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MODELS OF THE DISTRIBUTION OF *ZYGODONTOMYS BREVICAUDA* (ALLEN & CHAPMAN, 1893) (MAMMALIA: MURIDAE) IN THE SAVANNAS OF RORAIMA, NORTHERN BRAZIL [1]

(With 7 figures)

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ABSTRACT: The present study describes the distribution of *Zygodontomys brevicauda* (Rodentia, Sigmodontinae) relating the presence/absence of the species to a digital database on the vegetation of savannas of the northeastern State of Roraima , Brazil. The study area is situated in the Surumu River region, between 03°58'-04°27'N and 60°13'-61°16'W, and is composed mainly of savanna formations. In a total effort of 9479 trap days, the trap success for *Z. brevicauda* was 0.57%. The probability of capture of the species was calculated for each trap station through logistic regression, using structural characteristics of each habitat. The association of capture probabilities with different habitat classes using a LANDSAT-TM satellite image allowed a spatial view of the potential distribution of the species considering the habitat mosaic of the region. The species is at least partially dependent on the savanna-forest boundary. The models show a high frequency of apparently unsuitable areas, especially of open and closed savannas, which might suggest that habitat occupancy is far from saturated. *Zygodontomys brevicauda* appears to be a colonizing species, and was shown to be associated particularly with the edges of the gallery forests. This habitat type may act as source habitats for open savannas.

Key words: *Zygodontomys brevicauda*, Sigmodontinae, Lavrado, savanna, Roraima, GIS.

RESUMO: Modelos de distribuição de *Zygodontomys brevicauda* (Allen & Chapman, 1893) (Mammalia: Muridae) nas savanas de Roraima, norte do Brasil.

O presente estudo avalia a distribuição potencial de *Zygodontomys brevicauda* (Rodentia, Sigmodontinae) relacionando a presença/ausência da espécie através de uma base digital de dados sobre a vegetação das savanas do nordeste do Estado de Roraima, Brasil. A área de estudo situa-se na região do Alto e Médio Rio Surumu (3°58'-4°27'N; 60°13'-61°16'W) e é composta por várias formações, sendo mais extensas as de savana. Foram empregadas 9.479 armadilhas-dia e o sucesso de captura de *Z. brevicauda* foi de 0.57%. As probabilidades de captura da espécie foram calculadas para cada estação de captura através de regressões logísticas utilizando variáveis estruturais dos hábitats. As associações das probabilidades de captura com as diferentes classes de hábitats, reconhecidas via imagem de satélite LANDSAT-TM, permitiram avaliar a distribuição potencial da espécie no mosaico de hábitats da região. A espécie está parcialmente associada às áreas de contato savana-floresta. O modelo evidenciou alta freqüência de áreas potencialmente vagas, especialmente nas savanas arbóreas abertas e graminosas, sugerindo forte insaturação dos hábitats. *Zygodontomys brevicauda* é potencialmente uma espécie colonizadora dessas classes de hábitats, com as áreas de borda das matas de galeria atuando como hábitats-fonte para as savanas abertas.

Palavras-chave: *Zygodontomys brevicauda*, Sigmodontinae, Lavrado, savanas, Roraima, SIG.

INTRODUCTION

The relationships of organisms with habitat deals with structures that vary in size from a very small scale like topographic features to a very large scale, such as barriers that inhibit movements of the megafauna (McCOY & BELL, 1991). Changes in physical attributes at several scales, as from microhabitat to landscape, may have direct and significant effects upon the spatial distribution of organisms. Knowledge of the pattern of habitat used by a species is useful to understand the adaptations and the viability of populations. Habitats are commonly described in terms of vegetation types

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but may also include many other features such as soil type, topography, microclimate, and shelters. Savanna describes a range of vegetation characterized by its physiognomy as well as by its floristics (EITEN, 1982). The term includes several intermediate formations between evergreen forest and desert found in tropical and subtropical regions featuring a xeromorphic landscape or landscapes which vary from pure grassland to open woodland (STOTT, 1991). In tropical savannas the climate is warm, there is a long dry season, and the plants often are drought-tolerant.

The biogeographic history of Amazonia and the relationships between the Amazonian savannas and other regions of South America have been discussed extensively by several authors (COLINVAUX, 1987; HAFFER, 1987; MARROIG & CERQUEIRA, 1997; MÜLLER, 1973; SILVA, 1995; VOSS, 1991; WHITMORE & PRANCE, 1987). Nevertheless, information regarding the composition of the nonforest mammal fauna of northern Amazonia and its relationship with habitat and landscape features is either scarce or entirely absent. VOSS (1991) presented data on the distribution of several nonforest mammals in the northern Neotropics, including northern Brazil.

The relatively small patches of Amazonian savannas currently are disjunct in relation to other open landscapes (Llanos, Gran-Sabana, and Cerrado) of tropical South America (HUECK & SEIBERT, 1981). The largest continuous area occurs in the State of Roraima, although little is known of its floristic composition (MIRANDA & ABSY, 1997). The area has a long history of economic activity with cattle breeding and herding dating back to 1787 (RADAMBRASIL, 1975). This kind of activity may have influenced today's forest-savanna limit, particularly as a result of the annual burning of the savannas to favor cattle grazing. On the other hand, these limits varied greatly during the Holocene due to climatic fluctuations (DESJARDINS *et al.*, 1996).

The Amazonian savannas are similar in structure to the cerrados of central Brazil, but are classified differently due to the absence of some plant species which are characteristic of the Cerrado, and to differences in soil and climate (EITEN, 1978). Given the strong seasonality of the region, the organisms that inhabit these areas are subject to the effects of extensive environmental fluctuation, especially small mammals.

The recent increase in human population and in agricultural and pastoral activities have caused devastation of large areas, both in central Brazil and the Amazon. Open formations are particularly impacted by agricultural expansion (NEPSTADT *et al.*, 1997; RATTER *et al.*, 1997). Consequently, an understanding of the relationship between habitat features and distribution of the fauna is important in conservationist decision-making. The identification of the relationship between species and classes of habitat serves as reference source for the evaluation of the effects of environmental damage. Furthermore, savanna formations are subject to extreme variations in rainfall and usually by seasonal fires enhanced by the human habit of pasture burning (HAMMOND & STEEGE, 1998; NEPSTADT *et al.*, 1997). These pressures may influence species diversity and composition as well as population viability.

This research employs concepts used in *GAP Analysis* (SCOTT *et al.*, 1993), including the use of recent vegetation and land use maps and the interpretation of LANDSAT-TM satellite images as indirect indicators of species distribution. However, *GAP Analysis* is not refined enough to identify high quality areas (MUNGER *et al.*, 1998). This information may be refined through the interpretation of species/habitat association via logistic regression and evaluation of landscape features.

Zygodontomys rodents occur in savannas, in xeromorphic formations, and grasslands of northwestern Central and South America. The species inhabits lowland and montane rainforest on a continental shelf island off northwestern North South America. Two species are recognized (*Z. brevicauda* (Allen & Chapmanm, 1893) and *Z. brunneus* Thomas, 1898) and several populations show disjunct distribution in isolated savannas north of the Amazon River, where they are considered an important element of open formations (VOSS, 1991). The species feed on seeds, fruit pulp, grass, and insects (VOSS, 1991; NOWAK, 1999).

The present study describes a logistic regression analysis relating the presence/absence of *Zygodontomys brevicauda* to a digital database of the savanna vegetation of northeastern Roraima, Brazil. The structural environmental variables examined were those considered potentially important for predicting the spatial distribution of small mammals in the region.

Such variables include the potential availability of shelters and variables related to the gradient between dense forest vegetation and the adjacent open savannas. Some variables express the habitat physiognomy of savannas in northeastern Roraima.

METHODS

STUDY AREA

This study was conducted in the region of the Surumu River in the State of Roraima, northern Amazonia, Brazil (Fig.1) (60°47'W and 4°11'N). The climate is mainly type Aw of the Köppen system, with mean temperatures varying from 26° to 29°C throughout the year. The dry season usually lasts from December through March and the rainfall in this season is on average 36.2mm/ month. Rainfall in the period from March to July usually surpasses 50% of the total volume of the annual rainfall (BARBOSA, 1997). The abundance of grass pollen shown by palynological records (Miocene-Pliocene) suggests a vast dominion of open savannas in northern Amazonia and Roraima (SCHAEFER & JÚNIOR, 1997). Formations in Roraima currently range from dense humid forests to open savanna formations. This span of physiognomies does not reflect the richness of savanna tree species (SILVA, 1997). The most plausible hypothesis used to explain the origin and present distribution of this mosaic is related to the paleoclimatic changes, although little information is available for Roraima (DESJARDINS, *et al.*, 1997). SANAIOTTI (1997) emphasized that only three species (*Byrsonima crassifolia, B. coccolobifolia* – Malpighiaceae, and *Curatella americana* - Dilleniaceae) together represent more than 80% of the relative dominance of trees in the savanna. The collective dominance of these species was independent of soil structure and nutrient content.

The inventory of savannas in Roraima is not complete. Therefore, the classification shown by the project RADAMBRASIL (1975) is usually used in research done on the region (*e.g.*, SILVA, 1997). Open landscapes, locally known as "Lavrados", cover approximately 16% of the state (37,800km²). Within the study area, the Radambrasil project recognized two phytoecological regions: Steppe Savanna and Savanna.

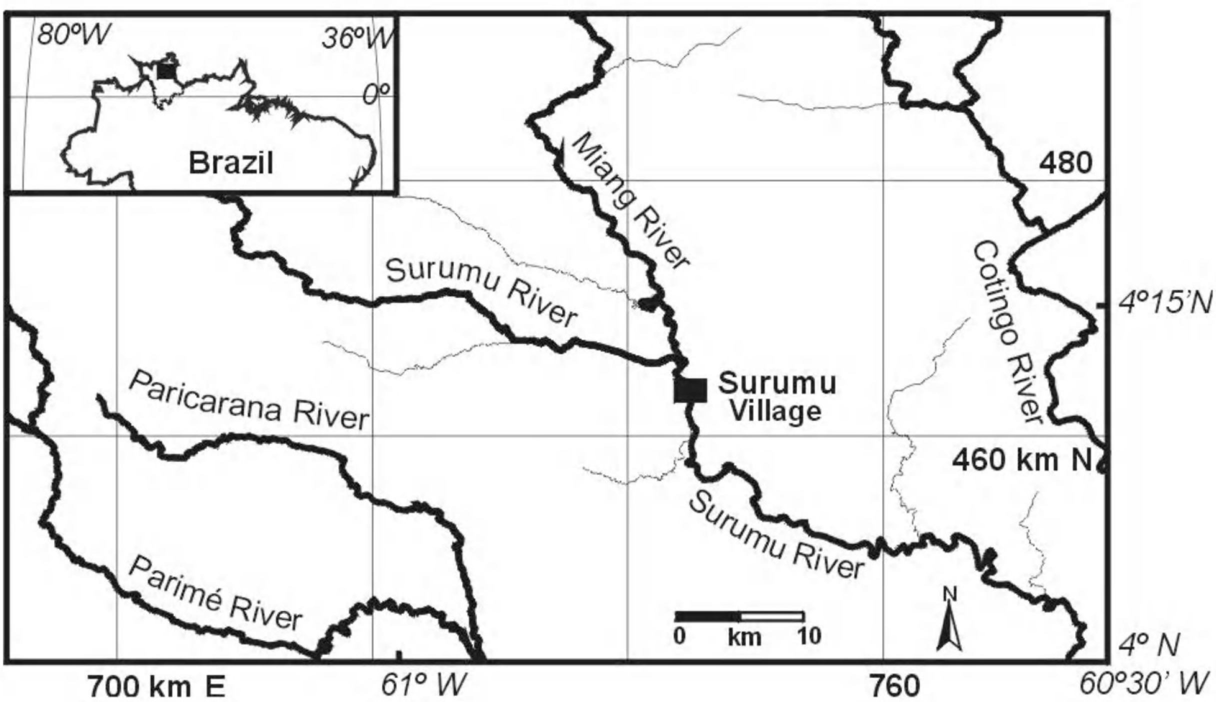

Fig.1- General position of the study area, showing the main village and major rivers of the Upper and Middle Surumu River region, Roraima, Brazil. Grid shows UTM coordinates.

Steppe Savanna ("Região da Savana Estépica") occurs in a sub-region of the dissected surface of the high Surumu River, on flat or hilly and uneven terrain. Steppe Savanna is further subdivided into four categories. (i) Dense Tree Steppe Savanna ("Savana Estépica Arbórea Densa") features a little known floristic composition with elements from the Amazonian forest adapted to a dry season (SILVA, 1997). The formation is deciduous and the tree species (*Aspioderma, Tabebuia, Schinopsis, Cassia, Acacia, Mimosa, Piptadenia, Spondia*, etc.) are xeromorphic and differ from the homologous genera from the Boreal Chaco and the Caatinga. The region also contains components of the Amazon Forest (*Mora, Centrolobium, Brosimum*). (ii) Open Tree Steppe Savanna ("Savana Estépica Arbórea Aberta") has an arboreal stratum composed by shorter, thinner, and more scattered trees than in Dense Tree Steppe Savanna, and the grass cover is more developed. (iii) Steppe Park Savanna ("Savana Estépica Parque") is similar to Open Tree Steppe Savanna except that it has a less continuous tree canopy. Cyperaceae and short grasses (Gramineae) are more evident in the herbaceous stratus. (iv) Grassy Steppe Savanna ("Savana Estépica Graminosa") is typical of flat areas in open valleys, on top of flat sandy areas, and also along small watercourses. Savanna grasses (*Andropogon* and *Trachypogon*) prevail in the ground layer.

The Savanna ("Região da Savana") features either hilly or flat areas and sediments of the Surumu Formation. It is associated with the dissected surfaces of the middle Surumu River, and consists of three subdivisions. (i) Open Tree Savanna ("Savana Arbórea Aberta") has a low and sparse cover of trees between 5 and 7m in height. Grass cover is relatively discontinuous with a prevalence of *Trachypogon* spp. and *Andropogon* spp. (ii) Park Savanna ("Savana Parque") features a grassland physiognomy but isolated trees may also be present. Some stands are composed by *Curatella americana*. (ii) Grassy Savanna ("Savana Graminosa") includes temporary ponds and is dominated by dense grass cover, particularly *Trachypogon plumosus* and *Andropogon angustatus*.

Habitat description

Trap stations where animals were captured (n=54) and a sample of the stations without captures (n=72) were used to estimate capture probabilities of *Z. brevicauda* at the trap sites and to evaluate the potential distribution of the species in the landscape mosaic. Several structural variables (Tab.1), described for the same set of captures by NUNES (2001), were used to describe each trap station. The structural variables and the landscape features were used to describe each physiognomic group in the LANDSAT-TM image. Trap sites and probabilities were then associated with the habitat classes recognized in a thematic map of vegetation and compared to the information available from the phytoecological map of the Radambrasil Project (RADAMBRASIL, 1975).

GIS analysis

GIS analysis was conducted with the help of Geographical Information System (GIS) IDRISI 2 for Windows (EASTMAN, 1997) and CartaLinx (HAGAN, 1998). The latter was used to elaborate vector format maps on a digitizing tablet, using map sheets NB.20-Z-D-V MI14 (Pereira Village) and NB.20-Z-D-IV/I MI-13/3 (Ereu River) on a scale of 1:100,000 (IBGE, 1980). These cartographic maps along with road and hydrologic maps were used to produce digital images. The phytoecological map from the project Radambrasil (map sheet NA./NB. 20 - Boa Vista / Roraima; scale 1:1,000,000), was digitized and later rasterized using the POLYRAS module in the IDRISI software.

Classification was done using LANDSAT (TM) image (orbit 232 – 057, of March 5th, 1996 in 30m resolution). A false color composition, with bands 3, 4, and 5 (COMPOSIT module), was used as a reference, followed by georeferencing (RESAMPLE module) into the UTM (Universal Transverse Mercator) reference system. An unsupervised classification (ISOCLUSTER module) with bands 3, 4, and 5 - LANDSAT (TM) and the false color composition were utilized to identify classes of vegetation. Vector files of points (500 points were recorded for several classes of habitat in the field, via GPS receptor - Global Positioning System Garmin II-Plus) were then used in EDIT module and integrated to a data bank containing information related to the descriptive variables of the landscape. These points were after used in the reclassification process (RECLASS module) to produce classes of vegetation cover. The phytoecological classification by the project RADAMBRASIL (1975) for the State of Roraima was used as reference.

Delimitations of the class Gallery Forest (GF) and of the contact areas between Gallery Forest and Open Tree Savanna (EOTSGF) and also between Gallery Forest and Open Tree Savanna on Hydromorphic Soil (EOTSHGF) were drawn based on the previously classified image. Any forest formation inside a buffer measuring 100m from each side of any course of water was considered Gallery Forest by the BUFFER module of the software IDRISI. This same module helped to define contact areas between Gallery Forest and both Open Tree Savannas (OTS and OTSH). Contact was considered as a 60m wide strip, a distance required to double the resolution of the LANDSAT (TM) image.

SAMPLING

Field studies of *Z. brevicauda* were conducted from 20th September to 10th October 1998. Trap lines were placed to maximally sample habitat heterogeneity in the region, including several types of savanna, gallery forest, and ecotones. Trap stations were placed 15m apart and consisted of only one trap, either a wire mesh cage trap (9x9x22cm or 11x12x29.6cm), a Sherman trap (7.5x9.4x30cm), or a snap–trap (Victor® Mouse Trap). The traps were baited with fresh cassava slices and a mixture of peanut butter, industrialized fishmeal, and oatmeal. Also, 36 sets of pitfall traps were arranged throughout the sampled habitats. Each pitfall set was composed of four buckets buried in the ground, one in the center and connected to the other three by a plastic sheet, forming a barrier to prevent small mammals from passing through the set (HANDLEY & KALKO, 1993). Traps were checked every morning for a total of 9,479 trap days. Some habitats outside the areas were sampled to complement the information, but

Table 1. Definition of thirteen structural variables measured at each trap site to compare *Zygodontomys brevicauda* presence/absence.

VARIABLE	DESCRIPTION OF VARIABLE QUANTIFIED AT EACH TRAP SITE
FHD100	Foliage height density from 20cm to 100cm. Based on ROSENZWEIG & WINAKUR (1969) and modified by OLIVEIRA (1990).
LIT	Relative importance of litter. Calculated by multiplying litter cover versus height where cover was measured by a tube measuring 2.1cm in diameter and placed vertically to soil (OLIVEIRA, 1990).
RIHERB	Relative importance of herb layer. Calculated by multiplying herb cover height and cover. Cover was measured similarly to LIT (OLIVEIRA, 1990).
HSHRUB	Mean height of shrubs around the trap site (NUNES, 2001).
CANHT	Canopy height. Estimated through the use of a clinometer.
CANCV	Canopy cover. Estimated through the use of a spherical densiometer (NUNES, 2001).
ROCK	Percentage of rock cover. Measurement refers to rock cover on soil in two transects which were centered on the capture station. Cover measurements obtained in a manner similar to that used in LIT (OLIVEIRA, 1990).
NUMTREE	Total number of trees in a circle centered on the trap site.
TREEDIS	Mean distance between trees in a 10m radius circle on the trap site.
GALFDIS	Distance from the capture station to the nearest Gallery Forest.
WATDIS	Distance from the capture station to the nearest body of water.
RIROCK	Relative importance of rocks. Results were obtained by using the presence of rocks in classes 1, 2, 3, and 4 (arbitrary scale) considering squares centered in the capture station (NUNES, 2001). The result represents the average number of classes in the squares.

not included in the analysis. Five species of small mammals were trapped besides the *Z. brevicauda* captured (Didelphidade: *Monodelphis brevicaudata* (Erxleben, 1777); Muridae: *Oligoryzomys* sp., *Sigmodon alstoni* (Thomas, 1881), *Rhipidomys nitela* Thomas, 1901; Echimyidae: *Proechimys* cf. *guyannensis*). Karyotype data of the studied population and comparisons with those reported for Venezuela and Costa Rica, and with other regions of northern Amazonia are provided by MATTEVI *et al.* (2002). Voucher specimens are deposited in the Mammal Collection of the Museu Nacional, Rio de Janeiro, Brazil.

STATISTICAL ANALYSIS

The information collected in the surveys was used to derive a statistical habitat association model for *Z. brevicauda* based on logistic regression. The environmental structural variables were standardized to unit variance (Z transformed) (STATISTICA, 1999). To estimate capture probability, trap sites were coded for the presence (=1) and absence (=0) of species. Occurrence probabilities were estimated by use of the Logistic Regression equation.

$$P_i = 1 / (1 + e^{-Z})$$

where

$$Z = b_0 + b_1X_1 + b_2X_2 + \ldots\ldots + b_nX_n$$

and X_n the habitat structural variables, b_n the regression coefficients and b_0 the coefficient estimated from the data (intersections). Estimated probabilities were then associated with the identified habitats in the LANDSAT (TM) image classification used as basis for the identification of potential species distribution in the study region.

Four models were built in order to evaluate the potential distribution of *Z. brevicauda*:

Model I - all variables and all trapping sites, which are related to all classes of habitat (Savannas and Gallery Forest), were included in the analysis;

Model II - all variables are included, while all trapping sites, which were in Dense Tree Savanna (DTS), were excluded from the analysis;

Model III - all variables and all trapping sites in Dense Tree Savanna and Gallery Forest (DTS and GF) were excluded from the analysis;

Model IV - all variables and all trapping sites in Dense Tree Savanna (DTS), Gallery Forest (GF), Edge of Open Tree Savanna and Gallery Forest (EOTSGF) and Edge of Open Tree Savanna on Hydromorphic Soil and Gallery Forest (EOTSHGF) were excluded from the analysis.

The goodness of fit of each model was evaluated by the χ^2 test. The acceptance of significance suggests that the model produced adequately models the data and that regression parameters are statistically significant (STATISTICA, 1999).

To estimate the concordance and discordance percentages between the captures and the predicted occurrence, probabilities associated to each station that had rates over 0.5 (50% probability) were considered positive (1) and when less than 0.5, were considered negative (0). Occurrence probabilities for *Z. brevicauda* were represented by the median capture probability in capture stations in each class of habitat. Whenever the median probability for a given class of habitat was more than 0.5 (capture expected by the model), a distribution map along with classes which showed the same pattern was generated. Furthermore, a high capture probability zone (occurrence probability median of more than 75%), this time with a higher requirement in order to include classes of habitat, was established for probabilities higher than 0.75.

RESULTS

Classes of vegetation identified by unsupervised classification of the satellite image are described on table 2. Based on the distribution patterns of the observed classes and the phytoecological regions taken from the Radambrasil Project (RADAMBRASIL, 1975), the Steppe Savanna Region included 16.78% of forest cover and a rougher relief compared to the Savanna phytoecologic region, which showed 3.37% of forest cover. The Savanna region is recognized by the prevalence of open formations where landscape is composed largely of Grassy Savannas on Hydromorphic Soil (61.45%). Herbaceous savannas correspond to the regions most affected by human activity, which is almost entirely represented by extensive cattle breeding areas.

Small-mammal capture success was 1%, of which 57% were *Z. brevicauda*, the most abundant species. Percentages of concordance and discordance of each model built via logistic regression are shown on table 3. All models of capture probability of *Z. brevicauda* (PiZYG) were significant ($P<0.05$), showing concordance among the results between 72.2 and 75.4%. In models I and II ($\chi^2=21.264$; d.f.=12; $P=0.0047$ and $\chi^2=24.240$; d.f.=12; $P=0.019$, respectively), which correspond to the potential distribution of *Z. brevicauda* (PiZYG), habitat distribution showed similar results when the median probability was considered. The Edge of Open Tree Savanna on Hydromorphic Soil and Gallery Forest (EOTSHGF) was the only habitat to show medians higher than 0.5 (Fig.2). This class showed a higher median in Model II, going from 0.53 to 0.7 (Fig.3). When Dense Tree Savanna (DTS) and Gallery Forest (GF) habitats were excluded from the analysis (Model III; χ^2=25.615; d.f.=12; P=0.012), the importance of transition zone between Open Tree Savanna on Hydromorphic Soil and Gallery Forest (EOTSHGF) was emphasized. The edge zone between Open Tree Savanna and Gallery Forest was also shown to be important. Both edge zones appear to be the most suitable areas of occurrence of this species (Fig.4).

The layout of these probabilities among the classes of habitat remained the same in Model IV (χ^2=20.071; d.f.=12; P=0.066). However, none of the habitat classes showed median probability over 0.5 for *Z. brevicauda* (Fig.5). Although *Z. brevicauda* is a known nonforest species (VOSS, 1991), it rarely occurred in open areas distant from forests. Patches of microhabitat (not shown on this scale) found within classes of tree and herbaceous savannas could be important elements for population viability. In contrast to what was expected, considering that *Z. brevicauda* normally prefers open areas, the probability map drawn from potential distribution maps emphasize edge habitats (EOTSGF and EOTSHGF) as areas of high occurrence. These classes, when gathered into one potential distribution map with criteria above 50% of probability (Fig.6), show high probability zones for the species, where EOTSHGF (Fig.7) is related to a high occurrence probability (median higher than 0.75). These zones feature patches or linear forms dispersed throughout the landscape and are associated with transition areas between open and closed formations, sometimes adjacent to seasonal water courses that drain the hills. Cover by edge zones (EOTSGF and EOTSHGF) constitute a very small proportion (4.93%) in comparison to that of savanna in the region.

Table 2. Classes of vegetation and their areas in the upper and middle Surumu River region, identified via classification of a LANDSAT-TM image (Thematic Map of Actual Vegetation).

CLASSES	DESCRIPTION	AREA (km²)
Woodland	Occurring along the Phytoecologic region in Dense Tropical Forest, as well as covering the main mountain ranges of the Savanna region (Serra do Mel, Marari, Banco, Alemanha, etc.).	554.33
Woodland 1	Open Forest without Palm trees (RADAMBRASIL, 1975).	252.61
GF	Gallery Forest. Forest formations under the influence of a 100m wide border.	244.73
EOTSGF	Edge of Open Tree Savanna and Gallery Forest.	96.09
EOTSHGF	Edge of Open Tree Savanna on Hydromorphic Soil and Gallery Forest. Like EOASGF, EOTSHFG distributes linearly throughout the landscape (Figs. 6 and 7).	84.68
DTS	Dense Tree Savanna. A well-developed tree layer, sparse or lacking herb and shrub layer. Rock outcrops (granite) in its interior.	459.76
OTS	Open Tree Savanna. Discontinuous tree layers where shrubs are either lacking or very sparse. Herb layer present although discontinuous. Usually presenting rocky ground.	609.51
OTSH	Open Tree Savanna on Hydromorphic Soil. Discontinuous tree layers where shrubs are either lacking or very sparse. Herb layer is well-developed. Deeper, more humid soil when compared to OAS.	252.56
GSH	Grassy Savanna on Hydromorphic Soil. Tree and shrub layers are absent. Herbaceous layer where short grasses prevail.	1,650.603.00
GSPE	Grassy Savanna on Partially Exposed Soil. Herb layer sparse and discontinuous.	108.60
TEMPL 1	Temporary Lakes with dense vegetation on its banks.	91.35
TEMPL 2	Temporary Lakes with less water and less dense vegetation.	4.01
RPLANT	Rice Plantation.	5.27
TESOIL	Totally Exposed Soil.	43.18
EROCK	Exposed Rocks.	17.01
CLOUD	Cloud cover at the time of data collection by satellite.	39.76

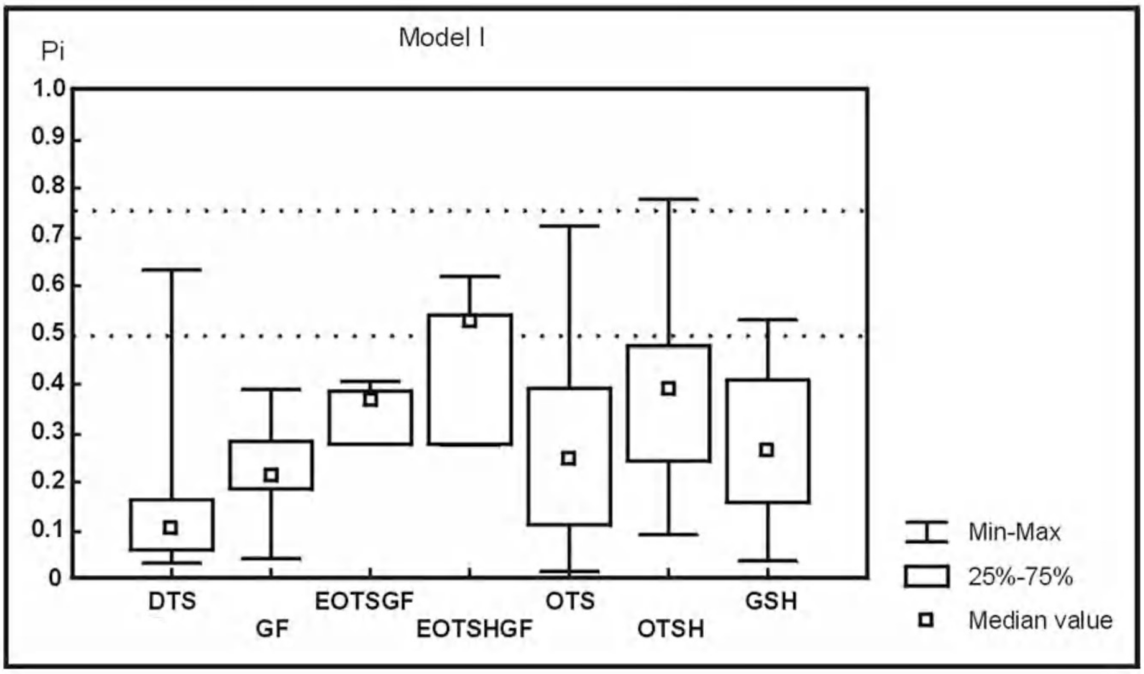

Fig.2- Distribution of the probabilities of occurrence (PiZYG) of *Zygodontomys brevicauda* in classes of habitats (Model I). Abbreviation of the classes of habitat according to table 2.

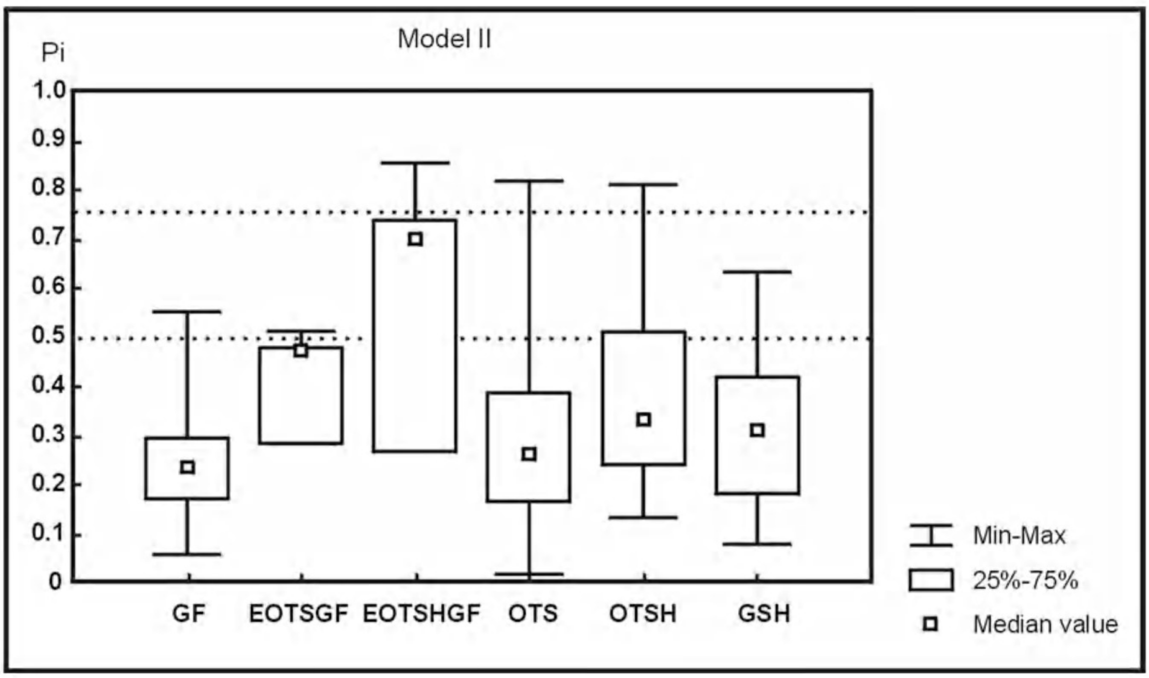

Fig.3- Distribution of the probabilities of occurrence (PiZYG) of *Zygodontomys brevicauda* in classes of habitats (Model II). Abbreviation of the classes of habitat according to table 2.

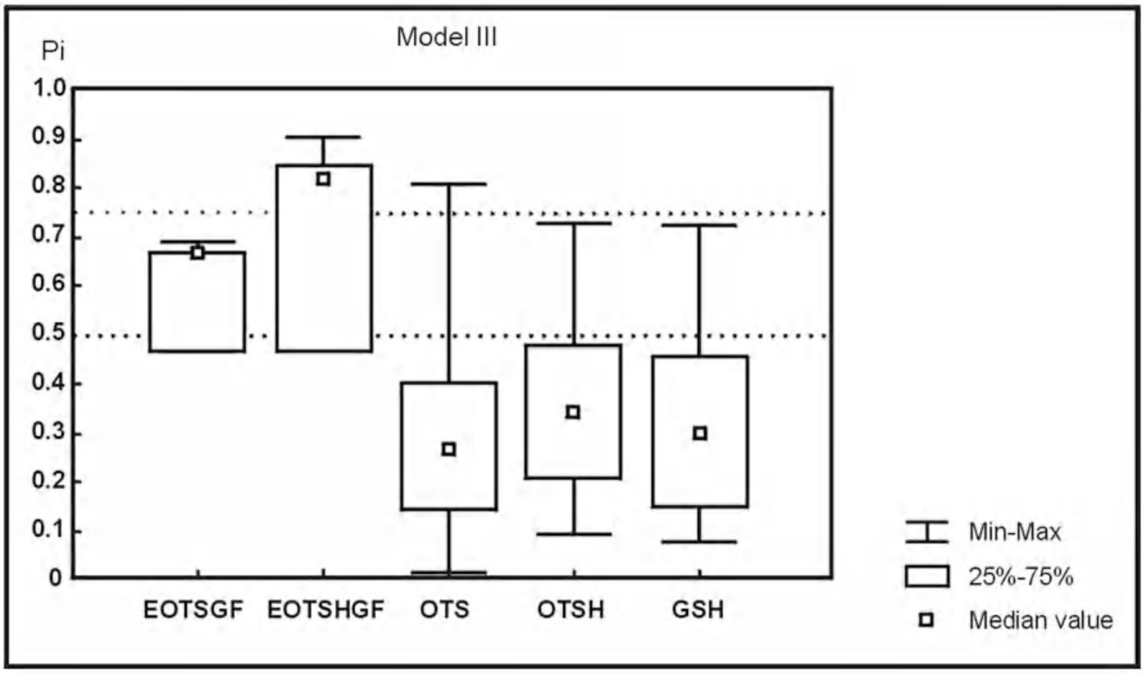

Fig.4- Distribution of the probabilities of occurrence (PiZYG) of *Zygodontomys brevicauda* in classes of habitats (Model III). Abbreviation of the classes of habitat according to table 2.

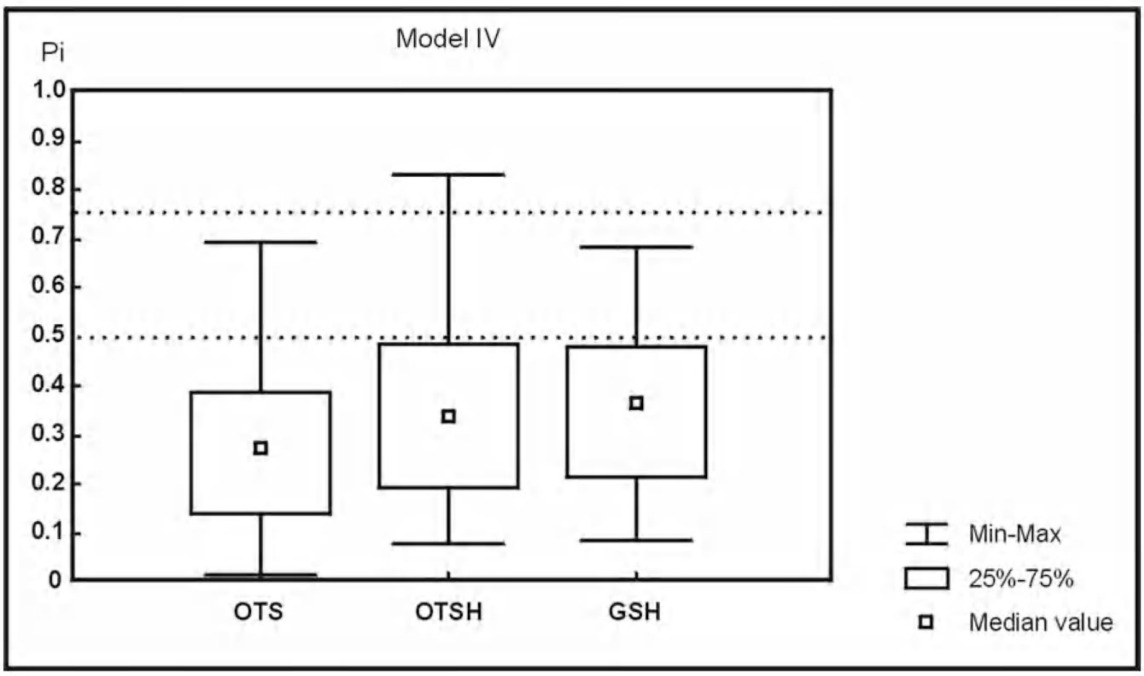

Fig.5- Distribution of the probabilities of occurrence (PiZYG) of *Zygodontomys brevicauda* in classes of habitats (Model IV). Abbreviation of the classes of habitat according to table 2.

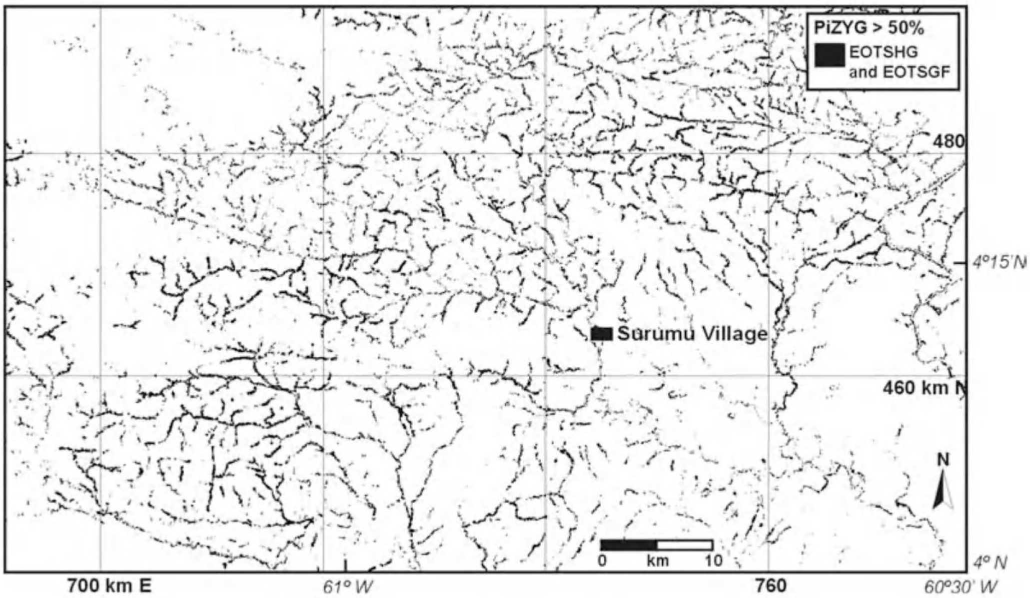

Fig.6- Occurrence-probability map for *Zygodontomys brevicauda* in the Upper and Middle Surumu River region, Roraima, Brazil. EOTSGF (Edge of Open Tree Savanna and Gallery Forest) and EOTSHGF (Edge of Open Tree Savanna on Hydromorphic Soils and Gallery Forest) correspond to an occurrence probability zone of over 50% (PiZIG>0.50). Grid shows UTM coordinates.

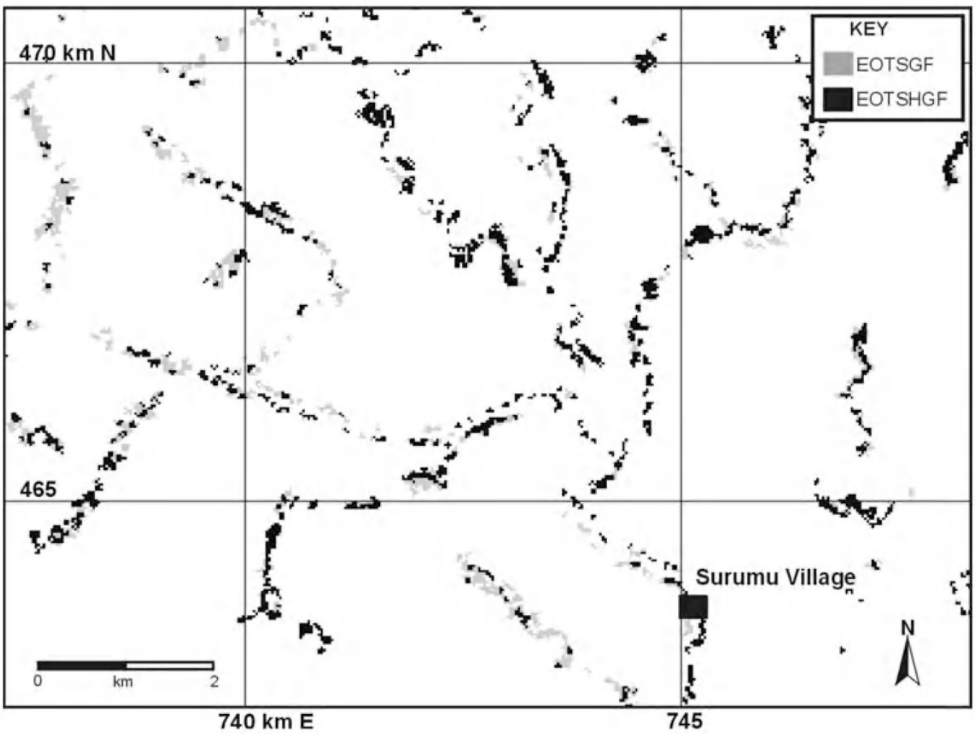

Fig.7- Detail of figure 6: occurrence probability map for *Zygodontomys brevicauda* in the Upper and Middle Surumu River region, Roraima, Brazil – around the Surumu Village. EOTSGF (Edge of Open Tree Savanna and Gallery Forest) corresponds to an occurrence probability zone of 50% (0.75>PiZIG>0.50) and EOTSHGF (Edge of Open Tree Savanna on Hydromorphic Soils and Gallery Forest) to a high probability zone, for occurrence probabilities of over 75% (PiZIG>0.75). Grid featuring UTM coordinates.

Table 3. Regression coefficients (Logistic Regression) of variables and their contribution to prediction of the occurrence of *Zygodontomys brevicauda*.

	χ^2 (df=12) P [a]	β_0 [b]	Structural Variables of Habitats [c]												Concordance Discordance (%) [d]
			FHD100	LIT	RIHERB	HSHRUB	CANHT	CANCV	ROCK	TREEDIS	NUMTREE	GALFDIS	WATDIS	RIROCK	
Model I	21.26	-1.038	0.194	-0.074	-0.058	0.564	0.046	0.237	0.269	0.214	-0.253	-0.321	0.901	-0.871	72.2
	0.005**		0.35	0.77	0.80	0.03**	0.88	0.41	0.25	0.33	0.30	0.28	0.01**	0.00**	27.8
Model II	24.24	-0.814	0.266	-0.099	-0.132	0.671	0.358	0.360	0.250	0.169	-0.415	-0.734	1.5220	-0.522	73.9
	0.019**		0.22	0.68	0.58	0.01**	0.26	0.23	0.42	0.45	0.12	0.06*	0.00**	0.09*	26.1
Model III	25.61	-0.575	0.200	-0.079	-0.244	0.724	0.171	0.267	0.113	0.069	-0.465	-1.142	1.178	-0.542	73.0
	0.012**		0.37	0.76	0.33	0.01**	0.63	0.38	0.66	0.77	0.09*	0.01**	0.01**	0.09*	27.0
Model IV	20.07	-1.344	0.282	-0.560	-0.265	0.659	-0.724	0.573	0.123	0.170	-0.443	-0.751	1.652	-0.595	75.4
	0.066*		0.24	0.26	0.30	0.02**	0.26	0.10*	0.64	0.47	0.13	0.17	0.02**	0.07*	24.6

(*) 0.10≥ P>0.05; (**) P<0.05; (a) Chi-Square (χ^2), degree of freedom (df) and significant value (P) for each Model; (b) intersection; (c) regression coefficient of the variables and significant value. Abbreviation of the structural variables shown on table 1; (d) concordance was considered either when estimated capture probabilities, via regression, were over to 0.5 and captures were positive, or when probability was below 0.5 and captures did not occur.

DISCUSSION

Low rates of capture success are common for tropical small mammal communities in savanna areas (O'CONNELL, 1982; AUGUST, 1983; FONSECA & REDFORD, 1984). Poor conditions are usually reflected in low capture success in spite of serious trapping efforts (O'CONNELL, 1982). BARNETT & CUNHA (1998) had a capture success of 1.82% and ascribe it to environmental and zoogeographic features. Density, especially for *Zygodontomys*, could be higher in the beginning of the dry season, decreasing towards its end in consequence of heavy flooding in seasonal habitats. However, population fluctuations are not regular and show strong differences as regards dry seasons of previous years, but density is always higher than that in the wet season (O'CONNELL, 1982). The role of forest-savanna boundaries either in mammal assemblage features or in species distribution in the Neotropics is poorly understood. The dependence of mammal species on forest-savanna boundaries considering the vegetation types, its degree of vagility, and its type of interaction with plants and its size category were studied by MEDELLIN & REDFORD (1992). Restricted distribution along gallery forests, and the importance of contact zones with other habitat types has been stressed for small mammal on savannas of central Brazil (LACHER *et al.*, 2001; MARES *et al.*, 1986; MARES *et al.*, 1989; NITIKMAN & MARES, 1987). A low proportion of species, where observed, associated solely with savannas. We found that *Z. brevicauda*, which is associated with open areas, showed high probability of occurrence in transition areas between both types of Open Tree Savannas and Gallery Forest. This suggests that these areas present mesic conditions when compared to adjoining habitats that may present resource limitation and other local factors related to vegetation cover, setting a lower limit on local density. Such habitats may serve as buffer from environmental fluctuations as drought, high solar incidence, fire and eventually flooding. As density increases, individuals should occupy alternative habitats toward open savannas but these habitat types may be more extreme. Savannas in Roraima feature a dry period (December-March) as well as high solar incidence (BARBOSA, 1997). This may seriously affect small mammal fauna inhabiting open areas, especially in those subject to livestock ranching and seasonal fires. On the other hand, vast areas of savannas are not homogeneous in featuring adequate microhabitats; their availability and spatial arrangement must determine population viability of small mammals. The terrestrial small mammal captures in the region were mainly related to herbaceous and bushy formations associated with more humid soil. Nevertheless, ecotones make adequate habitats by offering mesic conditions and the viability of the population is at least partially dependent on the savanna-forest boundary. The models show a high frequency of potentially vacant areas, especially in open treeless savannas.

Distribution patterns of species in the region, particularly for *Z. brevicauda*, must be controlled by access to discrete suitable patches in the identified classes. The species may be a colonist of these habitat types where the edges of the Gallery Forest act as source habitats for open savannas. Patches of microhabitat, not shown on the studied scale, and found within classes of tree and herbaceous savannas could be important elements for population viability. Vacant habitats and microhabitats, either those of ephemeral or temporally unstable conditions, may be a feature of the region and extensive temporary empty areas may be a special characteristic of grasslands of northern Amazon. This can be an important aspect in the seasonal dynamics of small mammal fauna of northern Brazil. Additionally, forest-savanna complexes are being altered by cattle grazing and agriculture, and may qualitatively and quantitatively set new levels for the viability of components of the fauna in this poorly known region.

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