GPS SAMPLING INTENSITY AND LARGE MAMMAL BEHAVIOR

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Abstract

We used intensively collected location data from a dispersal-aged male black bear (*Ursus americanus floridanus*) in south central Florida from May through August 2007. Location data obtained at 20 minute intervals was transmitted via cell phone text messages to an office base station. Twenty minute data improved the accuracy and capacity to identify road crossings, and to characterize behavior near highways. Intensive data did not improve the accuracy of basic habitat use analyses, although some habitats were under-represented in less intensively sampled subsets. The capacity of the latest generation of GPS tracking devices for large mammals has created the need for new analytical methods such as the kernel pathway analysis that we describe here. Intensively collected GPS data will improve the power of analyses for, and effectiveness of, conservation programs for imperiled, wide-ranging species such as the black bear.

Keywords. Black bear, animal movements, highway crossings, habitat use

Introduction

Even after the advent of radio telemetry and global positioning system (GPS) technologies in wildlife studies, sample size problems have been a constant (Morrison et al., 1998). A challenge facing wildlife researchers who use (GPS) technology to track study animals is determining the duty cycle necessary (Rodgers, 2001) to answer questions that demand more data than are usually obtained with traditional VHF telemetry. Locations collected as infrequently as once each week during the day may be useful in understanding annual patterns of habitat use and some aspects of social ecology, but the finer details of travel and other behaviors may remain cloaked. In addition, some species exhibit nocturnal activities that are missed if tracking is done

In Proceedings of the 6th Southern Forestry and Natural Resources GIS Conference (2008), P. Bettinger, K. Merry, S. Fei, J. Drake, N. Nibbelink, and J. Hepinstall, eds. Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA.

only during daylight hours. Increasingly, land managers and conservation planners are challenged to recommend approaches for ameliorating expanding human infrastructure and its impacts on wide-ranging species. The best advice will be based on sufficiently detailed locational data that provide subsequent recommendations with a high level of confidence. Certainly, the greater the frequency with which locations are collected, the closer the results will approach a virtual travel path. Such data will likely demand a new set of analytical tools that can take advantage of the voluminous data that GPS telemetry systems can provide.

Another problem relevant to studies of reclusive, difficult-to-capture species such as the black bear (*Ursus americanus*), is obtaining the data once it is collected. This is an issue that has not been adequately solved in a decade of technology development (Merrill et al., 1998). The standard in the industry is a store-on-board system that saves a record of every position acquisition attempt during the life of the unit. The researcher is then faced with the challenge of retrieving the collar and downloading the data. This can be done in two primary ways: a) the animal is captured and the collar is removed; or b) the collar drops off of the animal and is retrieved by the researcher homing in on a VHF radio beacon. These methods are fraught with difficulty. Targeting a specific animal for recapture is difficult because individual animals learn to avoid traps, or they travel to places that are off limits to researchers. Using an integrated drop-off in the collar is problematic because electronic devices that are programmed to fall off on a particular date are prone to fail due to environmental factors. Bears are particularly troublesome because they lead rugged lives that are physically damaging to the units.

Another way of dealing with this uncertainty is to utilize data transmission systems to deliver the data remotely through satellite signals or UHF signals. The former approach uses the Argos satellite system, whereas the latter requires a line-of-sight approach of the study animal in the field. An Argos system requires a bulky external antenna to be attached to the bear collar, whereas the latter requires close proximity with unimpeded views of clean collars (this set of conditions is rarely possible with forest-dwelling bears). When external antennas break, as they inevitably do on black bears, the remote data transmission capacity is eliminated. If the drop-off device fails, or if the unit experiences other difficulties so that it cannot be retrieved, the additional data that might be collected are lost. In this paper we report on a field test of a new device for remotely transmitting data, and examine the data that were frequently transmitted from a dispersal-aged male black bear in Florida. We asked whether different sampling intensities would change: 1) estimates of travel rates, 2) frequency, location, and speed of road crossings, and 3) estimates of habitat use.

Methods

Study Area

The study was conducted in south-central Florida (Figure 1), an area of remnant forests, agriculture, and a rapidly growing human population (Maehr et al., 2004). Of Florida's 67 counties, 50 of them support the black bear (Brady and Maehr, 1985), and 45 are more than 25% forested (Brown, 2007). The most imperiled bear populations inhabit the central and southern parts of the state, where a high proportion of native prairies lead to the establishment of intensive cattle ranching and forest clearing. Computer simulations predicted an absence of bears in

Highlands and Glades counties (Hoctor, 2003). The species was once found across all of the more than 720 km that stretch between Georgia and the Florida Keys, incorporating many biotic elements from the tropics and temperate zone. Today, the black bear population in Highlands and Glades counties experiences a high degree of habitat fragmentation which forces dispersing and resident bears alike to frequently cross highways. This is a major cause of death in this population (Maehr et al., 2004).

Technology

In our quest to find the ideal tracking and data transmission system, we tested a new Lotek Wireless, Inc. (2008) GPS Wildcell tracking collar that transmits data via the Global System for Mobile Communications (most commonly used in Europe). A single unit was deployed on a dispersal-aged male in May 2007. Capture and handling methods can be found in Maehr (1997). The bear was tracked successfully for 3 months until the on-board memory filled after collecting 72 locations per day (every 20 minutes) during this time. The data were transmitted via cell phone text messages to a base station in the Forestry building on the University of Kentucky campus. The frequency of data acquisition was intended to provide details of behavior associated with highways, habitat fragmentation, human habitation, and time of day. The high frequency of text message transmission (one message is sent for every 7 GPS locations acquired) meant that if the unit subsequently failed (hit by a car, poached, damaged by the bear, etc.), virtually all data

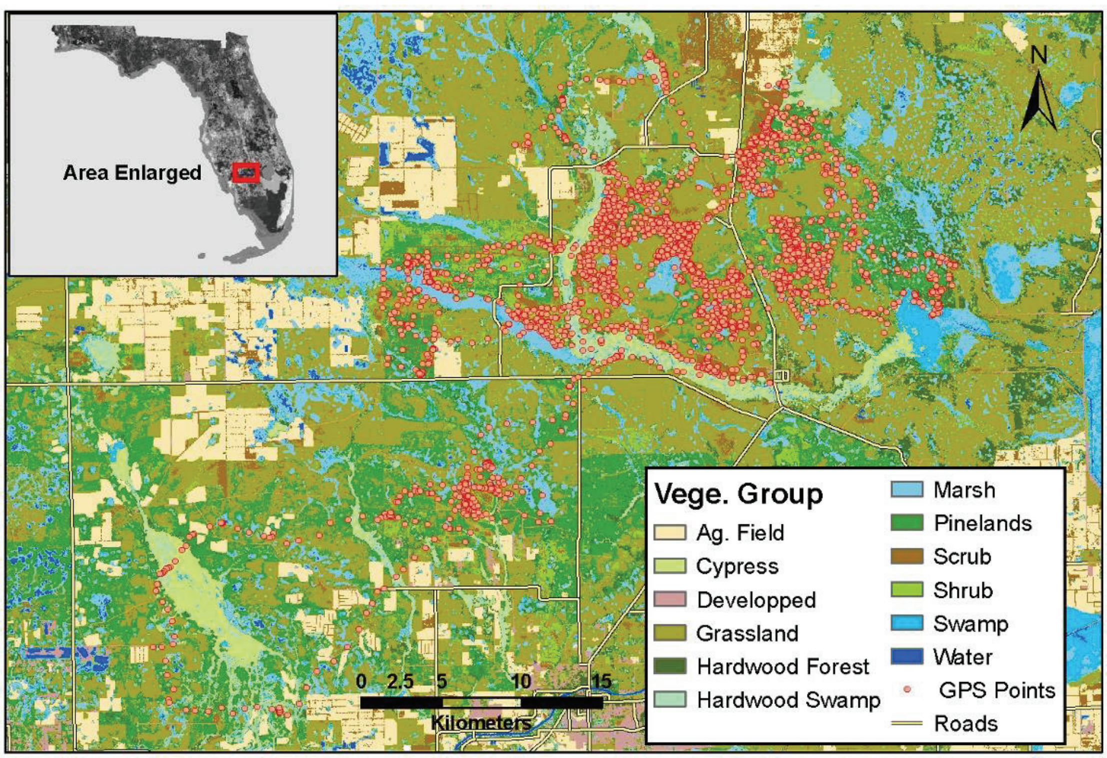

Figure 1. Black bear GPS locations and the associated landcover types.

collected would be successfully transmitted to the researcher up to the moment of failure. This is a 100% improvement over store-on-board units that fail to drop off, and a significant improvement over Argos-based GPS systems that lose their link with satellites or do not drop off due to equipment failure.

Data Analysis

All GPS points were first imported into a database. To study the effects of different sampling intensities, we created subsets of data representing sampling intervals of 20 minutes, 2 hours, 4 hours, 6 hours, and 24 hours. We maximized sample size and minimized autocorrelation using the following protocol: starting from the first GPS point (x_1) in the database, we checked the consecutive points against the first point to see if any points met the specified time interval (e.g., 2 hours); if a point (x_i) met the specified interval, both x_1 and x_i were placed into the subset, and the process continued with x_{i+1}; if the next point did not meet the specified interval, we re-started the process using x_2 and consecutive points until the specified time interval was met. A shapefile was then created using GPS points in each sampling intensity subset, and straight-line paths were created for pairs with specified time interval in ArcGIS.

Black bear traveling speed was calculated using the distance between two consecutive points divided by travel time. Day and night movements were distinguished by defining night from 10 PM to 5 AM. Average traveling speed was calculated for all five sampling intensities. To identify road crossings, a road layer was added and a selection by location function was used to find any paths that crossed roads. Night crossings and day crossings were also distinguished. Three methods were used to understand the effect of sampling intensity on black bear habitat use. The first method involved point value extraction. GPS points were superimposed on a Florida 2003 landcover map (Figure 1), and the corresponding landcover type for each point was extracted in ArcGIS. The proportion of points located in each landcover type was then summarized for each of the five sampling intensities. To test the difference of proportion of habitat use among the five different sampling intensities, we regressed the habitat use proportion in one sampling intensity against all other sampling intensities and tested whether the slope was significantly different than one.

The second method involved kernel density of sample points. A kernel density function in ArcGIS was used with the following specification: sample points in each subset were used as the input, cell size of the Florida 2003 landcover map was used as the output cell size (30 x 30 m), and the default radius (the shortest width of the extent of input points divided by 30) was used as the search radius. Areas within 90% of the kernel were extracted to estimate home range. Total areas and associated landcover types were then summarized in the home range and compared among the five sampling intensities. Proportions of habitat use among the five different sampling intensities were then compared.

A new method, involving path-based kernel density, was also applied in this study. This approach is similar to the second method, except that line features (paths), instead of point features, were used as the inputs. Areas within 90% of the kernel were also extracted to estimate home range. As with the second method, total areas and associated landcover types were summarized and compared among the five sampling intensities.

Results

Of the 7,010 initiated GPS fix attempts from 10 May through 19 August 2007, 5,501 (78.5%) were successfully geo-referenced (Figure 1), and were included in our database. Sample sizes (GPS points) for 20 minute, 2 hour, 4 hour, 6 hour, and 24 hour interval subsets were 4, 327, 891, 471, 322, and 82, respectively. During these three months, the longest distance between any two points was 55 km, whereas the distance traveled by adding the distances between all consecutively acquired 20 minute locations was 1,218 km.

Travel Speed

Travel rates were different during day and night (Figure 2). The 20-minute-interval sampling data indicated that the black bear moved less than 0.5 km per hour during both day and night over 50% of the time. However, the bear was more likely to travel more than 2.0 km per hour at night. Maximum speed observed was 4.6 km per hour during daytime and 5.8 km per hour at night. Similar distribution patterns were observed for other sampling intensities. Due to the method used in calculating traveling speed (linear distance divided by time), the longer the sampling interval the slower the overall traveling speed. Maximum traveling speed was 3.3 and 2.9 km per hour when sampling interval increased to 2 hours and 4 hours, respectively.

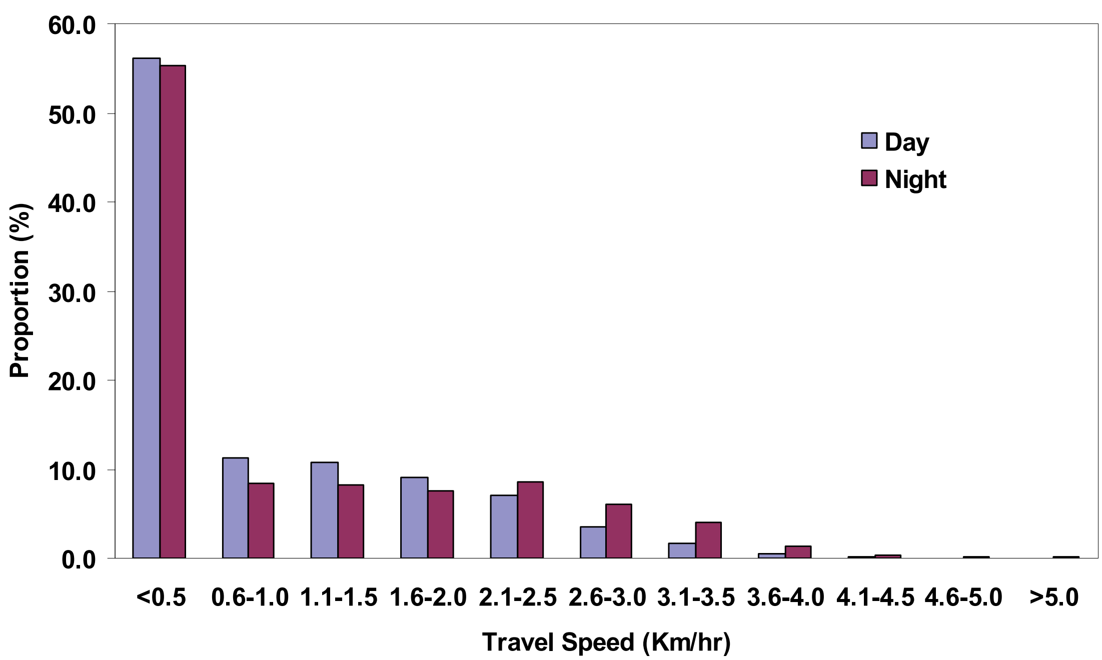

Figure 2. Distribution of black bear traveling speed by day and night.

Road Crossing

The highest number of road crossings occurred within the 20 minute interval, although the differences among sampling intensities was not dramatic (Table 1). At least one double road-crossing event occurred in a 20 minute period and this was followed 40 minutes later by another road crossing. Most of the crossings occurred after 10 PM and before 5 AM. Of the 22 road crossings in the 20 minute interval sample, 15 were at night. As with overall travel speed, the longer the sampling interval, the slower the road crossing speed. For the 20 minute interval, the average road crossing speed was 2.5 km per hour and the maximum speed was 4.1 km per hour. Although different sampling intensity did not dramatically affect the number of road crossings, it did affect the estimation of road crossing locations. As an example, using the 4 hour interval resulted in noticeable position shifts relative to the 20 minute interval (Figure 3).

Habitat and Home Range

A total of 11 landcover types were associated with the fixed GPS points (Figure 4). Pinelands had the highest proportion, followed by grasslands (which likely included large areas of scrub habitat which is actually a forest type), hardwood swamps, and hardwood forests. Sampling intensity did not affect patterns of habitat use (Figure 4). Still, though the patterns were not statistically different, some landcover types were missed by low intensity sampling. The 24 hour sample did not capture the use of agriculture and developed lands, and 4 hour and 6 hour samples did not capture the use of agriculture lands.

Estimated habitat use based on point kernel density and path kernel density was nearly identical for different sampling intensities (Figures 5 and 6). Grassland and pineland were preferred black bear habitat, while agricultural field, developed area, and open water were avoided. Compared to the first method, the later two methods estimated different proportions and ranks of habitat types. Grassland was estimated as a more important habitat type for black bear in the second and third methods than the first method. The prominence of non-forested habitat in this analysis should not be surprising given the fragmented nature of the available forests that are inhabited by this population (Hoctor, 2003).

Table 1. Total number of road crossings and traveling speed observed in five different sampling intensities.

Sampling intensity	Crossings	Speed (km per hour)
20 minute	22	2.75
2 hour	20	1.74
4 hour	21	1.28
6 hour	18	1.10
24 hour	19	0.45

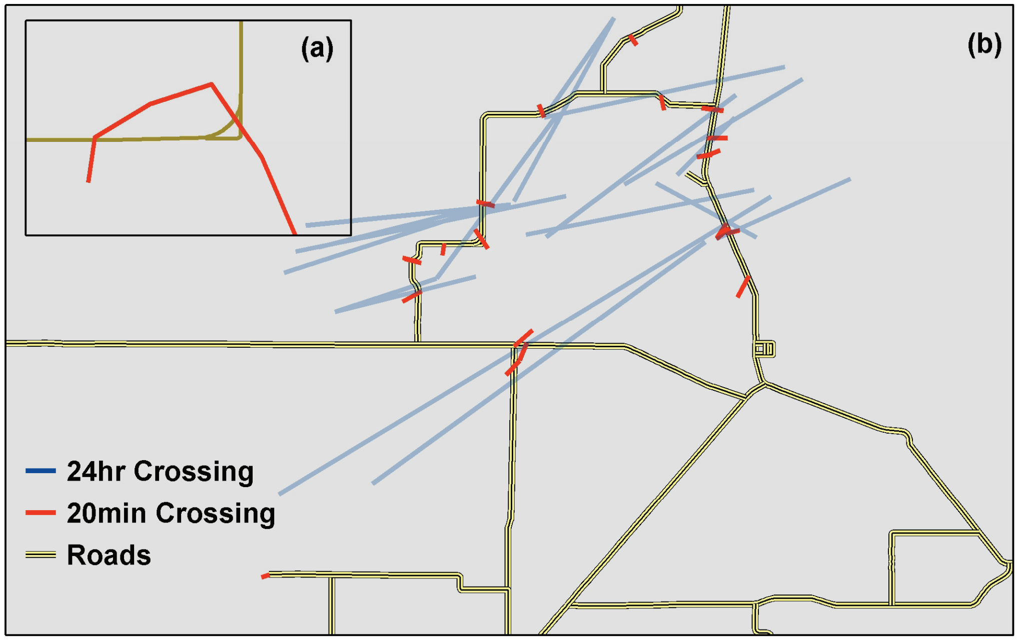

Figure 3. Examples of black bear road crossing: a) double crossing within an 80 minute interval; b) all road crossings with a 20 minute sampling intensity (red), and with a 4 hour sampling intensity (blue).

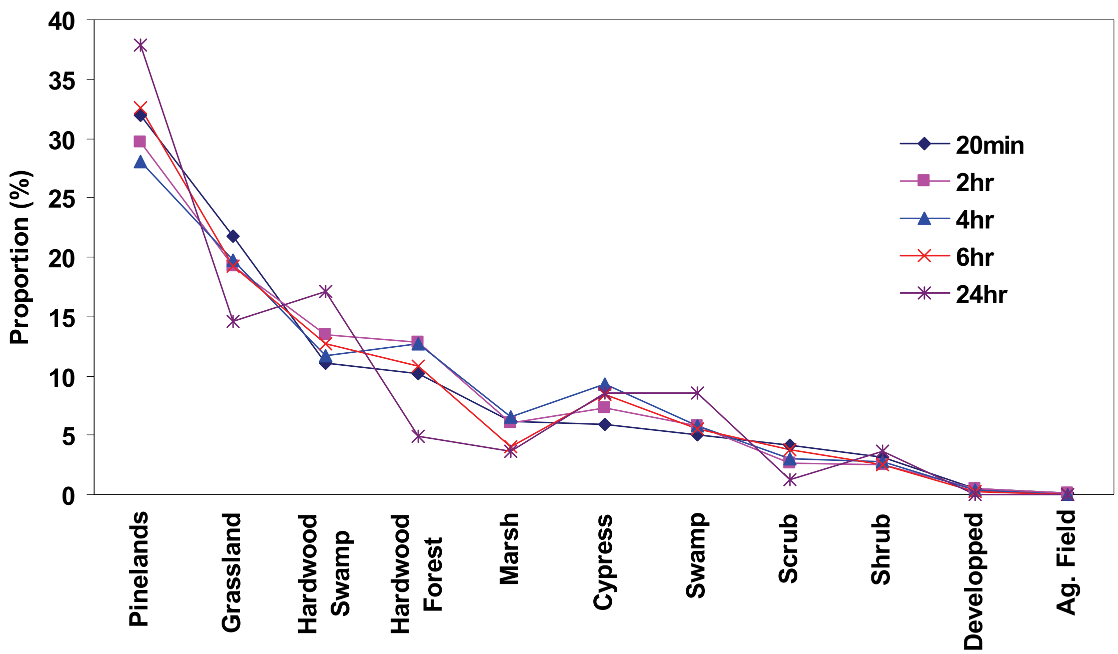

Figure 4. Proportion of points observed in each landcover types by different sampling intensities.

Home range was also estimated using kernel density based on points and paths for different sampling intensities (Figure 7). Home range size decreased as the sample intensity decreased in both methods. However, the rate of decrease was much more dramatic for the point-based estimates than the path-based estimates. Compared to the home range estimated by the 20 minute -interval sample points, 86% of the area was retained in the home range estimated by the 2 hour-interval sample, and 73%, 68%, and 42% by the 4 hour, 6 hour, and 24 hour-interval samples, respectively. Compared to the home range estimated by the 20 minute-interval path, 91% of the area was retained in the home range estimated by the 2hr-interval path, and 86%, 86%, and 67% by the 4 hour, 6 hour, and 24 hour-interval paths, respectively. Additionally, the general shape of the home range was better retained by the path-based kernel than the point-based kernel from the 20 minute-interval sample to at least the 6 hour-interval sample.

Conclusions

Conservation efforts for wide-ranging large mammals such as the black bear will increasingly demand refined and voluminous data sets that enable high confidence in descriptions of their spatial ecology and impacts of denatured landscapes. Intensively collected data not only help explain how and when black bears cross roads, but can pinpoint the specific places that should be considered for wildlife underpasses and other structures that reduce highway mortality. Although intensive sampling and traditional analyses only marginally improve our understanding of general habitat use patterns, a new method, path-based kernel density, depicts the home range

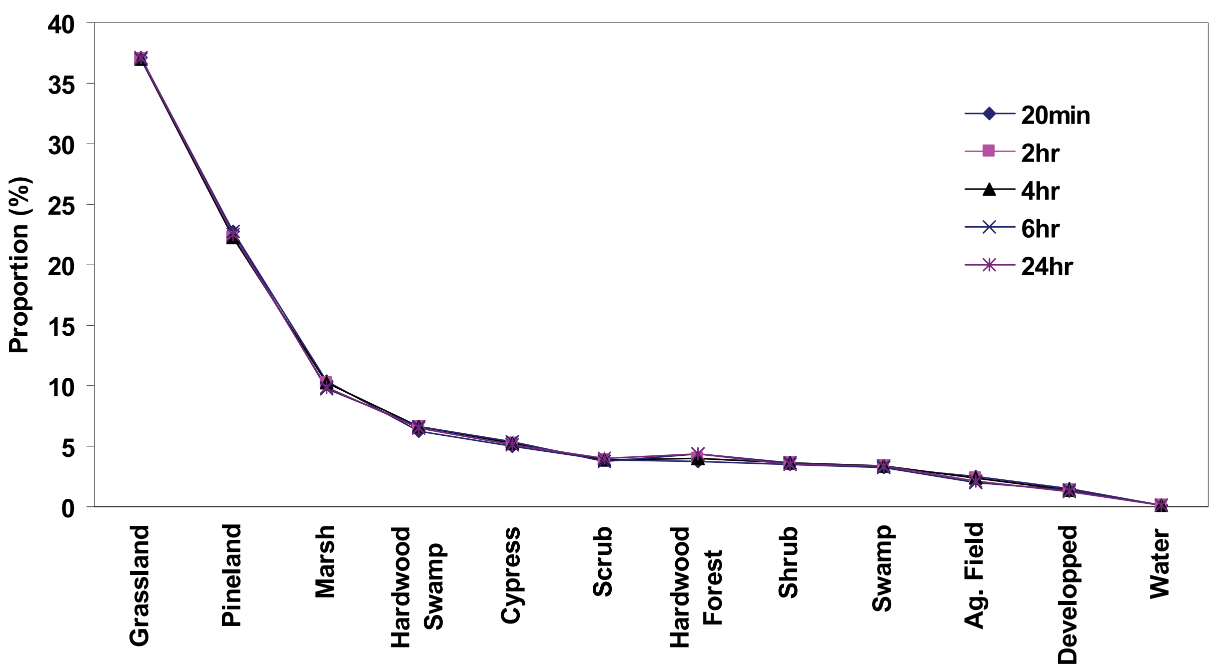

Figure 5. Proportion of landcover type within 90 percent point based kernel density by different sampling intensities.

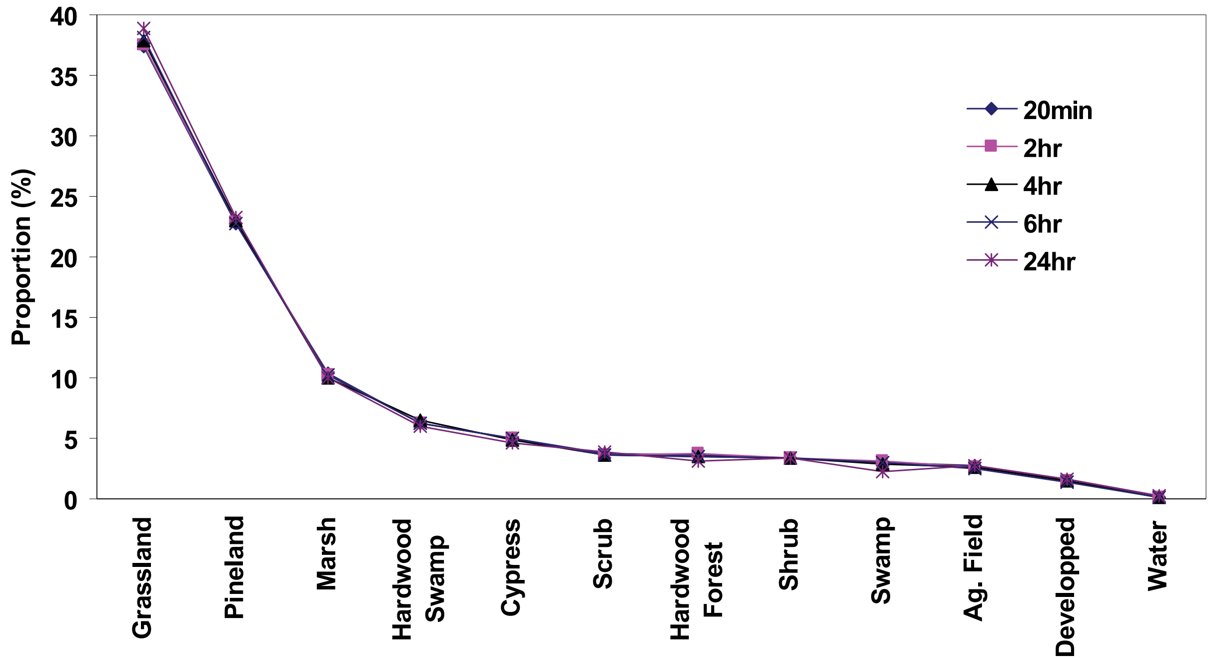

Figure 6. Proportion of landcover type within 90 percent path based kernel density by different sampling intensities.

more accurately than other approaches. As GPS technology evolves and is used more widely in wildlife ecology research, the basic data sets generated will draw closer to creating virtual spatial analyses that will spur new analytical methods, and more effective conservation. Future investigations that utilize such detail information should consider the application of state-space models (Patterson et al., 2008). Such data could also be used as the foundation of animation models that set the GPS points in motion across a digital image of the landscape (White and Garrott, 1990).

References

Brady, J.R., and D.S. Maehr. 1985. Distribution of black bears in Florida. Florida Field Naturalist. 13: 1-7.

Brown, M.J. 2007. Florida's forests – 2005 update. Resource Bulletin SRS-118. Asheville, NC: USDA Forest Service, Southern Research Station.

Hoctor, T.S. 2003. Regional landscape analysis and reserve design to conserve Florida's biodiversity. Ph.D. dissertation. Gainesville, FL: University of Florida.

Lotek Wireless, Inc. 2008. WildCell 2-way Communication with Your Cell Phone. Available at: http://www.lotek.com/wildcell.htm. Accessed 10 March 2008.

Maehr, D.S. 1997. Comparative ecology of bobcat, black bear and Florida panther in south Florida. Bulletin of the Florida Museum of Natural History. 40: 1-177.

Maehr, D.S., J.N. Layne, T.S. Hoctor, and M.A. Orlando. 2004. Status of the black bear in south-central Florida. Florida Field Naturalist. 32: 85-101.

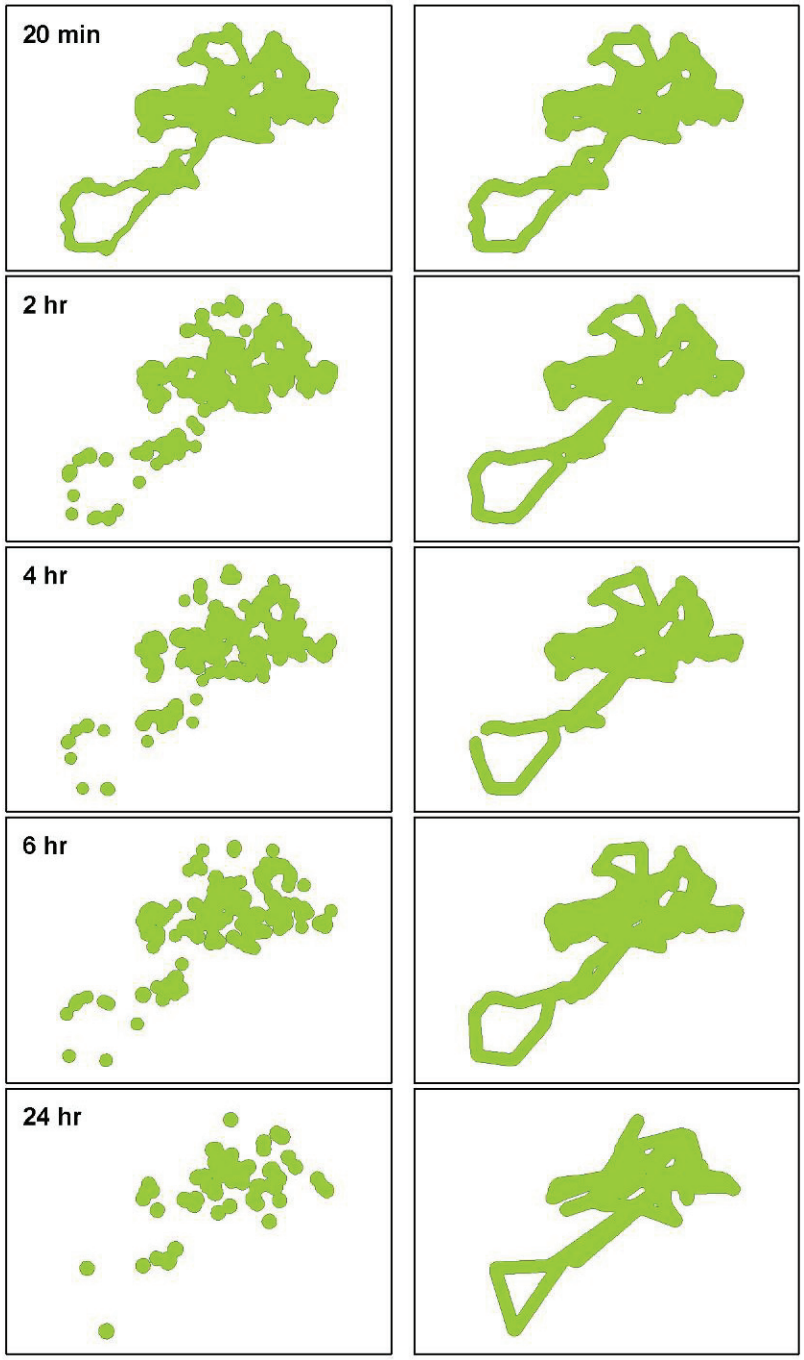

Figure 7. Home range estimation for black bear using 90 % kernel density based on GPS points (left column) and paths (right column) for each sampling intensity (by row).

Merrill, S.B., L.G. Adams, M.E. Nelson, and L.D. Mech. 1998. Testing releasable GPS radio collars on wolves and white-tailed deer. Wildlife Society Bulletin. 26: 830–835.

Morrison, M.L., B.G. Marcot, and R.W. Mannan. 1998. Wildlife-Habitat Relationships: Concepts and Applications. Second edition. Madison, WI: University of Wisconsin Press.

Patterson, T.A., L. Thomas, C. Wilcox, O. Ovaskainen, and J. Matthiopoulos. 2008. State-space models of individual animal movement. Trends in Ecology and Evolution. 23: 87-94.

Rodgers, A.R. 2001. Recent telemetry technology. In Radio Tracking and Animal Populations, 79-121, J.J. Millspaugh and J.M. Marzluff, eds. San Diego, CA: Academic Press.

White, G.C., and R.A. Garrott. 1990. Analysis of Wildlife Radio-Tracking Data. San Diego, CA: Academic Press.