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How does sampling protocol affect the richness and abundance of small mammals recorded in tropical forest? An example from the Atlantic Forest, Brazil

Como o protocolo de amostragem influência a riqueza e a abundância de pequenos mamíferos? Um exemplo na Mata Atlântica, Brasil

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Abstract

Small mammals are important elements of tropical forests but there is not a protocol for sampling these animals. In this study, we aimed at evaluating which sampling design maximizes the richness and/or the abundance of small mammals in a given area. We used data available in studies carried out in the Brazilian Atlantic forest. The variables analyzed for each study were number of marsupial species, number of rodent species, number of marsupial individuals and number of rodent individuals (dependent variables), sampling effort (trap-nights), design (grid or transect), number of strata sampled, number of nights and number of trap types used (independent variables). We did an analysis of covariance using the type of forest (evergreen or semideciduous) as the co-factor and factoring out the sampling effort to verify if the patterns of richness and abundance of species changed between these types of forests. The same analysis was done using the design as the co-factor in different forest types. Therefore, we performed analyses of variance in each forest type using the number of strata sampled, number of traps types and number of nights as factors to verify the effects of these factors on richness and abundance of the species. The capture effort was the most important variable to explain the richness and abundance of small mammals. The forest type influenced the abundance of species. Marsupials seemed to be more abundant in the semideciduous forest and rodents in the evergreen forest.

Key words: live trap, inventories, sampling design, sampling effort.

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Resumo

Os pequenos mamíferos são importantes elementos das florestas tropicais, entretanto não existe um protocolo de como amostrar esses animais. O principal objetivo desse estudo é avaliar qual desenho amostral maximiza a riqueza e a abundância de pequenos mamíferos em uma dada área. Para isso, utilizamos dados disponíveis na literatura de estudos realizados na Mata Atlântica. As variáveis analisadas de cada estudo foram número de espécies de marsupiais, número de espécies de roedores, número de indivíduos marsupiais e número de indivíduos roedores (variáveis dependentes), esforço de amostragem (armadilhas/noite), desenho amostral (transecto ou grades), número de estratos amostrados, número de noites, tipos de armadilhas utilizadas e tamanho da área amostrada (variáveis independentes). Para verificar se os padrões de riqueza e abundância das espécies mudam de acordo com o tipo de floresta, foi realizada uma análise de co-variância usando o tipo de floresta como co-fator. A mesma análise foi feita usando o desenho amostral como co-fator nos diferentes tipos de florestas. Depois foram realizadas análises de variância em cada tipo de floresta, usando o número de estratos amostrados, o número de noites e os tipos de armadilhas como fatores para verificar os efeitos desses fatores na riqueza e na abundância das espécies. O esforço de captura foi a variável que mais influenciou a riqueza e a abundância de pequenos mamíferos. O tipo de floresta também influenciou a riqueza e a abundância das espécies. Os marsupiais parecem ser mais abundantes na floresta semidecidual, e os roedores, na floresta ombrófila densa.

Palavras-chave: armadilhas de captura viva, desenho amostral, esforço de captura, inventários.

Introduction

Information on diversity and abundance of non-volant small mammals (marsupials and rodents) in the tropics is central to understand ecological processes, such as population dynamics and community structure. Such information is also important for the elaboration of management plans, since small mammals are present in several trophic levels and play important roles in natural communities, such as seed dispersion and predation (e.g. Cáceres *et al*., 1999; Grelle and Garcia, 1999; Solari *et al*., 2002).

Some studies have argued about the importance of trap types (Cerqueira *et al*., 1990; Lambin and MacKinnon, 1997; Schittini *et al*., 2002), trap interval (Tew *et al.*, 1994; Slade and Russel, 1998), number of strata sampled (Malcolm, 1991; Passamani, 1995; Grelle, 2003; Vieira e Monteiro-Filho, 2003), number of nights (Woodman *et al.*, 1995) and design (Read *et al*., 1988; Pearson and Ruggiero, 2003; Vieira *et al*., 2004) for correct evaluation of number of species and their abundance. However, there is not a standard protocol for sampling non-volant small mammals. This group is comprised mainly by marsupials and rodents, which include many species, showing high levels of endemism. For instance, the Brazilian mammal fauna has at least 652 species, and 287 of these are marsupials and rodents (Reis *et al.*, 2006).

The rapid disappearance of the tropical forests, and the extinction of some species, has increased the interest and the importance in understanding and conserving their diversity, and the Atlantic forest is not an exception (Grelle *et al*., 1999; Grelle *et al*., 2005). The ability to obtain a good sample of small mammal richness in an area is critical to studies of mammalian diversity. Hence, many times, researchers face the problem of how to evaluate the minimum sampling effort necessary to obtain a representative sample of the small mammal richness in an area (e.g. Bergallo *et al*., 2003). Many inventories of small mammals have been carried out in Atlantic forest areas. However, they were done by different researchers using different methodologies (see examples in Cerqueira *et al*., 1993; Passamani, 1995; Grelle, 2003). In most cases, the small mammals were sampled in a grid or in transect using from one to three types of live traps. Capture effort, number of strata sampled, area size, and types of vegetation sampled in Atlantic forest also differed among studies (*e.g.* Bergallo, 1994; Fonseca and Robinson, 1990; Freitas, 1998). These differences in methodologies can result in biases when comparing patterns of species richness.

The traditional capture method for small mammals, using baited traps does not work for all species. Some species such as the bamboo rat, *Kannabateomys amblyonix* (Kierulff *et al*., 1991), and some cursorial small mammals, such as the short-tailed opossums of genus *Monodelphis* (Voss and Emmons, 1996; Umetsu *et al.*, 2006), need special methods of capture. However, most small mammal species are sampled with live-traps, mainly of two types (Sherman and Tomahawk) commonly used in inventories and in studies on population and community ecology.

Another factor that can influence the number of species and individuals is vegetation type. The Atlantic forest is a mosaic, occurring along the Brazilian coast as a continuum of "floristic composition of both evergreen and semideciduous forests" (Oliveira-Filho and Fontes, 2000). In this mosaic, evergreen and semideciduous Atlantic forests can be differentiated by the pluviometric patterns. A semideciduous forest shows greater rainfall seasonality than an evergreen forest (Oliveira-Filho and Fontes, 2000) and this can influence the productivity of the ecosystem (Morellato *et al*., 2000) and, therefore, the number of species and individuals of small mammals.

In this study, we compiled data from studies carried out in the Atlantic forest of Brazil to determine which variables influence the small mammal richness and abundance, and to provide guidelines for choosing the sample design that maximizes the richness and abundance of small mammals in Atlantic forest areas. Some hypotheses could be addressed:

(i) The vegetation type will influence the richness and abundance of marsupials and rodents, since the organisms can answer in different ways to different pluviometric patterns.

(ii) The increase in capture effort (number of trap-nights) will increase the number of species and individuals of rodents and marsupials sampled in an area.

(iii) The number of strata sampled will influence the number of marsupial and rodent species and abundance, since some rodents and the majority of marsupial species present some level of scansoriality or arboreality (Fonseca *et al.*, 1996).

(iv) The number of trap types used will influence the number of marsupial and rodent species and individuals sampled because some traps are biased for catching more individuals while others catch more species (e.g. Woodman *et al.*, 1995).

(v) The design used will influence the number of species and individuals sampled. Usually the transect arrangement samples more individuals and species than the grids, because it covers more small-mammals' home ranges and greater microhabitat diversity (e.g. Read *et al.*, 1988; Pearson and Ruggiero, 2003; Vieira *et al.*, 2004).

(vi) The number of trapping nights will influence the number of species and individuals, since some species and individuals are more trap-shy and are not caught on the first days of sampling.

Material and methods

Dataset. To evaluate which variables influence the number of species and abundance of small mammals we used data from studies carried out in Atlantic Forest of Brazil (Table 1; Figure1). The following variables were recorded in each study: total number of species, number of marsupial species, number of rodent species, total number of individuals, number of marsupial individuals, number of rodent individuals, sampling effort (trap-nights), design (grid or transect), number of arboreal strata sampled, number of nights and number of trap types used. The variable "area sampled" was not considered in this study because it was highly correlated with the sampling effort.

Over the past twelve years eighteen articles were compiled from the literature, with ten having been carried out in evergreen forests and eight in semideciduous forests. In some cases more than one site was sampled per study (Fonseca and Robinson, 1990; Moura, 1999). These sites were so distant that they were considered different localities (Table 1). Some studies sampled more than one site in different successional stages (Paglia *et al.*, 1995; Palma, 1996; Fonseca and Robinson, 1990; Fonseca, 1997) or at different altitudes (Vieira and Monteiro-Filho, 2003). In such cases, to avoid pseudoreplication (*sensu* Hurlbert, 1984), we assumed each study as one sampling unit, for which we considered the totality of species richness and the sum of abundances of marsupials and rodents, except in the last one (Vieira and Monteiro-Filho, 2003). In this case we considered each site separately, since different altitudes have different communities. In summary, we obtained a total of 21 sampled sites for our analyses (Table 1; Figure 1).

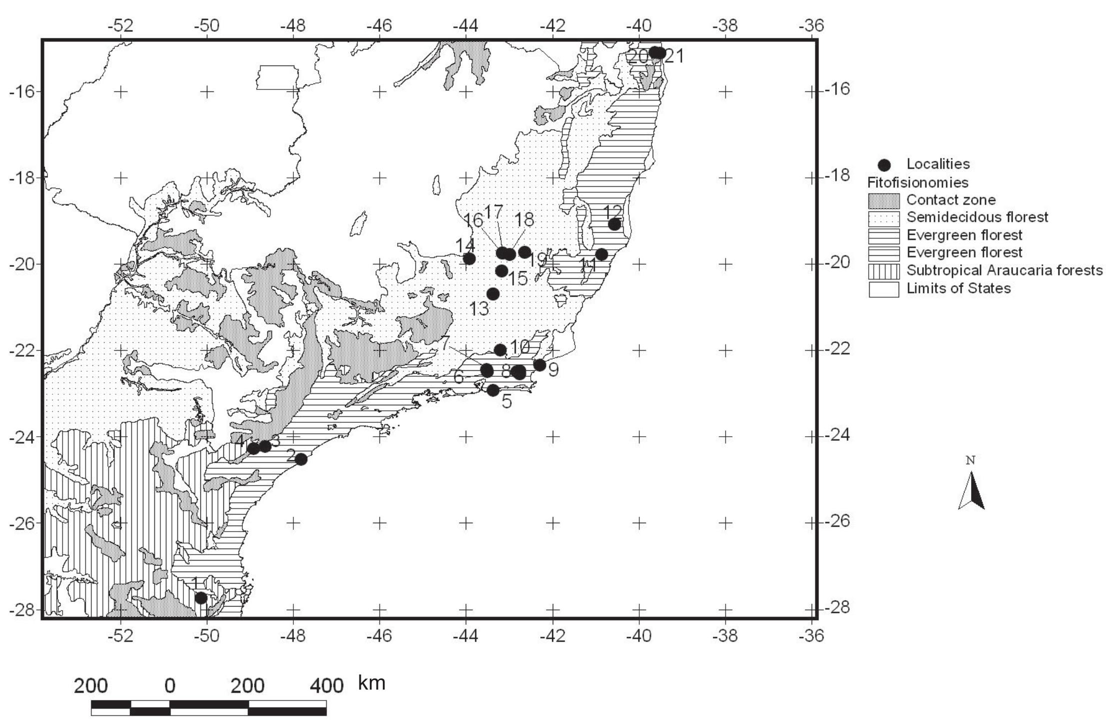

Figure 1. Map of the Atlantic forest, Brazil, showing the localities where small mammals were sampled. The number of localities following Table 1. Limits of vegetations adapted from Rede ONGs da Mata Atlântica *et al.* (2001).

Table 1. Small mammal sampling carried out in the Atlantic Forest.

Localities[a]	State	Vegetation Type	Source
01. Parque Estadual Serra do Tabuleiro	SC	EV	Voltolini, 1997
02. Estação Ecológica Juréia-Itatins	SP	EV	Bergallo, 1994
03, 04. Parque Estadual Intervales	SP	EV	Vieira and Monteiro-Filho, 2003
05. Restinga da Barra de Marica[b]	RJ	EV	Cerqueira *et al.,* 1993
06. Estação Ecológica Estadual Paraíso	RJ	EV	Bergallo, unpublished data
07. Garrafão	RJ	EV	Freitas, 1998
08. Reserva Biológica Poço das Antas	RJ	EV	Oliveira, 1993
09. Restinga de Jurubatiba	RJ	SD	Bergallo *et al.,* 2004
10. Vale do Pamparrão	RJ	SD	Gentile, 1996
11. Estação Biológica Santa Lucia	ES	EV	Passamani, 1995
12. Reserva Florestal da Companhia Vale do Rio Doce	ES	EV	Palma, 1996
13. Viçosa	MG	SD	Paglia *et al.,* 1995
14. Peti	MG	SD	Herrman, 1991
15. Rio Casca	MG	SD	Fonseca and Robinson, 1990
16. Parque Estadual do Rio Doce	MG	SD	Stallings *et al.,* 1991
17. Reserva Florestal da Companhia Vale do Rio Doce	MG	SD	Stallings *et al.,* 1991
18. Companhia Agro-Florestal Santa Bárbara	MG	SD	Fonseca, 1997
19. Caratinga	MG	SD	Fonseca and Robinson, 1990
20. Rebio Una	BA	EV	Moura, 1999
21. Fazenda Jueirana	BA	EV	Moura, 1999

EV – evergreen forest, SD – semidecidual forest. [a] number of localities as in Figure 1, [b] we considered restinga as a formation of Atlantic Forest. Note: The localities named Estação Ecológica Estadual Paraíso (locality 06), Guapimirim (locality 07), Parque Estadual do Rio Doce (locality16) and Reserva Florestal da Companhia Vale do Rio Doce (localitie 17) are too close to be differentiated in Figure 1.

Statistical analyses. We used an analysis of covariance (ANCOVA) to verify if the patterns of richness and abundance of marsupials and rodents changed between evergreen and semideciduous forests, using sampling effort as covariate. The effect of the sampling design (grid or transect) in richness and abundance of marsupials and rodents was also determined with ANCOVA using the sampling effort as the covariate.

The effects of the independent variables (number of arboreal strata sampled, trap types and number of nights) on rodent and marsupial abundance and rodent species richness were tested with analysis of variance (ANOVA). We considered each type of vegetation separately and run the analysis using the number of strata sampled, number of trap types and number of nights as factors. The effect of number of strata sampled on marsupial richness was tested with the Kruskal-Wallis' non-parametric test, since the variances among strata were not homocedastic (Levene's test, $P = 0.043$). All the analyses were done in Systat 11.0.

Results

The ANCOVA showed that except for the number of marsupial species, the richness of rodents, as well as the abundance of marsupials and rodents increased with the increase of sampling effort (Table 2). The type of forest had a significant effect in the species abundance, being the slope steeper in the semideciduous forest for the marsupials (P=0.003) and in the evergreen forest for rodents (P=0.001) (Table 2; Figure 2). Specifically, the results of ANCOVA

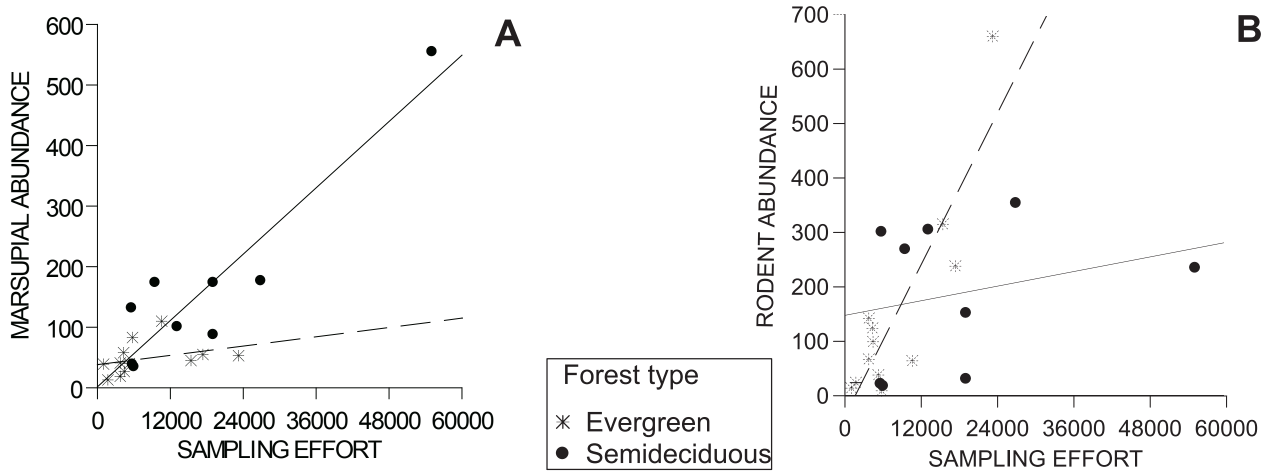

Figure 2. Relationships between marsupial (A) and rodent (B) abundance with capture effort in the two types of forests. The evergreen forest is represented by a dashed line and the semideciduous forest is represented by a solid line. Figure A shows that the abundance of marsupials is higher in the semideciduous forest, whereas Figure B shows that the rodent abundance is higher in the evergreen forest.

Table 2. Analysis of covariance showing the effect of the forest type (evergreen or semideciduous) on richness and abundance of marsupials and rodents (N=21) using sampling effort (Sample) as covariate. Darker cells indicate a significant effect of forest type on species abundance.

	Marsupial richness		**Rodent richness**		**Marsupial abundance**		**Rodent abundance**	
	F	**P**	**F**	**P**	**F**	**P**	**F**	**P**
Slope test								
Sample	0.560	0.464	4.503	0.049	21.317	0.0002	21.162	0.0003
Forest	0.680	0.421	0.948	0.344	1.308	0.269	5.545	0.031
Sample * Forest	2.239	0.153	2.184	0.158	12.115	0.003	14.371	0.001
Elevation test								
Sample	3.578	0.075	2.274	0.149				
Forest	0.112	0.742	0.012	0.913				

showed that rodents are more abundant in the evergreen forest and marsupials in the semideciduous forest. The design also affected the rodents (*P*=0.018) in the evergreen forest, being the slope of transects steeper than grids (Table 3; Figure 3). Hence, a greater number of rodent individuals are sampled in studies using transect arrangements. We did not find a relation between species richness and the type of design used. It was not possible to perform these analyses for studies carried out in the semideciduous forest because all the studies carried out there used transect design.

None of the factors explained the variation in the number of marsupial and rodent species or their abundances in the evergreen forest (Table 4). In the semideciduous forest, the number of strata was positively related to the abundance of marsupials and nearly significant with number of marsupial species (Table 5).

Discussion

The capture effort was the most important variable influencing the number of species and individuals sampled. Even studies with more than 50,000 trap-nights appear to be incomplete and the sampling effort of 500 trap-nights suggested by Jones *et al*. (1996) for inventories of small mammals seems to be still insufficient for sampling small mammals in Atlantic forest areas.

The abundance of rodents and overall (marsupials and rodents) showed differences between forest types, being higher in the evergreen forest. The number of rodent and marsupial species did not show differences between forest types, but the abundance of marsupials was higher in the semideciduous forest. The abundance of marsupials and rodents can be influenced by differences in pluviometric patterns of the semi deciduous and evergreen forests. Apparently, the marsupials can maintain higher population densities in habitats with some months of drought (e.g. Fonseca and Kierulff, 1989; Stallings, 1989; Cerqueira *et al*., 1993; Gentile *et al*., 2000). On the other hand, since the rodents are less abundant in the semi-deciduous forests, it is possible that they are negatively affected by the decrease in rainfall levels in these forests. In fact, there is

Table 3. Analysis of covariance showing the effect of the sampling design (grid or transect) on richness and abundance of marsupials and rodents in Evergreen forests (N=12) using sampling effort (Sample) as covariate. Darker cells indicate a significant effect of the sampling design on species abundance.

	Marsupial richness		Rodent richness		Marsupial abundance		Rodent abundance	
	F	P	F	P	F	P	F	P
Slope test								
Sample	0.305	0.596	1.858	0.210	2.216	0.175	37.176	0.0003
Design	0.519	0.492	0.0001	0.997	0.082	0.782	0.885	0.374
Sample* Design	0.136	0.722	0.251	0.630	1.055	0.334	8.891	0.018
Elevation test								
Sample	0.425	0.531	2.335	0.161	1.786	0.214		
Design	0.516	0.491	0.401	0.542	0.616	0.452		

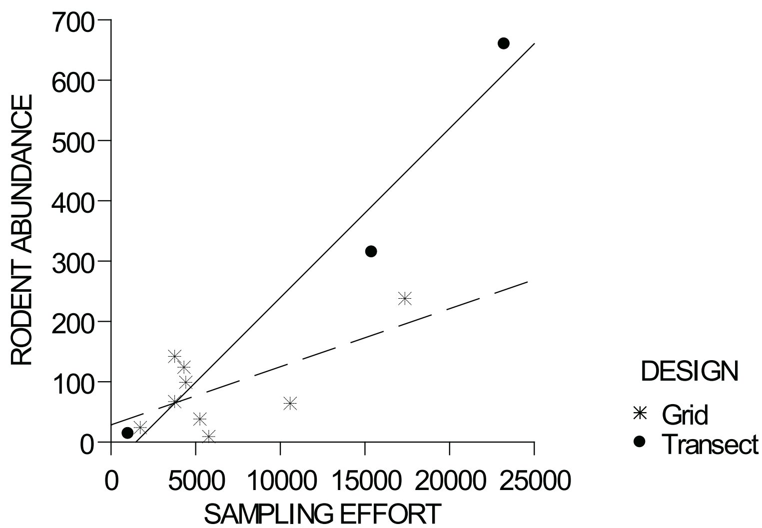

Figure 3. Relationships between abundance of rodents with sampling design (grid or transect) in evergreen forests. Grids are represented by a dashed line and transects are represented by a solid line. The figure shows that more rodent individuals are captured in transects than in grids.

Table 4. Analysis of variance among the number of marsupial and rodent species and abundance of marsupials and rodents and strata, trap types and number of nights in the evergreen (N=12) and semideciduous forests (N=9). Darker cells show significant results.

	Marsupial richness		Rodent richness		Marsupial abundance		Rodent abundance	
	Test value	P	Test value	P	Test value	P	Test value	P
Evergreen Forest								
Strata	0.669	0.536	1.268	0.327	0.997	0.406	0.470	0.639
Trap Types	0.244	0.632	0.358	0.563	0.008	0.931	0.001	0.988
Nights	0.634	0.654	1.239	0.376	0.860	0.531	0.581	0.687
Semideciduous Forest								
Strata	5.602*	0.061*	3.815	0.085	21.532	0.002	0.818	0.485
Trap Types	2.053	0.209	0.561	0.598	0.348	0.719	1.337	0.331
Nights	0.574	0.591	3.075	0.120	0.430	0.669	0.930	0.445

Legend: * In this case, we used Kruskal-Wallis test (see text for detail).

evidence that the rodent reproduction is strongly influenced by pluviometric patterns (Cerqueira *et al*., 1989; Fonseca and Kierulff, 1989; Bergallo and Magnusson, 1999). Apparently, the high number of rodent individuals is maintained by the indirect effects of rainfall in the evergreen forest.

In the semideciduous forest, the number of strata influenced positively the number of marsupial species caught. Several marsupial species occurring in the Atlantic forest have some degree of arboreality (Vieira, 2006) hence traps placed on the ground and in trees, increase the chance to catch more species.

The lack of relationship between the number of rodents and marsupials and their abundance with number of nights could be explained by the dataset compiled. All studies selected for this analysis performed samplings from three to seven nights. Apparently, this small range did not affect the catchability of the species nor their abundance.

The transect design samples a larger area and consequently more individual home ranges and different habitat types are covered by the transect, resulting in more rodent individuals captured in the evergreen forest. The areas sampled by the transect arrangements seem not to be large enough to capture a greater number of marsupials than in the grids. This could be explained because marsupials' home ranges are usually wider than rodents' home ranges (Gentile *et al*., 1997), making it difficult to find a difference in abundance of marsupials between the grid and the transect arrangement. Apparently, the sampled areas of grids and transects were not sufficient to show differences in species richness of marsupials and rodents between grids and transects.

For the small-mammal fauna to be well represented in an area, a sampling design with the highest capture effort should be used. If the aim of the study is to sample the richness and abundance of marsupials, one must sample more than one stratum. If the study is carried out in a semi-deciduous area, probably a greater number of individuals of marsupials will be sampled. The transect arrangement also captures a greater number of rodent individuals than the grid design. If the study is carried out in an evergreen area, probably a higher number of species and of rodent individuals will be sampled. Thus, researchers should select the methodology that best fits the goals of their study.

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