

SAMPLING CONSIDERATIONS FOR AMERICAN BLACK AND BROWN BEAR HOME RANGE AND HABITAT USE

JERROLD L. BELANT,¹ Department of Biology and Wildlife, University of Alaska Fairbanks, Box 757000, Fairbanks, AK 99775, USA

ERICH H. FOLLMANN, Institute of Arctic Biology, University of Alaska Fairbanks, Box 757000, Fairbanks, AK 99775, USA email: ffeh@uaf.edu

Abstract: We deployed 72 collars with global positioning system (GPS) receivers on female brown bears (*Ursus arctos*) and American black bears (*U. americanus*) in southcentral Alaska during 1998–2000 to evaluate collar performance and to estimate home range and habitat use. Overall, 67% of relocation attempts were successful (range = 10–93%). Most frequent causes for unsuccessful relocation attempts were inadequate number of satellites available and GPS antenna failure. There were differences ($P < 0.05$) in proportion of successful relocations by time of day, with lower success during 0800–1359 and 1800–0159 h. The proportion of successful relocations also decreased ($P < 0.05$) across half-month intervals. Using minimum convex polygon (MCP) and fixed kernel simulations for 6 individuals of each species, we estimated that >40 locations were typically required to estimate May–September home ranges and that >40 and >50 locations were typically necessary to estimate spring (late May–Jun) and summer (Jul–late Sep) home ranges. Precision of both models increased with sample size. More locations were generally required to describe the total area used by a bear (MCP method) than the utilization distribution using the fixed kernel method. For each bear, within-year habitat use differed ($P < 0.05$) seasonally. Within-season habitat use differed ($P < 0.05$) among individuals for each species. Furthermore, diurnal (0700–1859 h) and nocturnal (1900–0659 h) seasonal habitat use differed ($P < 0.05$) in 13% and 42% of all cases for black and brown bears, respectively. Acquiring adequate relocations to estimate home range and habitat use with conventional VHF (very high frequency) telemetry may be prohibitive, particularly in remote areas. Potential biases from obtaining locations during only a portion of the 24-h period should also be considered. Analyses and interpretation of habitat data derived from studies with too few locations should be made with caution. Future investigators of black and brown bear home range and habitat use need to consider sampling designs seriously to ensure that data collected meets study objectives.

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Key words: Alaska, American black bear, brown bear, fixed kernel, global positioning system, GPS, habitat use, home range, minimum convex polygon, radio telemetry, *Ursus americanus*, *Ursus arctos*

Radio telemetry has been used in studies of free-ranging wildlife for almost 40 years (Rodgers 2001). The most common type of wildlife radio telemetry or radio tracking involves very high frequency (VHF) transmitters attached to animals from which investigators use a receiver to obtain the transmitted frequency to estimate animal locations. Although initial cost of VHF telemetry equipment is comparatively low, costs increase rapidly as the number of animals and locations required to meet study objectives increase. Wildlife studies in remote or extensive study areas frequently require aerial radio telemetry, which can increase costs even more. Furthermore, because of logistic and economic constraints, certain types of studies (e.g., fine-grained habitat use) may not be practical. In the early 1980s, substantial advances in technology resulted in the development of satellite telemetry systems, most notably Argos- and GPS-based systems (Fancy et al. 1988, Harris et al. 1990, Tomkiewicz 1996, Rodgers 2001). Depending on study objectives and location, these systems offer considerable potential for reducing logistical problems.

Various methods for estimating animal home ranges have been developed, beginning with the minimum area polygon (Mohr 1947). Despite several shortcomings of this technique (White and Garrot 1990, Seaman et al.

1999), the minimum area polygon remains one of the most common home range estimators in use. Numerous non-parametric home range estimators and associated software have since been developed including the harmonic mean, Fourier series, bivariate and modified bivariate normal model 95% ellipse estimator, and adaptive and fixed kernel methods (Jenrich and Turner 1969, Koepl et al. 1975, Dixon and Chapman 1980, Anderson 1982, Worton 1987, Seaman et al. 1999). Of the nonparametric methods available, the fixed kernel has been recently considered the most suitable for estimating animal home ranges (Worton 1995; Seaman et al. 1998, 1999).

Although telemetry technology and home range modeling techniques have received considerable attention, less emphasis has been placed on determining the number of locations necessary to define with precision the home range of animals. Several authors have recently conducted simulation analyses using theoretical or empirical datasets (Worton 1995, Seaman and Powell 1996, Hansteen et al. 1997, Seaman et al. 1999). Little information, however, is available for determining the number of locations necessary to define the home ranges of bears. Arthur and Schwartz (1999) modeled brown bear home ranges on the Kenai Peninsula, Alaska, using MCP and kernel methods. Through simulation using empirical data, these authors found that >60 (MCP) and >80 (fixed kernel) locations were required to obtain precise (coefficient of variation [CV] < 0.50) estimates of home ranges during June–September. We are not aware of simulations with

¹ Present address: National Park Service, Pictured Rocks Science Center, Box 40, Munising, MI 49862, USA, email: Jerry_Belant@nps.gov

empirical data that estimated the number of locations necessary to define black bear annual home ranges or seasonal home ranges of either species.

Estimating the use of space within the home range of an animal is critical for assessing habitat use. Several previous bear habitat use studies have employed what has been termed a Design I study (Thomas and Taylor 1990, Manly et al. 1993). In Design I studies, habitat is measured at the population level and individuals are not considered. The potential shortcomings of this design have been described (White and Garrott 1990, Manly et al. 1993, Otis and White 1999). Other bear habitat use studies have employed Design II and III studies, which consider the individual animal and are preferable for habitat use analysis (Manly et al. 1993, Otis and White 1999). Advantages include using design-based rather than model-based inferences, employing techniques at the individual rather than population level, and ability to examine possible differences among cohorts (Manly et al. 1993).

In addition to an improved understanding of basic experimental design, considerable effort has been focused recently on improving analytical models for habitat use studies (Aebischer et al 1993, Manly et al. 1993, Cherry 1996, Gautestad et al. 1998). With the exception of seasonal habitat use (e.g., Costello and Sage 1994, Waller and Mace 1997, McLellan and Hovey 2001), however, little attention has focused on potential temporal effects on habitat use. Schooley (1994) documented problems associated with pooling habitat use data across years for black bears. This author found that preferred habitats differed among years and that combining data from multiple years masked these preferences. Beyer and Haufler (1994) documented variation in daily sampling period for determining habitat use of elk (*Cervus elaphus*), noting significant differences between day and night habitat use. Thus, substantial temporal variation in habitat use may exist that is not typically incorporated in studies of bear habitat use. In addition, the number of locations required to define adequately home ranges to provide estimates of habitat availability appear to be considered infrequently.

Our goal was to determine sampling requirements necessary to describe black and brown bear home range and habitat use. Specific objectives were (1) to evaluate the efficacy of GPS collars on black and brown bears, (2) to determine the precision of annual and seasonal home ranges using MCP and fixed kernel methods, and (3) to determine if habitat use differs between seasons and by time of day.

STUDY AREA

The study was conducted during May–September, 1998–2000 in southcentral Alaska, bounded by the Alaska

Range to the north and between the Yentna and Chulitna river drainages on the west and east, respectively. The study area included the southeastern portion of Denali National Park and Preserve and Denali State Park. Elevations ranged from about 180–1,650 m. Several medium-sized glacial-fed rivers traversed the study area. Lower elevations were characterized by spruce (*Picea glauca* and *P. mariana*), white birch (*Betula papyrifera*), and alder (*Alnus* spp.) with numerous wet meadows containing sedges and grasses. Mid elevations (about 400–800 m) contained shrub-dominated habitat including dwarf birch (*B. glandulosa*) and willow (*Salix* spp.). With the exception of stream drainages which contained shrubs or small trees, elevations >800 m were dominated by tundra, exposed rock slopes, and glaciers.

METHODS

Capture and Handling

Bears were captured opportunistically by aerially searching mountain slopes, river drainages, and open meadows and tundra. Bears initially observed by spotters in fixed-wing aircraft were captured using immobilizing darts fired from a helicopter (Taylor et al. 1989). Bears were immobilized with equal parts tolazoline and zolazepam (Telazol®, Fort Dodge Laboratories, Inc., Fort Dodge, Iowa, USA). We monitored body temperature, respiration, and heart rate of bears during handling procedures. Female bears were fitted with a GPS store-on-board collar with VHF transmitter which weighed 1.7 kg. After handling, bears were typically left at the capture site to recover from the immobilant and were checked by aircraft 1–2 days later to assess recovery. Capture and handling procedures were approved by the University of Alaska Fairbanks Institutional Animal Care and Use Committee.

We deployed 72 GPS collars, typically during May. Collars ($n = 12, 24,$ and 36 in 1998–2000, respectively) were distributed equally between independent females of each species each year. Memory was not restored on 11 collars refurbished for use in 1999; these collars were excluded from analyses. We attempted to retrieve all collars at the end of each field season and sent them to the manufacturer to download location data and refurbish collars for use in subsequent years.

Telemetry System

We used first- and second-generation GPS store-on-board collars (Telonics Inc., Mesa, Arizona, USA). Characteristics of these collars have been described previously (Tomkiewicz 1996, Schwartz and Arthur 1999). Depending on the model and year, these collars were programmed

to attempt locations of animals at 5 h, 95 min, or 60 min intervals beginning 5 or 10 May at 0000 h Greenwich Mean Time. GEN I collars recorded fix number, date, time, latitude, longitude, and general cause of unsuccessful location. GEN II collars included information contained in GEN I collars in addition to whether the location was 2D or 3D, horizontal dilution of precision, and satellites used to obtain locations.

GPS Collar Performance

We summarized causes of failure to obtain successful locations for each bear as recorded by the GPS receivers. To avoid potential bias between individual bears, only bears for which we obtained locations throughout an entire field season were used in analyses ($n = 20$ black bears and 12 brown bears).

To compare percent of successful locations during the 24-h period, we divided data into twelve 2-hr intervals beginning at 0000 h. To assess temporal trends, data were divided into approximate half-month intervals beginning with late May. Location data for each bear were arcsine transformed before performing repeated measures analysis of variance (SAS Institute, Inc. 1988). Statistical significance for these and all other analyses was established as $P < 0.050$.

Home Range

We selected 6 individuals of each species that received GPS collars during 2000 for home range analyses. Home ranges were modeled using the MCP and fixed kernel methods (Hayne 1949, Seaman and Powell 1996). We chose the MCP method because of its frequent use in estimating home ranges and the fixed kernel method with least-squares cross validation because of its improved performance over other nonparametric estimators (Worton 1995, Seaman et al. 1999). We modeled MCP ranges using a modification of a previously developed computer program (White and Garrott 1990, Arthur and Schwartz 1999). Fixed kernel ranges were modeled using the software program KERNELHR (Seaman et al. 1998). In addition to modeling overall home ranges (late May–late Sep), we also modeled spring (late May–Jun) and summer (Jul–late Sep) home ranges for each bear. We defined fixed kernel home range estimates as the 95% use distributions estimated from bear locations.

For each bear-season, we randomly selected telemetry locations (without replacement) in increments of 10 locations. To approximate field conditions more closely using standard VHF telemetry techniques, selection of locations was restricted such that not more than 1 location/day was used for each random draw. Locations within a day were also selected at random. We used a maximum of 40 locations for spring, 80 for summer, and 100 for

spring and summer combined. Because of the relative low number of locations obtained for 1 black bear, a maximum of 70 locations was used for this individual during summer. We obtained 1,000 random draws for each combination of bear, season, and sample size. Thus, for each bear, we conducted 4,000 simulations during spring, 8,000 during summer, and 10,000 combined home range estimates using MCP and fixed kernel methods. We plotted mean home range size against sample size for each bear-season combination. To assess precision in home range estimates and make direct comparisons among home range methods, species, and seasons, we plotted the CV against sample size. We arbitrarily chose a CV of <0.20 to represent reasonable precision in home range estimates (Boulanger and White 1990, Otis and White 1999).

Home range size generally changes asymptotically with sample size for both the MCP (area increases) and fixed kernel (area decreases) methods (White and Garrott 1990, Seaman et al. 1999). At present, no standardized technique exists for determining when the number of locations obtained adequately represents the home range of an animal. Metzgar and Sheldon (1974) used regression techniques to determine the asymptote of change in area with increasing sample size to estimate home range. Other authors (e.g., Van Dyke et al. 1995, Seaman et al. 1999) have used the approximate asymptote of area as an indication of suitable sample size. Odum and Kuenzler (1955) suggested that a sample size in which each additional location resulted in an area increase of $\leq 1\%$ was adequate. We plotted percent change in mean home range size relative to the next lower sample size for each combination of method, bear, and season. We then approximated the suggestion of Odum and Kuenzler (1955) as described by Arthur and Schwartz (1999) in which the sample size was considered adequate to describe the home range when each additional 10-location increment resulted in a home range change of $\leq 10\%$.

Habitat Use

Habitat use was determined from a landcover map developed from 1985 multi-spectral satellite imagery with 80-m resolution resampled to 50 m (K. Fitzpatrick-Lins, G.F. Droughty, M. Shasby, and S. Benjamin, 1989, Alaska interim land cover mapping program—final report, Open-File Report 89-128, U.S. Geological Survey, Reston, Virginia, USA). ArcInfo (Environmental Systems Research Institute, Redmond, California, USA.) was used to extract habitat use data from imported bear location data. No catastrophic events (e.g., fire) occurred in the study area between image acquisition and this study. Habitats defined for analyses included conifer forest (overstory $>66\%$ conifer), deciduous forest (overstory $>66\%$ deciduous), mixed forest (overstory $<66\%$ conifer or deciduous),

shrub, tundra, and sparse or non-vegetated.

We compared seasonal habitat use for individual bears during each year. In addition, we determined whether habitat use differed among individuals within each species by season each year. For additional habitat use analyses, we defined diurnal as 0700–1859 and nocturnal as 1900–0659 to distribute the number of locations approximately equally between periods and because the diurnal period generally approximated the time period used in previous radiotelemetry studies of bear habitat use conducted during daylight hours. Day and night time periods were not designed to reflect the amount of daylight in southcentral Alaska, which exceeded the defined diurnal period during the study.

To ensure sample sizes were large enough to avoid violating analytical assumptions (Zar 1984, White and Garrot 1990), we analyzed habitat use only for bears with ≥ 150 locations/season. We used chi-square statistics (SAS Institute, Inc. 1988) to compare habitat use between seasons and time periods for each bear and within each season among individuals by species.

RESULTS

GPS Collar Performance

Overall, 67% of relocation attempts were successful (range = 10–93%). Most frequent causes for unsuccessful relocation attempts were inadequate number of satellites available and GPS antenna failure (Table 1). During 1998–99, GPS antenna failure was apparently a result of the GPS antenna separating from the canister. This problem was particularly evident with grizzly bears; for example, in 1998, virtually no locations were obtained for 5 of 6 grizzly bears after June. The manufacturer consequently modified the GPS antenna, which resolved the problem for the 2000 field season. The overall increase in percent successful locations from 1998–2000 was largely a consequence of correcting this problem. Thus, we believe that data collected during 2000 reflected actual collar performance.

Percent of successful location attempts differed among 2-hr intervals for both species ($F = 33.37$; 11, 330 df; $P < 0.001$; Fig. 1). Fewer locations were obtained for black bears than brown bears from 0800–1359 ($F = 9.88$; 11, 330 df; $P < 0.001$). Percent of successful location attempts for black bears was lower from 0800–1359 h than during the rest of the day. For brown bears, percent of successful relocations was lower during 1000–1359 h and 1800–0159 h.

There was a general decline overall in percent of successful locations across half-month intervals ($F = 29.82$; 7, 210 df; $P < 0.001$, Fig. 2) for both species. There was

Table 1. Characteristics of GPS collar performance for black and brown bears, southcentral Alaska, May–September 1998–2000.

Species	Year	Mean % (SD) successful fixes	Cause for location failure mean % (SD)	
			Too few satellites	No GPS time ^a
Black	1998	66.1 (7.5)	20.5 (4.1)	10.5 (8.0)
	1999	61.4 (12.3)	10.3 (5.4)	25.5 (7.9)
	2000	75.9 (7.2)	17.2 (3.8)	5.4 (4.5)
	Combined	70.2 (10.9)	15.8 (5.6)	11.8 (10.6)
Brown	1998	33.3 (17.8)	15.7 (8.4)	50.1 (25.7)
	1999	44.1 (29.8)	12.5 (6.7)	43.2 (33.5)
	2000	80.6 (7.7)	13.4 (5.0)	5.2 (3.2)
	Combined	63.3 (26.3)	13.7 (6.0)	22.2 (27.4)

^a Includes GPS antenna failure (see Results).

also an interaction of location success and species ($F = 6.30$; 7, 210 df; $P < 0.001$), with percent of successful locations declining at a greater rate for brown bears than black bears.

Home Range

MCP home ranges for both species typically reached an asymptote as sample sizes increased (Figs. 3, 4). An exception was black bear 9952, whose summer and combined home ranges did not clearly reach an asymptote after 80 and 100 locations, respectively. In contrast, black and brown bear fixed kernel home ranges consistently decreased in area as sample sizes increased (Figs. 3, 4). The only notable exception was black bear 0079, whose spring home range area continued to decrease at a similar rate through 40 locations.

Initial MCP home range areas were usually smaller than fixed kernel home ranges but were ultimately larger as sample sizes increased (Figs. 3, 4). For black bears during spring, MCP home ranges generally became larger than fixed kernel home ranges between 20–30 locations (Fig. 3). However, the summer and combined home ranges of 2 black bears did not converge until 80 locations were modeled. Brown bear MCP and fixed kernel home ranges typically converged at 10–30 locations (Fig. 4).

Differences in MCP and fixed kernel home ranges were considerable for both species in all seasons. Black bear spring, summer, and combined MCP home ranges were as much as 5 times greater than the same home ranges using fixed kernel (Fig. 3). Variation for brown bears was even greater, with spring, summer, and combined MCP home ranges as much as 17 times greater than fixed kernel home ranges (Fig. 4).

Precision of home range estimates varied considerably between species and seasons (Figs. 5, 6). Coefficients of variation were typically lower for MCP home ranges than fixed kernel home ranges of comparable sample size (Table 2). Similarly, CV for MCP home ranges stabilized with fewer locations than did CV for fixed kernel home ranges.

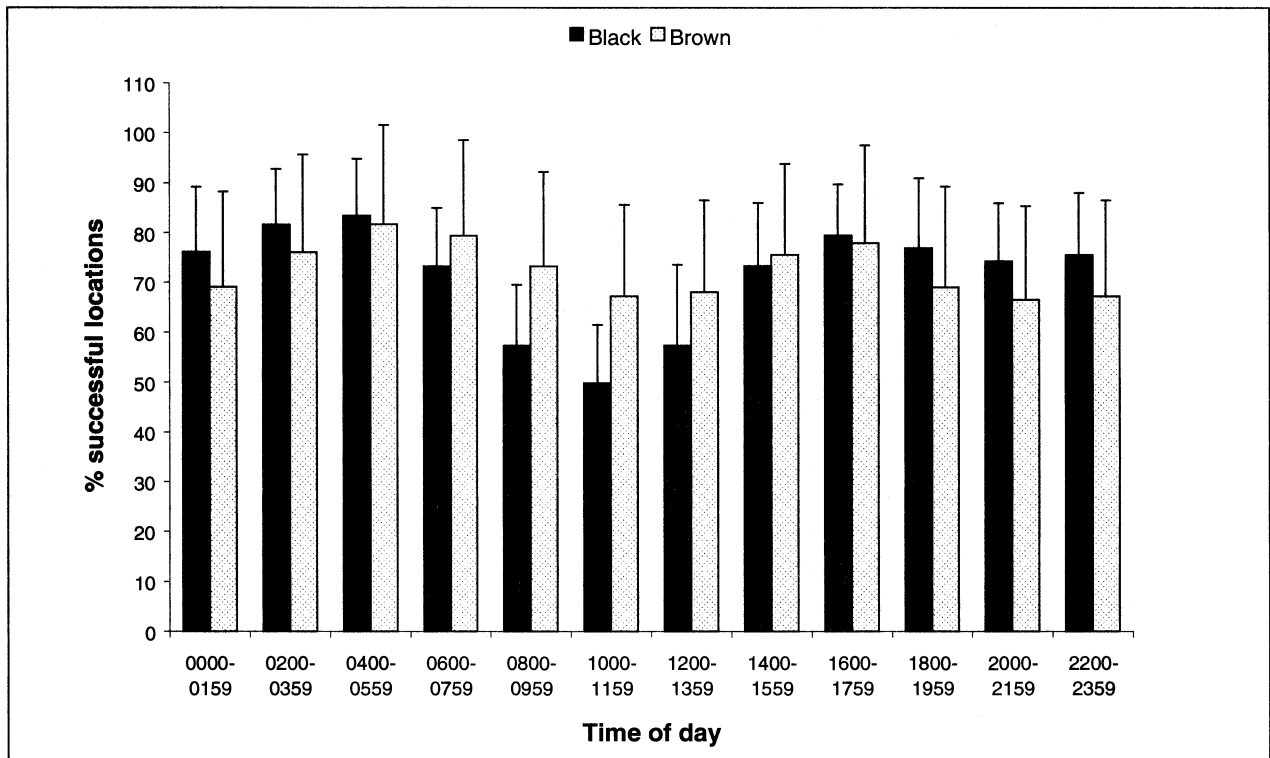


Fig. 1. Mean (\pm SD) percent successful locations by 2-hr interval obtained for female black ($n = 20$) and brown ($n = 12$) bears with GPS collars, southcentral Alaska, USA, May–September 1998–2000.

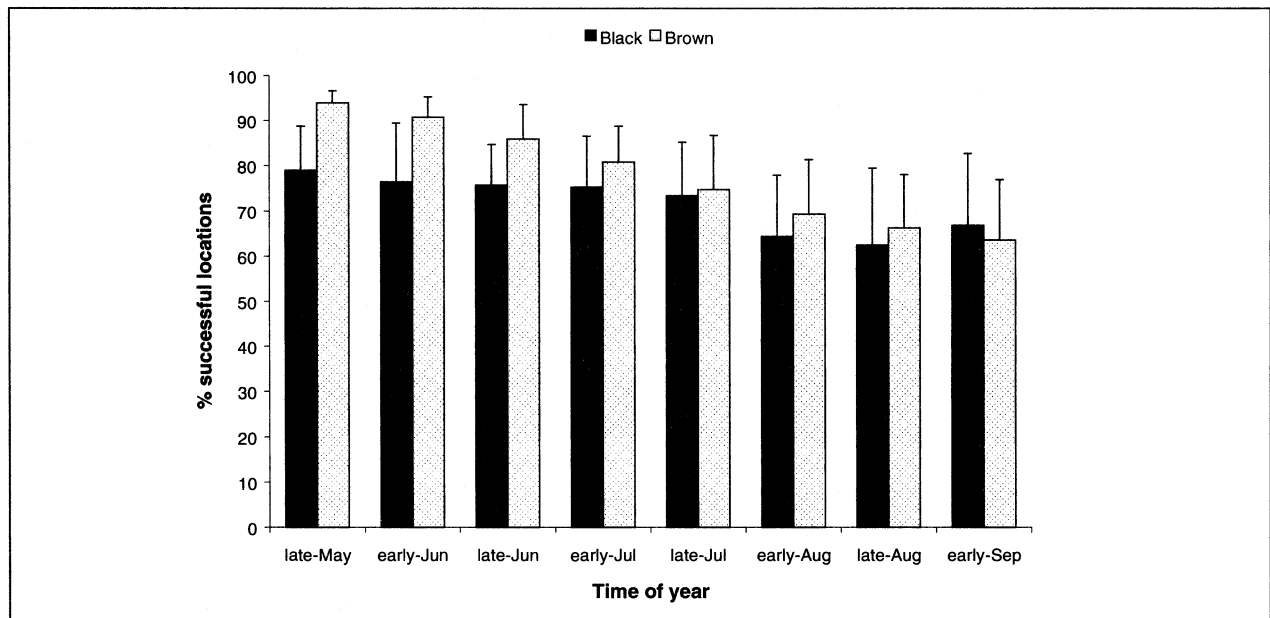


Fig. 2. Mean (\pm SD) percent successful locations by half-month interval obtained for female black ($n = 20$) and brown ($n = 12$) bears with GPS collars, southcentral Alaska, May–September, 1998–2000.

Variability among fixed kernel estimates within a season was greater than MCP estimates for both species.

Black bear MCP home ranges during spring, summer, and combined were generally of adequate precision ($CV < 0.20$) between 20–30, 20–40, and 20–50 locations, re-

spectively (Fig. 5, Table 2). The exception was black bear 9952, which required >70 locations during summer for CV to be <0.20 . The CV for this individual's combined MCP home range was 0.23 for 100 locations. Variability of black bear fixed kernel home ranges during spring re-

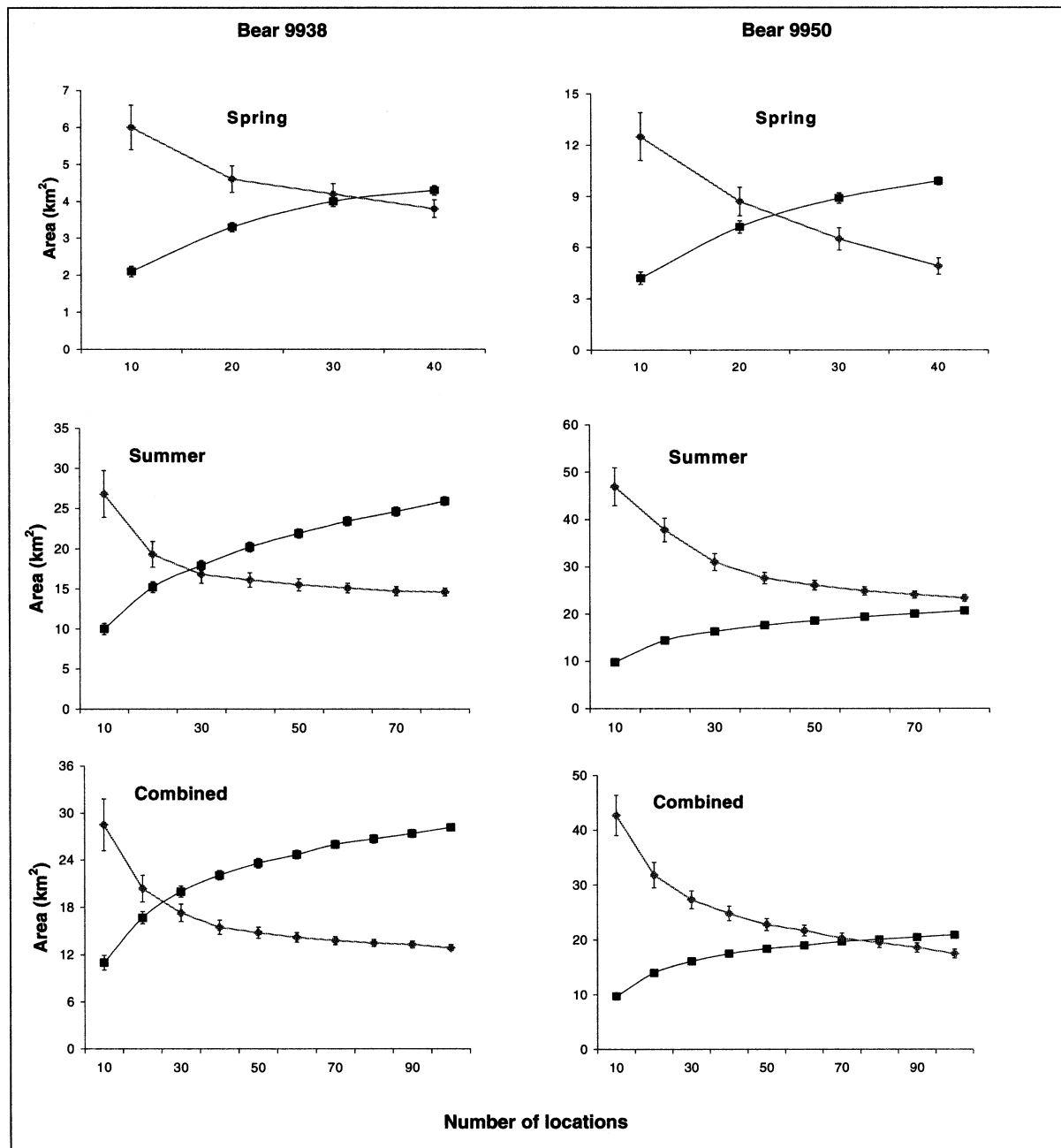


Fig. 3. Examples of effects of sample size on area (km^2) estimates ($\pm\text{SE}$) of spring (late May–Jun), summer (Jul–late Sep), and combined (late May–late Sep) home ranges using minimum convex polygon (squares) and fixed kernel (diamonds) for two female black bears, southcentral Alaska, 2000. Each data point represents 1,000 simulations using randomly-selected subsets of data.

remained high, with CVs of 0.33–1.06 at 40 locations. Precise estimates of combined black bear home ranges generally required >80 locations, with 3 individuals requiring >100 locations.

Fewer than 40 locations were needed typically for spring and summer brown bear MCP home ranges to have a CV <0.20 (Fig. 6, Table 2). The exception was an individual which required >60 locations for the combined home range. In contrast, variability of 5 of 6 brown bear spring

fixed kernel home ranges was >0.20 at 40 locations. Variability was high (CV >0.32) for 4 and 5 brown bear summer and combined home ranges using 80 locations. In fact, 5 of 6 brown bear combined home ranges using the fixed kernel method were imprecise (CV >0.31) with 100 locations.

More than 40 locations were required for 4 black bears during spring to have a reduction in MCP home range area of $<1\%$ /location (Fig. 7). For a similar rate of area

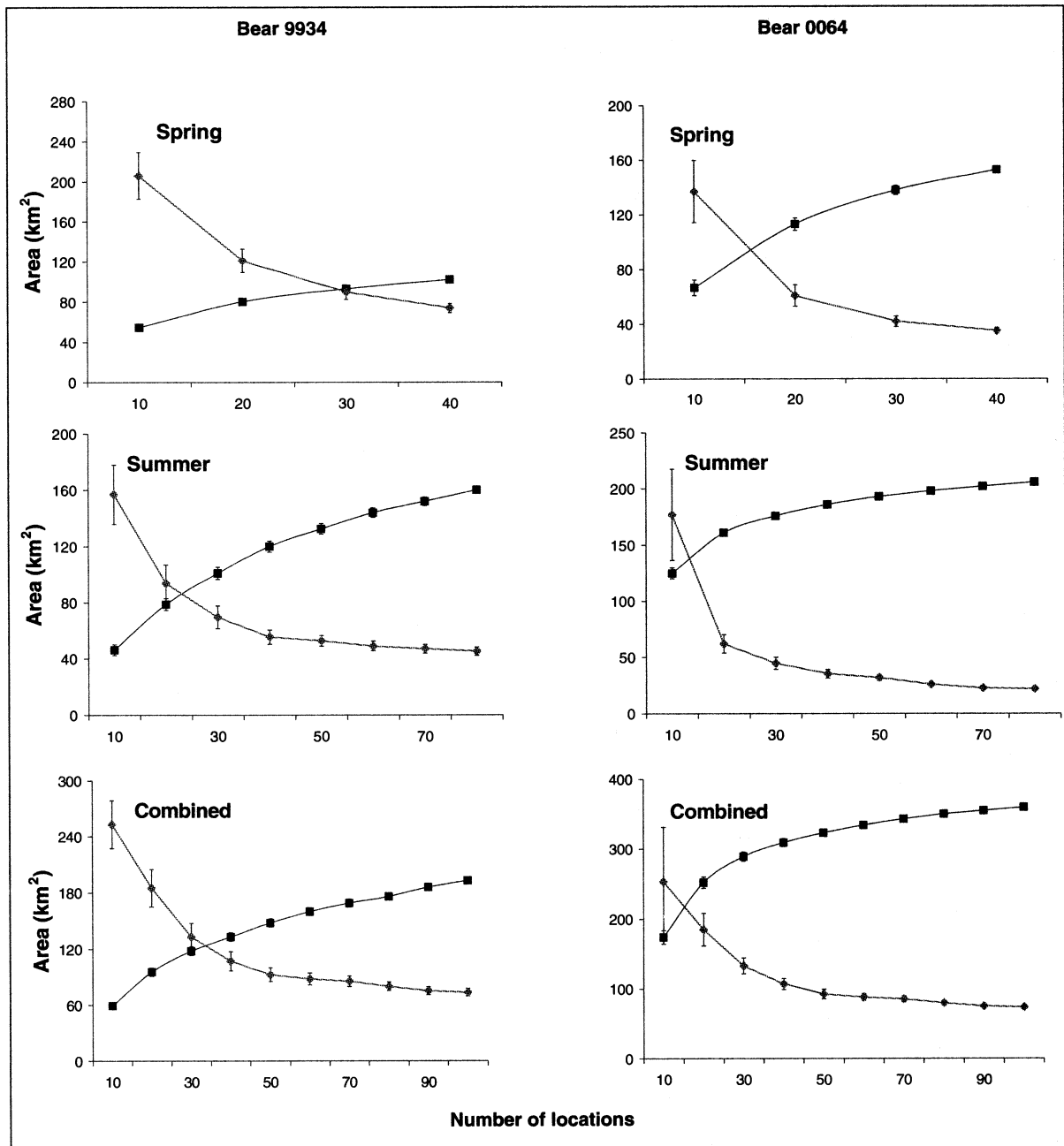


Fig. 4. Examples of effects of sample size on area (km²) estimates (\pm SE) of spring (late May–Jun), summer (Jul–late Sep), and combined (late May–late Sep) home ranges using minimum convex polygon (squares) and fixed kernel (diamonds) for two female brown bears, southcentral Alaska, USA, 2000. Each data point represents 1,000 simulations using randomly-selected subsets of data.

reduction in summer and combined MCP home ranges, 3 black bears required >30 locations, 2 required >40 locations, and 1 required >70 locations. Number of locations required for fixed kernel home range estimates was even greater. More than 40 locations were necessary for 5 of 6 spring black bear home ranges. In summer, 4 black bears required >40 locations, and for combined home ranges, >40 locations were needed for 3 individuals.

More than 40 locations were required for 3 brown bears during spring to have a reduction in MCP home range area of <1%/location (Fig. 8). Similarly, 5 brown bears required >30 locations during summer and 3 brown bears required >40 locations for combined MCP home ranges. Using fixed kernel, all 6 bears required >40 locations for home range estimates during spring, summer, and combined seasons. For summer and combined home range

Table 2. Number of locations needed to define minimum convex polygon (MCP) and fixed kernel home range asymptote (<1% mean change in area/additional location) and precision (CV < 20%) for female black and brown bears, southcentral Alaska, USA 2000.

Parameter	Season	Black bear		Brown bear	
		MCP	Fixed kernel	MCP	Fixed kernel
Accuracy	Spring	≥40	30–≥40	≥40	>40
	Summer	40–80	40–70	50–>80	50–>80
	Combined	40–90	40–60	50–80	50–80
Precision	Spring	20–40	>40	≥40	≥40
	Summer	20–80	70–>80	40–>80	40–>80
	Combined	20–>100	70–>100	80–90	80–90

estimates, 3 and 2 individuals, respectively, needed >70 locations.

Habitat Use

In all cases, spring and summer habitat use differed for individual black and brown bears ($\chi^2 = 14.99-781.67$, 4–5 df, $P \leq 0.010$). In addition, seasonal habitat use differed ($\chi^2 = 292.71-3,482.91$; 20–75 df; $P < 0.001$) among individuals within each species during each year (e.g., Fig. 9).

Several individuals of both species exhibited differences ($P < 0.050$) between diurnal and nocturnal habitat use (Table 3). For black bears, day and night habitat use differed ($P < 0.050$) in 11% and 14% of instances during spring and summer, respectively. For brown bears, day and night habitat use differed ($P < 0.050$) in 29% and 56% of instances during spring and summer, respectively. Diurnal and nocturnal seasonal habitat use differed ($P < 0.050$) in 13% and 42% of all cases for black and brown bears, respectively (e.g., Fig. 10).

DISCUSSION

GPS Collar Performance

Vegetation may have affected GPS collar performance in this study; percent of successful locations declined temporally for both species, with highest success obtained during May–early July. Similarly, Schwartz and Arthur (1999) documented a temporal decline in successful locations obtained for brown bears in the Kenai Peninsula, Alaska. These authors concluded that GPS performance was largely unaffected by vegetation; however, increased vegetative closure was inversely associated with fix rate. Although temporal variation was not assessed, vegetation also was determined to have a significant effect overall on successful location attempts of black bears and moose (*Alces alces*; Rempel et al. 1995, Moen et al. 1996, Obbard et al. 1998). The decrease in number of locations obtained in our study may have resulted in part from a general increase in vegetative cover as summer progressed.

Although location acquisition rates declined temporally

for both species, the rate of decline was greater for brown bears. This decline coincided with salmon (*Oncorhynchus* spp.) spawning runs which began in July (summer) each year. At this time, brown bears typically moved to lower elevation riparian areas containing denser overstory vegetation to feed on salmon. Black bears moved less extensively and did not make comparable movements. Thus, the greater temporal reduction in successful locations for brown bears was likely influenced by major shifts in habitat use.

The lower number of successful locations observed during parts of the 24-hr period may be attributed to bear behavior. For example, bears moving into dense cover or lying down during a fix acquisition attempt would preclude successful locations. Similar to our study, Obbard et al. (1998) documented variability in successful location attempts for black bears by time of day, with fewer locations generally obtained during the afternoon and early morning. Lower success of locations obtained for brown bears in this study corresponds reasonably well with observed resting periods for grizzly bears in Denali National Park north of the Alaska Range (Stelmock and Dean 1986).

Home Range and Habitat Use

Although home ranges of some bears in this study were adequately described with as few as 30 locations, home ranges for the ‘population’ of bears were not defined during some seasons until ≥ 80 locations were obtained. For seasonal home ranges, this represented obtaining >1 location/day. More locations were necessary to define home ranges with adequate precision (CV < 0.20). The minimum number of locations recommended previously for kernel home range analyses (≥ 30 or ≥ 50 ; Seaman et al. 1999) appear too few for defining black and brown bear home ranges, at least in our study area. For fixed kernel analyses, we recommend obtaining ≥ 80 locations to describe black and brown bear annual home ranges. For annual home ranges using MCP, we recommend using 60–90 locations.

Based on study objectives and definition of home range used, either MCP or fixed kernel may be employed for home range analyses. The MCP is useful for estimating

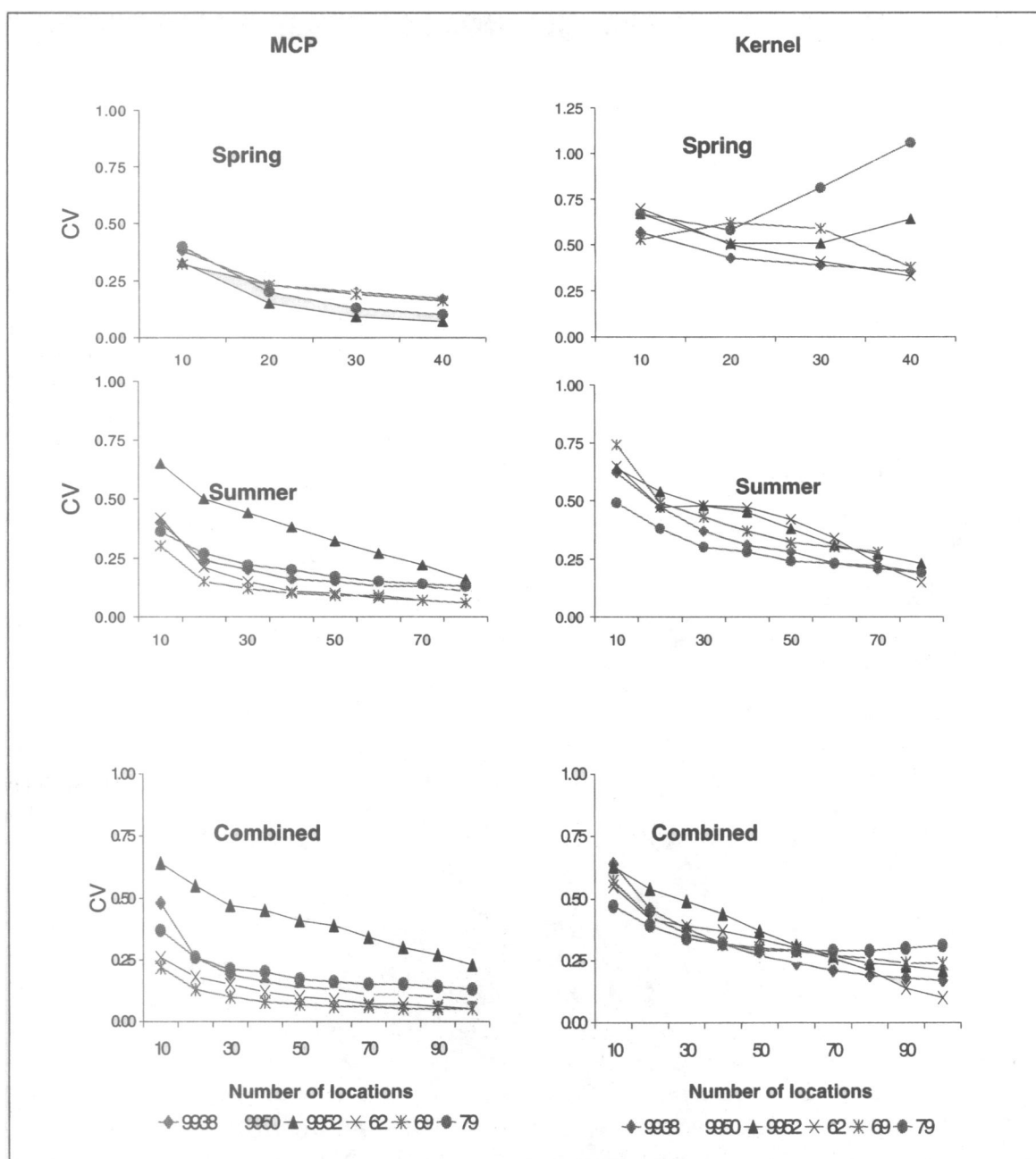


Fig. 5. Effect of sample size on coefficient of variation (CV) of home range estimates during spring (late May–Jun), summer (Jul–late Sep), and combined (late May–late Sep), using minimum convex polygon and fixed kernel methods for female black bears, southcentral Alaska, USA, 2000. Each data point represents the mean of 1,000 simulations using randomly-selected subsets of data.

the total area used by an individual, and has been used to evaluate home range overlap (Horner and Powell 1990, Wertz et al. 2001). In contrast, kernel methods provide a density estimate of the area used by an individual (White and Garrott 1990, Seaman et al. 1999) and are more suitable for resource selection studies.

Seaman et al. (1999) recognized that estimates along the periphery of home ranges are unreliable relative to

estimates of core areas. Outer portions of the home range often contribute substantially to the total area, yet the least amount of data are available to support these estimates. This appears to have a greater influence on MCP home ranges than kernel home ranges. Seaman et al. (1999) recommended that future studies place greater emphasis on core areas for home range and habitat selection analyses. Additional research with simulated and empirical data

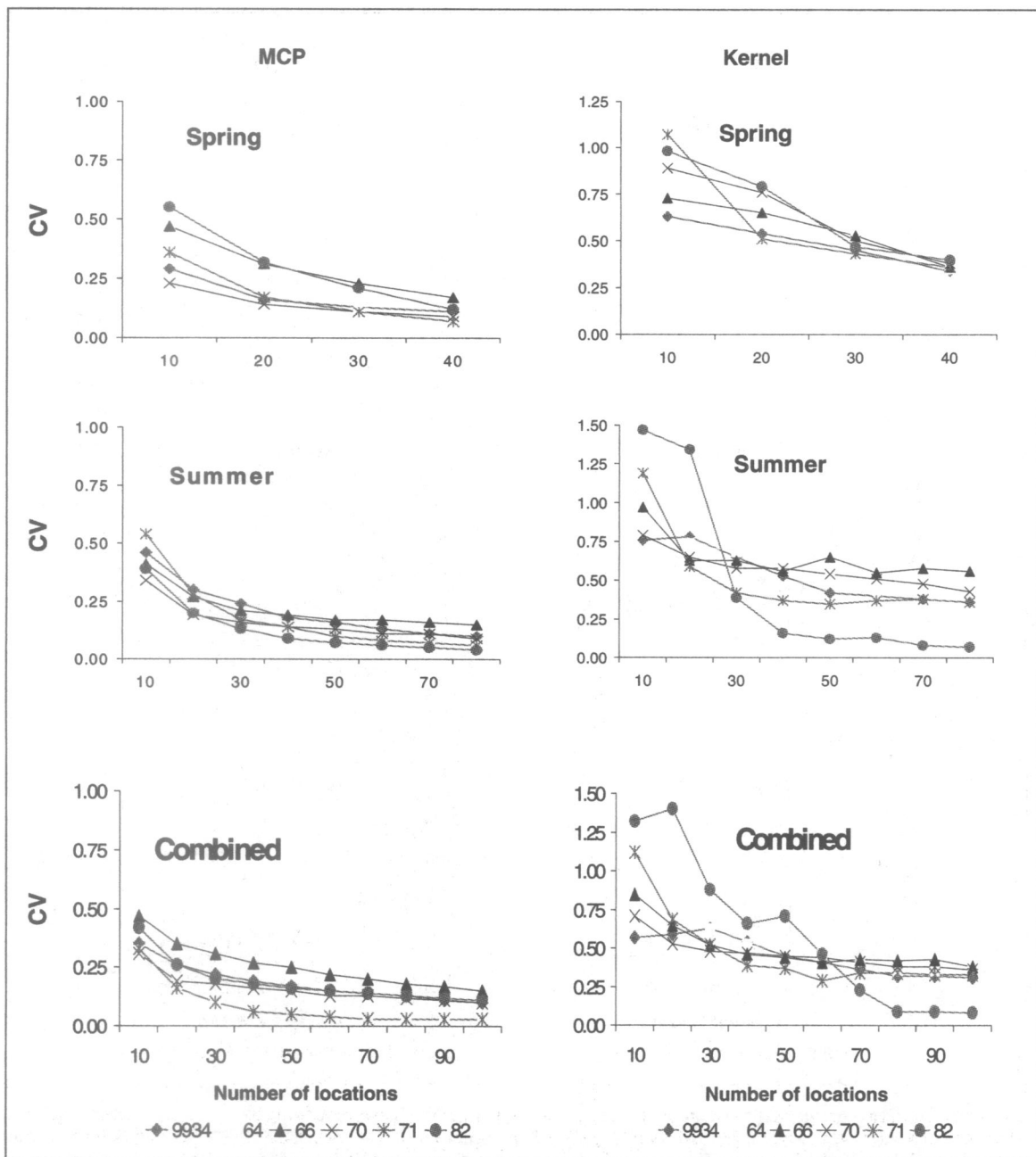


Fig. 6. Effect of sample size on coefficient of variation (CV) of home range estimates during spring (late May–Jun), summer (Jul–late Sep), and combined (late May–late Sep), using minimum convex polygon and fixed kernel methods for female brown bears, southcentral Alaska, USA 2000. Each data point represents the mean of 1,000 simulations using randomly-selected subsets of data.

is required to assess the effects of sampling intensity on accuracy and precision of core areas within home ranges. Sample size and model used has been demonstrated to affect home range (Arthur and Schwartz 1999, Seaman et al. 1999, this study); similar effects may exist for core areas within home ranges.

Autocorrelation, or dependence of radio telemetry locations, often has been reported as a problem for home

range and habitat use analyses (Swihart and Slade 1985, Litvaitis et al. 1994). Conversely, other authors have stated that autocorrelation typically will not be problematic, provided habitat use is defined at the individual level and data collection for home range analyses is unbiased during the period of interest (Swihart and Slade 1997, Otis and White 1999). Using Schoener's index t^2/r^2 (Schoener 1981, Swihart and Slade 1985) on black bears in North

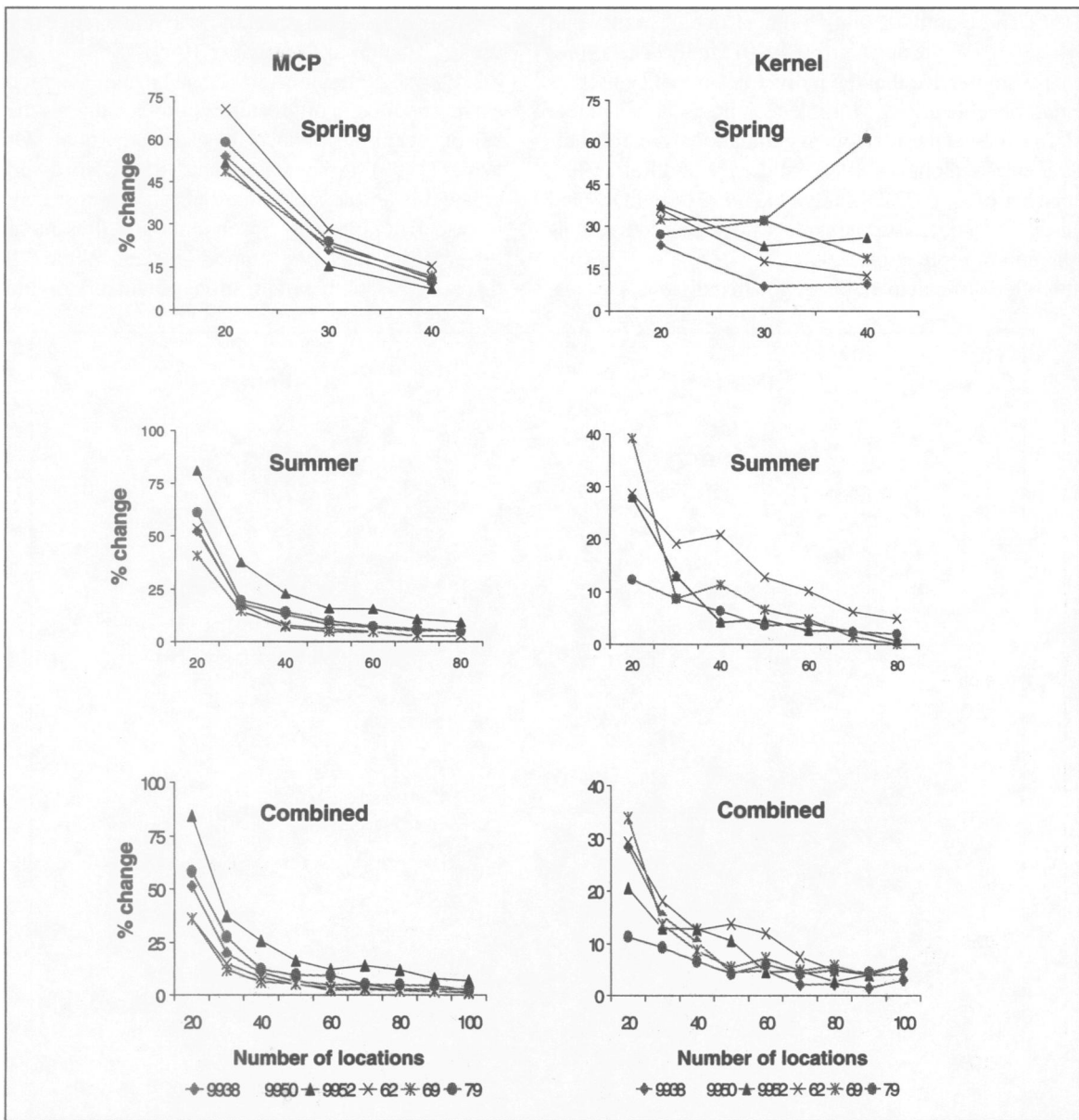


Fig. 7. Percent change in female black bear mean home area using successively increasing locations during spring (late May–Jun), summer (Jul–late Sep), and combined (late May–late Sep), southcentral Alaska, USA, 2000. Percent change is relative to mean area estimate for 10 fewer locations. Each data point represents the mean of 1,000 simulations using randomly-selected subsets of data.

Carolina, Powell (1987) determined that it may not be possible to obtain enough statistically independent locations to estimate home ranges. Although we did not determine independence of locations, if Powell’s (1987) estimates of the time interval for independence between locations were valid for our study, it would be difficult or impossible to determine home ranges on a seasonal or annual basis. We believe that bear movements within a home range are not independent but are in part a result of previous movements and experience. Although data for

individual bears in this study were not independent, because data were collected systematically throughout defined intervals, we do not believe that autocorrelation of data is of concern (see Swihart and Slade 1997, Otis and White 1999).

A suitable number of locations were obtained in our study using GPS collars to assess habitat use at the individual level. Using location estimates as the sampling unit among individuals in a population to determine habitat use is a form of pseudoreplication (Otis and White

1999). These authors, among others (e.g., Thomas and Taylor 1990, White and Garrott 1990, Manly et al. 1993), have recommended that the individual animal be used as the unit of replication. Multiple techniques are available to define habitat use for a given population using the individual animal (Johnson 1980, Alldredge and Ratti 1986, Aebischer et al. 1993). Manly et al. (1993) and Otis and White (1999) described advantages of using individuals as the unit of replication.

It is often difficult to monitor enough individuals to have

high power to detect differences in home range or habitat use (see Arthur and Schwartz 1999). Statisticians (e.g., Zar 1984) have demonstrated that the number of individuals represented is of greater importance than is the number of locations obtained for each individual. Otis and White (1999) further stated that GPS collars could exacerbate this problem because their greater cost may result in researchers buying fewer units and thus monitoring fewer individuals. We support Otis and White (1999) in that both the number of locations obtained/individual and

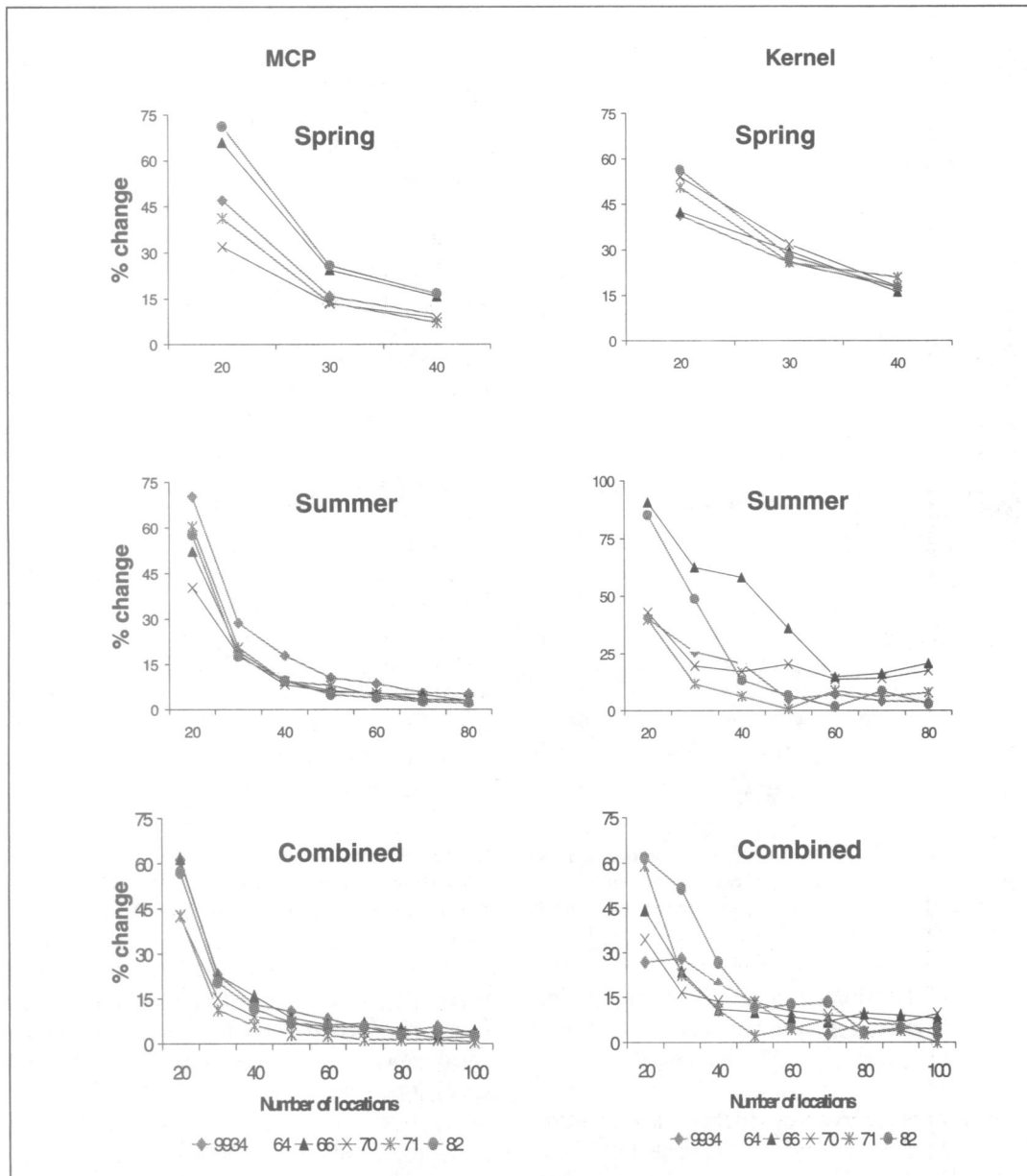


Fig. 8. Percent change in female brown bear mean home area using successively increasing locations during spring (late May–Jun), summer (Jul–late Sep), and combined (late May–late Sep), southcentral Alaska, USA, 2000. Percent change is relative to mean area estimate for 10 fewer locations. Each data point represents the mean of 1,000 simulations using randomly selected subsets of data.

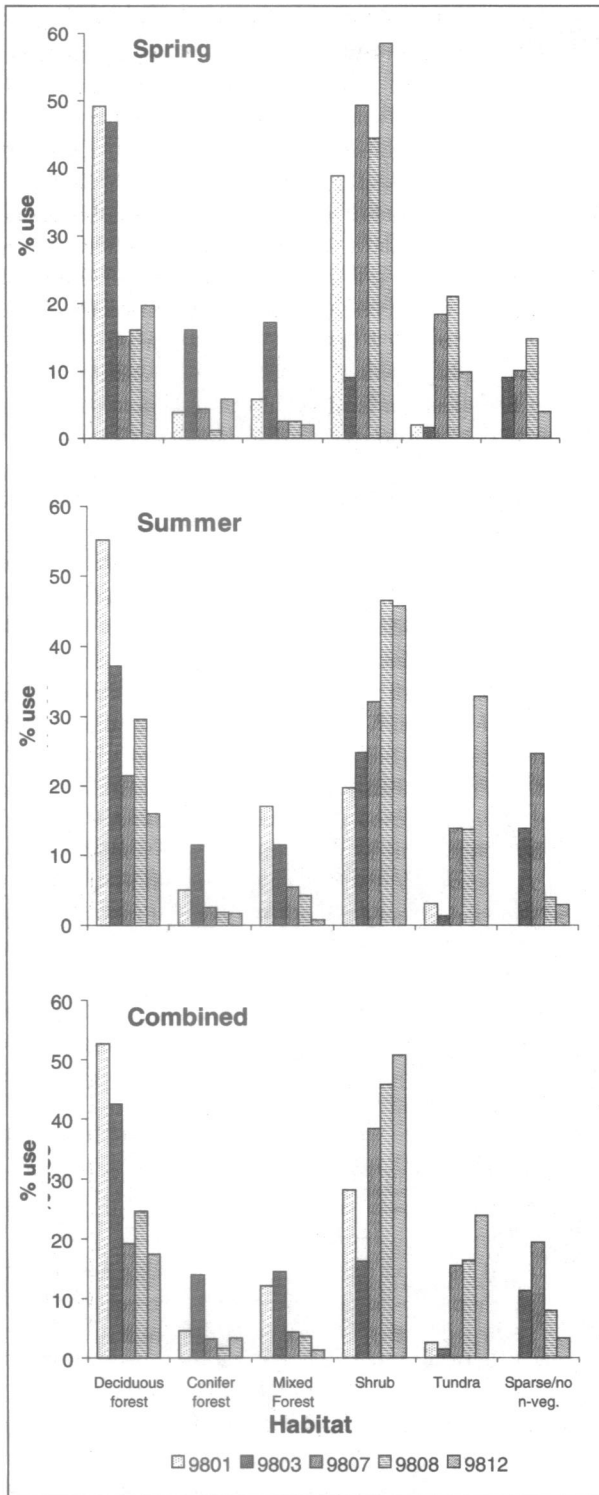


Fig. 9. Individual female black bear habitat use during spring (May–Jun), summer (Jul–Sep), and combined, southcentral Alaska, USA, 1998.

total number of individuals monitored is critical for assessing habitat use for a population. Too few individuals monitored will not adequately reflect the population; simi-

Table 3. Number of individual female black and brown bears exhibiting differences between night (1900–0659) and day (0700–1859) seasonal (spring = late May–Jun; summer = Jul–late Sep; combined = late May–late Sep) habitat use, southcentral Alaska, USA, 1998–2000.

Species	Season	No. bears differing in diurnal and nocturnal habitat use			Total
		$P < 0.05$	$0.05 \leq P < 0.10$	$P \geq 0.10$	
Black	Spring	3	4	20	27
	Summer	4	3	21	28
	Combined	7	7	41	55
Brown	Spring	5	0	12	17
	Summer	10	2	6	18
	Combined	15	2	18	35

larly, too few locations/individual will not represent the individual, which in turn cannot represent the population. Ensuring that enough locations are obtained to define the home range, whether seasonal or annual, will reduce error and provide better estimates of habitat use.

Otis and White (1999) mentioned the need to theoretically address the effects of variable numbers of locations obtained among individuals on habitat use. Indeed, in our study the number of locations varied by several hundred, which could result in biased assessments of habitat use among bears. One solution would be to standardize the number of locations used among bears. A second method would be to standardize the precision among home range estimates. A third means to potentially reduce this problem is to use locations only to define the relative area used by each bear, for example, using the fixed kernel method to define individual 95% and 50% contours. In this case, habitat selection could be assessed by comparing habitat within the 50% contour ('preferred') to habitat within the 95% contour ('available'). This form of analyses may also aid in reducing the potential adverse effects of vegetative closure on fix rate. It should be recognized that heterogeneity of habitat (e.g., patch size and juxtaposition) could affect derived selection indices in this analyses. Using bears as the unit of replication would provide equal weight among individuals, further reducing this potential bias.

We reviewed 32 articles on black and brown bear habitat use published in the *Journal of Wildlife Management* (1977–2000) and from proceedings of *The International Conference on Bear Research and Management* (1977–1994) and *Ursus* (1998) to assess timing of data collection. A majority (79%) of these studies reported collecting habitat data only during the diurnal period or did not provide adequate detail to determine the timing of data collection. We presumed that the majority of studies that did not report the timing of collection obtained habitat use information collected during the day only. Our study illustrates the importance of sampling habitat use based on the entire 24-h period. For example, diurnal sampling of black bear habitat suggested higher than expected use of

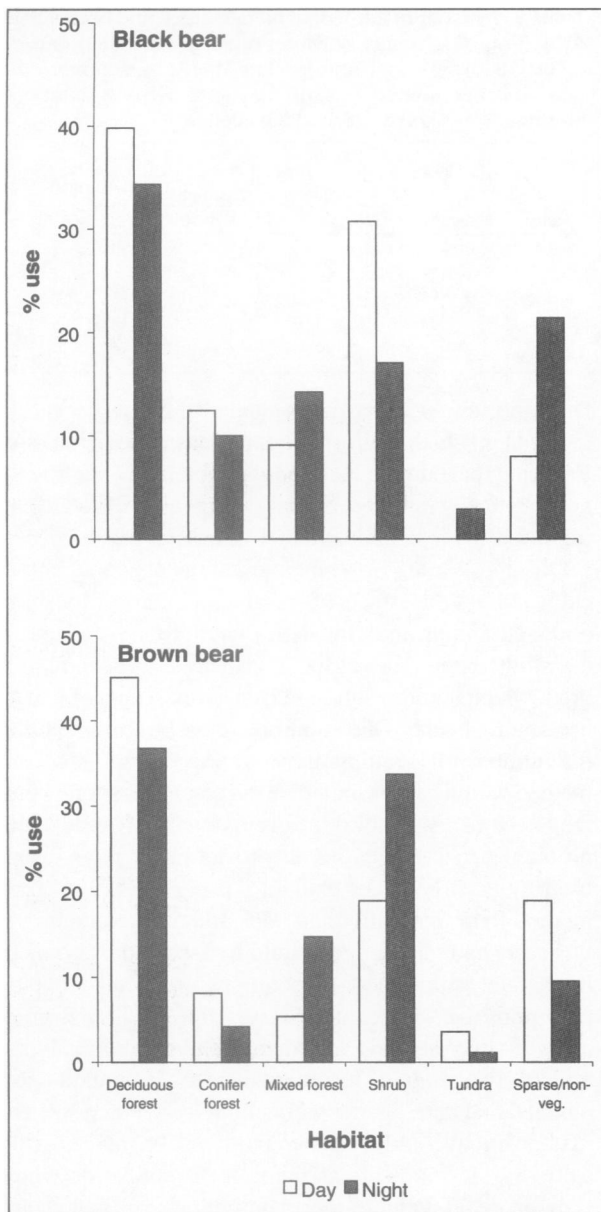


Fig. 10. Examples of variation in summer (Jul–Sep) diurnal (0700–1859) and nocturnal (1700–0659) percent habitat use by a female black bear during 1998 and a female brown bear during 2000, southcentral Alaska.

shrub habitat, whereas sampling at night revealed the relative importance of sparsely-vegetated habitat (Fig. 10). Similarly, diurnal brown bear habitat use was predominantly deciduous forest, whereas night sampling revealed almost equal use of shrub habitat.

In many portions of their range, brown and black bears have been reported as being primarily diurnal or crepuscular (Amstrup and Beecham 1976, Lindzey and Meslow 1977, Garshelis and Pelton 1980, Bjarvall and Sandegren

1987, Mace and Waller 1997). In addition to the relative ease and convenience of collecting data during the day, this may explain why a majority of studies of bear habitat use were conducted during the diurnal period. However, many of the above-mentioned studies reported that bears were also active at night. Furthermore, that several studies have documented extensive diurnal or crepuscular activity does not imply that bears under some circumstances or in portions of their range cannot be at least as active during night as during the day. For example, Ayres et al. (1986) reported that black bears in Sequoia National Park (California, USA) that relied in part on food from campgrounds were active primarily during night, whereas bears that relied on natural foods were primarily crepuscular. Brown bears have also been reported to be highly active at night (Pearson 1975, Roth 1983, Roth and Huber 1986, Stelmock and Dean 1986). Activity patterns and levels of activity can vary among cohorts (e.g., subadults, adult females with young), seasons, and even individual bears (Roth 1983, Roth and Huber 1986, Stelmock and Dean 1986, Gunther 1991, Mace and Waller 1997). Thus, habitat use studies should conduct initial assessments of bear activity patterns before establishing timing of location estimates.

MANAGEMENT AND RESEARCH IMPLICATIONS

Use of GPS collars offers several advantages over conventional VHF transmitters or other telemetry systems including collection of data during inclement weather, greater frequency of locations, reduction of human error, and increased cost effectiveness for multi-year studies (Schwartz and Arthur 1999). Accuracy of locations using satellite telemetry systems has been enhanced recently due to disablement of selective availability (Hulbert and French 2001). Satellite and GPS telemetry now provide biologists greater opportunity to collect data over 24 hours (Rodgers et al. 1996, Craighead 1998, Obbard et al. 1998). For home range and habitat studies in remote or large geographic areas, GPS or another satellite-based system may be the only practical alternative.

Because of differences in habitat use observed in this study, pooling location data for bears within or across seasons is not recommended. Pooling seasonal data could mask habitat selection, as has been demonstrated with between-year habitat selection for black bears (Schooley 1994). Because diurnal and nocturnal habitat use can also differ for bears, inferences from data collected during only part of the 24-hr period cannot be extrapolated to the entire 24-hour period *a priori*. In our simplistic example, managers considering only daytime (0700–1859 h) brown

bear habitat use may have decided to reduce human development in shrub and sparsely-vegetated areas, whereas if 24-hour data had been available, greater emphasis may have been placed on protecting shrub habitat. Thus, management recommendations based on data collected during part of the 24-hour period could be misleading or even detrimental to affected populations. Timing of sampling and the potential limitations of habitat use data should be explicitly stated prior to formulating decisions.

We believe that additional integration of home range and habitat use methods is necessary to understand resource selection of bears as well as other species. Incorporating appropriate sampling efforts relative to species' activity patterns and daily and seasonal use of resources is essential to define home ranges and associated habitat selection. Analyses and interpretation of habitat data derived from studies where habitat use was not a primary objective (i.e., too few locations) should be made with caution. Future studies need to collect enough locations to ensure reasonable estimates of home range and habitat use. Having adequate numbers of locations to analytically define home range or habitat use does not in itself mean data are unbiased. Additional research on apparent biases of canopy cover and bear behavior on location acquisition rates are needed to ensure accuracy of data. Future investigations of black and brown bear home range and habitat use must seriously consider sampling designs to ensure that data collected meets study objectives.

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