Effects of GPS Sampling Intensity on Home Range Analyses

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Abstract: The two most common methods for determining home ranges, minimum convex polygon (MCP) and kernel analyses, can be affected by sampling intensity. Despite prior research, it remains unclear how high-intensity sampling regimes affect home range estimations. We used datasets from 14 GPS-collared, white-tailed deer (*Odocoileus virginianus*) to describe the size and location accuracy of home range estimates calculated from different sampling regimes. We compared monthly home range estimates from seven sub-samples (480, 360, 180, 90, 60, 30, and 15 locations) to the home range estimates of the complete datasets (720 locations). Minimum convex polygon (MCP) home range size estimates calculated from datasets with >180 locations were not statistically different. Areas calculated with 60–90 locations may underestimate MCP size by 50% or more. As demonstrated in past studies, we found that kernel home range analyses accurately estimated home range size for all sampling regimes. However, considerable locational errors were associated with lower sampling regimes, resulting in misclassifications of areas of use and non-use. An average locational error >40% was observed for our least intensive sampling regime, while sampling regimes collecting 480 and 360 locations had less than 10% relative error. Since GPS technology can generate large sample sizes, researchers should use kernel analyses because MCP ignores much of the data generated. Also, because significant location error may be associated with MCP home ranges calculated from small sample sizes, the results of many previously published studies should be interpreted with care.

Key words: deer, GPS collars, *Odocoileus virginianus*, sampling intensity

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Global Positioning System (GPS) technology has increased the accuracy and precision of animal location estimates and has allowed researchers to generate more frequent and larger datasets that are useful in home range analyses (Girard et al. 2002). Researchers often must consider tradeoffs between sampling rate and battery longevity when developing sampling protocols for long-term studies. To determine optimal sampling rate and study duration it is important to understand the effects of sample size on accuracy and precision of home range estimations.

Minimum convex polygon (MCP) and kernel analyses, the two most common methods for estimating home ranges, are affected by changes in sampling intensity (Silverman 1986, Harris et al. 1990, Seaman et al. 1999, Powell 2000, Girard et al. 2002, Mills et al. 2006). Generally, ≥100 locations are required to accurately describe a MCP area, with <100 locations resulting in underestimations (Harris et al. 1990, White and Garrot 1990, Seaman et al. 1999, Powell 2000, Girard et al. 2002, Mills et al. 2006). However, kernel analyses are less sensitive to sampling rates than MCP estimators (Boulanger and White 1990, Worton 1995, Seaman and Powell 1996, Hansteen et al. 1997, Kenward 2001, Mills et al. 2006). Nevertheless, Seaman et al. (1999) and Girard et al. (2002) reported that smaller datasets tend to overestimate kernel home range size.

Given the nonparametic nature of kernel range calculations, the number of locations needed to accurately describe a home range cannot be easily calculated, although the topic has been explored in depth without a consensus (Silverman 1986, Seaman et al. 1999, Girard et al. 2002). Under several restrictions, Silverman (1986) concluded that only 19 locations were necessary to accurately describe home ranges, whereas Girard et al. (2002) concluded that as many as 300 locations were needed.

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Recent improvements in battery life allow GPS devices to collect ≥24 locations per day for an entire year. Despite prior research on this topic, it remains unclear how high-intensity sampling regimes affect home range estimations. Whether sampling rates of this magnitude can improve the accuracy of home range estimates has received little research attention. Mills et al. (2006) described the effects of varied sampling regimes on the home range estimates of wolves (*Canis lycaon*) in Ontario, Canada. They found an average of 127 locations was needed to accurately describe the size of MCP home ranges, whereas as few as 12 locations were needed to accurately describe the size of kernel home ranges. However, Mills et al. (2006) focused their analyses solely on home range size and did not assess the location accuracy of their home range estimates.

Herein, we used datasets collected from GPS-collared white-tailed deer (*Odocoileus virginianus*) to describe the effects of different sampling intensities on accuracy of home range size and location estimates.

Study Area

We collected datasets for our analyses at two study sites: Chesapeake Farms (CF) and the Great Cypress Swamp (GCS). Chesapeake Farms in Kent County, Maryland, was composed of 13.4 km^2 of forest, fragmented by agricultural fields. Great Cypress Swamp in Sussex County, Delaware, was 44.5 km^2 of unfragmented forest surrounded by agricultural fields. Forests at both locations contained tree and shrub species common to southern forests (*Acer rubrum*, *Diospyros virginiana*, *Clethra alnifoia*, *Ilex opaca*, *Liquidambar styraciflua*, *Liriodendron tulipifera*, *Pinus taeda*, *Quercus alba*, *Q. nigra*, *Smilax* spp., and *Vaccinium corymbosum*). In addition, GCS had stands of *Chamaecyparis thyoides* and *Taxodium distichum*. Agricultural fields at both locations and surrounding them were used to grow corn (*Zea mays*) and soybeans (*Glycine max*). In addition to those agronomic crops, both locations had plantings of wildlife food crops including *Lolium multiflorum*, *Sorghum bicolor*, *Trifolium* spp., and *Triticum aestivum.*

Shaw (2005) estimated the CF preharvest deer density at 33 deer/km^2. In 2006, the CF deer population had an estimated sex ratio of 1.0:1.5 M:F (M. C. Conner, Chesapeake Farms, unpublished data). In 2005, GCS was reported to support about 36 deer/km^2 (DNREC 2006). A camera survey in 2006 estimated the GCS deer sex ratio at about 1:1.

Methods

Deer Capture and Handling

We fitted 14 female deer (≥1.5 years old) with Televilt Tellus Basic, 5H1D GPS collars (Televilt/TVP Positioning AB, Lindesberg, Sweden) during February 2006–August 2007. Four deer were collared at GCS and 10 were collared at CF. We captured deer by darting or rocket netting. We used 3-ml transmitter darts (Pneu-dart Inc., Williamsport, Pennsylvania) with a 7.0 mg/kg Telazol (Fort Dodge Animal Health, Fort Dodge, Iowa)/6.5 mg/kg xylazine hydrochloride (Cervizine, Wildlife Laboratories, Inc., Fort Collins, Colorado) combination as an immobilization agent in our darting protocol. Deer captured in rocket nets were immobilized with a 10.7 mg/kg ketamine hydrochloride (Ketaset, Fort Dodge Animal Health, Fort Dodge, Iowa)/2.2 mg/kg xylazine hydrochloride injection. During immobilization, we monitored vital signs, treated minor injuries, lubricated eyes, and blindfolded each deer. We injected 400 mg of tolazoline hydrochloride (Tolazoline, Lloyd Laboratories, Shenandoah, Iowa) to reverse effects of xylazine. Animal handling procedures were approved by the University of Georgia Institutional Animal Care and Use Committee (#A3437-01).

Telemetry and Analysis

We programmed GPS collars to collect and store locations in the form of X, Y coordinates. The collars were programmed to collect 24 locations/day at equal intervals during the study period. Each collar was equipped with a remote-release designed to allow collars to fall from the deer upon activation at the end of our study. However, only two release mechanisms functioned properly (12 failed). We subsequently retrieved each of these collars by harvesting the animals. We used Televilt Tellus TPM Project Manager software (Televilt/TVP Positioning AB, Lindesberg, Sweden) to download the data to our computer.

For our analysis, we included only data collected during August, September, February, and March. Data from other months were censored to minimize the effects of seasonal movements associated with breeding and parturition (D'Angelo et al. 2004, Tomberlin 2007, Kolodzinski et al. 2010). In total, we analyzed each of 33 months of data for the 14 deer (23 from CF and 10 from GCS). Data from each month were analyzed independently.

We grouped each month's data into eight subsets to simulate differences in sampling intensities (i.e., 24, 16, 12, 6, 3, 2, 1, and 0.5 locations/day). We grouped data within each subset into time blocks based on the average number of hours between sampling points. For example, 24 locations/day, 12 locations/day and 0.5 locations/day subsets were grouped into 1-hr, 2-hr, and 48-hr blocks, respectively. We then randomly-selected a data point from each time block for each deer to create the eight datasets. We therefore used all data points for the 24 locations/day dataset (720 locations) and created seven subsampled datasets by subsampling the actual dataset as described (480, 360, 180, 90, 60, 30, and 15 locations). Non-fix locations and locations with dilution of precision (DOP) values >6 were filtered out, yielding an average fix rate of 92%.

We used Home Range Tools for ArcGIS extension (Rodgers et al. 2007) to calculate a 95% adaptive kernel home range for each data set. The tool calculates href as the square root of the mean variance in x and y coordinates divided by the sixth root of the number of points (Worton 1995). Although this method may over smooth the distribution for animals that have multiple centers of activity, inspection of the location distribution of our study animals indicated this was not the case. Mean cell size was set at a mid-level resolution (70x70) because the overall home ranges were large and we were not investigating fine-scale movements. We calculated the accepted home ranges using the sampling rate of 24 locations/day (720 locations) and the simulated home ranges from the seven subsampled datasets. We also calculated accepted and simulated MCP home ranges with Hawth's Analysis Tools for ArcGIS (Beyer 2006).

We compared simulated home ranges to the accepted ranges and determined areas of under- or overestimation (Figure 1). We expressed the area of locational error as a percentage of the simulated home range size ([underestimation area + overestimation area]/simulated kernel area*100). We examined the changes in home range size and error for each of the sampling rates. We determined statistical differences by the non-overlap of 95% confidence intervals.

Figure 1. Example of accepted (720 locations) and simulated (360 locations) monthly kernel home ranges and the resultant locational errors in home range estimations for a female white-tailed deer at Chesapeake Farms, Maryland, 2006.

Results

MCP areas calculated from datasets with sampling rates >6 locations/day (>180 locations) were not different from the accepted home range size (95% confidence intervals overlapped, Figure 2a). The average MCP size increased more than five times between the least and the most intensive sampling regimes. All errors in MCP ranges were the result of underestimations of home range size. Error rates tended to increase as sampling rates decreased (Figure 3a). We observed errors as high as 80% for our least-intensive sampling regime.

Kernel home ranges did not differ statistically (Figure 2b). However, locational errors in kernel area tended to increase as sampling rates decreased (Figure 3b). The shape of kernel home ranges became less stable as sampling rates decreased, resulting in higher locational errors. Most of the error was a result of overestimations, but as sampling rates decreased, the destabilization of

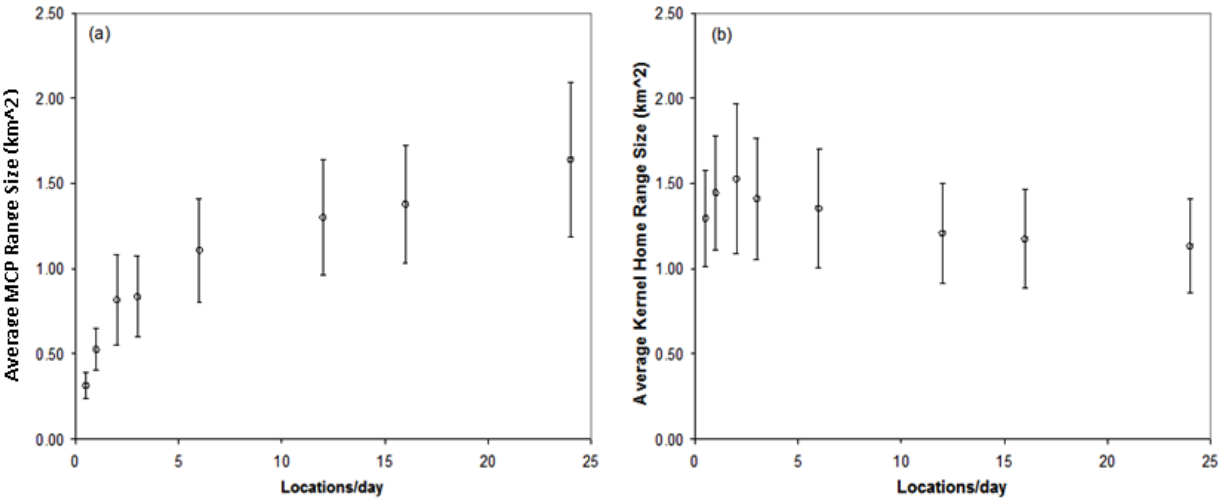

Figure 2. (a) Average MCP home range size estimates and (b) average kernel home range size estimates by sample intensity for 14 female white-tailed deer at Chesapeake Farms, Maryland, and the Great Cypress Swamp, Delaware, 2006–2007. Error bars denote 95% confidence intervals.

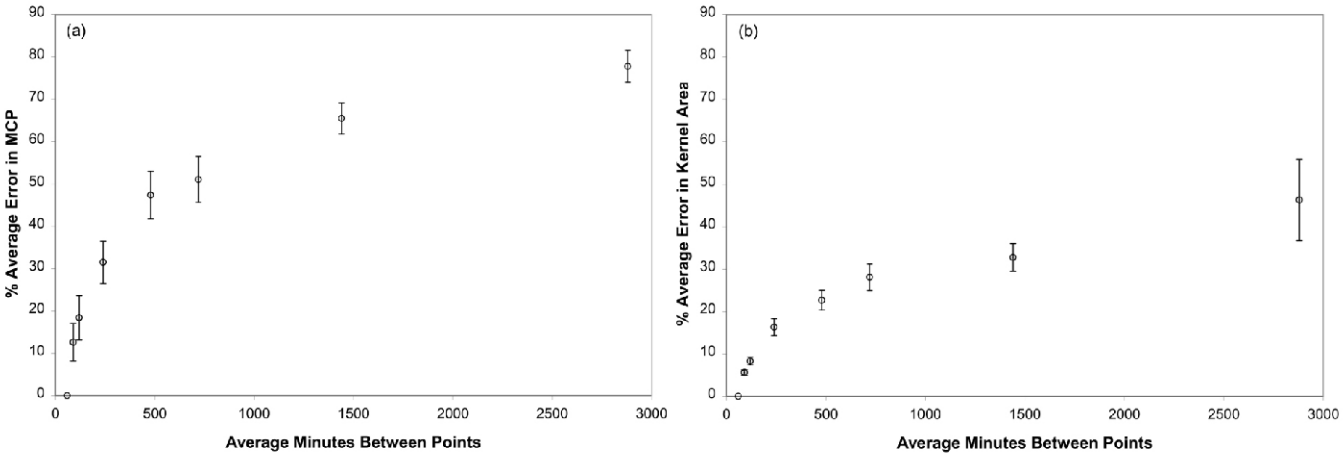

Figure 3. Average locational errors in (a) MCP home range estimates and (b) kernel home range estimates according to intensity of sampling for 14 female white-tailed deer at Chesapeake Farms, Maryland, and the Great Cypress Swamp, Delaware, 2006–2007. The x-axis represents increasing time intervals between locations; average % error is relative to the 60 minutes between points sampling rate. Error bars denote 95% confidence intervals.

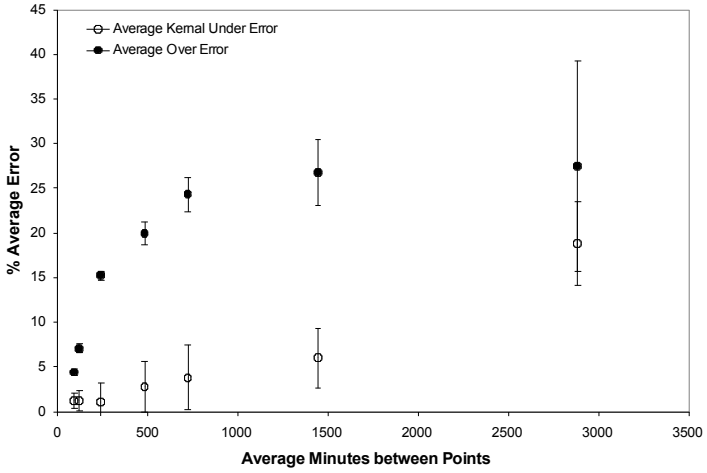

Figure 4. Changes in average under- and overestimation error rates for kernel home range estimates as sampling intensity decreased for 14 female white-tailed deer at Chesapeake Farms, Maryland, and the Great Cypress Swamp, Delaware, 2006–2007. The x-axis represents increasing time intervals between locations. Error bars denote 95% confidence intervals.

home range shape resulted in an increased ratio of underestimation errors (Figure 4). Sampling regimes collecting 16 and 12 locations/day (480 and 360 locations) had <10% locational error relative to the accepted home range, whereas locational errors >40% were observed in the least intensive sampling rates.

Discussion

Similar to other studies (Harris et al. 1990, White and Garrot 1990, Seaman et al 1999, Powell 2000, Girard et al. 2002, Mills et al. 2006), our results demonstrate that MCP home range size estimates are sensitive to changes in sampling intensity; whereas, kernel home range size can be accurately estimated with only a few locations (i.e., 15). In addition, although kernel home range size can be accurately estimated from relatively few points, a more intensive sampling regime is required to correctly classify areas of use and non-use.

As mentioned by Mills et al. (2006), these findings suggest that care should be used when interpreting the results of studies that used MCP analyses of low-intensity sampling regimes (often associated with radiotelemetry) as well as studies that compared home ranges calculated from datasets with different sampling intervals. However, we found that the effects of low-intensity sampling regimes are more severe than Mills et al. (2006) suggested. Past studies that used sampling regimes of two–three locations/day (<90 data points) may have underestimated MCP areas by more than 50%. With the same sampling interval, kernel area size will be accurately estimated but areas of use and non-use may be misrepresented by 30% or more.

The number of points needed to accurately describe an animal's home range is undoubtedly linked to the behaviors of individual species and the precision requirements of the study. Regardless, as sampling regimes become less intensive, areas of use and non-use may be misrepresented in home range estimates. Although the consequences of low-intensity sampling regimes may not be as significant for populations of white-tailed deer, greater repercussions likely exist for other populations (i.e., endangered species).

As technology advances and analyses begin to focus on fine-scale movement and habitat selection, intensive sampling regimes are more necessary. Because of large error rates associated with infrequent sampling, misrepresented home range estimations could result in erroneous inferences. Critical errors can be avoided by

considering study objectives when choosing a sampling regime. However, we recommend that the most intensive sampling regime be used whenever possible, as higher sampling rates allow home ranges to be described more precisely.

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