DANIEL GALIANO

DINÂMICA POPULACIONAL E EFEITOS DE VARIÁVEIS AMBIENTAIS SOBRE A FAUNA DE PEQUENOS MAMÍFEROS EM UM FRAGMENTO DE FLORESTA COM ARAUCÁRIA NO SUL DO BRASIL

Dissertação apresentada ao Programa de Pós-Graduação em Biologia Animal, Instituto de Biociências, Universidade Federal do Rio Grande do Sul, como riquisito parcial à obtenção do título de Mestre em Biologia Animal.

Área de Concentração: Biologia e Comportamento Animal

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UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
PORTO ALEGRE
2010

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AGRADECIMENTOS

Thales Renato de Freitas, pela oportunidade de realizar esta pesquisa, orientação, confiança e principalmente pela amizade. Muito obrigado pela oportunidade de aprendizagem e crescimento.

Bruno Kubiak (meu grande irmão), que se envolveu em todas as etapas deste trabalho, pelo grande auxílio em campo e laboratório, e principalmente pela amizade. Valeu pia! Não teria conseguido sem você.

Cassiano Estevan, grande amigo, pelo empréstimo em algumas campanhas do carro, pelo grande auxílio em campo e laboratório, e principalmente pela amizade. Abraços Estevan!

Jorge Marinho, pelo empréstimo de todo material de campo, por toda ajuda e discussões, cervejas e principalmente amizade. Um grande abraço Marinho!

Luiz Hepp, por todo auxílio estatístico e discussões valiosas, grande auxílio no uso dos programas, e principalmente pela amizade! Valeu Bira!

Marcelo Malysz, por toda sua amizade, flonas, e todo o trabalho botânico. Valeu Malysz!

Ao "grande" colega e amigo que conquistei durante este período, Rodrigo Moraes, por toda sua amizade, auxílio em campo, sugestões e todo o trabalho com os artrópodos. Valeu Rodrigo!

Priscila Bugs, por sua enorme amizade e companherismo nas aulas e nos "RUs", por todas as discussões e auxílios, principalmente quando eu não estava em Porto Alegre. Muito obrigado Pri!

A todos os colegas de Museu (URI) e as pessoas que me auxiliaram no campo, pelas conversas descontraídas, tardes de chimarrão, cervejas e principalmente pela amizade.

Aos colegas do Laboratório de Citogenética e Evolução (Depto. de Genética/UFRGS) que, apesar de minha constante ausência, sempre compartilharam de discussões e pela grande amizade.

A toda minha família, em especial a minha mãe, por ter acreditado e pela formação dos meus valores e princípios morais, oportunidades concedidas e investimento em educação.

Ao IBAMA, especialmente a pessoa de Remi Weirich, que autorizou a pesquisa e forneceu todo o suporte necessário nos alojamentos, e todos os demais funcionários da FLONA, por auxiliarem o desenvolvimento de presente trabalho.

A todos que de alguma forma colaboraram na execução deste trabalho.

Ao CNPq, pela bolsa concedida.

SUMÁRIO

ABSTRACT

Natural populations of small rodents fluctuate continually over time and the population dynamics of any living organism are shaped by both intrinsic and extrinsic factors. Small mammals populations can show a continuum dynamic activity, ranging from stability to regular cycles of variable amplitude. The species dynamics is also known to be influenced by the seasonal structure of the environment. The community of small mammals present in the Araucaria forest could present similar patterns to forests occurring in other temperate regions of the planet and the large seeds of *Araucaria angustifolia* (dominant tree) are consumed by a large array of vertebrates, mainly rodents and large birds, which act as seed dispersers and predators simultaneously. When species are very similar like the two most abundant of this community (*Akodon montensis* and *Oligoryzomys nigripes*) the outcome of competition is often the partitioning of resources such as habitat or food. Plant species are crucial for rodents, because they are the main food source for many species, and this particular relation between rodents and plants is crucial for the process of forest regeneration, since the regeneration development are associated with details on the role of each rodent species as a seed disperser or seed predator. There are a lot of important factors interfering in the regeneration process, and changes in these factors are manifested in variables such as density of tree individuals, basal area, floristic composition, and species richness and diversity. To analyse the populational aspects of the rodents in the area and identify correlations between the *Araucaria angustifolia* trees with rodent community, to evaluate arthropod-small mammals species association and test the relationship between natural forest regeneration and rodent community, we established a trapping grid of two hectares with 231 trap stations (11 X 21 configuration, 10m spacing). Every trapping series, which consisted of 6 days, traps were placed on the ground and a capture-mark-recapture program was carried out two times per season between November 2008 and August 2009. We followed Cormarck-Jolly-Seber (CJS) method to estimate population parameters and density was estimated for each trapping session. The mean of population density was used as a dependent variable in a linear regression to investigate possible relations between densities and extrinsic factors. The arthropod abundance was quantified with pitfall traps during four of the eight sample periods and we measured regeneration variables that could potentially influence the spatial distribution of the small mammals. The association between rodent and arthropod communities was compared with the similarity matrix based on rodent composition using simple Mantel tests and we used DCA analysis to ordinate sample units based on rodent community. Significance of the associations between regeneration and rodent community was tested by 1000 Monte Carlo permutations based on Pearson's correlation. The populations of the two most abundant rodents in the community (*Akodon montensis* and *Oligoryzomys nigripes*) were considered inconstant and their population variations could have indirect effects on other species. Our result suggests that these two species are the main small mammal present in the area and if extrinsic factors do not operate all the times as showed, it strongly suggests that there must be variation in spacing and dispersal behavior of these species or extrinsic factors can also be acting in indirect ways. The presence of the species *Mus musculus* indicates that this forest area had or still haves anthropic influence. In general, secondary forests provide important habitats and resources to the rodent community and are distinctly associated to the species. Although indirectly, our results indicate that there is a complex combination of regeneration predation/dispersal by rodents and it seems that generalist species might select habitat characteristics primarily at a site level because they are able to use different local factors that exist in a variety of landscapes. Based on our results we can assume that small mammals associated with herbaceous or shrub cover, particularly in riparian areas, will decline when deforestation remove this cover. We also provide initial

insight for habitat features that are related to rodent community pointed out the correlations between numbers of individuals and natural regeneration.

1. INTRODUÇÃO

1.1 Pequenos mamíferos

Os pequenos roedores e insetívoros são grupos de mamíferos que tem despertado o interesse de vários pesquisadores, não apenas em virtude de sua abundância e da ampla classe de adaptações ecológicas, mas também por serem importantes componentes de quase todos os ecossistemas terrestres existentes (Delany 1974).

Este grupo de animais possui uma vasta classe de adaptações que permitem que eles explorem uma ampla variedade de formas de vida, como terrestre, arborícola, aquática ou aérea (Gentile e Fernandez 1999). Estudos que enfoquem as relações ecológicas dos pequenos mamíferos são extremamente importantes para a compreensão das relações destes animais com o ambiente.

Os padrões de distribuição das espécies, de distribuição da diversidade e de estrutura das comunidades de pequenos mamíferos não-voadores relacionados aos amplos gradientes ambientais observados no bioma Mata Atlântica ainda são pouco conhecidos. As comunidades diferem entre florestas de baixada e de altitude (Bonvicino *et al*. 1997, Vieira 1999, Vivo e Gregorin 2001, Vieira e Monteiro-Filho 2003, Geise *et al*. 2004) e entre florestas em diferentes estádios de regeneração ou níveis de perturbação (Vieira 1999, Pardini 2004).

Baseado no fato de que os pequenos mamíferos estão presentes em praticamente todos os ambientes terrestres, e que o entendimento das suas relações ecológicas pode fornecer informações importantes do ambiente como um todo, e que os dados sobre pequenos mamíferos da Floresta Nacional de Passo Fundo se apresentam deficientes é que se realizou o seguinte trabalho, com o intuito de analisar as características populacionais e relações ecológicas da comunidade de pequenos mamíferos em um fragmento de Floresta Ombrófila Mista. Tal fato torna-se relevante, pois além de serem importantes na manutenção do fluxo de energia nos diferentes sistemas que habitam, os pequenos mamíferos são ferramentas extremamente eficazes para o entendimento das relações ecológicas do ambiente em si. Também é importante salientar a inexistência de estudos deste caráter com as comunidades de pequenos mamíferos na região.

1.2 Ecologia populacional e estudos de captura-marcação-recaptura

Em um estudo de dinâmica populacional o esforço é concentrado em uma ou poucas populações de áreas de amostragem previamente determinadas. A compreensão de como é estimado o tamanho de tal população pode ajudar a entender o que determina o tamanho e a distribuição de todas as outras populações (Moss *et al*. 1982).

Grande parte dos estudos de ecologia de populações diz respeito aos efeitos de fatores ambientais e interações intra-específicas, como o tamanho populacional, densidade populacional, sobrevivência, recrutamento e área de vida. As conclusões de tais estudos são tanto confiáveis quanto às estimativas destes parâmetros (Fernandez 1995).

De maneira geral, as principais características abordadas em um estudo de ecologia de populações são o “tamanho populacional”, que corresponde ao número bruto de indivíduos capturados; a “densidade”, que consiste na relação entre o número bruto de indivíduos em uma determinada área; a “taxa de sobrevivência”, que corresponde à quantidade de indivíduos que sobrevivem a cada ciclo reprodutivo ou espaço de tempo; e o “recrutamento”, que indica a taxa de indivíduos que participa de um evento reprodutivo, além de indivíduos imigrantes (nascimentos+imigração).

Além disso, outros atributos podem ser descritos em um conjunto de indivíduos de uma população. A área de vida ou "home-range", representa a quantidade de espaço necessária para a manutenção dos processos vitais de cada indivíduo. Ao analisar o conjunto de áreas de vida temos a "distribuição espacial" dos indivíduos de uma população, que corresponde à disposição dos indivíduos no espaço em relação ao terreno e a outros indivíduos, sendo que esta distribuição pode auxiliar na compreensão da "organização social" da população analisada.

Uma das maneiras possíveis de se obter as características descritivas de uma população é através da realização de estudos de Captura-Marcação-Recaptura (CMR), em espécies onde a contagem direta não pode ser realizada (Moss *et al*. 1982, Fernandez 1995), como no caso dos pequenos roedores. Por isso, usa-se uma metodologia de marcação dos indivíduos com o uso de dispositivos especiais (brincos, etiquetas, colares, tatuagens, anilhas, microchips), adequados a cada tipo de organismo, de forma que estes possam ser identificados posteriormente, no próximo evento de captura. É presumível que desde que estas marcações não interfiram na fisiologia ou comportamento dos animais marcados, estes terão a mesma probabilidade do que os animais não marcados de serem capturados em uma próxima amostragem. Isto torna possível fazer estimativas de parâmetros descritores da dinâmica populacional da espécie com a qual se está trabalhando (Moss *et al*. 1982, Fernandez 1995).

Entretanto, uma população não é estática no tempo e seus indivíduos podem realizar movimentos migratórios, assim como a população está sujeita as mudanças nas taxas de natalidade e mortalidade de seus indivíduos. Estas estimativas podem ser calculadas através de correções, pois não sabemos a taxa real na população como um todo, sendo necessário um intenso programa de captura e recaptura para obterem-se dados confiáveis (Moss *et al*. 1982). Em animais onde o período entre um nascimento e outro é curto, como é o caso dos pequenos roedores, e existem ganhos e perdas entre os eventos de coleta, é correto aplicarem-se interpretações e estimativas próprias de populações abertas, onde se assume que há emigração e imigração, além de nascimentos e mortes.

Nestas populações portanto, admite-se que ocorrem variações no tamanho populacional (N) devido a uma série de fatores, como a mortalidade (D) e recrutamento (B). Os métodos para populações abertas permitem estimar N em diversos momentos sucessivos (n = 1,2,...n, onde n é o número de amostragens), mais a sobrevivência (ϕ = 1 - D) e o recrutamento (B) entre cada par de amostragens sucessivas (i.e. entre i e i + 1). È importante ressaltar que, de modo geral, estes métodos não podem distinguir apropriadamente mortalidade de emigração, nem recrutamento local de imigração (Fernandez 1995).

Estudos sobre as características populacionais de pequenos mamíferos para a região norte do estado do Rio Grande do Sul são escassos (Galiano 2007, Cenzi *et al*. 2008, Kubiak *et al*. 2008), sendo que o presente trabalho visou gerar dados que possam contribuir para o entendimento das características de dinâmica populacional e relações espaciais das espécies presentes no fragmento estudado, e que possam ser utilizados em programas de recuperação e preservação das mesmas.

1.3 Variáveis ambientais

Os milhões de hectares de formações florestais com *Araucaria angustifolia*, característica da Mata Atlântica da Região Sul, foram reduzidos a cerca de 2-4% da cobertura florestal original. A redução da cobertura florestal e a possibilidade de extinção de espécies vegetais resultam no isolamento de fragmentos florestais, com alterações nas densidades populacionais e na estrutura das comunidades animais (Guerra *et al*. 2002) .

A maioria dos aspectos ecológicos, e especialmente o microclima dos remanescentes de Mata Atlântica são pouco conhecidos (Siqueira *et al*. 2004). Neste mesmo contexto, os estudos sobre mamíferos na porção Sul do Brasil geralmente restringem-se a listas taxonômicas, eventualmente com comentários relacionados a capturas, enquanto parâmetros populacionais e comunitários, que permitem inferir padrões ecológicos e de habitat para cada espécie, são pouco abrangentes (Graipel *et al.* 2006).

Grande parte dos estudos de dinâmica de roedores realizados no hemisfério sul enfatizam os fatores exógenos (climáticos) como principais responsáveis pelas flutuações observadas (Pearson 1975, Jaksic e Lima 2003, Püttker *et al*. 2008, Antunes *et al*. 2009a, Antunes *et al*. 2009b). Porém, não se pode esquecer que as variáveis de microhábitat também são importantes gestoras de processos e funções no ecossistema. Fatores como temperatura, radiação solar, umidade, entre outros, afetam o crescimento vegetal, influenciando fisiologicamente processos como fotossíntese, respiração, germinação de sementes, atividade enzimática, e conseqüentemente a fauna (Kramer e Kozlowski 1979, Levitt 1980, Tromp 1980, Harmon 1986, Hungerford e Babbitt 1987, Fowells 1990).

Em áreas de Mata Atlântica, por exemplo, o aumento da pluviosidade e conseqüente aumento na disponibilidade de alimentos (frutos e artrópodes), apresentaram um efeito direto na atividade reprodutiva de fêmeas de roedores de *Nectomys squamipes* Brants, 1827, *Oryzomys intermedius* Leche, 1886, *Akodon cursor* Winge, 1887 e *Trinomys iheringi* Thomas, 1911 (Bergallo e Magnusson 1999, Bergallo e Magnusson 2002).

1.4 Regeneração natural

A Floresta Ombrófila Mista (FOM) é uma formação florestal típica do Sul do Brasil, ocorrendo nos Estados do Rio Grande do Sul, Santa Catarina e Paraná, nas partes mais altas do Planalto Sul-Brasileiro (Jarenkow e Baptista 1987) com algumas manchas esparsas em áreas de maior altitude do sudeste do Brasil. Esta formação é dominada pela *Araucaria angustifolia* (Bertol.) Kuntze, que se destaca por representar a maior abundância desta (Reitz e Klein 1966). Segundo Morellato *et al.* (1990), essa formação por apresentar inúmeras características específicas, apresentando grande interesse, tanto do ponto de vista biótico como abiótico, como área prioritária para conservação.

Segundo Rizzinni (1997), o estudo da vegetação abrange três aspectos: fisionomia, estrutura e composição, ou seja, a distribuição das formas de vidas no espaço e a flora envolvida. A diversidade de componentes que compõem o ambiente natural, porém, a vegetação é considerada um bom indicador das condições do meio e do estado de conservação dos ecossistemas envolvidos. Sendo a vegetação um componente que responde de forma rápida às variações ambientais, a sua avaliação é primordial para avaliar o estado de conservação dos componentes dos ambientes naturais (Dias 2005).

Os processos relacionados à dinâmica, sucessão ecológica e regeneração natural são de caráter imprescindível mediante a perturbações antrópicas (Pereira *et al*. 2001). A avaliação do potencial regenerativo de um ecossistema deve inferir sobre processos que visem à manutenção da comunidade vegetal e descrever padrões de substituição de espécies ou de alterações estruturais (Guariguata e Ostertag 2001). A regeneração de áreas naturais garante a manutenção e monitoramento de comunidades vegetais e animais, isso ocorre através de fontes regenerativas como banco de sementes, chuva de sementes e a rebrota de indivíduos presentes na comunidade, que são influenciados tanto por fatores bióticos com abióticos (Harper 1977).

O processo successional da vegetação não é necessariamente previsivel, e pode seguir trajetos distintos de acordo com as variações das circunstâncias ecológicas locais (Pickett e White 1985, Johnstone e Chapin 2003). Na FOM, as grandes sementes de Araucaria são consumidas por grande parte dos vertebrados que habitam esse sistema, principalmente roedores e os grandes pássaros, que atuam como dispersadores e predadores da semente simultaneamente (Guevara e Laborde 1993, Harvey 2000, Iob e Vieira 2008). Compreender a relação entre a fauna e a vegetação, e consequentemente a participação da fauna no processo de regeneração natural, sendo esta intervenção positiva ou negativa, é um passo importante para a compreensão das relações ecológicas e dos processos envolvidos na regeneração natural deste sistema.

2. OBJETIVOS

2.1 Objetivo Geral

Analisar características ecológicas da comunidade de pequenos mamíferos não voadores da Floresta Nacional de Passo Fundo.

2.2 Objetivos Específicos

Capítulo 1 - Artigo I

- Determinar aspectos da dinâmica populacional de *Akodon montensis* e *Oligoryzomys nigripes* em seu ambiente natural, tais como a densidade, o tamanho populacional, a razão sexual, a probabilidade de sobrevivência, a natalidade e a mortalidade;

- Verificar a associação dos fatores extrínsecos (Temperatura (ºC), Precipitação (mm), Humidade (%) e Insolação (horas)) e a densidade destas duas espécies.

Capítulo 2 - Artigo II

- Identificar correlações entre a árvore dominante na área de estudo (*A. angustifolia*) e a abundância das espécies de roedores presentes;

- Verificar a associação entre os artrópodes e a comunidade de pequenos mamíferos;

- Testar a relação entre a regeneração natural da vegetação e a comunidade de pequenos mamíferos.

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III. CAPÍTULO 1

POPULATION PARAMETERS OF TWO RODENT SPECIES IN AN AREA OF ARAUCARIA FOREST OF SOUTHERN BRAZIL

Daniel GALIANO, Bruno B. KUBIAK and Thales R. O. de FREITAS

We investigated the demographic parameters and the relationship between population density and extrinsic factors of two small-sized sigmodontine rodents (*Akodon montensis* Thomas, 1913 and *Oligoryzomys nigripes* Olfers, 1818) in an Araucaria forest of southern Brazil. We followed Cormarck-Jolly-Seber (CJS) method to estimate population parameters and density was estimated for each trapping session. Mean population density was used as a dependent variable in a linear regression to investigate possible relations between densities and extrinsic factors. The populations of these two rodents were considered inconstant and their population variations could have indirect effects on other local fauna species. Our result suggests that these two species are the main small mammal present in the area and if extrinsic factors do not operate all the times as showed, it strongly suggests that there must be variation in spacing and dispersal behavior of these species or extrinsic factors can also be affecting rodents numbers indirectly, via the effect of resource availability.

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Key words: density, extrinsic factors, population ecology, small mammals.

Running page headline: Population parameters of two rodents

A ser submetido:

Acta Theriologica
Published on behalf of the Polish Academy of Sciences
ISSN: 0001-7051
Frequency: Quarterly
Current Volume: 54 / 2009
Impact Factor 2008: 1.118

Introduction

Natural populations of small rodents fluctuate continually over time and the population dynamics of any living organism are shaped by both intrinsic and extrinsic factors (Berryman 1999). Several authors studied these linkages to intrinsic factors such as birth, death and migration or to extrinsic factors such as climate and resource availability. Density-dependence seems to vary greatly among the taxa in which it has been reported (Bergallo 1995, Bergallo and Magnusson 1999, Ims and Andreassen 2000, Telfer *et al.* 2002, Lima *et al.* 2001, Boutin 1990). Biotic factors, such as food availability can depend on abiotic variables like extrinsic factors (Vieira and Marinho-Filho 1998, Lima *et al*. 2002a) that are density independent and may influence the dynamics of rodent species, but in turn are not affected by those changes.

Small mammal populations show a continuum of dynamic activity, ranging from stability to regular cycles of variable amplitude (Turchin 1993, Turchin and Ellner 2000). The species dynamics is also known to be in influenced by the seasonal structure of the environment (Stenseth 1999), and current studies have shown that predation, as well as competition, can be a significant factor determining the population dynamics of small rodents (Lima *et al*. 1999, 2001, 2002b, Kittlein 2009).

The community of small mammals present in the Araucaria forest could present similar patterns to forests occurring in other temperate regions of the planet, as these forests are located in subtropical regions and apparently are less complex than tropical forests of central and northern South America (Anthony and Niles 1981, Dueser and Porter 1986, Dalmagro and Vieira 2005).

Akodon montensis Thomas, 1913 and *Oligoryzomys nigripes* Olfers, 1818 are two habitat generalist's rodents that inhabit the Araucaria Forests of southern Brazil. They have terrestrial and terrestrial/arboreal behavior, respectively (Fonseca *et al*., 1996), and feed on fruits, seeds and invertebrates, although not in the same proportion (Vieira *et al*. 2006). Many studies had reported their high abundance in the small mammals' communities present in these forests and they also are commonly found in areas with exotic vegetation, secondary or regeneration sites (Cherem and Perez 1996, D'andréa *et al*. 1999, Pires *et al*. 2002, Talamoni and Dias 1999, Vieria 2003, Dalmagro and Vieira 2005, Vieira *et al*. 2006, Horn *et al*. 2008, Püttker *et al*. 2008, Antunes *et al*. 2009a, Antunes *et al*. 2009b, Galiano *et al*. 2009).

Small mammal populations of cricetid rodents often exhibit strong fluctuations due to seasonal or demographic effects (O'Connell 1989, Ozgul *et al*. 2004). Therefore, it is crucial to determine the effects of seasonality on density and the demographic patterns of these rodent populations. In this context, the study reported here aimed to estimate demographic parameters of *Akodon montensis* and *Oligoryzomys nigripes* in their natural habitat, such as population size, population density, survival rate, recruitment and mortality rates, as well as investigate the relationship between population density and extrinsic factors.

Study area

The study was conducted in an area of mixed ombrophilous forest, dominated by the Araucaria 'pine' *A. angustifolia* (Araucaria forest), located in the National Forest of Passo Fundo (NFPF), southern Brazil (52°09'59''S; 52°12'35''W) (Fig. 1). The climate of the region has marked seasons and is of the Cfb type (according to Koeppen 1948): subtropical, with dominant influence of the territorial pattern, humid, with precipitation uniformly distributed through the year and soft summers. During the study period, the mean daily minimum temperature throughout summer was 14.3ºC and the mean daily maximum was 26.5 ºC, with a total rainfall of 316.5 mm for the season, according to a meteorological station located adjacent to the area that belongs to the Brazilian Company of Farming Research

(EMBRAPA). In winter these values dropped to a mean daily minimum of 1.7ºC and maximum of 20.5ºC, with a total rainfall of 871.9 mm (Fig. 2).

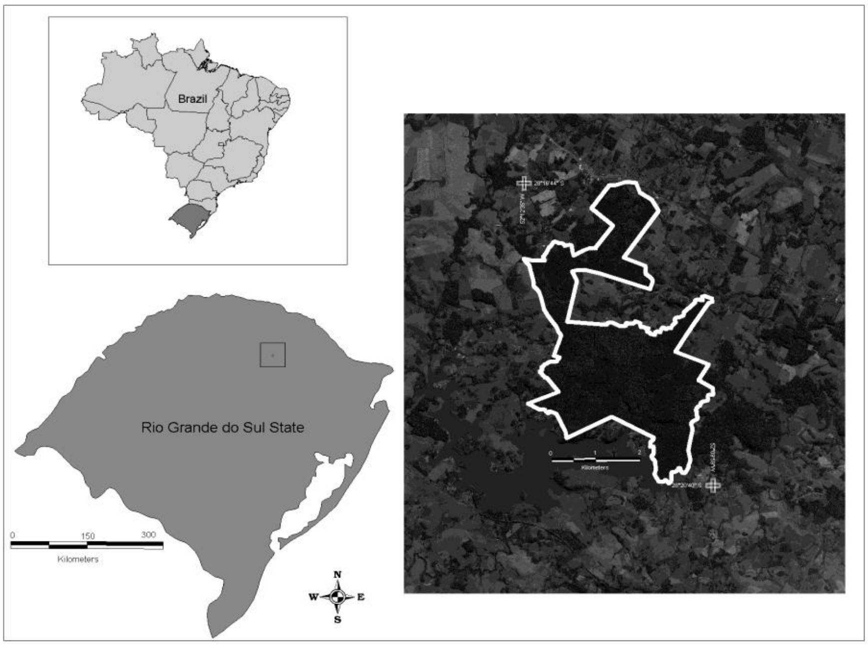

Fig. 1. Location of Floresta Nacional de Passo Fundo (NFPF), southern Brazil.

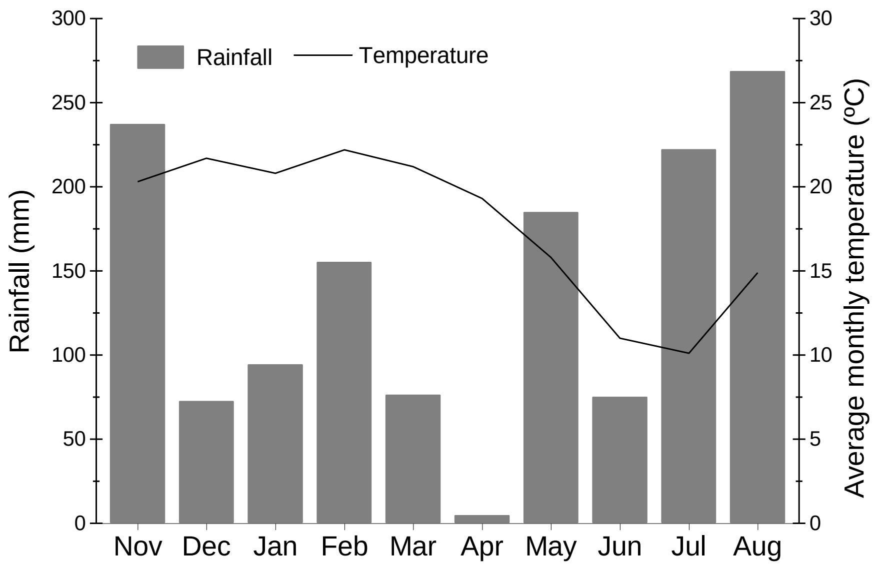

Fig. 2. Average monthly temperature and rainfall recorded between November 2008 and August 2009 in Passo Fundo, adjacent to the National Forest of Passo Fundo, southern Brazil (source: Brazilian Company of Farming Research – EMBRAPA).

The NFPF comprises a protected area of 1.358 ha varying from 600 to 781 m altitude. Its vegetation is formed by 365.4 ha of native forest (where the dominant tree species is *Araucaria angustifolia*), 391 ha of *Araucaria angustifolia* reforestation, *Pinnus* sp. (278 ha) and *Eucalyptus* sp. (7.4 ha) forestations, and 323.6 ha of roads, shrubbery and dams (Ibama 2008). The area has been legally protected from hunting and logging since 1968, but there's still been moderate disturbance. At present, this disturbance is caused by cattle that still occupy both open and forested habitats and also by illegal hunting.

We sampled the small mammals inside an area of native forest, where the vegetation community is composed by *Araucaria angustifolia* (dominant tree) and up to 30 other tree species most commonly *Casearia decandra* (Salicaceae), *Nectandra megapotamica* (Lauraceae), *Prunus myrtifolia* (Rosaceae), *Campomanesia guazumifolia* and *Campomanesia xanthocarpa* (Myrtaceae), *Matayba elaeagnoides* (Sapindaceae) and *Rollinia salicifolia* (Annonaceae) (M. Malysz, unpubl.).

Material and Methods

Field methods

We established a trapping grid of two hectares with 231 trap stations (11 X 21 configuration, 10m spacing). Every trapping series, which consisted of 6 days, traps were placed on the ground (two traps per station). We used Tomahawk traps of one size (12cm x 12cm x 25cm). A capture-mark-recapture program was carried out two times per season (Spring – Sp1 and Sp2; Summer – Su1 and Su2; Autumn – Au1 and Au2; Winter – Wi1 and Wi2) between November 2008 and August 2009, using a technique of moving transects (Alho 1979), with modifications. During the first three days only the odd numbered lines of the grid had traps, on the fourth day traps were moved to the even numbered lines, where traps remained until the sixth day. With this technique the sampled area was greater than that possible with regular transects and also reduced bias resulting from habituation to trap position. Total trapping effort amounted 11.088 traps (2.772 traps per season, average of 231 trap-nights). Traps were baited with a mixture of peanut butter, mashed banana and sardines applied to a slice of corn.

Traps were checked every morning and rebaited if necessary. Captured animals were identified, measured and marked individually by numbered ear tags (small animal tag size 1, National Band and Tag Co., Newport, KY, USA). All individuals were released at their respective trapping location on the same day they were caught.

Extrinsic factors

Extrinsic factors were provided by EMBRAPA (Brazilian Company of Farming Research) according to a meteorological station located adjacent to the area. Four parameters were analyzed: Temperature (ºC), Rainfall (mm), Humidity (%) and Insolation (hours). The last one consists in the total hours of sun incidence during the day. Variables were measured every day and the month average during the sampling period was used in the subsequent analyses.

Data analysis

To estimate population size, recruitment and survival rates for the two most abundant species (*Akodon montensis* and *Oligoryzomys nigripes*), we followed Cormarck-Jolly-Seber (CJS) method. Survival rates were standardized for a 30-day period, following the method proposed by Fernandez (1995). The standardized values was used to calculate mortality ((1 – survival rate) × population size). The minimum number known alive (MNKA, Krebs *et al*. 1969) was used to estimate population size when estimates by CJS were smaller than those by MNKA. It is not possible to estimate population size for the first and last trapping sessions, when the number of individuals captured was used. The population size was correlated with mortality and recruitment by means of Spearman correlations (Zar 1999). The program JOLLY (Hines 1998) was used to estimate recruitment and survival rates through the Cormack– Jolly–Seber method.

We estimated proportion of pregnant females following the methods proposed by Reed and Slade (2008). The sex ratio (proportion of males to females) was analyzed seasonally. Binomial tests were used to analyze deviations from the expected ratio 1:1 (Zar 1999).

Population densities were also estimated for these two species for each trapping session by dividing Population size/effective trapping area in hectares. The effective area of the grid was estimated by adding a boundary strip of half the mean maximum distance moved to the area of the grid (Otis *et al*. 1978, Wilson and Anderson 1985) for each species. Subsequently the mean of population density for each trapping period was used as a dependent variable in a linear regression to investigate possible relations between densities and extrinsic factors.

Results

Species, sex-ratio and population parameters

In total, 142 individuals belonging to six species were captured 286 times: *Oligoryzomys nigripes* (137 captures of 83 individuals), *Akodon montensis* (105 captures of 37 individuals), *Mus musculus* Linnaeus, 1758 (17 captures of 10 individuals), *Sooretamys angouya* Fischer, 1814 (19 captures of 7 individuals), *Thaptomys nigrita* Lichtenstein, 1829 (5 captures of 4 individuals) and *Oligoryzomys flavescens* Waterhouse, 1837 (3 captures of 1 individual) (Table 1). The total success of capture was 3%.

Table 1. Species, total number of individuals captured and number of captures, number of males (♂) and females (♀) captured and mean number of captures per individual.

Species	n total individuals (n captures)	Number of ♂:♀ captured		Mean number of captures per individual (±SE)	
		♂	♀	♂	♀
Akodon montensis	37 (105)	18	18	3.1 ± 0.6	2.7 ± 0.6
Oligoryzomys nigripes	83 (137)	40	35	1.9 ± 0.2	2.1 ± 0.4

The majority of the individuals captured were males, but the sex ratio did not differ significantly from 1:1 for all species. Females were recaptured more frequently than males except for *Akodon montensis* (Table 1). *A. montensis* presented reproductive females throughout the seasons, but for *Oligoryzomys nigripes* reproductive females were found during the winter's months and beginning of the spring. One reproductive female was found during the summer (February).

The average estimated population size was 7 for *A. montensis* and 11 for *O. nigripes*. The averages (± *SD*) for seasonally survival rate, recruitment and mortality rates for *A. montensis* were 0.48 ± 0.19, 0.96 ± 1.17 and 2.90 ± 1.34, respectively, and for *O.* nigripes were 0.64 ± 0.42, 1.77 ± 2.42 and 2 ± 2.9, respectively (Table 2; Fig. 3). Recruitment and mortality were not correlated with population size in any analysis (all $P > 0.05$).

Table 2. Estimates of population parameters for *Akodon montensis* and *Oligoryzomys nigripes* on Passo Fundo National Forest, southern Brazil. Estimated population size (N_i), survival rate ($\phi_{i,\ i+1}$), recruitment ($B_{i,\ i+1}$) and mortality ($D_{i,\ i+1}$). The symbol (a) indicates the number of individuals captured.

Seasons	*Akodon montensis*				*Oligoryzomys nigripes*			
	N_i	$\phi_{i,\ i+1}$	$B_{i,\ i+1}$	$D_{i,\ i+1}$	N_i	$\phi_{i,\ i+1}$	$B_{i,\ i+1}$	$D_{i,\ i+1}$
Spring 1	2[a]	0.33	–	1.33	8[a]	0.11	–	7.10
Spring 2	6	0.27	1.40	4.39	8	1.00	0.00	0.00
Summer 1	10	0.57	0.15	4.33	2	0.46	0.03	1.07
Summer 2	7.2	0.80	0.03	1.42	1	1.00	0.00	0.00
Autumn 1	6	0.53	0.39	2.84	1	1.00	4.00	0.00
Autumn 2	5	0.39	2.81	3.06	5	0.24	4.81	3.81
Winter 1	16	–	–	–	25	–	–	–
Winter 2	4[a]	–	–	–	36[a]	–	–	–
$\bar{X}$	7	0.48	0.96	2.90	11	0.64	1.77	2.00
SD	4	0.19	1.17	1.34	12	0.42	2.42	2.90
CV(%)	61				119			

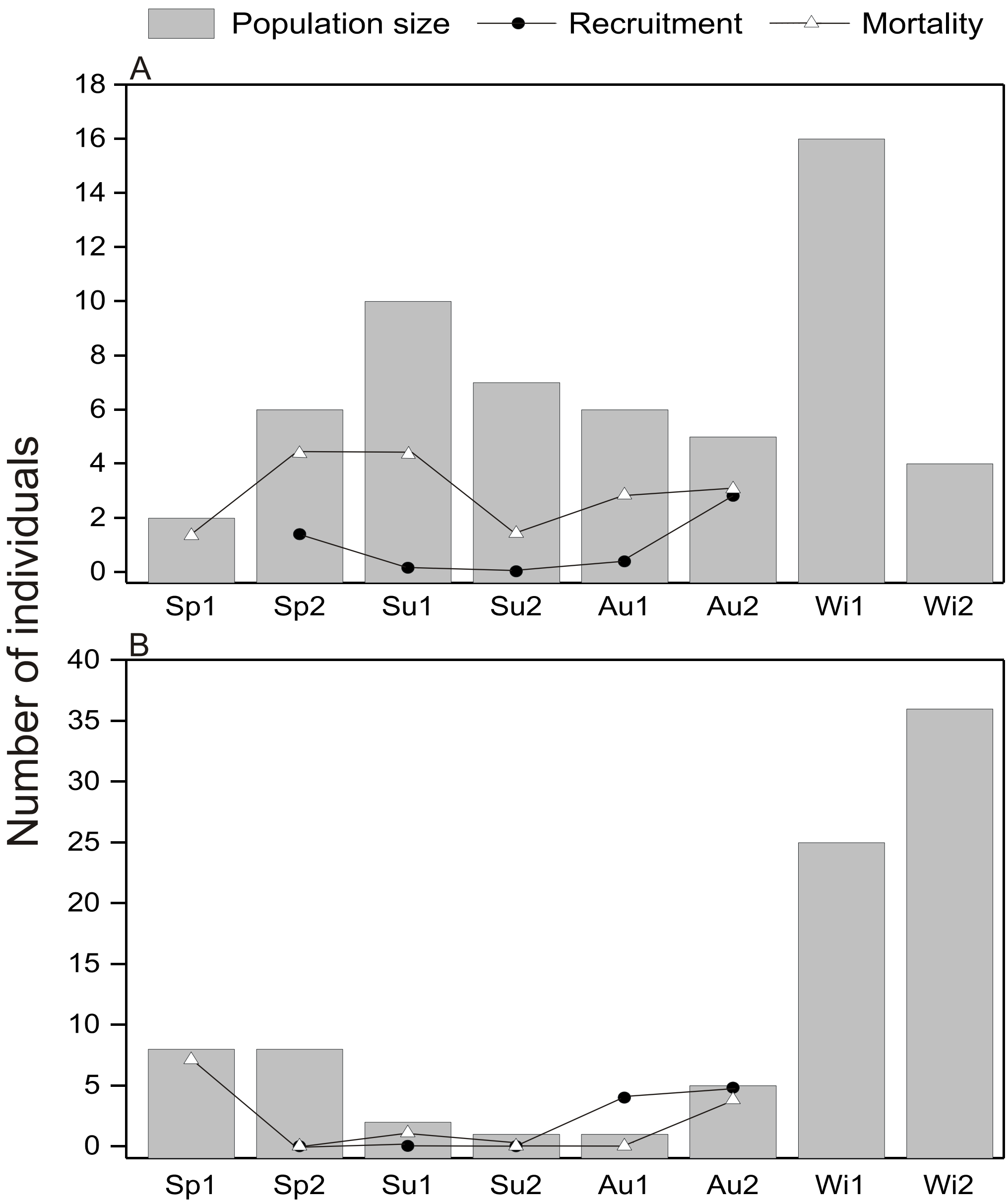

Fig. 3. Population parameters of *Akodon montensis* (A) and *Oligoryzomys nigripes* (B) on National Forest of Passo Fundo, RS, southern Brazil. The abbreviations (Sp, Su, Au and Wi) indicates the seasons: spring, summer, autumn and winter, respectively.

Population densities and extrinsic factors

The highest densities occurred in the winter for *O. nigripes* and winter 1 and summer 1 for *A. montensis*. During some of the seasons densities of these two species ranged oppositely, but there was no significant difference (F=0.535; p=0.517). *O. nigripes* and *A. montensis* showed a rapid density increase at the beginning of the winter, although for *A. montensis* the density decrease at the end of the season was also rapid (Fig. 4).

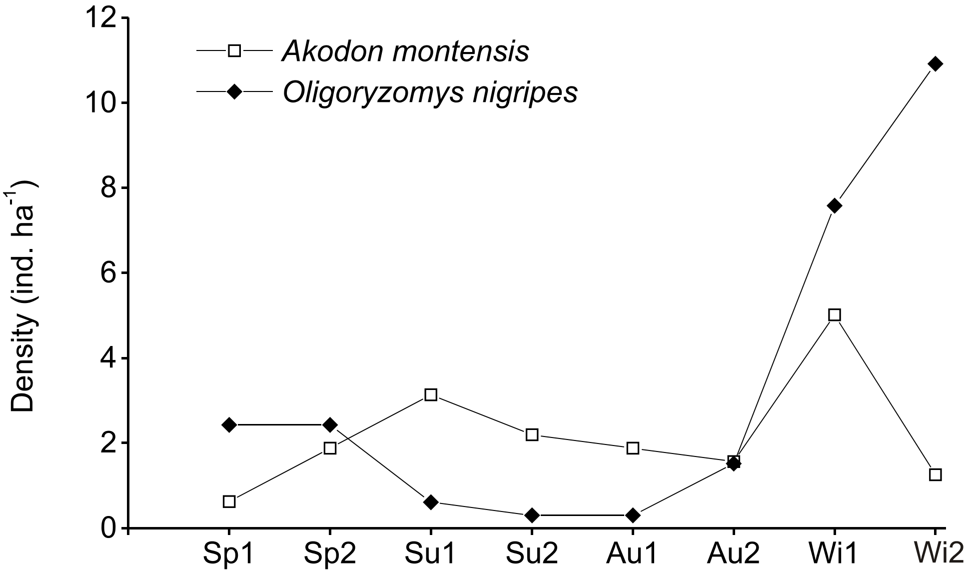

Fig. 4. Densities of *Akodon montensis* and *Oligoryzomys nigripes* on National Forest of Passo Fundo, RS, southern Brazil. The abbreviations (Sp, Su, Au and Wi) indicates the seasons: spring, summer, autumn and winter, respectively.

The linear regressions between the extrinsic factors and the population densities revealed different patterns for the two investigated species. The population densities of *A. montensis* were not significantly associated to any of the four variables (Temperature: R^2=0.209, P=0.253; Rainfall: R^2=0.008, P=0.825; Humidity: R^2=0.329, P=0.135; Insolation: R^2=0.397, P=0.093). However, the population densities of *O. nigripes* were associated with the variables Temperature and Rainfall. In *O. nigripes*, higher population densities were associated with low temperatures and rainfall increase (Temperature: R^2=0.530, P=0.038; Rainfall: R^2=0.522, P=0.041). The population density of *O. nigripes* was not significantly associated to also Humidity or Insolation (Relative humidity: R^2=0.177, P=0.299; Insolation: R^2=0.264, P=0.190).

Discussion

Previously data was reported in the literature for these two species, but comparisons of populations aspects are difficult because of the variety of methods employed for estimating population parameters and different localities. For example, Felicino *et al*. (2002) and Antunes *et al.* (2009b) reported the lowest abundance of *O. nigripes* on their studies, which are contrary with the observed here, where this species showed the higher abundance, population size and density in the half of the samples. *A. montensis* showed the greatest abundance, population size and density in three of the eight samples. A similar pattern was recorded in other studies in Santa Catarina Island and in areas of Atlantic Forest (Marinho 2003, Graipel *et al*. 2006, Kubiak *et al*. 2009). It seems that, as these two species are considered generalists, their occurrences even among areas located in the same vegetation type are associated mainly with local conditions such as food resources and specific microclimatic conditions.

The populations of *A. montensis* and *O. nigripes* can be considered inconstant, with a 61% and 119% coefficient of variation in 10 months, respectively. These temporal variations are probably associated with dispersal for food and mortality by predation. Considering that small mammals are important preys for a diversity of species found in this kind of forest and act as seed dispersers or seed predators from these species, their population variation could have indirect effects on other species.

Akodon montensis showed a continuous pattern of reproduction throughout the seasons, corroborating with other authors (Cerqueira *et al*. 1993, Feliciano *et al*. 2002, Cademartori *et al*. 2004, Graipel *et al.* 2006, Antunes *et al.* 2009b). In *O. nigripes*, Graipel *et al.* (2006) and Antunes *et al.* (2009a) found reproductive females from May to December, but Fonseca and Kierulff (1989) reported that this species reproduces throughout the year. Our data seems to corroborate with Graipel *et al.* (2006) and Antunes *et al.* (2009a), although we can't confirm it due to methodological procedures.

The population of *A. montensis* had superior estimated mortalities than recruitments for all the seasons, although the recruitment rate increases in the end of the autumn, followed by the increase of population size in the beginning of the winter. *O. nigripes* presented similar values for the estimated mortalities and recruitments during the seasons, with increasing tendencies in the end of the autumn. The population size increased substantially during the winter. Differently of the majority of ecosystems, the autumn-winter in the Araucaria Forest is characterized by the abundance of an important alimentary resource, largesized seeds, locally known as 'pinhões', that are very energetic and produced in high quantity (each strobile may produce from 20 to 198 seeds; Mattos 1994). It seems that the dynamic of these seeds is one of the major factors influencing the dynamics of these two species. Iob and Vieira (2008) in a study about seed predation of *Araucaria angustifolia* concluded that small rodents, including *A. montensis* and *O. nigripes*, were responsible by the majority of seed removal in the studied area. Such removal was lower in the grassland areas compared to forests, indicating that the open areas could serve as safer sites for the seeds. Further, rodent populations sizes can vary greatly within or between years in the same habitat. According to Adler (1998), reductions in survival rate for neotropical rodents can occur when resources are abundant in growing populations or due to severe seasonally food supply limitations.

The results related to the influence of extrinsic factors on density revealed differences on the investigated species. *A. montensis* showed no associations to any of the variables analyzed, whereas the density of *O. nigripes* was associated with by temperature and rainfall.

Akodon montensis and *Oligoryzomys nigripes* are considered habitat generalists in relation to habitat requirements (Talamoni and Dias 1999, Pardini 2004, Dalmagro and Vieira 2005, Horn *et al*. 2008, Püttker *et al*. 2008, Antunes *et al*. 2009a,b). The densities of these species were variable during the trapping period and the individuals are common in the study area, representing 26% and 59% of the captures, respectively.

Wolff (1997) concludes that most mammal populations probably are controlled by extrinsic factors. For *O. nigripes,* low temperatures and rainfall increase, which is typical of the region's climate during the winter, are associated with high densities, suggesting that the annual autumn-winter conditions will be determinant in the seasonal dynamics of the species. Our data corroborate Antunes *et al*. (2009a) which also showed that the reduction of the population size in the warm months is revealed by the existence of a negative correlation between abundance and temperature for this specie.

Fonseca and Kierulff (1989), Bergallo and Magnusson (1999) showed that the intra-annual population fluctuations in tropical ecosystems seems to be regulated by food availability (seeds, fruits or arthropods), influenced by the rainfall dynamics. The two species considered here are generalists and feed on fruits, seeds and invertebrates (Vieira *et al*. 2006), so extrinsic factors can also be affecting rodents numbers indirectly, via the effect of resource availability. A non-exclusive hypothesis could explain the patterns we found. If extrinsic factors do not operate all the times, it strongly suggests that there must be variation in spacing and dispersal behavior of these species by individual's differences.

Our results are very important for the conservation of the study site (NFPF) because it brings attention to the entire area, which is very poorly studied. Other small mammal species observed within the forest area include *Euryoryzomys russatus* Wagner, 1848, *Oxymycterus nasutus* Waterhouse, *1837*, *Scapteromys* sp., *Euryzygomatomys spinosus* G. Fischer, 1814, G*racilinanus* sp. and *Monodelphis sorex* Hensel, 1872 (D. Galiano, pers. comm.). These species are associated with different habitat kinds present in NFPF and studies that combine both population ecology and species interactions are deficient.

The presence of the species *Mus musculus* indicates that this forest area had or still having antropic influence, since this an alien species and that has successfully colonized many places over the world, including sub-Antarctic islands, due to its rapid reproduction and adaptability (Berry *et al*. 1978, Matthewson *et al*. 1994, Cuthbert and Hilton 2004). Like many other introduced mammals, the impact of house mice in altering the invertebrate and plant communities of sub-Antarctic islands is well recognized (Chown and Smith, 1993, Smith *et al*. 2002). A possible explanation is that as the study area was used for farming activities up to 50 years ago, by the time it was legally protected the individuals could already been established. This colonization hypothesis is sustained by the fact that we found juveniles and adult individuals during four of the eight sampling periods (Spring 1, Spring 2, Auntunm 1 and Winter 1). Males and females presented reproductive activity in all the periods, which indicates that the specie could be stablished. It is possible that the presence of *M. musculus* is affecting the local dynamic process of natural fauna and flora populations.

Additionally, our study is the first to provide detailed information about small mammals in NFPF. The rodents we studied are the two most abundant in this community. We conclude that *Akodon montensis* and *Oligoryzomys nigripes* are the main small mammal present in this Araucaria forest and the knowledge of how their demographic patterns changes can provide essential data for the Araucaria forest conservation and its characteristics species. The investigation revealed that population density of *O. nigripes* is associated with extrinsic factors while the density of *A. montensis* remains unaffected. Species like *A. montensis* or *O. nigripes*, which are less influenced by fragmentation effects (Püttker *et al.* 2008), might take advantage of less interspecific competition in this kind of forest. The results of this study underline that explicit knowledge about population dynamics responses are needed to contribute substantial data for conservation concepts in this region.

Acknowledgements

We are thankful to the Brazilian Institute for Environmental Resources (IBAMA), especially to Remi Weirich, for the authorization and support to our fieldwork in the National Park of Passo Fundo. We thank all colleagues from the MuRAU for their support in fieldwork; Professor Luiz U. Hepp made valuable comments and helped in the statistics analysis and the CNPq/Brazilian Ministry of Science and Technology, for granting a scholarship to the first author.

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IV. CAPÍTULO 2

SMALL MAMMALS COMMUNITY IN RELATION TO NATURAL FOREST REGENERATION AND ARTHROPOD COMMUNITY IN AN ARAUCARIA FOREST

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Introduction

The original area of Araucaria forest was 20 million hectares, but the high timber value of *Araucaria angustifolia* led to extensive logging of the Brazilian mixed forests in the last century, reducing them to 2–4% of their former extent (Guerra *et al*. 2002). Because of the high longevity and large size of adult southern conifers, their populations remain as dominant components of the forest biomass for long periods of time (frequently centuries) (Souza *et al*. 2008). The large seeds of *Araucaria angustifolia* are consumed by a large array of vertebrates, mainly rodents and large birds, which act as seed dispersers and predators simultaneously (Guevara and Laborde 1993, Harvey 2000, Iob and Vieira 2008). The tree successional process is not necessarily directional and predictable and may follow many different paths with changeable ecological conditions, and these conditions could diverge inside the same area (Pickett and White 1985, Johnstone and Chapin 2003).

The community of small mammals present in the Araucaria forest could present similar patterns to forests occurring in other temperate regions of the planet (Dueser and Hallett 1980, Dueser and Porter 1986, Dalmagro and Vieira 2005). Small mammal populations of cricetid rodents often exhibit strong fluctuations due to seasonal or demographic effects (O'Connell 1989, Lima *et al*. 2001, Ozgul *et al*. 2004) and understanding the relationships among small mammal abundances, habitat structure and resource abundance will provide insights into the ecological processes that control mammal communities which will help in their conservation.

Individual's abundance and habitat features can be useful to understand the relationship between species occurrence and habitat components, as well as the influence of microhabitat factors on the distribution of small mammals (Anderson and Gutzwiller 1996). These habitat relationships are poorly studied in the Araucaria forest (Dalmagro and Vieira, 2005) and little is known about the habitat relationships of most Araucaria forest small mammal species, and the actual knowledge is often based on subjective observations.

According to August (1983) and Malcolm (1995) differences in local configuration of the forest has been shown to be associated with variation in the abundance of several small mammals species, suggesting the habitat specificity for these species activities. These studies suggest that increasing habitat heterogeneity favours increased species richness. Lambert at al. (2006) supported in their study the hypothesis that increased resource abundance may drive the response of small mammals to disturbance (Malcolm 1995, 1997a, Ochoa 2000), although this relationship seems to be indirect. The authors affirm that it is possible that increased protection from predators and increased resource abundance interact to generate the increased small mammal abundances. These increases in some cases have been attributed especially to insect biomass on Neotropical small mammals (Malcolm 1995, 1997b, Ochoa 2000).

When species are related such as the two most abundant of the community present on National Forest of Passo Fundo (*Akodon montensis* and *Oligoryzomys nigripes*) the competition is often the partitioning of resources such as habitat or food (Schoener 1974, Kotler 1989, Stokes 1995), although they have terrestrial and terrestrial/arboreal behavior, respectively (Fonseca *et al*. 1996). Habitat selection is defined as a process by which an animal chooses from among alternative habitat resources it finds available (Johnson 1980).

Lambert *et al*. (2006) found that measures of resource abundance (insect biomass and number of fruiting trees) were related to habitat variables indicative of disturbed areas, edge-affected habitats, or both. This supports the possibility that small mammals may be more abundant in these habitats because of increased resource abundance. In their study, six species showed significant positive relationships with insect biomass and three species showed positive relationships with number of fruiting trees.

Most neotropical small rodents are considered to be omnivorous to some degree, but many are herbivorous or granivorous, and because of their diet and high abundance in neotropical forests, these animals influence plant species distributions and community structure (Terborgh 1986, Emmons and Feer 1997, Brewer and Rejmánek 1999, Silvius and Fragoso 2003, Vieira *et al*. 2006). Plant species are also crucial for rodents, because they are the main food source for many species (Emmons and Feer 1997), and these particular relation between rodents and plants is crucial for the process of forest regeneration, since the regeneration development are associated with details on the role of each small rodent species as a seed disperser or seed predator.

There are a lot of important factors interfering in the regeneration process and changes in these factors are manifested in variables such as density of tree individuals, basal area, floristic composition, and species richness and diversity (Brown and Lugo 1990, Aide *et al*. 2000). Therefore, in order to achieve a global understanding of factors influencing forest regeneration, one must consider site attributes as well as and species composition (Chazdon *et al*. 2007). The need to understand how the forest natural regeneration interfere on small mammals communities is crucial and poorly studied in the Araucaria forest.

The effects of specific microhabitat characteristics are important in determining abundance of populations, as the effects of habitat structure should be evaluated too. Studies on habitat use by mammals are essential to understand the mechanisms involved in their distribution and abundance. The distribution of species, particularly rodents, is heavily influenced by vegetation and substrate (Schmidly 1977). In this context, our objectives were to 1) identify correlations between the dominant tree (*A. angustifolia*) and abundances of the species present in the area, 2) evaluate arthropod-small mammals community association, and 3) test the relationship between forest regeneration and small mammals community.

Material and Methods

Study site

The study was conducted in an area of mixed ombrophilous forest, dominated by the Araucaria 'pine' *A. angustifolia* (Araucaria forest), located in the National Forest of Passo Fundo (NFPF), southern Brazil (52°09'59''S; 52°12'35''W) (Fig. 1). The climate of the region has marked seasons and is of the Cfb type (according to Koeppen 1948): subtropical, with dominant influence of the territorial pattern, humid, with precipitation uniformly distributed through the year and soft summers. During the study period, the mean daily minimum temperature throughout summer was 14.3ºC and the mean daily maximum was 26.5 ºC, with a total rainfall of 316.5 mm for the season, according to a meteorological station located adjacent to the area that belongs to the Brazilian Company of Farming Research (EMBRAPA). In winter these values dropped to a mean daily minimum of 1.7ºC and maximum of 20.5ºC, with a total rainfall of 871.9 mm.

The NFPF comprises a protected area of 1.358 ha varying from 600 to 781 m altitude. Its vegetation is formed by 365.4 ha of native forest (where the dominant tree species is *Araucaria angustifolia*), 391 ha of *Araucaria angustifolia* reforestation, *Pinnus* sp. (278 ha) and *Eucalyptus* sp. (7.4 ha) forestations, and 323.6 ha of roads, shrubbery and dams (Ibama 2008). The area has been legally protected from hunting and logging since 1968, but there's still been moderate disturbance. At present, this disturbance is caused by cattle that still occupy both open and forested habitats and also by illegal hunting.

We sampled the small mammals inside an area of native forest, where the vegetation community is composed by *Araucaria angustifolia* (dominant tree) and up to 30 other tree species most commonly *Casearia decandra* (Salicaceae), *Nectandra megapotamica* (Lauraceae), *Prunus myrtifolia* (Rosaceae), *Campomanesia guazumifolia* and *Campomanesia xanthocarpa* (Myrtaceae), *Matayba elaeagnoides* (Sapindaceae) and *Rollinia salicifolia* (Annonaceae) (M. Malysz, unpubl.).

Field methods

We established a trapping grid of two hectares with 231 trap stations (11 X 21 configuration, 10m spacing) (Fig. 1). Every trapping series, which consisted of 6 days, traps were placed on the ground (two traps per station). A capture-mark-recapture program was carried out two times per season (Spring – Sp1 and Sp2; Summer – Su1 and Su2; Autumn – Au1 and Au2; Winter – Wi1 and Wi2) between November 2008 and August 2009, using a technique of moving transects (Alho 1979), with modifications. During the first three days only the odd numbered lines of the grid had traps, on the fourth day traps were moved to the even numbered lines, where traps remained until the sixth day. With this technique the sampled area was greater than that possible with regular transects and also reduced bias resulting from habituation to trap position. Total trapping effort amounted 11.088 traps (2.772 traps per season, average of 231 trap-nights). Traps were baited with a mixture of peanut butter, mashed banana and sardines applied to a slice of corn.

Traps were checked every morning and rebaited if necessary. Captured animals were identified, measured and marked individually by numbered ear tags (small animal tag size 1, National Band and Tag Co., Newport, KY, USA). All individuals were released at their respective trapping location on the same day they were caught.

To analyze the association between arthropod-small mammals community and test the relationship between forest regeneration and small mammals community we stablished 25 plots inside the trapping grid (20X20 configuration, 400 m^2 of area each one) totalizing a sampling area of one hectare (Fig. 1).

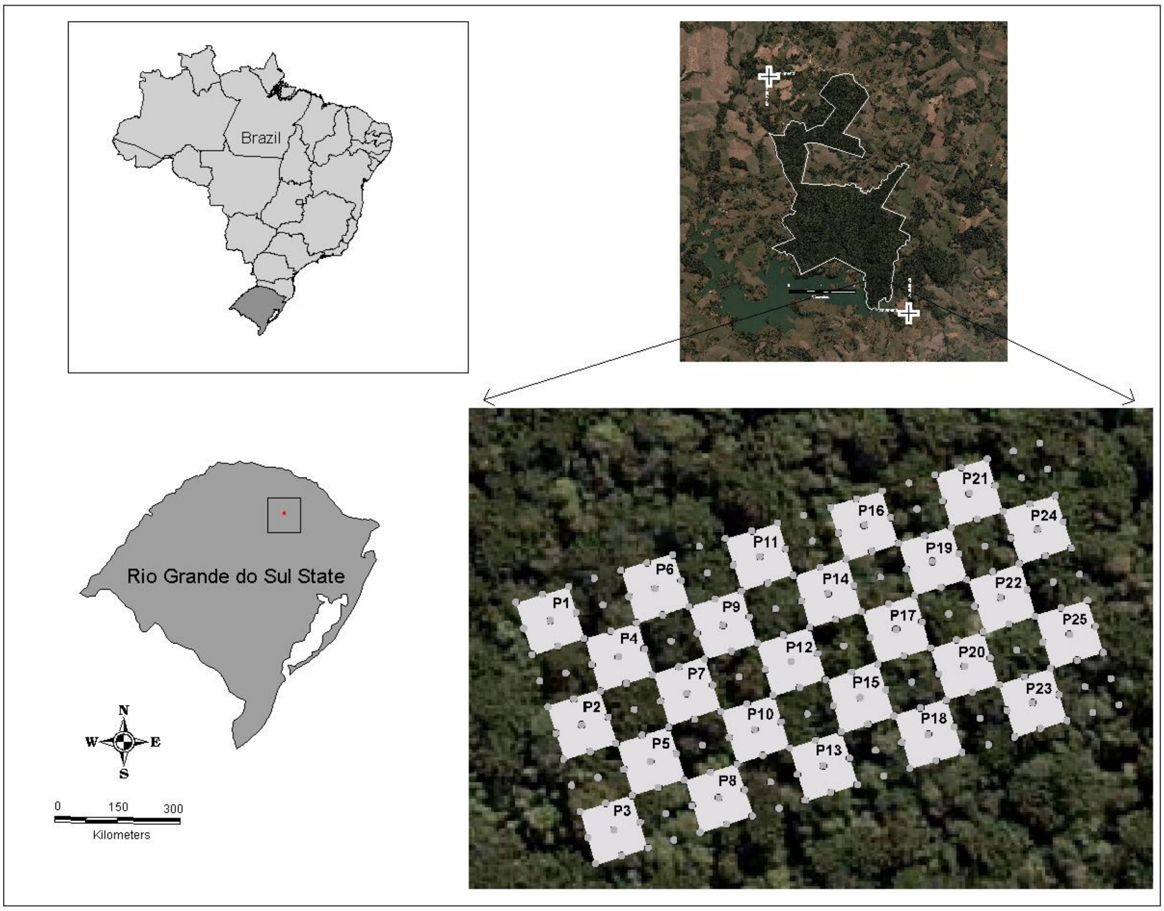

Fig. 1. The location of Floresta Nacional de Passo Fundo (NFPF), southern Brazil. In details at right, the trapping grid and the 25 plots (light-gray squares) established in the grid area. Points (●) represent the 231 trap stations.

Arthropod abundance

Arthropod abundance was quantified with pitfall traps during four of the eight sample periods. Two pitfall traps were installed in each of the 25 plots and every trap was laid in the center of the plot 10 meters apart from each other, totalizing 50 traps. The pitfall traps were open over six consecutive days each sample during the same period small mammals were being sampled. Traps were composed of plastic cups (500 ml, 15 depth x 10 of diameter) and formaldehyde (4%, plus a few drops of domestic detergent for reduce the water superficial tension). A protection under the traps was added for ensure the trap's integrity. All traps in period out of sampling were blocked up. In laboratory, the arthropods were classified by taxonomic order and just the five most representative orders (Coleoptera, Formicidae, Orthoptera, Araneae and Blattodea) were used in the subsequent analysis.

Regeneration variables

We measured regeneration variables that could potentially influence the spatial distribution of the small mammals. For these measurements we considered 20 plots (of a total of 25) inside the grid (20X20 configuration, 400 m^2 of area each one) totalizing a sampled area of 0.8 hectares. The surveys of natural regeneration were made in all the trees with height $\geq$ 0.30 m were sampled. The survey started in the same month small mammals were being sampled and finished two months later. The total height and diameter at soil height of all the individuals were measured and botanical material was collected for identification. The material was identified by field observations, comparison with material in the herbarium at the Universidade Regional Integrada do Alto Uruguai e ds Missões/Erechim (URI) (Central Herbarium) and with the help of specialists whenever necessary.

Each plot was considered a sampling location and for each quadrant we evaluated the following regeneration variables: diversity (Shannon index), abundance, richness, tree basal area (m^2), height (m), diameter (cm), volume (m^3) and species composition. We also evaluated the abundance of *A. angustifolia*, that was the only adult tree analyzed.

Regeneration densities of each plot were considered to analyze the species composition of regenerating trees.

Data analysis

The association between rodent and arthropod composition was compared with the similarity matrix based on rodent composition using simple Mantel tests (Manly 1997; Legendre and Legendre, 1998). Significance of the associations was tested by 1000 Monte Carlo permutations and Mantel statistic was based on Pearson's product-moment correlation. Detrended correspondence analysis (DCA) was conducted on the community composition data to identify gradients in the small mammal assemblages over the 25 study plots. Correlations between the DCA axes and the arthropod abundance were evaluated using Pearson correlation.

We also used DCA analysis to ordinate sample units (plots in the grid) using the function DECORANA in the vegan package (Oksanen *et al*. 2008) with R for Statistical Computing (R Development Core Team 2008). DCA uses the weighted averages of species abundance within a site to generate species-site joint plots in which sample scores in the ordination diagram lie at the centroids of the position of species that occur at each site (Hill and Gauch 1980). Since each plot could be characterized by its rodent composition, natural regeneration variables and *A. angustifolia* density, we fit these vegetation variables to the plots using the function envfit in the vegan package with R. Additionally, significance of the associations between regeneration and rodent community was tested by 1000 Monte Carlo permutations based on Pearson's correlation.

Results

We captured 142 individuals of six species of rodents: *Oligoryzomys nigripes* (137 captures of 83 individuals), *Akodon montensis* (105 captures of 37 individuals), *Mus musculus* (17 captures of 10 individuals), *Sooretamys angouya* (19 captures of 7 individuals), *Thaptomys nigrita* (5 captures of 4 individuals) and *Oligoryzomys flavescens* (3 captures of 1 individual). The total success of capture was 3%.

According to the Mantel test, there was a significant correlation in rodent composition and arthropods composition (rM = 0.153; p = 0.027). However, no significant association was found when removing *Akodon montensis* or *Oligoryzomys nigripes* from the rodent community matrix, respectively (rM = 0.165, p = 0.062; rM = 0.065, p = 0.286).

The first two DCA axes with the 25 plots explained 42.4% of the variation in small mammal community composition (Table 1). The eigenvalues of the first and second axis were 0.233 and 0.191, respectively. The first axis (DCA 1) was significantly positively correlated with Coleoptera (r=0.387; p=0.05), whereas the second axis (DCA 2) was not correlated to any of the arthropods. The DCA showed no distinct groups and there was no obvious partitioning among the small mammal community (Table 1; Fig. 2).

Table 1. Total abundance of arthropods and pearson's correlation coefficients of arthropod abundance with the first two axes derived from detrended correspondence analysis (DCA).

Arthropods	Total abundance	DCA1	DCA2
Coleoptera	907	0.883*	0.467
Formicidae	931	0.782	0.622
Orthoptera	591	-0.997	0.068
Araneae	337	0.595	-0.803
Blattodea	127	0.910	0.412
Eigenvalues		0.233	0.191

* $P \leq 0.05$

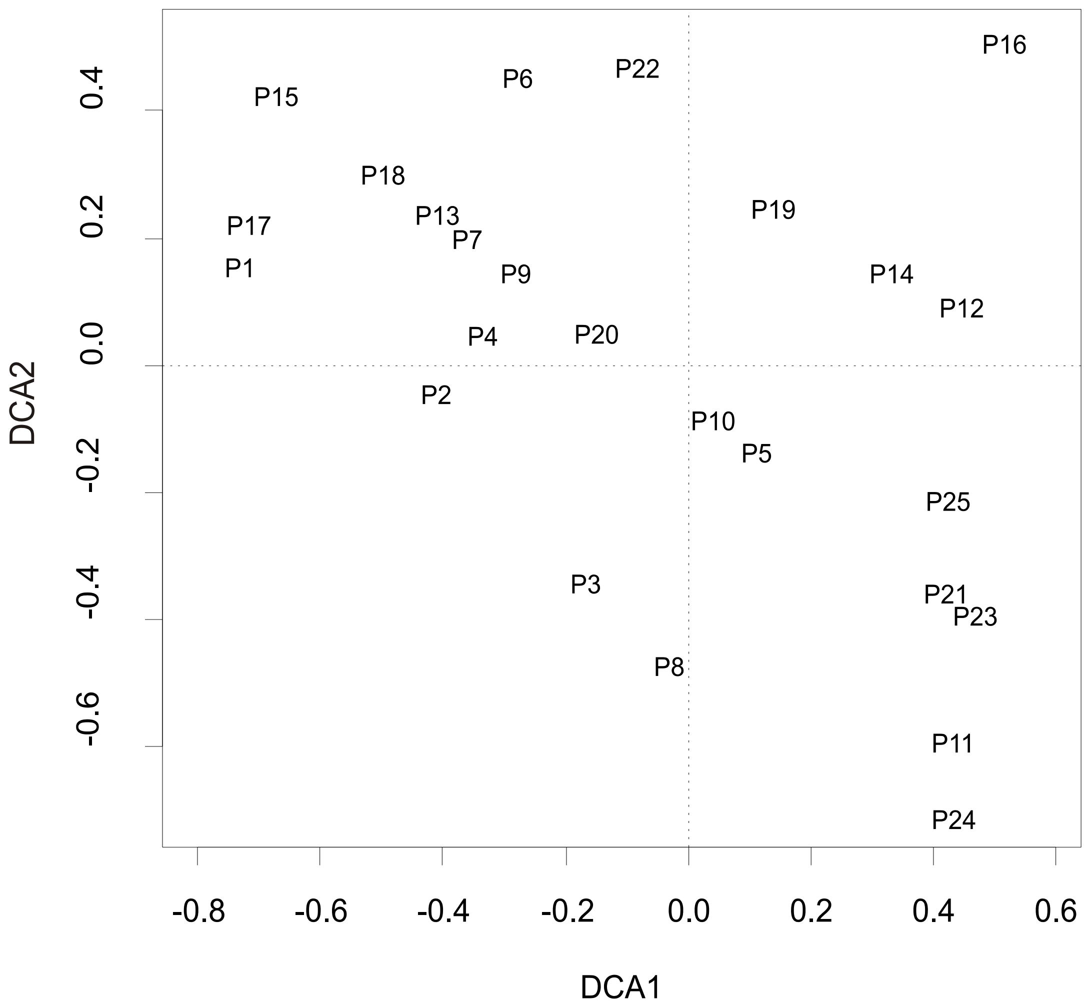

Fig. 2 Plot of the first two axes of the detrended correspondence analysis showing the 25 sampling plots based on the small mammal community composition.

Detrended correspondence analysis revealed differences in small mammal composition among plots. Plots were separated along the axes, but the analysis did not uncover any grouping pattern for rodent community among the plots. Although, the regeneration variables revealed an interaction between cover and rodent composition. DCA showed that tree abundance was significantly related to rodent community. Regardless, from a total of 17 745 tree regenerating individuals, divided in 78 species belonging to 32 families, only 8 species showed significant association to rodent community. The only adult tree analyzed (*A. angustifolia*) did not presented a significant association (Table 2; Fig. 3).

Table 2. Detrended correspondence analysis axes (DCA1 E DCA2) and pearson's correlation coefficients (r^2) of regeneration variables and small mammal community. In species densities of regenerating trees, only the significant iterations are shown.

Variables		DCA1	DCA2	r^2
Diversity		0.989	0.144	0.081
Abundance		0.953	-0.301	0.454**
Richness		0.630	-0.776	0.192
Basal area (m^2)		0.634	0.772	0.240
Height (m)		-0.068	0.997	0.079
Diameter (cm)		-0.643	0.765	0.229
Volume (m^3)		0.640	0.768	0.226
Species densities				
	ARAUCARIACEAE (Adult tree)			
	Araucaria angustifolia	-0.950	-0.311	0.038
	Regeneration			
	LAURACEAE			
	Nectandra megapotamica	0.587	-0.809	0.365*
	ROSACEAE			
	Prunus myrtifolia	0.965	0.259	0.425*
	FABACEAE			
	Parapiptadenia rigida	0.954	-0.297	0.437*
	MYRTACEAE			
	Myrceugenia miersiana	0.615	-0.787	0.467**
	STYRACACEAE			
	Styrax leprosus	0.782	-0.622	0.704**
	ELAEOCARPACEAE			
	Sloanea monosperma	0.397	-0.917	0.428*
	SOLANACEAE			
	Brunfelsia pilosa	0.387	-0.921	0.557**
	CANNABACEAE			
	Celtis brasiliensis	0.521	-0.853	0.545*

* P < 0.01, ** P < 0.001.

No major gradients are apparent in the ordination (Fig. 3). Three correlative relationships occurred among rodents and regeneration: (1) rodent abundances were different whether or not the vegetation differed between plots, (2) rodent abundances were the same when the vegetation among the plots was different, and (3) rodent abundances did not vary across the gradient in grid area.

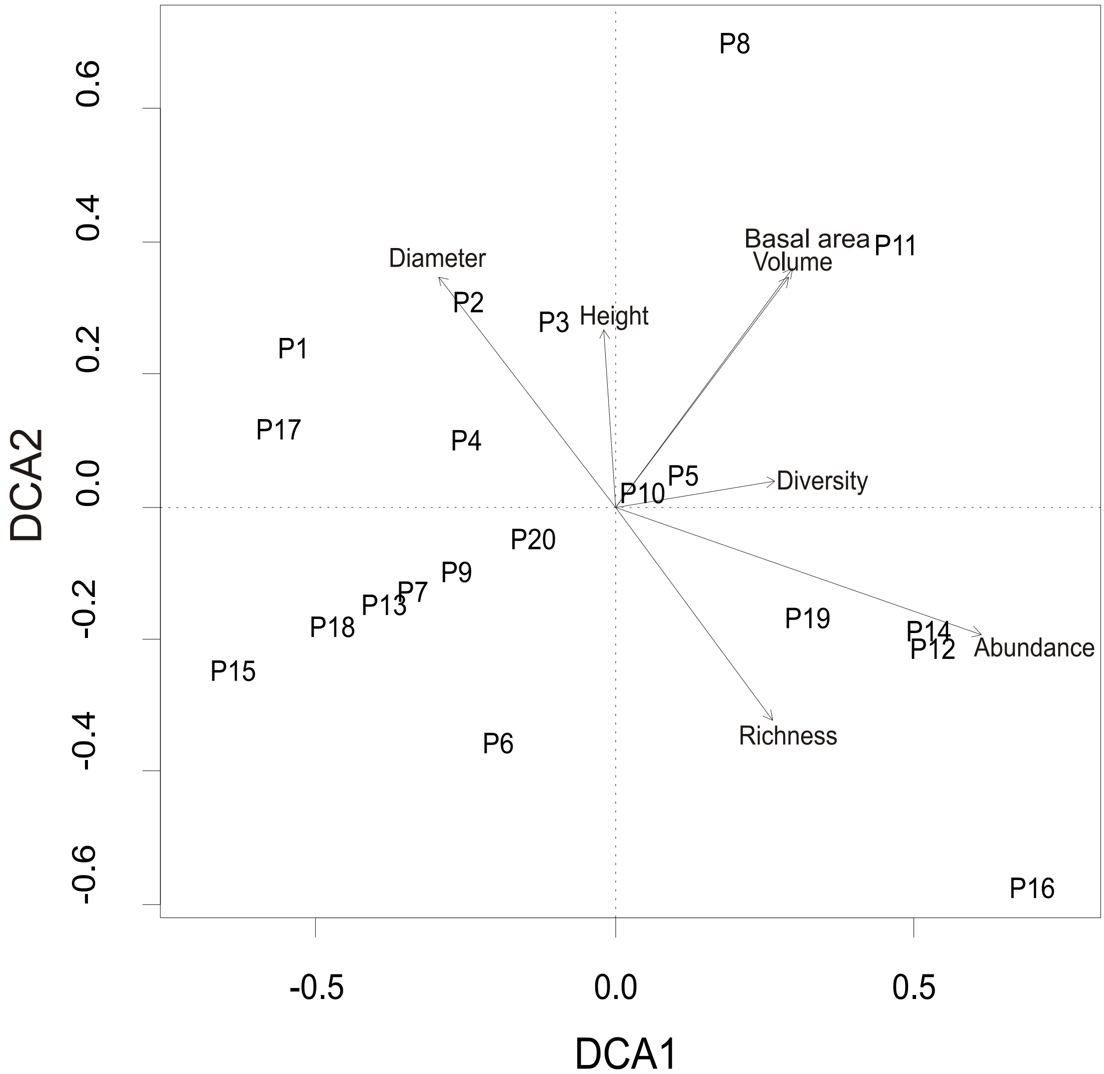

Fig. 3. Plot of the first two axes of the detrended correspondence analysis showing the 20 sampling plots based on small mammal community composition. Vectors represent the regeneration variables measured.

Discussion

Our study of how the small mammal community is influenced by arthropod community composition and natural regeneration across the extension of an Araucaria forest revealed many interesting aspects. Despite no major gradients were apparent in the distinct plots, some correlative relationships were found among rodents and natural regeneration and arthropods community.

Ground-dwelling arthropods are small, diverse, sensitive to environmental variability and may be therefore used as indication of habitat heterogeneity, ecosystem and diversity (McGeoch 1998). Mantel tests showed a significant correlation in rodent community composition and arthropods community, which was expected, since the diet of neotropical rodents is considered to be frugivorous-omnivorous or insectivorous-omnivorous (Fonseca *et al*. 1996). When removing *A. montensis* or *O. nigripes* from the community, no significant correlation was found, suggesting that arthropod community is an important resource from these two habitat generalist rodents, specially Coleoptera, that presented a significant association with the rodents. Most ground beetles are predators which play a key role in regulating populations of soil invertebrates and serving as prey to salamanders, small mammals and birds (Clarke and Grant 1968, Hance 1990). Vieira *et al*. (2006) showed that small mammals species in an Araucaria forest (including *A. montensis* and *O. nigripes*) fed on plant, animal and fungus, and the animal diet was based only on invertebrates. Talamoni *et al*. (2008) also indicated that these two rodents feed on invertebrates, but mainly *A. montensis*, that demonstrated a uniform consumption of animal and vegetal items as observed in other species of *Akodon* (Meserve *et al*. 1988, Martinez *et al*. 1990). The authors suggested that the items of animal origin, especially insects, were important resources for *A. montensis*. However, as Malcolm (1997b) points out, different types of insect traps sample different parts of the insect community, thus the measure of insect abundance used in this study may not directly represent the total amount of insect resources directly available to the small mammals, like *O. nigripes* and *S. angouya*, that have terrestrial/arboreal behavior (Fonseca *et al*. 1996), and could access a different extent of arthropods.

The only adult tree analyzed in this study and the dominant tree in the area (*A. angustifolia*) was not significantly associated to the rodent community, which is contrary to our expectations, since it produces an important alimentary resource, largesized seeds, locally known as ‘pinhões’, that are very energetic and predated by Araucaria forest mammals and other faunal species, including arthropods (Vieira *et al*. 2006, Souza *et al*. 2010). This weak correlation is probably a result of the study design that did not quantified the seed production or identified the seeding trees during the autumn-winter seasons, when seeds were produced. Also, Souza *et al*. 2010 found that the species did not show mast seeding behavior by any of their used criteria. In their study, seed crop did not show a bimodal distribution, characteristic of strict and normal masting, and in most studied localities presented a variation in population seed production. Masting occurs because resources accumulated over several years are used in a large reproductive effort, producing significant, endogenous, negative seedfall autocorrelations in iteroparous plants or synchronous death in semelparous plants (Kelly, 1994). Finally, according with the Resource Match hypothesis, seed crop size may simply track the variation in weather, largely reflecting the availability of resources directly linked to plant productivity like water and solar energy (Kelly 1994). Although we did not found a correlation between rodents and Araucaria, Vieira *et al*. 2006 proved that *O. nigripes* consumes the tree seeds, but not depends entirely on it.

Rodents play important ecological roles as consumers, secondary producers, and mechanical processors (Brown 1986). In particular, rodents are important seed and spore dispersers, consumers of vegetation, seeds, and fruits (Reichman and Price 1993), and form the base of the mammalian food chain (Eisenberg 1980). The correlations of rodent community to natural regeneration indicates that the abundance of regenerating trees were associated with higher rodent abundances. Regardless, from all the secondary forest plants, only 8 species were significantly associated to the community, and even though we identified which regenerating trees are influencing on rodent community, we did not identify specific species features that affect rodents.Vieira *et al*. (2006) showed that medium-sized seeds of *Myrceugenia miersiana* (Myrtaceae) were not damaged by digestion by *O. nigripes*. This rodent feeds on the fruit mesocarp but not on the seeds, leaving them entirely cleaned. This tree specie was also associated to rodent community in our study.

High cover of shrubs can provide both protection from predators, and food (because seeds may be concentrated under shrub canopies; Thompson 1982). The response of species to resources also takes various forms, further blurring the distinction between resource and predator-related effects.

Because small mammals play an important role as seed dispersers in forest ecosystems and form the base of the mammalian food chain (Eisenberg 1980, Compton *et al*. 1996, Shine *et al.* 1998, Shanahan and Compton 2000), understanding the effects of natural regeneration on small mammals is needed to determine proper forest management strategies.

This study shows that secondary forests provide important habitats and resources to the rodent community and are distinctly associated to the species. Although indirectly, our results indicate that there is a complex combination of regeneration predation/dispersal by rodents. It seems that generalist species, like the two most abundant we found (*A. montensis* and *O. nigripes*), might select habitat characteristics primarily at a site level because they are able to use different local factors that exist in a variety of landscapes.

It is important to note that statistical procedures, such as correlations, do not imply causation of associations between rodent community and factors analized. However, they do provide initial insight for habitat features that are related to this community pointed out the correlations between individuals and arthropod community and regeneration variables.

Based on our results that rodent community is associated with secondary forest abundance, we can assume that small mammals associated with herbaceous or shrub cover, particularly in forested areas, will decline when deforestation remove this cover. We conducted the study in a medium-sized natural fragment of Araucaria forest where the potential loss of fragment sensitive competitors may have distorted the original ecological relationship between species. The area we studied in NFPF also represents a post-farming successional stage (about 50 years since the farming activities stopped). Regardless, more work is needed if we are to understand the response of small mammals to habitat characteristics across a wide range of Araucaria forests and habitat types.

Acknowledgements

We are thankful to the Brazilian Institute for Environmental Resources (IBAMA), especially to Remi Weirich, for the authorization and support to our fieldwork in the National Park of Passo Fundo. We thank all colleagues from the MuRAU for their support in fieldwork; Professor Luiz U. Hepp made valuable comments and helped in the statistics analysis and the CNPq/Brazilian Ministry of Science and Technology, for granting a scholarship to the first author.

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(De acordo com as normas do periódico *Acta Theriologica*, Anexo 1).

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6. CONCLUSÕES

1) A ocorrência de *Akodon montensis* e *Oligoryzomys nigripes*, duas espécies habitat-generalistas, mesmo entre áreas com o mesmo tipo de vegetação, parece estar associada principalmente às condições locais, como a disponibilidade de recursos e condições microclimáticas específicas.

2) As populações de *A. montensis* e *O. nigripes* foram consideradas instáveis, com um coeficiente de variação de 61% e 119%, respectivamente. Estas variações temporais provavelmente estão associadas à dispersão por recursos e mortalidade por predação, sendo que as espécies agem como consumidores/predadores de sementes e são consideradas importante fonte de alimento para uma grande diversidade de espécies presentes no local, sendo que a instabilidade de suas populações pode acarretar efeitos indiretos sobre outras espécies.

3) Em relação aos fatores extrínsecos, os resultados demonstraram que *A. montensis* não apresenta associação com nenhuma das variáveis analisadas, enquanto que *O. nigripes* foi afetado pelas variáveis temperatura e precipitação. Para *O. nigripes*, baixas temperaturas e um aumento na precipitação estão associados ao aumento na densidade da espécie.

4) As relações obtidas entre os fatores extrínsecos e as espécies demonstram que deve existir uma variação nos comportamentos espaciais e de dispersão para cada espécie.

5) A presença da espécie *Mus musculus* indica que a área da floresta estudada sofreu ou ainda sofre com influências antrópicas, sendo que a espécie é considerada exótica e colonizou com sucesso diversos lugares no decorrer do mundo. Uma possível explicação é que no local, a cerca de 50 anos atrás, existia a presença de gado e atividade agropecuária, sendo que é possível que a espécie tenha colozinado e se estabelecido desde então.

6) Os testes de Mantel demonstraram uma correlação espacial significativa entre a composição da comunidade de artrópodos e de roedores, o que já era esperado, tendo em vista que a dieta dos roedores neotropicais é considerada frugívora-onívora ou insetivora-onívora.

7) A árvore dominante (*A. angustifolia*) e produtora de um importante recurso alimentar na área, o pinhão, não apresentou uma associação significativa com a comunidade de roedores, o que é contrário ao esperado, devido ao pinhão ser comprovadamente consumido por roedores e outras espécies presentes. Porém, tal fato pode estar relacionado às características da espécie, como a fenologia e a razão sexual de seus indivíduos na área, que não foram analizadas no presente estudo.

8) As correlações da comunidade de roedores e a regeneração natural da floresta demonstraram que a abundância da regeneração está associada a um aumento na abundância dos roedores. Das 78 espécies analisadas, apenas 8 apresentaram uma relação significativa com a comunidade. Apesar disso, um aumento na abundância de vegetação secundária parece fornecer proteção de predadores e recurso alimentar para as espécies.

9) A partir de nossos resultados, pode-se dizer que as florestas secundárias apresentam uma interação com a comunidade de roedores e provém recursos essencias para a manutenção da mesma, e estão distintamente associadas às espécies presentes, fornecendo recursos alimentares e abrigo para estas espécies.

7. ANEXOS

Anexo 1. Normas para publicação do periódico *Acta Theriologica*.

Manuscript

General. We recommend the authors to follow: The CBE manual for authors, editors, and publishers: Scientific style and format. Sixth edition, the Council of Biology Editors, Inc. Chicago, 1994.

The manuscript should be concise but informative, written in correct idiomatic English. Spelling should follow: Crowther J. (ed) 1998. A. S. Hornby – Oxford advanced learner's dictionary of current English. Fifth edition, Oxford University Press, Oxford (or later editions) for British English. It should be in final form, type-written with font size 12, not hyphenated, double spaced (up to 30 lines per page), with wide margins. Do not right-justify margins. Avoid proportional fonts and underlining in the text. The first submitted version must be automatically line-numbered. All pages should be numbered consecutively. Subtitles should be on a separate line, and their hierarchy should not exceed three.

Binomial or trinominal **latin names** should be used in accordance with:International Code of Zoological Nomenclature. The International Trust for Zoological Nomenclature, London, 1961. Authority and the year of description of the species being a topic of the paper should be given at first mention in the abstract and text. Nomenclature and taxonomic arrangement should follow: Wilson D. E. and Reeder D. M. 2005. Mammal species of the World: A taxonomic and geographic reference. Third edition, The Johns Hopkins University Press, Baltimore . Latin terms (eg names of animals) should be indicated throughout the paper in italic font, and not by underlining.

Units should conform to the International System of Units (SI). Other units may be reported in parentheses at the option of the author, if this helps understanding or is needed for replication of the work. Give latitude and longitude when describing localities. For numbers, use digits except at the beginning of the sentence. Reported data should include no more significant digits than the methods used warrant. For decimal quantities < 1, place a zero before the decimal point. Use spaces instead of commas for grouping numbers into three-digit groups (thousands). For numbers with four digits only, the space is not necessary, eg 44 567 but 2987.

Spelling should follow:

- Crowther J. (ed) 1998. A. S. Hornby - Oxford advanced learner's dictionary of current English. Fifth edition, Oxford University Press, Oxford (or later editions) for British English.

Research papers should adhere to the following sections and order: **1.** title page(s)(including title, authors' first- and surnames, abstract, authors' institutional affiliations and addresses, key words, and running page headline), **2.** text (divided into Introduction, Study area, Material and methods, Results, Discussion, Acknowledgements, and References), **3.** tables, **4.** appendices, **5.** figure legends, **6.** figures. The text of review papers may be divided at the authors' will. Persons wishing to write a book review should contact the Editor in Chief. Style should conform to format in Acta Theriologica.

Title should be brief, containing words useful for indexing and information retrieval. Mention of the authority of scientific name or higher taxon than family should be avoided. If both the vernacular and scientific names are used, the latter is written in italics, and not separated by comma or parentheses.

Author(s). Give full first name(s) in lower letters, middle initials and surname(s) in capital letters. The names of two authors are connected by "and"; the names of three or more authors are separated by commas, with the last two separated by "and."

Abstract, in the form of one paragraph, should not exceed 200 words and contain a concise statement of findings of the paper. It should be informative rather than indicative. Avoid statistics, lengthy discussions of methods, and do not include references in the abstract.

Addresses. The authors' institutional affiliations, and postal and e-mail addresses should be inserted under the abstract. Initials given in parentheses link the authors' names with their affiliations.

Key words. Provide 4 to 6 key words in alphabetic order indicating the scope of the paper. Avoid repeating those already contained in the title.

Running page headline should be short (not more than 40 characters and spaces).

Acknowledgements should be a brief statement in a single paragraph that recognises contributions of others and support from patrons and agencies.

References. Cite only essential sources. Citation of abstracts, unpublished works and website pages should be avoided but if they are necessary, they should not be included in References. References in the text should be given in a chronological order in the following forms: (Helle 1957, Fulander *et al.* 1963, Collins and Urness 1988), Helle (1957) said ..., (Lopez, in press). Avoid unpublished citations but, if necessary, add first name initials:R. Smith (unpubl.), (K. Kowalski, pers. comm.), (S. A. Brown, in prep.). For two or more papers produced by the same authors in the same year, use "a", "b", "c", etc. in order to abbreviate citations: Kowalski 1988a, b, (Brown *et al.* 1994a, b, c).

Reference list should be ordered alphabetically by the senior author's name, then by the alphabetical order of the junior authors' names, and then chronologically by date. List only works referred to in the text. Show issue number if pagination is not consecutive throughout the volume.

Titles in languages not using Roman script should be given in transliteration according to the standard of the British Standards Institution (BSI). Paper titles, originally appearing only in languages other than English, French, German and Spanish, should be translated into English and given in brackets [ ] along with information on the original language of the paper. Do not use brackets if English summary is provided. Titles of journals in languages not using Roman script should be given in transliteration according to the standard of the British Standards Institution (BSI). Full titles (without abbreviations) of journals, proceedings and other sources should be given. Follow the examples shown below:

Journals:

Cardini A. 2004. Evolution of marmots (Rodentia, Sciuridae): combining information on labial and lingual sides of the mandible. Acta Theriologica 49: 301–318.

Zorenko T. A., Smorkacheva A. V. and Aksenova T. G. 1994. Reproduction and postnatal ontogenesis of mandarin vole *Lasiopodomys mandarinus* (Rodentia, Arvicolinae). Zoologicheskii Zhurnal 73(6): 120-129. [In Russian with English summary]

Books:

Niethamer J. and Krapp F. (eds) 1990. Handbuch der Säugetiere Europas. Band 3-1. Insektenfresser-Herrentiere. Aula-Verlag, Wiesbaden: 1-524.

Yudin B. S. 1989. [Insectivorous mammals of Siberia]. Nauka - Sibirskoe Otde- lenie, Novosibirsk: 1-360. [In Russian]

Chapter in a book:

Grodziński W. and Wunder B. A. Jr 1975. Ecological energetics of small mammals. [In: Small mammals: their productivity and population dynamics. F. B. Golley, K. Petrusewicz and L. Ryszkowski, eds]. Cambridge University Press, Cambridge: 173-204.

Kowalski K. and Ruprecht A. L. 1984. [Order: Bats - Chiroptera]. [In: Keys to mammals of Poland. Z. Pucek, ed]. Państwowe Wydawnictwo Naukowe, Warszawa: 85-138. [In Polish]

Proceedings and transactions:

Wolf O., Jakob W., Lange A., Rudolph M., Borchers K., Glatzel P. S., Thiede S., Habendank B., Brackmann J., Krasiński Z. A., Krasińska M., Hartmann L. and Frölich K. 2000. Balanoposthitis of the European bison (*Bison bonasus*). [In: Proceedings of International Symposium "European bison – yesterday, today and tomorrow", 9–10 December 2000, Šiauliai, Lithuania. L. Balčiauskas, ed]. Šiauliai University, Šiauliai: 68–73.

Theses or dissertations:

Testone R. 1996. [Observations of the small mammals of Friuli lowlands]. MSc thesis, University of Trieste, Trieste: 1-120. [In Italian]

Zenuto R. R. 1999. Sistema de apareamiento en *Ctenomys talarum* (Rodentia: Octodontidae). PhD thesis, Universidad Nacional de Mar del Plata, Mar del Plata: 1-108.

Software:

GraphPAD InStat 1.13. 1990. GraphPAD InStat version 1.13. GraphPAD Software, San Diego, CA. SYSTAT V5. 1992. Systat for Windows, version 5.0. SYSTAT, Inc., Evanston, IL.

Reference list not conforming to this format will be returned for revision. Authors are responsible for ensuring the accuracy and completeness of the references cited.

All **tables**, **figures** and **illustrations** must be referred to in the text. Avoid the presentation of the same data in both text, graphical and tabular form. Figures should be provided in a vector graphics format (e.g. Corel Draw, Windows Metafile).

Tables should be clearly headed, if possible, self explanatory, and typed on separate pages. They should be numbered consecutively with Arabic numerals. Continue long tables onto 1 or more pages, but foldouts are not accepted. Double space throughout, omit vertical lines, and leave margins. All explanations that apply to a given table should be included in the table title (not in footnotes!). Every column must be provided by explanatory heading. To create columns in tables use table-options of your text editor, not space-bar or tab-keys.

All **illustrations** (including photographs) should be used with discretion and planned for the smallest size possible. They are only justified if they clarify or reduce length of the text. They are classified as figures and numbered consecutively. They should be suitable for 50% reduction and should be drawn so that on reduction they will not exceed the print area (190 × 135 mm). Colour illustrations are acceptable but all costs will be paid by the author(s). Computer-drawn curves and lines must be smooth. Use line patterns; avoid shading, very dense cross-hatching and very thin or light lines because they do not reproduce well, especially when reduced to 50%. Figures, letters, and other symbols on illustrations should be drawn large enough so that they will be at least 2.5 mm high when reduced. Place labels parallel to the axes. Font style (Arial is preferred on illustrations) and size when reduced should be the same in all figures. Do not use bold fonts. Give maps in frames and show latitude and longitude co-ordinates on frames. Captions to figures should be self-explanatory and must be presented on a separate page. All illustrations should bear figure number.

Abbreviations, symbols, units and italics

Using abbreviations and symbols saves space, but their excessive use makes articles difficult to read. Do not begin a sentence with an abbreviation. Use the % sign with numerals; otherwise, spell out percent or percentage. Follow the examples shown below.

Abbreviations:

am	– ante meridiem (before noon)	Max	– maximum
a.s.l.	– above sea level	Min	– minimum
avg	– average	Mr	– Mister
ca	– circa	Mrs	– Mistress
cf	– compare	MS	– manuscript
diam	– diameter	MSc thesis	– Master of Science thesis
Dr	– doctor	N	– north
E	– east	PhD thesis	– Doctor of Philosophy thesis or dissertation
ed(s)	– editor(s)	pm	– post meridiem (after noon)
eg	– exempli gratia (for example)	Prof	– professor
etc	– et ceatera (and so on)	S	– south
Fig.	– figure	viz	– namely
Figs	– figures	vs	– versus
ie	– id est (that is)	W	– west

Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec – for months in the text, tables and figures

Pay attention to the fact that most abbreviations are without full stops! For other abbreviations see: Crowther J. (ed) 1998. A. S. Hornby - Oxford advanced learner's dictionary of current English. Fifth edition, Oxford University Press, Oxford (or later editions).

Authors may also create their own new abbreviations if they are identified the first time they are mentioned in the manuscript.

Biological, mathematical and statistical symbols:

A	mean number of alleles per locus	log	logarithm
ANOVA, ANCOVA, MANOVA	analysis of variance, covariance, etc	ME	median
coef	coefficient	MMD	mean measure of divergence
CV	coefficient of variation	MU	measure of uniqueness
D	Nei’s genetic distance	*n*	number, sample size
df = 2, 18	degrees of freedom	n	number of chromosomes (eg 2n = 48)
F_{IS}	inbreeding coefficient	*N*	number of adults (in genetic studies)
F_{IT}	overall inbreeding coefficient	N_e	effective population size
F_{ST}	relative genetic differentiation	ns	not significant
FA	fluctuating asymmetry	*p*	level of significance
$\mathrm{FA}_{\mathrm{NM}}$	mean proportion of asymmetric traits per individual	p	mean number of base substitutions per nucleotide
FN	fundamental number	*P*	proportion of polymorphic loci
G_{ST}	genotypic diversity	π	nucleotide diversity (Nei 1987) or mathematical π = 3.14159
GPI, 5.3.1.9, ß-	symbols and E.C. numbers of	*r*	correlation coefficient

GAL, 3.2.1.23	enzymes		
Gpi-1, -2, ß-Gal	symbols of loci	r_P	Pearson correlation coefficient
h	nucleon (haplotype) diversity (Nei 1987)	r_S	Spearman correlation coefficient
h_e	expected allelic frequency / heterozygosity	*r*2	coefficient of determination
h_o	observed allelic frequency / heterozygosity	R^2	correlation coefficient of multiple determination
H’	Shannon-Weiner index of diversity	s^2	variance of sample
H_0	null hypothesis	SD	standard deviation
H_1	alternative hypothesis	SE	standard error
H	average heterozygosity	*F*-, *G*-, *t*-, *U*-, χ^2-, ..., -test	statistical tests
H_e	expected average heterozygosity	*T*	generation time
H_o	observed average heterozygosity	x, y, z	co-ordinate axes
I	Roger’s genetic similarity	#	consecutive number(s), eg of animal(s) tested
I_3, M^2	teeth		

For clarification and usage of statistical symbols please refer to: Sokal R. R. and Rohlf F. J. 1995. Biometry: the principles and practice of statistics in biological research. Third edition, W. H. Freeman and Company, New York.

Write Latin expressions in italics as: *ad hoc, ad libitum, a posteriori, a priori, et ante, et al. (et alii), ex situ in situ, in schedis, in utero, in vitro, in vivo, inter alia, per capita, per se, sensu*

Units

h, hr	hour(s)
ha	hectare(s)
km	kilometre(s)
m	metre(s)
min	minute(s) in tables and figures
minute(s)	minute(s) in the text
per annum = per year = /yr	
s	second(s) in tables and figures
yr(s)	year(s)
8:00	8 o’clock am
20:30	half past 8 pm
°C	degrees Celsius

Italics: symbols and constants in mathematical formulas, all Latin names of animal or plant species and genera (but not higher taxa!), and symbols given in italics above.

Submission and processing of manuscript

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