Primates (2009) 50:81–84
DOI 10.1007/s10329-008-0113-2

SHORT COMMUNICATION

Choice of analytical method can have dramatic effects on primate home range estimates

Cyril C. Grueter · Dayong Li · Baoping Ren · Fuwen Wei

Received: 11 December 2007 / Accepted: 24 October 2008 / Published online: 21 November 2008

Abstract Primate home range sizes can vary tremendously as a consequence of the analytical technique chosen to estimate home range. This is exemplified by a recent dataset on free ranging snub-nosed monkeys (*Rhinopithecus bieti*) in Northwest Yunnan, China. Our findings show that the grid cell method cannot substitute for the minimum convex polygon (MCP) method and vice versa. MCP-based estimates are far too large, especially when the form of the home range is irregular due to forays into peripheral areas. Here, we propose an adjusted polygon method, whereby unsuitable and never visited areas are clipped out from the polygon, thus producing more accurate results. Compared to the grid cell method, the adjusted MCP is much more robust when the number of group relocations is limited; MCP turned out to be the method of choice for calculation of monthly and seasonal home ranges. The grid cell method on the other hand yielded the most precise estimates for total or annual home ranges. The style of ranging exhibited by a given primate taxon or population determines which analytical procedures should be applied to estimate home range size, and we would stress the need for thorough evaluation of the pros and cons of home range estimators before conducting field work and analysing data.

Keywords Grid cell method · Home range estimates · Minimum convex polygon · Primate

C. C. Grueter (✉)
Anthropological Institute and Museum,
University of Zurich-Irchel, Winterthurerstrasse 190,
8057 Zurich, Switzerland
e-mail: ccgrueter@aim.uzh.ch

D. Li
Qinling Golden Snub-nosed Monkey Research Centre,
College of Life Science, Northwest University,
710069 Xi'an, China

B. Ren · F. Wei
Key Laboratory of Animal Ecology and Conservation Biology,
Institute of Zoology, Chinese Academy of Sciences,
100101 Beijing, China

Introduction

Various analytical techniques exist to quantify the home ranges of non-human primates, and each technique has its strength and limitations. By far the most commonly applied methods are the grid cell method and the minimum convex polygon (MCP) method. Using the grid cell method (White and Garrott 1990; Adams and Davis 1967), the area traversed by a study group is dissected by a grid of cells or squares, and the sum of the grid cells with associated positional records provides an estimate of home range size. The grid cell method often produces underestimates of range sizes (e.g. Sterling et al. 2000). On the other hand, the grid cell method may also overestimate home range size because it is highly affected by the size of the grid squares employed (e.g. Lehmann and Boesch 2003; Kool and Croft 1992).

An MCP is constructed by connecting the outer locations to form a convex polygon, and the area of this polygon is then calculated (Hayne 1949; White and Garrott 1990; Harris et al. 1990). The drawbacks of this method are manifold: MCPs provide only crude outlines of primates' home ranges, generally overestimate home range area, are highly sensitive to outliers (i.e. effect of excursions), and can incorporate large areas that are never used, etc. (Powell 2000; Ostro et al. 1999; Burgman and Fox 2003).

Our methodological comparison demonstrates that the choice of a particular analytical technique can have substantial consequences on the corresponding home range estimates. This is exemplified by a recent dataset on black-and-white snub-nosed monkeys (*Rhinopithecus bieti*).

Methods

Data were collected on a partially habituated group of *R. bieti* at South Baimaxueshan Nature Reserve (27°34′N, 99°17′E) over a period spanning 15 months (September 2005–November 2006). The study area is a montane and temperate forest. We took a location record, i.e. a GPS reading of the study group's position, every 30 min or when we found fresh scat. Instead of doing conventional group follows for five consecutive days per month, we trailed the group whenever conditions were favourable and obtained an average of 82 location records per month. The usual 5-day-per-month sampling regime would have resulted in a drastic under-representation of the monthly home ranges because the group covers vast areas over the course of a whole month.

GPS readings for group location were entered into ArcView (http://www.esri.com/software/arcgis/arcview/about/features.html. Total home range size was obtained by adding up the areas of all grid cells visited by the study group. The size of a grid cell is 0.0625 km^2, i.e. 250 × 250 m. Lacunae, i.e. cells not entered by the study group but surrounded by entered cells, were eliminated provided they contain supposedly suitable habitat (in our case all kinds of forest as opposed to open land), and isolated grid cells were linked with the minimum number of intervening cells containing suitable habitat. Three grid cells known to be pastures (unsuitable habitat) were not included in the computation of the home range size even though they were surrounded by grids having been visited by the focal group.

For the calculation of seasonal and monthly home ranges, we applied a combination of the 100%-MCP method (MCP estimates based on all the fixes collected) and the grid cell method. We first created monthly and seasonal polygons ('unadjusted polygons') and then adjusted them by clipping out grid cells containing unsuitable habitat and grid cells that had never been visited. Unvisited grid cells became visible after overlaying the seasonal and monthly polygons with the total grid cell-based home range map. All 'ever-visited' grid cells fell into forested areas (based on a GIS vegetation strata map and ground truthing).

Results

Monthly range sizes varied enormously, depending on the method applied, e.g. the June range was 16.96 km^2 based on the uncorrected MCP and 14.52 km^2 based on the adjusted MCP; the grid cell approach, however, yielded an estimate of only 1.06 km^2 (Table 1). The value obtained using MCP is 16 times larger than the grid-based value. The original MCP consistently yielded the largest estimates of monthly and seasonal home ranges, while the grid cell method yielded the most conservative ones. The adjusted polygon method yielded intermediate results (Table 1; Fig. 1). Furthermore, the total home range size estimate increased with increasing grid size. Using a 250 m grid, the home range size was 24.75 km^2, using a 500 m grid, it was 34.25 km^2.

Discussion

It is an established fact that the same data analysed by different methods may yield highly variable numerical range size estimates (Macdonald et al. 1980). This is in line with our findings. Thus, choice of an inappropriate method may lead to

Table 1 Monthly home range size estimates (in km^2) for the Gehuaqing group of *Rhinopithecus bieti* based on different methodologies. *MCP* Minimum convex polygon

Month	No. of location records	Original MCP	Adjusted MCP	250 m grid	Relative difference between grid and MCP
September 2005	55	5.44	5.13	0.94	5.79
October 2005	107	1.27	1.27	1.25	1.02
November 2005	76	7.86	7.36	1.06	7.41
December 2005	90	5.96	5.83	1.88	3.17
January 2006	40	0.85	0.73	0.5	1.7
February 2006	42	9.94	5.13	1.31	7.59
March 2006	120	11.39	8.95	3.0	3.80
April 2006	124	19.52	12.77	4.06	4.81
May 2006	89	1.75	1.75	1.0	1.75
June 2006	53	16.96	14.52	1.06	16.00
July 2006	83	6.03	6.03	1.56	3.86
August 2006	103	15.60	10.48	2.44	6.39

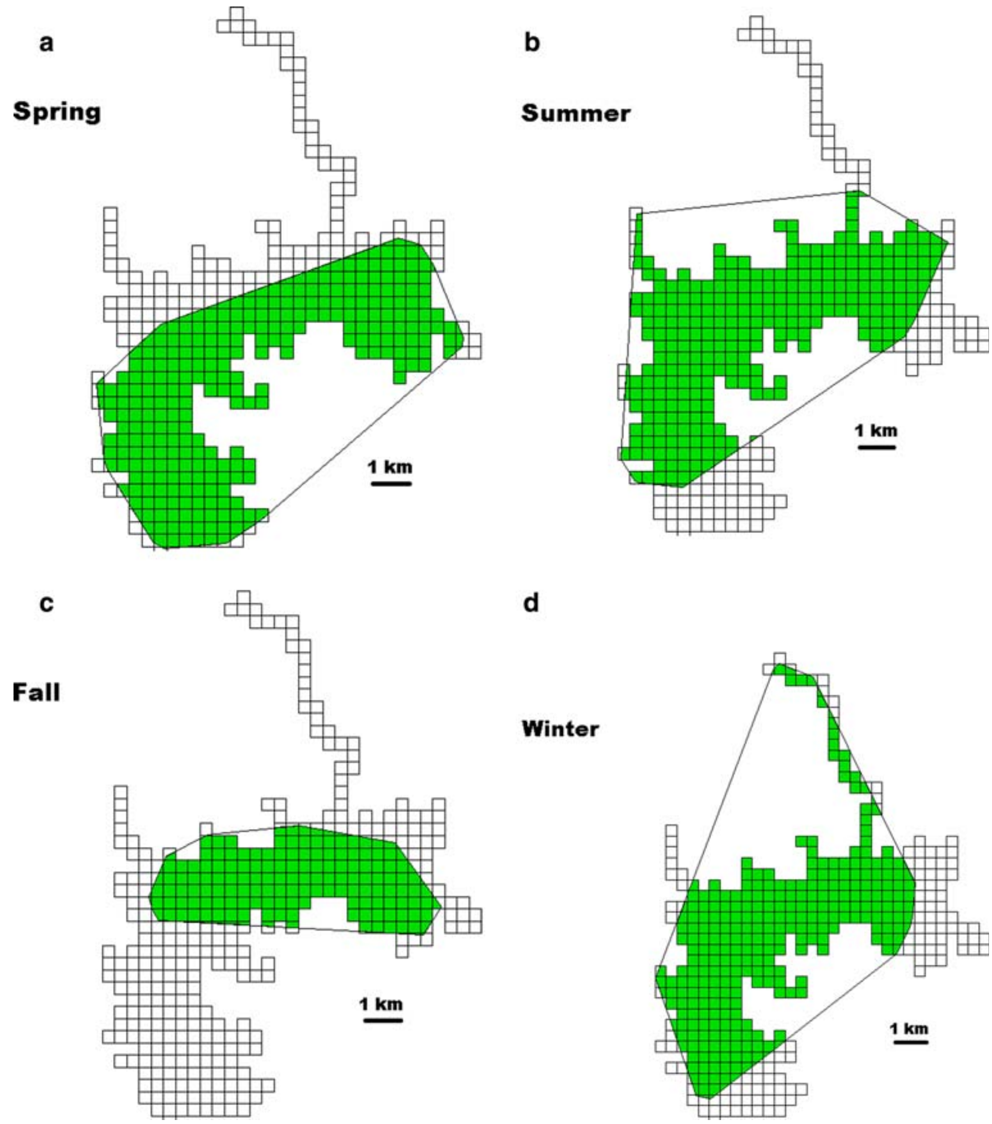

Fig. 1 Construction of adjusted polygons for seasonal home ranges of the Gehuaqing group of *Rhinopithecus bieti*. 'Unadjusted polygons' for each season were overlaid with the total grid cell-based home range map. Polygons were then adjusted by clipping out unvisited grid cells. For more details, see "Methods"

the mischaracterisation of a species' spacing system (Ostro et al. 1999), and this may have far-reaching consequences if such estimates of home range are used for drafting management concepts and for comparative socioecological analyses.

The grid cell method is greatly affected by sampling intensity, and should be the method of choice only if labourious continuous group follows over a long time period are feasible. Otherwise, application of the grid cell method results in an underestimation of monthly and, to a lesser degree, seasonal home range size estimates because visits of the group to many grid cells within the home range will go undetected.

Compared to grid cell, the MCP method gives a far better approximation of monthly and seasonal home ranges in snub-nosed monkey studies. The MCP eradicates the problem of grid cells within the home range that are not visited, and is more precise when the number of data points/location records is low (Robbins and McNeilage 2003). However, because of peripheral data points, uncorrected MCP yields far too large, and hence unrealistic, estimates. This disadvantage can be reduced by creating adjusted monthly and seasonal polygons, i.e. by clipping out unsuitable habitat and areas never visited (cf. Li and Rogers 2005; Mills and Gorman 1987). The adjusted polygon method generates the most precise results. Instead of removing unused/unsuitable areas from the 100%-MCP, a 95%-MCP, whereby a certain proportion of the outermost locations are excluded (Worton 1995), is another way of mitigating the effects of outliers. However, this lacks any biological basis (White and Garrott 1990), whereas our method is more precise and biologically meaningful since the areas deleted from the polygon are not random, but correspond to areas known to constitute unused or unsuitable habitat.

Another issue that needs to be taken into consideration when employing the grid cell method is selection of an appropriate cell size. White and Garrott (1990, p 168) state that "the choice of grid cell size is an arbitrary decision for which no biologically based, objective procedures are known". However, one of the main assumptions underlying the choice of grid size is that it should be related to the typical spread of the group (as measured in two dimensions, e.g. Olson 1986; Ostro et al. 1999). Moreover, in setting a grid cell size, the decision should be based on the average (or median) distance between consecutive locations (White and Garrott 1990), and—where GPS is applied—also take into consideration satellite reception and associated positional accuracy of location records. We chose a 250 m grid because we found the usual spread of the band to be around 200 m.

It is beyond the scope of this methodological discourse to examine in more detail other relatively complex techniques such as Fourier series and fractal estimators (for more exhaustive reviews, see e.g. Harris et al. 1990; White and Garrott 1990; Powell 2000; Sterling et al. 2000; Kernohan et al. 2001). Recently, Kernel methods have become increasingly widespread in primate/animal ecology and are considered rather powerful (provided that some underlying assumptions, such as independence of locational observations, are met (e.g. Izumiyama et al. 2003; Fashing et al. 2007). We did not use Kernels and therefore cannot offer a quantitative assessment of the two methods. The kernel method provides an estimate for the utilisation distribution, i.e. a probability density function that estimates an individual's or group's relative use of space. It shows the probability of locating an animal at a particular location on a plane (Worton 1989). Compared to traditional MCP, which uses information only about home range borders and assumes a uniform probability distribution, kernels give a more detailed and useful estimate of home range use and should be considered as alternatives to grid cell, MCP and adjusted polygons in future studies of snub-nosed monkeys. The adjusted polygons presented here provide a rather simple method that reliably computes monthly and seasonal home ranges of primates having large home ranges such as snub-nosed monkeys. This method is also preferable when sampling effort is irregular—an inherent problem associated with difficult-to-track snub-nosed monkeys. However, it must be remembered that adjusted polygons require the incorporation of data on the distribution of vegetation communities (suitable vs unsuitable habitat) based on which the home range analysis can be fine-tuned.

Acknowledgments Jiaoyan Zhuang is acknowledged for helping with GIS analyses, and Lao Feng, Xuesheng Feng and Xuewen Feng for helping with GPS data collection. The following granting agencies supported the research: Janggen-Pöhn-Stiftung, A. H. Schultz Stiftung, Zürcher Tierschutz, Zoological Society of San Diego, Offield Family Foundation, Primate Conservation, Inc., G. & A. Claraz-Schenkung, Goethe-Stiftung, Schweizerische Akademie der Naturwissenschaften SANW, and Primate Action Fund of Conservation International.

References

Adams L, Davis SD (1967) The internal anatomy of home range. J Mammal 48:529–536

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

Fashing PJ, Mulindahabi F, Gakima J-B, Masozera M, Mununura I, Plumptre A, Nguyen N (2007) Activity and ranging patterns of Angolan black-and-white colobus (*Colobus angolensis ruwenzorii*) in Nyungwe Forest, Rwanda: possible costs of large group size. Int J Primatol 28:529–550

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

Hayne D (1949) Calculation of size of home range. J Mammal 30:1–18

Izumiyama S, Mochizuki T, Shiraishi T (2003) Troop size, home range area and seasonal range use of the Japanese macaque in the Northern Japan Alps. Ecol Res 18:465–474

Kernohan BJ, Gitzen RA, Millspaugh JJ (2001) Analysis of animal space use and movements. In: Millspaugh JJ, Marzluff JM (eds) Radio tracking and animal populations. Academic, San Diego, pp 125–166

Kool K, Croft D (1992) Estimators for home range areas of arboreal colobine monkeys. Folia Primatol 58:210–214

Lehmann J, Boesch C (2003) Social influences on ranging patterns among chimpanzees (*Pan troglodytes verus*) in the Tai National Park, Côte d'Ivoire. Behav Ecol 14:642–649

Li Z, Rogers M (2005) Habitat quality and range use of white-headed langurs in Fusui, China. Folia Primatol 76:185–195

Macdonald D, Ball F, Hough N (1980) The evaluation of home range size and configuration using radio tracking data. In: Amlaner C, Macdonald D (eds) A handbook on biotelemetry and radio tracking. Pergamon, Oxford, pp 402–424

Mills MGL, Gorman ML (1987) The scent-marking behaviour of the spotted hyaena *Crocuta crocuta* in the southern Kalahari. J Zool 212:483–497

Olson DK (1986) Determining range size for arboreal monkeys: methods, assumptions, and accuracy. In: Taub DM, Kay FA (eds) Current perspective in primate social dynamics. Van Nostrand Reinhold, New York, pp 212–227

Ostro LET, Young TP, Silver SC, Koontz FW (1999) A geographic information system (GIS) method for estimating home range size. J Wildl Manage 63:748–755

Powell R (2000) Animal home ranges and territories and home range estimators. In: Boitani L, Fuller T (eds) Research techniques in animal ecology. Controversies and consequences. Columbia University Press, New York, pp 65–110

Robbins M, McNeilage A (2003) Home range and frugivory patterns of mountain gorillas in Bwindi Impenetrable National Park, Uganda. Int J Primatol 24:467–491

Sterling E, Nguyen N, Fashing P (2000) Spatial patterning in nocturnal prosimians: a review of methods and relevance to studies of sociality. Am J Primatol 51:3–19

White G, Garrott R (1990) Analysis of wildlife radio tracking data. Academic, San Diego

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

Worton BJ (1995) A convex hull-based estimator of home range size. Biometrics 51:1206–1215