. norvegicus*  
175 were not full grown adults whose weight is too large for *Tyto alba* (Husson (1978) gives ca.  
176 420 g for the average of 5 adult *R. norvegicus* from Suriname).

177

178 - *Rattus rattus* (Linnaeus, 1758): 2 individuals were identified by comparison with voucher  
179 specimens from French Guiana and by examining the characters currently in use for  
180 recognizing *R. rattus* from *R. norvegicus* in owl pellets (Corbet and Harris 1991; Niethammer  
181 and Krapp 1978). In French Guiana, *R. rattus* weighs ca. 120 g (average of 35 adult animals:  
182  $121 \pm 33$  g – unpublished data).

183



184 - *Proechimys guyannensis* (E. Geoffroy, 1803) : one single damaged skull was identified  
185 through its typical dental pattern and by comparison with voucher materials. This was an  
186 adult with all molars erupted, corresponding to a weight of ca. 190 g (Catzefflis and Steiner  
187 2000).

188

189

190 Two taxa are new for French Guiana (Catzefflis 2010; Lim 2012): *Cryptonanus* sp. and  
191 *Sigmodon alstoni*. Before the recent discovery of *Cryptonanus* in Brazilian Amapa (da Silva  
192 et al. 2013), the nearest locality for that diminutive opossum was Crato (07°14'S; 39°23'W)  
193 in Brazilian Ceara state for the species *C. agricolai* (Voss et al. 2005), that is ca. 2000 km  
194 south-east from Sinnamary. Da Silva et al. (2013) mention the capture of one specimen of  
195 *Cryptonanus* sp. in a grassy savanna landscape from south-east Amapa, in a locality along  
196 Highway BR-156 (0°05' S; 51°10' W ) near the Maraca River, that is still a distance of ca. 650  
197 km south-east from Sinnamary. In September 2013 two adult *Cryptonanus* were caught in  
198 pitfalls at Sinnamary (unpublished data of F. Catzefflis and B. de Thoisy), and those preserved  
199 animals are under study for their identification to species level.

200 The discovery of *Sigmodon alstoni* in the pellets of the Barn owl from Sinnamary should be  
201 no surprise, as the presence in French Guiana of this savanna dweller was suspected by Voss  
202 (1992) who wrote that “*alstoni* should occur in the coastal savannas there “ because at that  
203 time *S. alstoni* was known from Suriname (Husson 1978; Williams et al. 1983) and Brazilian  
204 Amapa (Carvalho 1962). This species was also recently caught in southern Amapa, in grassy  
205 savannas near Ferreira Gomes (da Silva et al. 2013). *Sigmodon alstoni* is apparently not  
206 common around Sinnamary, as only two skulls were found (less than 1% of all 259 identified  
207 small mammals), whereas the similar-sized *Zygodontomys* accounts for 15 % of the preys.

208

209 At Sinnamary, Barn owls have a large range of prey sizes, from the tiny species around 15 g  
210 (*Cryptonanus* sp.; *Mus musculus*; *Oligoryzomys fulvescens*) to the larger taxa around 250 g  
211 (juvenile of *Philander opossum*; *Proechimys cayennensis*; subadults of *Rattus norvegicus*).  
212 Four species comprise 88% of all preys and 90% of the eaten biomass: by decreasing  
213 frequency those are *Holochilus* (157 g on average), *Oligoryzomys* (17 g), *Zygodontomys* (58  
214 g), and *Nectomys* (177 g) (Table 3). Clearly, the “food value” (the energy) derived from an  
215 *Holochilus* is much higher than the one provided by an *Oligoryzomys*, and it is apparently  
216 more profitable for owls to select larger prey. With 106 individuals or 41% of all 259 prey  
217 items, *Holochilus sciureus* was apparently very common in the hunting area of the Barn owls,  
218 and it has been shown elsewhere in the Guianan Region that this rodent species might  
219 fluctuate in numbers up to high densities (Twigg, 1965). At Sinnamary, where grassy marshes  
220 and savannas are the most abundant places within a 3 to 4 km radius from downtown  
221 (unpublished data based on the examination of aerial pictures), the Barn owls secure 78 % of  
222 their consumed biomass of non-volant mammals through two species of “large”  
223 sigmodontines: *Holochilus sciureus* and *Nectomys rattus* (Table 3). But the selection of larger  
224 prey-species is not the rule everywhere, as shown by Scheibler and Christoff (2004) in agro-  
225 ecosystems of southern Brazil where *Tyto alba* preyed mostly (82% of 3618 vertebrates) upon  
226 *Mus musculus*, despite the fact that much larger rodents (*Akodon*; *Necromys*) were common in  
227 their study area.

228

229 Most authors who have compared inventories of small mammals through pellets analysis and  
230 through conventional trapping have concluded that those methods were complementary  
231 (Bonvicino and Bezerra 2003; Magrini and Facure 2008; Rocha et al. 2011; Scheibler and  
232 Christoff 2007). Thus our results can not be taken as an inventory of the non-volant small  
233 mammals living in the grassy savannas, marshes and shrublands around Sinnamary. Future  
234 research in these areas there should use conventional trapping as well as pitfalls for improving

235 our knowledge of rodents and opossums living in the non-forested coastal landscapes of  
236 French Guiana.

237

238

239

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247

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320  
321

322 Tables

323

324 Table 1: Measurements (mm) of four craniodental variables in adult *Holochilus sciureus* and

325 *Nectomys rattus*

326

	<i>Holochilus sciureus</i>	<i>P-value</i>	<i>Nectomys rattus</i>
LIB	4.8 ± 0.3 (4.0-5.4) 91	< 0.001	6.7 ± 0.4 (6.1-7.7) 25
M <sup>1</sup>	3.0 ± 0.1 (2.6-3.3) 90	NS	3.0 ± 0.1 (2.8-3.2) 10
M <sup>1</sup> M <sup>2</sup>	4.9 ± 0.2 (4.4-5.3) 92	NS	4.9 ± 0.2 (4.5-5.3) 11
ZB	20.1 ± 1.3 (17.9-22.8) 39	NS	21.0 ± 2.1 (17.1-24.1) 8

327

328 Summary statistics include the sample mean ± one standard deviation, the observed range (in

329 parentheses), and the sample size. P-values for Mann-Whitney tests.

330 Abbreviations: LIB = Least Interorbital Breadth; M<sup>1</sup>, M<sup>2</sup>: lengths of upper molars; ZB =

331 Zygomatic Breadth; NS = non significant at p = 0.05 level

332

333

334 Table 2: Measurements (mm) of four craniodental variables in *Oligoryzomys fulvescens* skulls

335 from Sinnamary pellets and in adult voucher specimens from French Guiana.

336

	Sinnamary owl's pellets	P-value	Reference specimens
LIB	3.6 ± 0.2 (3.3-4.1) 35	NS	3.6 ± 0.2 (3.3-4.2) 29
M <sup>1</sup> M <sup>3</sup>	3.0 ± 0.1 (2.7-3.1) 38	NS	3.0 ± 0.1 (2.8-3.2) 29
BR	4.3 ± 0.3 (3.9-5.1) 26	NS	4.3 ± 0.3 (3.8-5.1) 26
LBP	3.9 ± 0.1 (3.6-4.2) 23	NS	3.8 ± 0.2 (3.0-4.1) 25

337

338 Summary statistics include the sample mean ± one standard deviation, the observed range (in

339 parentheses), and the sample size. P-values for Mann-Whitney tests.

340 Abbreviations: LIB = Least Interorbital Breadth; M<sup>1</sup>M<sup>3</sup>: lengths of upper molars; BR =

341 Breadth of Rostrum; LBP = Length of Bony Palate; NS = non significant at p = 0.05 level

342 Reference specimens examined for *Oligoryzomys fulvescens*: MNHN-1981-183, 1986-174,

343 175, 177, 480, 482, 956 to 959, 962 to 966, 968 to 973, 975; 1998-673; MHNG-1979.04;

344 Catzeflis V-1007, V-1899.

345



346

347 Table 3: Relative contribution of each prey species to energy intake of the Barn owl, as  
348 expressed by the product of the sample size by the average weight of an individual. The total  
349 weight of all 259 ingested preys is 27'475 g, and energy intake is represented by the weight.

350

	Weight (ref.)	N ind.	% ind.	% energy
<i>Cryptonanus sp.</i>	15 (a)	10	3,9	0,5
<i>Marmosa murina</i>	41 (a)	7	2,7	1,0
<i>Philander opossum</i>	220 (a)	1	0,4	0,8
<i>Holochilus sciureus</i>	157 (b)	106	40,9	60,6
<i>Nectomys rattus</i>	177 (c)	26	10,0	16,7
<i>Oligoryzomys fulvescens</i>	17 (a)	59	22,8	3,7
<i>Sigmodon alstoni</i>	61,5 (d)	2	0,8	0,4
<i>Zygodontomys brevicauda</i>	58 (a)	38	14,7	8,0
<i>Mus musculus</i>	14 (a)	1	0,4	0,1
<i>Rattus norvegicus</i>	300 (a)	6	2,3	6,6
<i>Rattus rattus</i>	120 (a)	2	0,8	0,9
<i>Proechimys cayennensis</i>	190 (e)	1	0,4	0,7

351

352 Abbreviations: (ref.) = reference for the average weight. a = unpublished data from wild-  
353 caught animals in French Guiana; b = Twigg (1965); c = Catzefflis (2012); d = Vivas (1986); e  
354 = Catzefflis and Steiner (2000).

355