Revista Chilena de Historia Natural
61: 223-229, 1988

Home range assessment: a comparison of five methods

Evaluación de ámbito de hogar: una comparación de cinco métodos

TERESA AGÜERO and JAVIER A. SIMONETTI

Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile.

ABSTRACT

The similarity of five methods for estimating trap-revealed home range size was empirically tested using data from captures of small mammals in central Chile. Distance between successive recaptures, adjusted range length, minimum area, exclusive boundary strip and Mazurkiewicz elliptical method usually ranked individual home range sizes in a similar fashion. Sensitivity of home range estimates to sample size varied between methods and species. Distance between recaptures was less biased by small sample size than minimum area. Based on the demands upon the data base, sample size sensitivity, and other factors, it is recommended to calculate home ranges of South American small mammals using either the distance between recaptures, or the minimum area method.

Key words: Home range, sample size sensitivity, small mammals, South America.

RESUMEN

Se analiza empíricamente la similitud de cinco métodos para estimar tamaños de ámbitos de hogar basados en datos de trampeo. Los métodos de distancia entre capturas sucesivas, longitud ajustada de movimiento, área mínima, franja de borde exclusiva y elipse de Mazurkiewicz generalmente ordenaron los tamaños de ámbitos de hogar individuales en forma similar. La sensibilidad de las estimaciones de ámbito de hogar al tamaño de la muestra difiere entre métodos y especies. Las estimaciones basadas en distancias entre capturas sucesivas son menos sesgadas que aquellas basadas en el área mínima para tamaños muestreales pequeños. En base a los requerimientos a la base de datos, sensibilidad y otros factores, se sugiere que para los micromamíferos sudamericanos, los ámbitos de hogar debieran calcularse según los métodos de distancia entre recapturas sucesivas o área mínima.

Palabras clave: Ambito de hogar, sensibilidad a tamaño muestral, pequeños mamíferos, Sudamérica.

INTRODUCTION

Home range is the area occupied by an individual during its daily activities (Burt 1943). Trap-revealed home ranges for small mammals are based frequently on the location of capture-recapture events within a trapping grid. Several methods are available to calculate home range size (De Blase & Martîn 1981). One group of methods utilizes the distance between recaptures, expressing results in linear units. These indices include: a) distance between successive recaptures, and b) adjusted range length. The first index is the mean distance traveled between successive recaptures, whereas the second adds one-half the distance between traps to each end of the maximum linear displacement (Stickel 1954, Brant 1962). Another group of methods estimates home range area utilizing the points of capture. These include: a) minimum area, b) convex polygon, c) exclusive boundary strip and d) Mazurkiewicz elliptical model. The minimum area method is the area enclosed by connecting the peripheral capture-recapture points in a counterclockwise fashion (Jennrich & Turner 1969). The convex polygon method is the area enclosed by the connection of capture points to form the smallest convex polygon possible. The exclusive boundary strip method estimates the enclosed area by adding a strip equal to half the distance between traps to the minimum area (Stickel 1954). Finally, the Mazurkiewicz method

(Received 14 October 1987. Accepted 15 November 1988)

calculates home range size by estimating the area of an ellipse determined by the covariance of the capture points (Mazurkiewicz 1971; see also Jennrich & Turner 1969).

A growing number of studies are including estimates of home range sizes for South American small mammals. The distance between successive recaptures has been used by Greer (1965), Contreras (1973), Dalby (1975), Pearson & Ralph (1978), Pearson (1983), Simonetti (1986), Murúa *et al.* (1987), and Nitikman & Mares (1987), and the adjusted range length by Fulk (1975). The minimun area method has been used by Alho & Souza (1982) and R.A. Ojeda (1986, personal communication), the exclusive boundary strip by Contreras (1972), the inclusive boundary strip by Ernest & Mares (1986), and Mazurkiewicz's method by González *et al.* (1982) and Murúa *et al.* (1986). In some cases, different methods have been used for the same species: *e.g.* the boundary strip, distance between recaptures, and Mazurkiewicz ellipse have all been used to estimate home range size of *Oryzomys longicaudatus* (Bennett 1832), and the adjusted range length, distance between recaptures, and Mazurkiewicz ellipse methods have all been used for *Akodon olivaceus* (Waterhouse 1837) (Contreras 1972, Fulk 1975, González *et al.* 1982, Murúa *et al.* 1986, 1987).

The use of different methods for a single species renders comparisons, and eventual generalizations, difficult to interpret. Differences in home range size could be either a real biological difference or an artifact of the methodology used in the calculations. Our goal is to compare the results of five methods commonly used for home range assessment using the same set of data. If two or more methods yield comparable results, the ranking of individuals and species according to home range size should be positively correlated. Support of this hypothesis would allow one to compare, qualitatively at least, populations studied by different methods.

At the same time, we tested the sensitivity to sample size of the simplest home range methods. Home range calculations are strongly dependent on the number of recapture events with the accuracy of the estimates increasing asymptotically with sample size (Mares *et al.* 1980, Swihart & Slade 1985). In general, no clear procedure has been followed by researchers of South American mammals in this regard. Criteria for inclusion of data in the analysis range from just one up to at least seven recaptures (*e.g.*, Ernest & Mares 1986, Nitikman & Mares 1987). Therefore, even when using the same method, comparison between populations or species may be obscured by the undetected effect of sample size.

MATERIAL AND METHODS

Empirical testing of the similarity and sensitivity of home range methods was effected on small mammal populations in central Chile. Field work was carried out at San Carlos de Apoquindo, 20 km E of Santiago. Vegetation was a shrubland dominated by *Lithraea caustica* (Mol.) H. et Arn. and *Quillaja saponaria* Mol. The herbaceous layer was dominated by *Vulpia megalura* (Nott.) Rydberg, *Trifolium glomeratum* L., *Bromus* spp., and *Torolis nodosa* (L.) Gaertn.

Trapping was conducted in four periods: 11-24 August 1984; 28 August-12 September 1984, 17 October – 17 November 1984, and 8 January-5 February 1985. Two adjacent trapping grids 70 m apart were used. These grids had a 5 x 10 arrangement, at 10–m intervals, with one Sherman trap per station. Traps were operated on a 24 hr basis, and all animals were individually marked by fur-clipping.

The five methods compared were: a) distance between successive recaptures, b) adjusted range length, c) minimum area, d) exclusive boundary strip, and e) Mazurkiewicz ellipse. Comparisons were performed both intra and interspecifically. Intraspecific comparisons and the analysis of the effect of sample size on home range size was performed on *A. olivaceus* and *O. longicaudatus*, for which the largest data set was available. Home range size was estimated for each individual with at least three captures. Interspecific comparisons and sample size sensitivity was studied for the two simplest methods, distance between successive recaptures, and minimum area. The percentage change in home range size with increasing number of recaptures as compared to the home range size estimate based on the total number of recaptures was calculated for each individual. For each sample size category, the mean percentage of change was then calculated.

RESULTS

A total of 156 individuals of six species was caught during the study period. However, only 70 (45%) of these were captured three or more times. Analyses were therefore based on six out of 13 *Akodon longipilis* (Waterhouse 1837), 20 of 34 *A. olivaceus*, seven of 22 *Marmosa elegans* (Waterhouse 1838), five of 12 *Octodon degus* (Molina 1782), 27 of 60 *O. longicaudatus*, and five out of nine *Phyllotis darwini* (Waterhouse 1837).

Ranking of home range size for individuals according to: a) distance between successive recaptures (DBR), b) adjusted range length (ARL), c) minimum area (MAR), d) exclusive boundary strip (EBS), and e) Mazurkiewicz ellipse (MEL) were positively correlated for both *A. olivaceus* and *O. longicaudatus*, except MAR-DBR and MAR-MEL in *A. olivaceus* (Table 1).

TABLE 1

Similarity of home range estimates. Figures are Spearman rank correlation coefficients for home range ordinations based on five different methods. Values above the diagonal are for estimates on *Akodon olivaceus* (n = 20 individuals), below the diagonal are for *Oryzomys longicaudatus* (n = 27). All correlations are significant at $P < 0.025$, except for MAR-MEI an MAR and DBR ($P > 0.05$) in *A. olivaceus*. Symbols for methods are: DBR = distance between successive recaptures; ARL = adjusted range length; MAR = mimimum area; EBS = exclusive boundary strip; and MEL = Mazurkiewicz ellipse.

Similitud de estimaciones de ámbito de hogar. Los valores son los coeficientes de correlación por rangos de Spearman para ordenamientos de ámbitos de hogar basados en cinco métodos diferentes. Los valores sobre la diagonal son para estimaciones en *Akodon olivaceus* (n = 20), aquellos bajo la diagonal son para *Oryzomys longicaudatus* (n = 27). Todas las correlaciones son significativas a $P < 0.025$, excepto para MAR-MEL y MAR-DBR ($P > 0.05$) en *A. olivaceus*. Los símbolos para los métodos son: DBR = distancia entre recapturas sucesivas; ARL = longitud ajustada de movimiento; MAR = área mínima; EBS = franja de borde exclusiva, y MEL = elipse de Mazurkiewicz.

METHODS	DBR	ARL	MAR	EBS	MEL
DBR	–	.78	.34	.56	.72
ARL	.44	–	.70	.88	.67
MAR	.42	.78	–	.89	.47
EBS	.38	.76	.97	–	.53
MEL	.59	.77	.82	.72	–

That is, individuals which had the largest range length generally had the greatest home range areas. The strength of the correlation varied, however. Unfortunately, no test is available to determine the significance of the differences between Spearman rank correlation coefficients (Conover 1980). Despite this shortcoming, the data suggest that individuals are ranked in a similar fashion according to their home range size, estimated either by distance or area method. Similarly, species were ranked basically in the same order also by the distance between successive recaptures and mimimun area method (Spearman rank correlation coefficient rs = 1.00, P = 0.005; Table 2).

Home range size varied according to sample size, and sensitivity changed according to both the method used and the species studied. Sixteen or more recaptures per individual were required to achieve, on the average, less than 10% change in home range size when assessed by the distance between successive recaptures for both *A. olivaceus* and *O. longicaudatus*. However, while eight recaptures were required to attain less than 10% change in area when determining home range by the minimum area method for *A. olivaceus*, 20 recaptures were needed to achieve such a reduction of variability for *O. longicaudatus* (Fig. 1). The standard deviation of the estimates also varied with sample size, method, and species. Standard deviation of distance between successive recaptures decreased as sample size increased for both *A. olivaceus* and *O. longicaudatus*, although markedly more so for the latter species. In contrast, standard deviation of minimum area estimates did decrease with sample size for *A. olivaceus* and did not for *O. longicaudatus* (Fig. 2).

Relatively few individuals were recaptured the 10 or more times required to obtain a reliable estimate of home range size. Only three out of 34 *A. olivaceus* and five out of 60 *O. longicaudatus* were recaptured at least thirteen times in a total of 8,775 trap-nights (Fig. 3). On the average, individuals of *A. olivaceus* and *O. longicaudatus* were captured 4.2 and 4.5 times, respectively. Modal number of captures was one for the two species. If individuals with no recaptures are excluded, modal numbers were two and three captures for *A. olivaceus* and two captures for *O. longicaudatus* (Fig. 3).

TABLE 2

Home range size of small mammals of central Chile. Estimates are calculated as distance between successive recaptures (DBR, m) and minimum area (m^2). Figures are mean ± standard error. N is number of individuals and M is the modal number of captures per species.

Tamaño de ámbito de hogar de micromamíferos de Chile central. Las estimaciones se basan en los métodos de distancia entre recapturas sucesivas (DBR, m) y área mínima (m^2). Los valores son promedios ± error estándar. N es el número de individuos, y M es el número modal de recapturas por especie.

Species	Minimum area	N	DBR	N	M
Akodon longipilis	379.7 ± 34.1	3	19.0 ± 3.8	5	2
Akodon olivaceus	514.9 ± 163.2	11	20.6 ± 2.9	20	2
Marmosa elegans	694.9 ± 115.8	6	30.7 ± 3.7	6	2
Octodon degus	361.1 ± 110.2	4	16.0 ± 2.4	5	3
Oryzomys longicaudatus	683.5 ± 119.6	24	23.8 ± 2.0	27	2
Phyllotis darwini	135.3 ± 27.5	2	9.6 ± 1.4	5	2

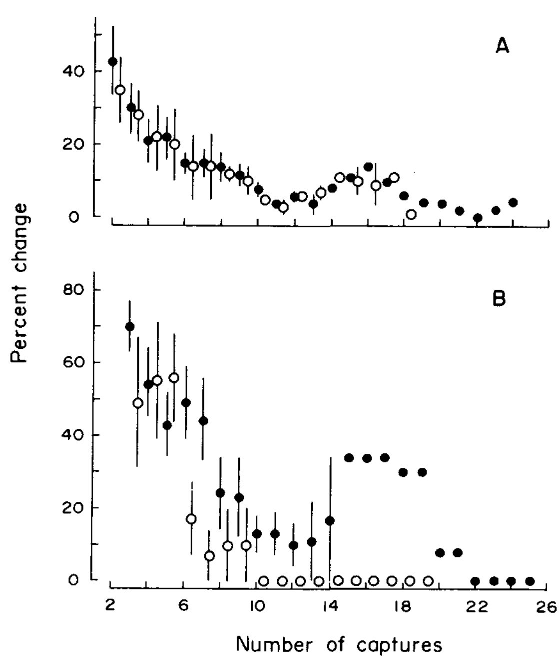

Fig. 1: Mean percent change of home range size (± SE) as related to the number of captures for *Akodon olivaceus* (o) and *Oryzomys longicaudatus* (●) based on: (A) distance between succesive recaptures, and (B) minimum area.

Porcentaje promedio de cambio (± EE) del tamaño del ámbito de hogar en función del número de capturas para *Akodon olivaceus* (o) y *Oryzomys longicaudatus* (●), según los métodos de: (A) distancia entre recapturas sucesivas, y (B) área mínima.

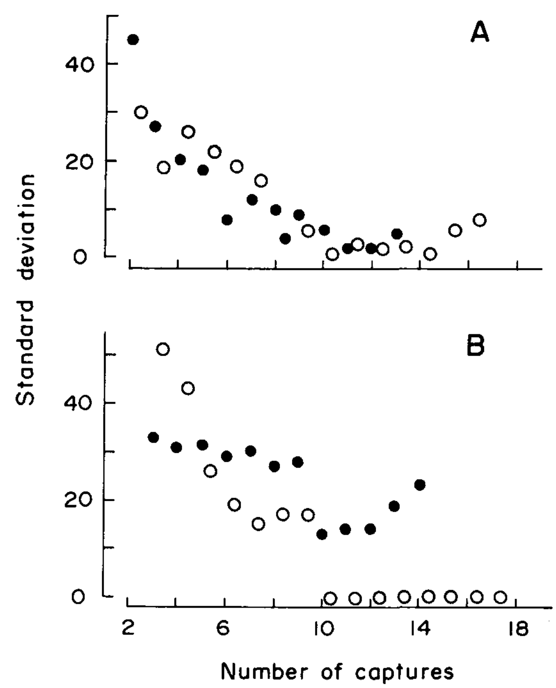

Fig. 2: Standard deviation of home range size as related to the number of captures for *Akodon olivaceus* (o) and *Oryzomys longicaudatus* (●), based on: (A) distance between successive recaptures, and (B) minimum area.

Desviación estándar del tamaño del ámbito de hogar en función del número de capturas para *Akodon olivaceus* (o) y *Oryzomys longicaudatus* (●), según los métodos de: (A) distancia entre recapturas sucesivas, y (B) área mínima.

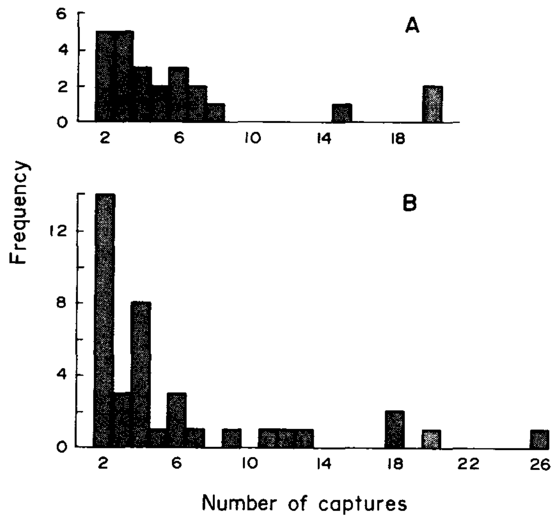

Fig. 3: Frequency distribution of captures of *Akodon olivaceus* (A) and *Oryzomys longicaudatus* (B).

Distribución de frecuencias de capturas de *Akodon olivaceus* (A) y *Oryzomys longicaudatus* (B).

DISCUSSION

The results for the five methods compared generally ranked home range size of individuals and species in a similar order. Home range estimates are, therefore, comparable. These results may not appear surprising, as the data set is the same for all calculations. However, under this same condition, other home range estimates may not give comparable results (Stickel 1954, Mohr & Stumpf 1966, Jennrich & Turner 1969), as was our case for MAR-DBR and MAR-MEL.

Trap-revealed home ranges are sensitive to trap spacing. The larger the spacing between trapping points, the larger the absolute estimates. At the same time, because usually a fraction of the possible area occupied by an animal is sampled by trapping, home range estimates tend to be smaller than estimates based on direct observations or telemetry (Flowerdew 1976).

The dependency of home range estimates on the configuration of the trapping grid determines that trap-revealed home ranges are relative measures. For any given method, absolute magnitudes of home range size are valid as long as trap spacing is the same. Our results indicate that rank order comparisons will be valid even if estimates are based on different methods. Differences in home range size within and between species could be attributed to the biology of the organism, and not to spurious results emerging from different methodologies, with the possible exception of comparisons based on MAR.

So far, choice of any method over the others for home range assessment cannot be recommended based on our comparisons, as all five methods yielded similar home range size rankings. However, the methods differ in their demands upon the data base, sensitivity to sample size, and degree of biological realism. These differences allow us to choose among them.

Mazurkiewicz ellipse is a probabilistic model that requires bivariate normal data (Mazurkiewicz 1971). Whether trapping data meet this requirement and/or how the model resists violations of this assumption is not known. Actually, bivariate normality is rarely true and difficult to assess (Anderson 1982). Nonstatistical techniques such as the distance between recaptures, adjusted range length, minimum area, and exclusive boundary strip methods do not involve the assumption of normality or any other statistical distribution, which is an advantage as compared to Mazurkiewicz elliptical and other statistically-based methods.

Among nonstatistical methods, neither the adjusted range length nor the exclusive boundary strip techniques have proven to be biologically more accurate or realistic than the simplest distance between recaptures and minimum area methods (Flowerdew 1976). Therefore, by parsimony alone these two methods should be preferred.

For all four analyses of sample size sensitivity, accuracy of estimates increased with the number of recaptures. Few individuals are recaptured enough times as to achieve less than 10% bias in home range estimate. Actually, most individuals of both *A. olivaceus* and *O. longicaudatus* are trap-shy. That is, they are captured less often than expected by chance. This phenomenon is common among other small mammals of central Chile (Simonetti 1986). Trap-shyness determines that few individuals from the potentially trappable population are recaptured enough times to render accurate estimates of their home ranges.

Accuracy is higher when home ranges are estimated by the distance between successive recaptures than by the minimum area. With low sample sizes, which is the usual situation in studies of small mammals of central Chile, mean percent change and standard deviation are smaller using distance than area estimates (Figs. 1 & 2; see also Jennrich & Turner 1969, Anderson 1982, Swihart & Slade 1985). Furthermore, this technique maximizes the heuristic value of field data. Several individuals (two *A. longipilis*, five *A. olivaceus*, two *O. degus*, two *O. longicaudatus* and three *P. darwini*) were recaptured in only one trapping row or column, determining straight lines which do not allow calculation of area. This phenomenon is common when traps are set in grid patterns, particularly if trap stations are located far apart (Chitty 1937). Therefore, the number of individuals with useable data increases when the distance between successive recaptures is used as an index of home range size. However, much biological information is lost, *e.g.*, degree of home range overlap, and space utilization distributions.

A final point should be considered. Home range estimates require that each recapture event be independent. Home range size is underestimated when calculations are based on successive recaptures that are autocorrelated. Statistical techniques for assessing home range size are more sensitive to autocorrelation than nonstatistical ones. Among the latter, the minimum area performs better than distance between recaptures if successive recaptures are dependent events (Swihart & Slade 1985).

None of the five methods compared are free of problems, nor are the variety of other available techniques (*e.g.* Anderson 1982, Jennrich & Turner 1969). Considering the methods so far used for South American small mammals, we suggest that nonstatistical methods should be preferred over statistical ones. From these, an index —distance between successive recaptures— and estimate —minimum area— are the simplest. Given its relative accuracy at low sample size and its widespread use, distance between successive recaptures should be preferred over the minimum area if recapture events prove to be independent. Otherwise, trapping design should be modified to attain such independency (Swihart & Slade 1985) or sample size should be increased to allow use of the minimum area method.

ACKNOWLEDGMENTS

This research has been partially supported by a Sigma Xi Grant-in-Aid and by grant DIB N 2596-8714, both to J.A. Simonetti. Roberto Murúa kindly provided us with a copy of the Mazurkiewicz method. This research is part of the graduate work of T. Agüero.

LITERATURE CITED

ALHO CJR & MJ de SOUZA (1982) Home range and use of space in *Zygodontomys lasiurus* (Cricetidae, Rodentia) in the Cerrado of central Brazil. Annals of the Carnegie Museum 51: 127-132.

ANDERSON DJ (1982) The home range: a new nonparametric estimation technique. Ecology 63: 103-112.

BRANT DH (1962) Measures of the movements and population densities of small rodents. University of California, Publications in Zoology 62: 105-184.

BURT WH (1943) Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 24: 346-352.

CHITTY D (1937) A ringing technique for small mammals. Journal of Animal Ecology 6: 36-53.

CONOVER WT (1980) Practical nonparametric statistics. 2nd. ed., Wiley, New York, x + 462 pp.

CONTRERAS JR (1972) El home range en una población de *Oryzomys longicaudatus philippi* (Landbeck) (Rodentia, Cricetidae). Physis (Argentina) 31: 353-361.

CONTRERAS JR (1973) Ecología del ratón de campo *Akodon azarae* en la región semiárida del sudoeste bonaerense. Laguna de Chasicó, Partido de Villarino. Deserta (Argentina) 4: 15-24.

DALBY PL (1975) Biology of Pampa rodents. Balcarce area, Argentina. Publications of The Museum, Michigan State University 5: 153-271.

DE BLASE AF & RE MARTIN (1981) A manual of mammalogy. 2nd. ed. W.C. Brown, Dubuque, Iowa. 436 pp.

ERNEST KA & MA MARES (1986) Ecology of *Nectomys squamipes*, the neotropical Water rat, in central Brazil: home range, habitat selection, reproduction and behaviour. Journal of Zoology, London (A) 210: 599-612.

FLOWERDEW JR (1976) Ecological methods. Mammal Review 6: 123-159.

FULK GW (1975) Population ecology of rodents in the semiarid shrublands of Chile. Occasional Papers, The Museum, Texas Tech University 33: 1-140.

GONZALEZ LA, R MURUA & R FEITO (1982) Densidad poblacional y padrones de actividad espacial de *Akodon olivaceus* (Rodentia: Cricetidae) en habitats diferentes. In Salinas P (ed) Zoología Neotropical. Actas VIII Congreso Latinoamericano de Zoología, Mérida, Venezuela: 935-947.

GREER JK (1965) Mammals of Malleco Province, Chile. Publications of The Museum, Michigan State University 3: 51-151.

JENNRICH RI & FB TURNER (1969) Measurement of non-circular home range. Journal of Theoretical Biology 22: 227-237.

MARES MA, MR WILLIG & NA BITAR (1980) Home range size in eastern chipmunks, *Tamias striatus*, as a function of number of captures: statistical biases of inadequate sampling. Journal of Mammalogy 61: 661-669.

MAZURKIEWICZ M (1971) Shape, size and distribution of home ranges of *Clethrionomys glareolus* (Schreber; 1870). Acta Theriologica 26: 23-60.

MOHR CO & WA STUMPF (1966) Comparison of methods for calculating areas of animal activity. Journal of Wildlife Management 30: 293-304.

MURUA R, LA GONZALEZ & PL MESERVE (1986) Population ecology of *Oryzomys longicaudatus philippi* (Rodentia: Cricetidae) in southern Chile. Journal of Animal Ecology 55: 281-293.

MURUA R, PL MESERVE, LA GONZALEZ & C JOFRE (1987) The small mammal community of a Chilean temperate rain forest: lack of evidence of competition between dominant species. Journal of Mammalogy 68: 729-738.

NITIKMAN LZ & MA MARES (1987) Ecology of small mammals in a gallery forest of central Brazil. Annals of the Carnegie Museum 56: 75-95.

PEARSON OP (1983) Characteristics of a mammalian fauna from forests in Patagonia, southern Argentina. Journal of Mammalogy 64: 476-492.

PEARSON OP & CP RALPH (1978) The diversity and abundance of vertebrates along an altitudinal gradient in Peru. Memorias del Museo de Historia Natural "Javier Prado" 18: 1-97.

SIMONETTI JA (1986) Heterogeneity of recaptures in Chilean small mammals. Revista Chilena de Historia Natural 59: 59-63.

STICKEL LF (1954) A comparison of certain methods of measuring ranges of small mammals. Journal of Mammalogy 35: 1-15.

SWIHART RK & NA SLADE (1985) Influence of sampling intervals on estimates of home-range size. Journal of Wildlife Management 49: 1019-1025.