HOME RANGE OF MARSH RATS, *Holochilus sciureus*, A RODENT PEST IN RICE FIELDS OF VENEZUELA

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SUMMARY

Radio tracking techniques were used to determine the home range of marsh rats Holochilus sciureus *in rice fields of the Guárico River Irrigation System, Venezuela, in order to study movement patterns of tropical rodents and provide information for the management of this agricultural pest. After being captured using Tomahawk traps, ten adult rats were equipped with radio-transmitters and tracked during the 2004 dry season between 18:00 and 6:00. Home ranges were estimated based on four methods: minimum convex polygon, harmonic mean contours, fixed kernel and adaptive kernel. Home ranges of males and females ranged between 0.6 and 1.3ha depending on the method of estimation. Male-female range overlap and possible agonistic interactions between males, suggest male territoriality and a polygynic mating system. Males showed greater motility than females. The results also reveal relationships between these rodent movements and environmental changes produced within rice plantations. Ecological studies provide information for an integrated pest control program.*

Home range is an aspect of ecology that provides answers to many biological questions related to population dynamics, social interactions, and spacing patterns. Home range is defined as the area traversed by the individual in its normal activities of food gathering, mating and caring for young (Burt, 1943). It varies in size, shape and structure according to the characteristics of the individual, the population and/or the environment (McNab, 1963; Tew *et al*., 2000; Saiful *et al*., 2001; Priotto *et al*., 2002). The concept is not synonymous to territory, which refers to an individual's more or less exclusive area that is defended against the presence of conspecifics (Murie and Harris, 1978).

Spacing patterns are recognized as an important factor for population regulation (Ostfeld, 1990). Moreover, studying animal home range can prove necessary for the design of management strategies (Harris *et al*., 1990; Seaman and Powell, 1996; Kenward, 2001; Brown *et al*., 2003) and this is particularly so in the case of species considered as pests in agro-ecosystems. Rodents have been recognized as important pests in both agricultural fields and harvest storages. Rodent species have also been the focus of many studies of space use and home range, mostly in temperate regions. A few studies, however, have been conducted in tropical regions (*e.g.* Endries and Adler, 2005) and data is particularly scarce in Latin America, where many agro-ecosystems suffer the outbreaks of rodent populations and the concomitant economical consequences.

The marsh rat, *Holochilus sciureus* Wagner 1842, is the main rodent pest in rice and sugar cane fields in Venezuela and other Neotropical countries. It belongs to the Muridae family and is a nocturnal semi-aquatic species, possessing membranes in its hind feet and building its nests above the water level in flooded fields, making it a very successful rodent in inundated crops (Agüero, 1979; Cartes, 1979; Agüero and Castillo, 1981; Cartaya, 1983; Agüero *et al*., 1985; Cartaya and Aguilera, 1985; García-Rangel, 2002; Barreto and García-Rangel, 2005). Its average weight is ~130g, but males over 300g have been captured by the authors and by Agüero (1979). This rat feeds mainly on grass stalks, leaving the tillers in mounds on the ground and causing serious damage to the crops mentioned, and despair among the farmers (Twigg, 1962, 1965; Martino and Aguilera, 1989).

Current management of this species in rice fields consists mainly on the use of second generation rodenticides and bounty schemes. These are applied by the growers themselves, with very little planning and poor safety precautions. The rodenticides are distributed along the banks of the rice tanks, in indiscriminate amounts and with questionable results. To make things worse, in outbreak years, growers become desperate and choose to use organo-phosphide insecti-

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cides as a "more effective" alternative. The main reason for this ill-planned management of *H. sciureus* is that very little research has been done on its ecology, with the end result that virtually no novel management strategies have been designed, as it is the case with most tropical rodent pests in South America. Thus, there is the need to study the ecology of this species with the purpose of offering alternatives regarding its control that are more cost effective and more environmentally friendly than those used today.

The home range of *H. sciureus* in rice fields in Venezuela was previously estimated (±SE) at 0.278 ±0.403ha by Cartaya and Aguilera (1984) employing mark-recapture techniques in a 1ha grid and using minimum convex polygons. They considered this result as an underestimate of the real value due to the low capture frequency and the fact that some individuals were recaptured 2-3km away from the grid, 1-2 months after the previous capture. For that reason, the use of an alternative sampling approach, such as radio-tracking, became necessary as well as the use of methods of range estimation other than minimum convex polygons which have been already proved to be biased (Burgman and Fox, 2003). Therefore, this study aims to determine the home range of *H. sciureus* in rice fields as revealed by radio-tracking techniques, with the intention of improving previous estimations and providing useful information for the development of novel management strategies.

Study Area

The study was conducted in rice plantations (plots 152 and 173) located within the Guárico River Irrigation System (SRRG; 8°50'43"N, 67°32'34"W), near the city of Calabozo, Guárico State, Venezuela. The plots are divided in strips parallel to the inclination of the terrain, which are in turn subdivided in rectangles ~3.5ha by earth banks, canals and roads creating 'tanks' that can be flooded and drained in order to manage the water level in the field. The climate is seasonal, with a rainy season lasting from May to October and a dry season from December to March. April and November are transitional months. Mean annual rainfall is 1328mm. The dominant vegetation consists of rice (*Oryza sativa*) in different stages of development. Most abundant rodent species present in the area are *Holochilus sciureus*, *Sigmodon alstoni*, *Zygodontomys brevicauda* and *Oligoryzomys* sp. (García-Rangel, 2002).

Materials and Methods

Trapping program

Tomahawk® live traps (79 ±31 units) were set 10 steps apart along earth banks surrounding tanks over a 1-2 night period per trapping session between Oct 2003 and Feb 2004, for a total of 628 trap nights. The traps were set and baited using pumpkin (*Cucurbita maxima*) pieces between 16:00 and 19:00, and were checked and closed between 6:00 and 10:00 the next day. Rodents captured were anesthetized using Halothane (Fluothane®), weighed with a dynamometer (Pesola AG, Switzerland), measured, and identified to the species level. Those identified as *H. sciureus* were further classified as adults or juveniles according to their weight (Agüero, 1979). On occasions when trapping efficiency was very low, manual trapping was performed taking advantage of the habitat disturbance caused by the plough. Large *H. sciureus* specimens that escaped the plough were caught using a net. The rats caught by this method were checked for injuries and then released in a site different from that of capture because of the lack of vegetation cover left by the plough.

Tracking program

A total of 10 adult marsh rats, six males and four females, were equipped with radiocollars SOM 2380 (weight ~10g) or SOM 2070 (weight ~3g) from Wildlife Materials, Inc., USA, according to each individual's weight, verifying that the transmitters did not exceed 5% of the animal's body mass, percentage that does not significantly increase their energy expenditure, following Berteaux *et al.* (1996). Transmitters for each individual were tuned to a different frequency in the 219MHz range. Once each rat recovered from anesthesia, it was released at the site of capture, except in cases of manual capture, where the animal's habitat had been destroyed and they were released along the nearest canal. All procedures were performed following guidelines for humane treatment of animals.

Radio tracking began as the radiocollars were fitted to the rodents and was continued until April 2004. In this way, an entire rice cycle was covered, particularly the dry season one, which is the one that suffers the most intense attack by rodents. Fixes were obtained by triangulation every 30min between 18:00 and 6:00 each night using a VHF receptor, a three-element portable yagi antenna, a compass and a GPS for a total of 40 track nights in six months. One to three animals were tracked each night. UTM coordinates were used throughout the study.

Incremental area analysis and home range estimation were performed using the software Ranges 6 (Kenward *et al.*, 2003). Incremental area analyses were performed for each animal in order to establish if sufficient location fixes had been obtained by recalculating the area of the minimum convex polygon (100% of the fixes) as successive locations were added.

Data analysis

Four methods of home range estimation were used: minimum convex polygons (MCP), harmonic mean contours (HMC), fixed kernel (FK) and adaptive kernel (AK). The percentage of fixes (for MCP), or the utilization distribution in the probabilistic methods (HMC, FK and AK) to be used as estimates of home range were established examining the discontinuities in utilization plots, which calculate the area of home range cores of different percentages. Home range estimation using the MCP employed the established percentage of the location fixes closest to the center of each animal's range. We chose the range center as the harmonic mean of the spatial coordinate components to guarantee that it would lay within an area with high density of location fixes. HMC estimation was performed using a 150×150 matrix without location centering. FK and AK estimations were performed using a 40×40 matrix and the smoothing parameter h was chosen as the median of the values for each range calculated by least squares cross validation. To facilitate comparisons with other studies, we calculated home range size for each rat using the 100% MCP method, the most commonly reported method. Areas of intensive use were termed core areas and were calculated as 40% of the utilization distribution. The ratio of core area to home range (the set percentage for each method) sizes was calculated to determine the relative sizes of core areas within home ranges. Home range and core area contours were plotted on a map of the area.

The median of home range values was used as a measure of central trend because data were not normally distributed. Differences between sexes in home range size, core area and core area to home range ratios were examined using Mann-Whitney tests. Methods of estimation of home range size were compared using Friedman's ANOVA and were further examined employing Wilcoxon's pair wise comparisons. Independence of fixes was examined by calculating Schoener's t^2/r^2 index (Swihart and Slade, 1985) as implemented by Ranges 6.

The distances traversed by individuals in 30min were calculated and compared between sexes using a Mann-Whitney test and between individuals using Kruskall-Wallis tests. Individual differences were further analyzed using Tukey's multiple contrasts test. Furthermore, maximum distances traversed in 30min were identified, as well as maximum distances reached from the point of release and from the center of the home range for each rat.

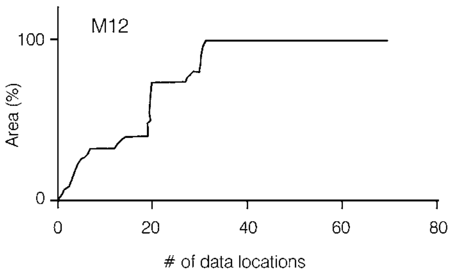

Figure 1. Incremental area analysis of individual M12.

Results

A total of 10 animals, six males (referred to as M3, M5, M8, M9, M12 and M14) and four females (F1, F2, F6 and F7), were radio-tracked. Between 7 and 375 location fixes were obtained per rat. Males weighed 224-276g and females 114-212g. Only animals M3 and M9 were released at locations different from the site of capture. In the field, it was perceived that individuals M14 and F7 occupied two home ranges, each separated in time.

Incremental area analyses for the home ranges of individuals M5, M9, M12, M14, F1, F6 and F7 reach asymptotes indicating sampling saturation (Figure 1). The second perceived ranges of animals M14 and F7 were examined separately and stabilization was observed, confirming that each of these rats had two temporarily separated areas. As was expected, ranges for M8 and F2 did not reach an asymptote due to lack of data. The range for M3 did not stabilize in spite of having enough (50) location fixes.

The median home range size using the 100% MCP method was 3.90ha. Table I shows the median home range (95%) and core area (40%) sizes obtained in this study for *H. sciureus*, as well as median core area to home range indexes for each method of estimation. No significant differences were detected in these variables between males and females (lowest value of P obtained was Mann-Whitney Z= -0.71, P=0.48), regardless of the estimation method used.

TABLE I
MEDIAN HOME RANGE (95%) AND CORE AREA (40%) SIZES (IN ha) OF *H. sciureus* AS WELL AS MEDIAN CORE AREA TO HOME RANGE INDEXES FOR EACH METHOD OF ESTIMATION

	95%	40%	40% / 95%
MCP	0.635	0.166	0.261
HMC	1.288	0.116	0.156
FK	0.696	0.115	0.283
AK	1.098	0.089	0.190

MCP: minimum convex polygon, HMC: harmonic mean contour, FK: fixed kernel, AK: adaptive kernel. The median home range size using the 100% MCP method was 3.90ha.

The values estimated for home range size vary significantly according to the method employed in obtaining them (χ^2= 17.4, d.f.= 3, P=0.00). Further comparisons showed that estimations obtained by AK and MCP methods did not differ significantly (P=0.5). Differences were detected in all other comparisons (P<0.03), showing that estimations obtained by FK were significantly smaller than those of the other probabilistic methods whilst those obtained by HMC were the largest.

Figures 2 and 3 show the contours generated by each method for individuals M12 and F7 (first home range). It is worth noting that the area enclosed by the 100% MCP method (median= 3.89ha) is much larger than the size of the next contour (95% MCP of 0.64ha). The next contours, 95% and 40% MCP, show a smaller size difference (Table I).

Contours corresponding to the HMC, FK and AK methods show more rounded edges than those created by the MCP method (Figure 2). This becomes most pronounced in the case of the HMC method, where the home ranges in the present study are oval-shaped. The contours generated by the FK method are less uniform than both the shapes obtained by the HMC and AK methods. Furthermore, there is more variation between the different percentage contours presented for the AK method than for the FK method.

Home range overlap was detected between individuals F6 and M14 (first home range), and M14 (second home range) and F7 (first home range). M14's first

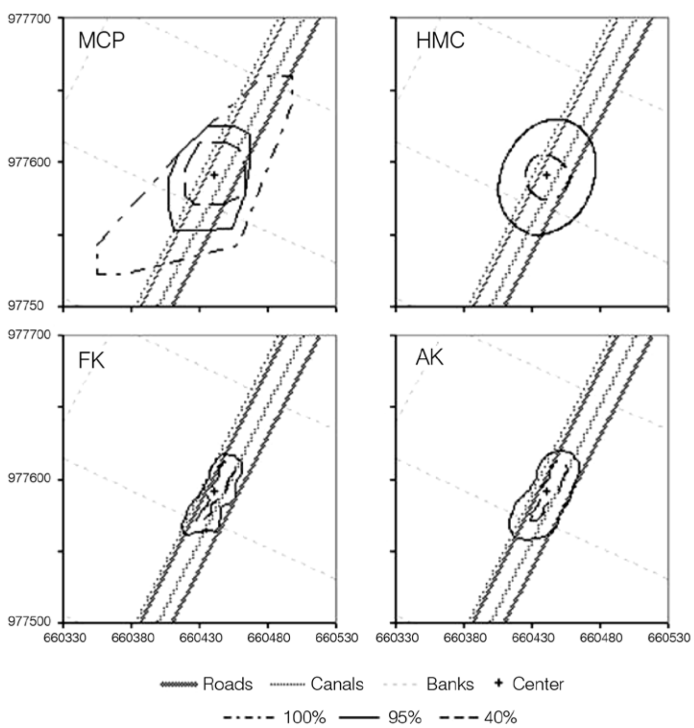

Figure 2. Home range and core area contours for M12 according to minimum convex polygon (MCP), harmonic mean contoun (HMC), fixed kernel (FK) and adaptive kernel (AK) methods of estimation.

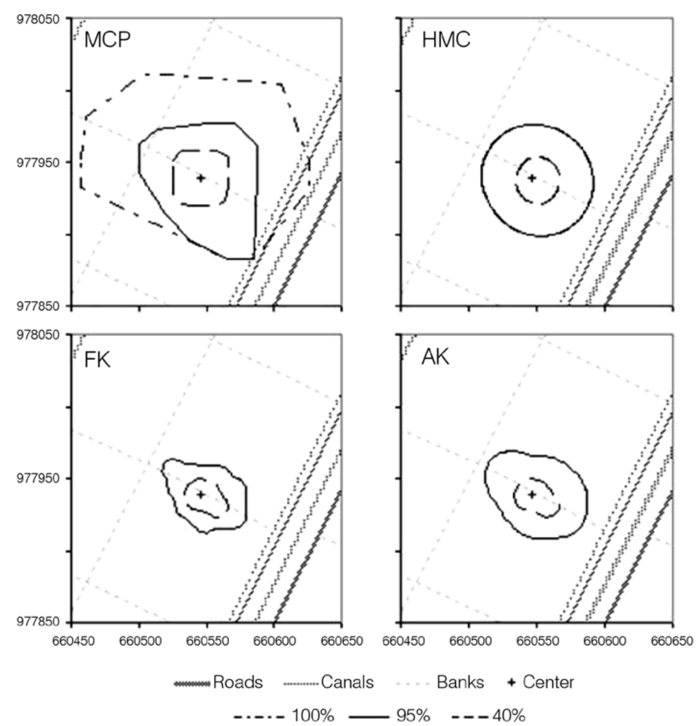

Figure 3. Home range and core area contours for F7 according to minimum convex polygon (MCP), harmonic mean contourn (HMC), fixed kernel (FK) and adaptive kernel (AK) methods of estimation.

home range contains between 19.7 and 75.4% of F6's area, depending on the method of estimation. However, overlap of F6's home range on M14's is only 3.6 to 18%. F6's home range center is localized inside M14's home range according to three of the estimation methods, while F6's core area is at least partially contained in M14's home range in every instance. M14's second home range overlaps 7.2% on F7's range, while F7's contains 6% of M14's second range, when analyzed using the MCP method only.

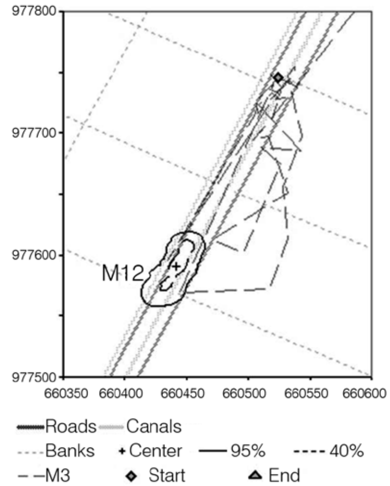

Figure 4. M3's route upon M12's home range.

Mean distance traversed in 30min by the individuals studied was 37.8 ±52.2m. No significant differences were detected between males and females in this variable (Mann-Whitney U-test z= -0.99, P=0.32). Mean distance reached from site of release was 469.6 ±375.5m for all individuals. The mean value of this measurement was 588.5 ±431.8m for males and 271.5 ±162.9m for females. The greatest distance traversed from the site of release was 1153.6m and corresponded to M3 in four nights. This male was released along the main drainage canal on plot 173 after being caught manually. It started moving along the canal and entered M12's home range core. At this time the location of both rats was the same and subsequently M3 traversed 140m in the next 30min. M3 then went across an adjacent tank, returned to the main drainage canal and met again with M12. M3 then started moving northeast and came across M9 in its home range core; it then traversed 189m in the next 30min. After that, M3 moved onto the next plot, reaching its greatest distance from the site of release. Finally, this animal signal was lost (Figure 4). This animal had not established a distinct home range.

M9, a male that was relocated after being manually captured, moved along the main drainage canal and was then repeatedly located in a home range adjacent to the main road on plot 173. The farthest position reached by this animal from the site of release was within this area.

In the case of M14, the greatest distance reached from the site of capture corresponded to its second home range. The centers of its home ranges were separated by 788m. Similarly, M7's maximum distance reached from the site of release felt within its second home range; its home range centers were separated by 197m.

Discussion

Home range estimation methods

The 100% MCP method estimation obtained in this study is 14 times the figure obtained previously by Cartaya and Aguilera (1984) for *H. sciureus* (0.278ha) in rice fields in the nearby Portuguesa State. The difference is due to the fact that these authors employed the capture-mark-recapture method for obtaining the individual locations within a 1ha square grid. This resulted in a small number of fixes per animal (<6) while in the present study calculations were performed employing a larger number of fixes (>30). Furthermore, the area studied by Cartaya and Aguilera (1984) was limited by the size of the trapping grid. The differences observed show the limitations of the capture-mark-recapture technique with respect to radio-tracking techniques for home range estimations.

Contours generated using the MCP method resulted in similar home range and core area estimations as those of the probabilistic methods employed. In particular, they did not differ significantly from the AK method estimations. Using the harmonic instead of the arithmetic mean for determining the home range center ensured that its location fell within an area with high density of fixes and not in a place seldom visited by the animal, suggested by Harris *et al.* (1990) and Kenward *et al.* (2003).

Results obtained employing the HMC method appear to be overestimations of the home ranges of the *H. sciureus* individuals studied when using other methods. Furthermore, it is very unlikely that the home ranges of animals will show oval shapes like those seen in Figures 2 and 3. In particular, it was anticipated that M12's home range would have an elongated shape aligned with the main drainage canal as shown by the other probabilistic methods (FK and AK). Furthermore, these results agreed with what was perceived directly on the field. Similar results were obtained by Seaman and Powell (1996) when they examined the estimations generated from real and simulated data using the HMC method. It is important to keep in mind that certain biased or leptokurtic distributions will cause errors in the estimations by this method (Harris *et al.*, 1990).

Estimations obtained using the AK method, were 1.6 times larger than those of the FK method, mainly because the former allows the smoothing parameter h to vary within the reference grid. As a result, areas with fewer fixes are assigned a larger h than areas of higher density, causing greater smoothing of these areas and increasing the importance of the edges of the distribution (Worton, 1989). By applying the AK method of estimation to sets of real and simulated data, Worton (1995) and Seaman and Powell (1996) determined that it produces overestimations of the home range size, and concluded that the FK approach offers a better description of the utilization distribution. Again, the range of M12 serves as a good example, since what was observed in the field corresponds more accurately to the estimation obtained by the FK method.

Interactions: territoriality

Male and female home ranges showed similar sizes. However, due to the apparent separation in classes of males (see below), the similarity is probably limited to females and "resident" males.

M3's encounters with individuals M12 and M9 and its subsequent travel across more than 100m in 30min suggests events of territory defense by resident rats (M12 and M9) where the intruder was expelled from their home ranges. In both instances, M3 was the smaller rat. Therefore, intrasexual territoriality seems to exist among males of *H. sciureus*, apparently causing males to be separated in two socially distinct classes according to their size: "residents" and "transients".

On the other hand, *H. sciureus* appears to show no intersexual territoriality as evidenced by the home range overlap between individuals M14 and F6, and their concurrences in space and time. Overlap was also observed in the field between individuals F6 and F1, suggesting no female intrasexual territoriality. Furthermore, workers in the rice fields claim to have found occupied nests only 10m apart.

Territoriality usually results from the need to defend resources that improve an individual's survival probability and reproductive success. Due to the large asymmetry in parental care between sexes among mammals, reproductive success among females is limited by the number of young they can successfully produce and rear, while in males it is limited by the amount of females they can fertilize (Clutton-Brock and Harvey, 1978). As a result, the existence of territoriality among females depends on the spatial distribution of food, while in males it depends on the spatial distribution of females (Ostfeld, 1985). The extensive rice field in which this study was carried out offers a very uniform habitat with an abundant and renewable food supply, in which the cost of defending this resource by females will be higher than the cost of tolerating intruders, as is suggested by Ostfeld (1990) for small mammals that feed on grass. Accordingly, no intrasexual territoriality is observed among females. The resulting spatial distribution of females appears to allow males to include the home ranges of several females within their own, while not tolerating other males, resulting in a pattern similar to that reported for *Microtus xanthognathus* by Wolff and Lidicker (1980).

Mobility

The mean distance traversed by the studied individuals in 30min suggests that they could potentially travel more than 900m in one night (12h) if they moved in one direction. Indeed, M3 was found 781m from the last fix recorded 23h before. The results indicate no significant difference in this enormous potential mobility between males and females. However, differences among the sexes in maximum distance traveled from the site of release were recorded. As a result, it can be seen that males move across larger distances than females in absolute terms. The greater absolute mobility observed in males could explain the deviations from the expected 1:1 sex ratio reported in a study by García-Rangel (2002) at the same site. In this study, the authors set the traps in the periphery of the cultivation tanks, possibly causing the capture of a sub-population conformed mainly of males and reflecting the differences in absolute mobility among the genders. Consequently, it may be time to reconsider the common practice of distributing rodenticides on the earth banks that surround the rice tanks. It is important to keep in mind that the habitat of these rats is covered by rice, and that it is very unlikely that they will especially go to the earth banks to eat the bait. The poor bait acceptance by rodents inhabiting areas with abundant food resources has been noted before (see Leung and Clark, 2005). Moreover, behavioral traits may prevent rats to ingest lethal amounts of poison, as it was demonstrated for brown rats by Brunton *et al*. (1993). Our results suggest that if some rats are going to be affected by rodenticides, they will be mostly “transient” males, but their death will not reduce the birth rate of the population. A plausible solution that has been implemented by one of the farmers consists on setting the rodenticide on plastic containers above the water level within the tanks. This practice, nonetheless, has not been assessed yet.

Migration

The management of extensive rice fields in the SRRG generates extensive disturbances (tank drainage, harvest, burning of leftover rice plants and soil preparation) in the habitat of *H. sciureus*, causing surviving individuals to migrate. This situation was exemplified by individuals M8, M14 and F7. M8 survived the harvest by remaining hidden underground, as was assessed by radio-tracking, and then began moving away from the site. Rat F7 shifted its home range after the harvest, while M14 changed its home range when the tank on which it was located was drained. However, after each of the mentioned disruptions, the vegetative cover is reestablished, due to the sprouting of rice plants previously harvested or to the beginning of a new cultivation cycle, again providing favorable conditions for rodents. As a result, these areas become available to animals that had been forced to migrate. This could explain the variations in the population of *H. sciureus* observed by García-Rangel (2002) according to the phase of cultivation. It is worth mentioning that sowing in the plots within the SRRG is done asynchronously, which is why there are always tanks with rice in differing stages of development. This promotes the existence of small populations of rats that continuously rotate between tanks. Intrasexual territoriality will then promote migration of males across greater distances than in the case of non-territorial females, which will find a new home range with greater ease, as was observed in this study. Because of these disruptions, both male and female rats will be forced to move across rodenticide-stocked earth banks. However, the large number of rats on the move will deplete the rodenticide that is available and create a breach in the perimeter that will allow other rats to move into the rice tanks without getting poisoned. Once these healthy rats get settled (females and “resident” males), it is very unlikely that they will expose themselves on the earth banks again.

Features of the ecology of marsh rats have been shown that help understand why control measures are not effective enough to prevent crop damage. Moreover, these control measures produce environmental consequences that affect both wildlife and human health. An integrated pest control program including biological control, trapping and a rational use of rodenticides based on knowledge of the ecology of the pest is much necessary in this and other regions throughout the neotropics. Additional studies including regional trends in population growth, predator-mediated regulation and experimenting different control measures will assist in the design of a cost-effective and environmentally friendly control program for this species.

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REFERENCES

Agüero D (1979) Análisis reproductivo de una población de *Holochilus brasiliensis* (Rodentia-Cricetidae) en cultivos de arroz del Estado Portuguesa. *Agron. Trop. 28*: 101-116.

Agüero D, Castillo P (1981) Recomendaciones sobre el control de ratas en el cultivo de arroz. *CIARCO 3*: 1-4.

Agüero D, Quevedo J, Tovar I, Flores A, Martínez V, Espinosa G (1985) Estimación de daños y observaciones sobre la rata arrocera (*Holochilus venezuelae*) en caña de azúcar. *C. azúcar 3*: 63-70.

Alvizu PE, Aguilera M (1998) Uso del espacio de *Marmosa robinsoni* (Didelphidae: Marsupialia) en una zona xerófila de los Andes Venezolanos. *Ecotrópicos 11*: 81-92.

Barreto GR, García-Rangel S (2005) *Holochilus sciureus. Mammal. Sp. 780*: 1-5.

Berteaux D, Masseboeuf F, Bonzom JM, Bergeron JM, Thomas DW, Lapierre H (1996) Effect of carrying a radiocollar on expenditure of energy by meadow voles. J. *Mammal. 77*: 359-363.

Brown PR, Leung LK, Sudarmaji P, Singleton GR (2003) Movements of the ricefield rat, *Rattus argentiventer*, near a trap-barrier system in rice crops in West Java, Indonesia. *Int. J. Pest Manag. 49*: 123-129.

Brunton CFA, Macdonald DW, Buckle AP (1993) Behavioural resistance towards poison baits in brown rats, *Rattus norvegicus. Appl. Anim. Behav. Sci. 38*: 123-129.

Burgman MA, Fox JC (2003) Bias in species range estimates from minimum convex polygons: implications for conservation and options for improved planning. *Anim. Cons. 6*: 19-28.

Burt WH (1943) Territoriality and home range concepts as applied to mammals. *J. Mammal. 24*: 346-352.

Cartaya E (1983) *Estudio de la Comunidad de Roedores Plaga Asociados a un Cultivo de Arroz (*Oryza sativa *L.) a lo largo de su ciclo de vida, en el Estado Portuguesa*. Thesis. Universidad Simón Bolívar. Sartenejas, Venezuela. 89 pp.

Cartaya E, Aguilera M (1984) Área de acción de *Holochilus venezuelae* Allen, 1904 (Rodentia, Cricetidae) en un cultivo de arroz. *Acta Cient. Venez. 35*: 162-163.

Cartaya E, Aguilera M (1985) Estudio de la comunidad de roedores plaga en un cultivo de arroz. *Acta Cient. Venez. 36*: 250-257.

Cartes A (1979) Biología de la rata arrocera (*Holochilus* sp., *Sigmodon* sp., *Sigmomys* sp. *Oryzomys* sp.). I: Morfometría y densidad poblacional. *Acta Cient. Venez. 30*(Supl. 1): 145.

Clutton-Brock TH, Harvey PH (1978) Mammals, resources and reproductive strategies. *Nature 273*: 191-195.

Endries MJ, Adler GH (2005) Spacing patterns of a tropical forest rodent, the spiny rat (*Proechimys semispinosus*), in Panamá. *J. Zool. (Lond) 265*: 147-155.

García-Rangel S (2002) Estudio de la comunidad de roedores asociada al cultivo de arroz (*Oryza sativa*) en el Estado Guárico. Thesis. Universidad Simón Bolívar, Sartenejas, Venezuela. 37 pp.

Harris S, Cresswell WJ, Forde PG, Trewhella WJ, Woollard T, Wray S (1990) Home range analysis using radio-tracking data - a review of problems and techniques particularly as applied to the study of mammals. *Mammal. Rev. 20*: 97-123.

Kenward RE (2001) *A Manual for Wildlife Radio Tagging*. Academic Press. London, UK 311 pp.

Kenward RE, South AB, Walls SS (2003) *Ranges 6 v1.2: For the Analysis of Tracking and Location Data*. Anatrack Ltd, Wareham, UK.

Leung LKP, Clark NM (2005) Bait avoidance and habitat use by the roof rat, *Rattus rattus*, in a piggery. *Int. Biodet. Biodeg. 55*: 77-84.

Martino AMG, Aguilera M (1989) Food habits of *Holochilus venezuelae* in rice fields. *Mammalia 53*: 545-561.

McNab BK (1963) Bioenergetics and the determination of home range size. *Am. Nat. 97*: 133-140.

Murie JO, Harris MA (1978) Territoriality and dominance in male Columbian ground squirrels (*Spermophilus columbianus*). *Can. J. Zool. 56*: 2402-2412.

Ostfeld RS (1985) Limiting resources and territoriality in microtine rodents. *Am. Nat. 126*: 1-15.

Ostfeld RS (1990) The ecology of territoriality in small mammals. *Trends Ecol. Evol. 5*: 411-415.

Priotto J, Steinmann A, Polop J (2002) Factors affecting home range size and overlap in *Calomys venustus* (Muridae: Sigmodontinae) in Argentine agro-ecosystems. *Mammal. Biol. 67*: 97-104.

Saiful AA, Idris AH, Rashid YN, Tamura N, Hayashi F (2001) Home Range of Sympatric Squirrel Species Inhabiting a Lowland Dipterocarp Forest in Malaysia. *Biotropica 33*: 346-351.

Seaman DE, Powell RA (1996) An evaluation of the accuracy of Kernel density estimators for home range analysis. *Ecology 77*: 2075-2085.

Swihart RK, Slade NA (1985) Testing for independence in animal movements. *Ecology 67*: 255-258.

Tew TE, Todd IA, Macdonald DW (2000) Arable habitat use by wood mice (*Apodemus sylvaticus*). 2. Microhabitat. *J. Zool.(Lond) 250*: 305-311.

Twigg GI (1962) Notes on *Holochilus sciureus* in British Guiana. *J. Mammal. 43*: 369-374.

Twigg GI (1965) Studies on *Holochilus sciureus barbirensis*, a cricetine rodent from the coastal region of British Guiana. *Proc. Zool. Soc. (Lond) 145*: 263-283.

Wolff JO, Lidicker WZ (1980) Population ecology of the taiga vole, *Microtus xanthognathus*, in interior Alaska. *Can. J. Zool. 58*: 1800-1812.

Worton BJ (1989) Kernel methods for estimating the utilization distribution in home-range studies. *Ecology 70*: 164-168.

Worton BJ (1995) Using Monte Carlo simulation to evaluate kernel-based home range estimators. *J. Wildl. Manag. 59*: 794-800.

ÁREA DE ACCIÓN DE LA RATA ARROCERA, *Holochilus sciureus*, UN ROEDOR PLAGA EN CAMPOS DE ARROZ DE VENEZUELA

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RESUMEN

Se determinó el área de vivienda de ratas arroceras, Holochilus sciureus*, en el Sistema de Riego Río Guárico, Venezuela, mediante técnicas de seguimiento por radio con el fin de contribuir al conocimiento de los patrones de movimiento de roedores tropicales y proveer de información útil para el manejo de esta plaga agrícola. Diez ratas adultas fueron capturadas usando trampas Tomahawk, se les colocó un radio-transmisor y se siguieron durante la estación de sequía de 2004 desde las 18:00 hasta las 06:00. El área de vivienda fue estimada con cuatro métodos: polígonos mínimos convexos, medias armónicas, kernel fijo y kernel adaptado. El área de vivienda de hembras y machos se estimó en 0,6 a 1,3ha, dependiendo del método empleado. Las áreas de machos y hembras se solaparon y posibles interacciones agonísticas observadas entre machos sugieren territorialidad y un sistema de apareamiento poligínico. Los machos mostraron mayor movilidad que las hembras. Estos resultados a su vez relacionan los patrones de movimiento de estos roedores causados por cambios ambientales en campos de arroz. Estudios ecológicos proveen información para la formulación de programas de control integral de plagas.*

ÁREA DE AÇÃO DO RATO AQUATICO DA ESPÉCIE *Holochilus sciureus*, UM ROEDOR PRAGA NOS PLANTAÇÕES DE ARROZ DA VENEZUELA

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RESUMO

Determinou-se a área de moradia de ratos aquáticos Holochilus sciureus, no Sistema de Irrigação Río Guárico, Venezuela, mediante técnicas de acompanhamento por radio com o fim de contribuir ao conhecimento dos padrões de movimento de roedores tropicais e prover informação útil para a manipulação desta praga agrícola. Dez ratos adultos foram capturados usando armadilhas Tomahawk, e foram monitorados, mediante o uso de radio transmissores, durante a estação de seca de 2004 desde às 18:00 até as 06:00. A área de moradia foi estimada com quatro métodos: polígonos mínimos convexos, medias armônicas, kernel fixo e kernel adaptado. A área de moradia de fêmeas e machos foi estimada em 0,6 a 1,3ha, dependendo do método empregado. As áreas de machos e fêmeas se sobrepuseram e possíveis interações agonísticas observadas entre machos sugerem territorialidade e um sistema de acasalamento poligínico. Os machos mostraram maior mobilidade que as fêmeas. Estes resultados por sua vez relacionam os padrões de movimento destes roedores causados por mudanças ambientais em plantações de arroz. Estudos ecológicos provêm informação para a formulação de programas de controle integral de plagas.