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Source: Mammal Study, 39(2):115-119.
Published By: Mammal Society of Japan
DOI: http://dx.doi.org/10.3106/041.039.0207
URL: http://www.bioone.org/doi/full/10.3106/041.039.0207

Mammal Study 39: 115–119 (2014)

Short communication

Influence of landscape attributes on American black bear den-site selection in Mississippi

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Increasingly, human activities influence wildlife populations in numerous ways including habitat selection, demography, behavior, and physiology (Apps et al. 2004). These effects are often magnified in urban and exurban environments; however, they also occur in rural and remote environments (Yorio et al. 2001; Reynolds-Hogland et al. 2007). Understanding types and magnitude of disturbances affecting species can be used to improve conservation, and is especially relevant to conservation of endangered species (Frid and Dill 2002). Anthropogenic disturbances (e.g., recreational activities and roads) may result in decreased habitat suitability as well as increased stress levels and energetic losses to animals (Linnell et al. 2000; White et al. 2001). Consequently, individuals of species such as grizzly bears (*Ursus arctos*) may select home ranges in areas that are uninhabited by, or inaccessible to, humans to avoid interaction (Apps et al. 2004).

Non-anthropogenic factors including conspecifics, habitat edges, and topographic features, also may result in disturbances to bears (White et al. 2001; Garneau et al. 2006). Risk to bears from conspecifics or competitors can cause variation in habitat use (Garneau et al. 2006; Belant et al. 2010; Libal et al. 2011) and mammalian carnivores (e.g., large male bears) commonly use streams, rivers, and habitat edges as travel corridors (Donovan et al. 1997; Reynolds-Hogland et al. 2007), which could disturb denning conspecifics. Additionally, streams and rivers can be a source of flooding which can cause American black bears (*U. americanus*) to select den-sites at higher elevations (White et al. 2001). Black bears may also avoid roads to reduce risk from human activities associated with roads (Reynolds-Hogland et al. 2007).

Our objective was to examine landscape attributes associated with potential disturbance risks on black bear den-site selection. We used two ecologically relevant spatial scales (i.e., autumn and annual home ranges) because the influence of landscape attributes on resource selection by bears can be scale dependent (Libal et al. 2012; Waller et al. 2013). Mississippi, USA, has a small re-colonizing black bear population (estimated at 50 individuals) that is state-listed as endangered and includes the federally-threatened Louisiana black bear (*U. a. luteolus*; USFWS 1992; Simek et al. 2012). We predicted black bears would select den sites located at higher elevations to avoid flooding (e.g., White et al. 2001; Waller et al. 2012) and farther from roads, habitat edges, and streams or rivers to reduce potential disturbance (e.g., Reynolds-Hogland et al. 2007).

Materials and methods

We conducted fieldwork in the Mississippi Alluvial Valley (MAV) of western Mississippi where most black bear sightings occur (Simek et al. 2012). The MAV is about 20,000 km^2 and has low topographic relief with elevations from 3 to 136 m above mean sea level (MARIS 2002). The humid subtropical climate produces long, hot summers and short, mild winters (Bowman 1999). The MAV consists of various land uses including agriculture, forests, and urban areas (Bowman 1999). Common trees include oak (*Quercus* spp.), hickory and pecan (*Carya* spp.), sweetgum (*Liquidambar styraciflua*), elm (*Ulmus* spp.), and cottonwood (*Populus deltoides*).

We captured black bears from 2005–2010 using modified Aldrich foot snares (Johnson and Pelton 1980) and culvert traps (e.g., Beeman and Pelton 1976). We immobilized captured individuals with tiletamine and zolazepam (Telazol; A. H. Robins Company, Richmond,

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Virginia, USA) at a dosage of 4–5 mg/kg of estimated body weight, administered with a dart syringe fired from a CO_2-powered pistol or syringe pole. We equipped captured bears with global positioning system (GPS) radio-collars (Telonics, Inc., Mesa, Arizona, USA; Advanced Telemetry Systems Inc., Isanti, Minnesota; Northstar, King George, Virginia, USA) and released bears at their capture site upon recovery. Capturing and handling of bears was approved by the Mississippi Department of Wildlife, Fisheries and Parks and the Mississippi State University Institutional Animal Care and Use Committee.

We located dens using aerial and ground-based telemetry and attempted den visits of all radio-collared bears during winters 2006–2011. We retrieved 3.5-, 5-, or 11-hour relocation data from GPS collars recovered during den visits and recaptures. We used 95% fixed kernel density estimators with least squares cross validation for bandwidth selection to estimate annual and autumn home ranges (Seaman et al. 1998) using relocation data for each bear and year with adequate data. Thus, multiple annual or autumn home ranges were calculated for bears with > 1 year relocation data, provided an associated den for that bear was located each respective year. We defined annual home range as the area used for ≥ 7.5 consecutive months within a 12-month period and autumn home range as the area used from 15 September to 14 December, similar to Benson and Chamberlain (2007) and Waller et al. (2013).

We used a geographic information system (GIS; Environmental Systems Research Institute, Redlands, California, USA) to quantify landscape attributes of dens and within home ranges of black bears. We estimated elevation of den sites using digital elevation models (30-m resolution; MARIS 2002) and estimated distance from each den to nearest stream or river and habitat edge using the National Hydrography Dataset (USGS 2011) and Mississippi Forest Inventory (MIFI) data (29-m resolution; Mississippi Institute for Forest Inventory 2010), respectively. We used Topologically Integrated Geographic Encoding and Referencing system data (U.S. Census Bureau 2010) to estimate distance to nearest road from each den. To estimate mean values of these same attributes within each annual or autumn home range, we first overlaid a 100 m × 100 m grid which approximated the distance of GPS relocation error onto each home range. We used the arithmetic centers of each cell to derive values for each of the attributes to calculate mean elevations and distances to respective features within annual and autumn home ranges.

We used binary logistic regression to analyze attributes of bear den site use relative to mean attributes of unused sites within annual and autumn home ranges. We modeled all combinations of independent parameters without interactions, but did not include pairs of parameters that were correlated ($|r| > 0.50$; Dormann et al. 2013) using Pearson's correlation coefficients. Next, to assess whether use of multiple years of den and home range data from the same bears influenced model performance by potential reduction of parameter variances, we initially conducted fixed effects and mixed effects logistic regression models using the global model with individual bear, year, and individual bear nested within year as random effects structures. We used Akaike Information Criterion adjusted for small samples (AIC_c; Burnham and Anderson 2002) to compare model performance among the four candidate global models. Use of random effect structures did not improve model performance; ΔAICc scores of the global random effects models were –1.8 to 2.4 of the fixed effects model. Therefore, for final analyses we used logistic regression with fixed effects only to evaluate landscape attributes of den sites in relation to annual and autumn home ranges. We used AIC_c to estimate the best-supported models using model ranks and weights, then used model-averaged weighting of all models to calculate parameter estimates (Burnham and Anderson 2002). We calculated unconditional standard errors (SE) and 95% confidence intervals (CIs) for model-averaged parameters and considered the parameters influential if their CIs did not include zero.

Table 1. Means (± standard deviation [*SD*]) of den and grand means of annual (n = 25) and autumn home range (n = 23) parameters for American black bears, Mississippi, USA, 2005–2011

Home range	Parameter[a]	Den		Home range	
		$\bar{x}$	$\overline{SD}$	$\bar{x}$	$\overline{SD}$
Annual	Distance to road	771	521	467	161
	Distance to habitat edge	219	279	307	84
	Distance to stream	623	550	462	160
	Elevation	30.7	8.1	29.6	6.6
Autumn	Distance to road	816	517	443	173
	Distance to habitat edge	243	289	300	86
	Distance to stream	573	505	458	183
	Elevation	31.1	8.3	30.8	7.5

[a]Parameters represent distance to nearest road, habitat edge, and stream or river and elevation (m).

Results

We estimated elevation and distance to nearest road, stream or river, and habitat edge for den sites of 13 bears and compared these to mean values of respective annual ($n = 25$) and autumn ($n = 23$) home ranges. We calculated more annual than autumn home ranges because our minimum data requirement for annual home range calculation was 7.5 months which did not always fully include our predetermined autumn dates (i.e., 15 Sept–14 Dec). Bears denned farther from roads compared to respective mean distances within annual and autumn home ranges (Table 1). However, bears denned closer to habitat edges relative to distances available within annual home ranges. Distance to nearest stream or river and elevation of den sites was similar to mean values within annual and autumn home ranges.

No independent variables were highly correlated ($|r| > 0.5$). The best-supported model within annual home ranges included distances to nearest road and habitat edge (den site = –0.8630 + 0.00372 distance to road –0.00459 distance to edge; w_i = 0.53; Table 2). The best-supported models within autumn home ranges included distances to nearest road and habitat edge

Table 2. Results of logistic regression models to predict sources influencing den-site selection by American black bears within annual and autumn home ranges, Mississippi, USA, 2005–2011

Home range	Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Annual	Distance to road + Distance to habitat edge	3	62.20	0	0.53
	Distance to road + Distance to stream + Distance to habitat edge	4	64.56	2.35	0.16
	Distance to road + Elevation + Distance to habitat edge	4	65.05	2.85	0.13
	Distance to road	2	66.15	3.95	0.07
	Distance to road + Distance to stream + Elevation + Distance to habitat edge	5	67.70	5.50	0.03
	Distance to road + Distance to stream	3	68.26	6.06	0.03
	Distance to road + Elevation	3	68.60	6.40	0.02
	Distance to road + Distance to stream + Elevation	4	71.09	8.89	< 0.01
	Distance to stream + Distance to habitat edge	3	71.27	9.07	< 0.01
	Distance to habitat edge	2	71.50	9.29	< 0.01
	Null	1	71.49	9.29	< 0.01
	Distance to stream	2	71.78	9.58	< 0.01
	Distance to stream + Elevation + Distance to habitat edge	4	74.01	11.81	< 0.01
	Elevation	2	73.54	11.33	< 0.01
	Elevation + Distance to habitat edge	3	73.92	11.71	< 0.01
	Distance to stream + Elevation	3	74.37	12.17	< 0.01
Autumn	Distance to road + Distance to habitat edge	3	56.81	0	0.42
	Distance to road	2	57.98	1.17	0.23
	Distance to road + Distance to stream + Distance to habitat edge	4	59.71	2.91	0.10
	Distance to road + Elevation + Distance to habitat edge	4	59.75	2.95	0.09
	Distance to road + Distance to stream	3	60.26	3.45	0.07
	Distance to road + Elevation	3	60.63	3.83	0.06
	Distance to road + Distance to stream + Elevation + Distance to habitat edge	5	63.02	6.22	0.02
	Distance to road + Distance to stream + Elevation	4	63.15	6.34	0.02
	Null	1	65.96	9.16	0.04
	Distance to stream	2	67.24	10.44	0.02
	Distance to habitat edge	2	67.50	10.69	0.02
	Distance to stream + Distance to habitat edge	3	68.20	11.39	0.01
	Elevation	2	68.35	11.54	0.01
	Distance to stream + Elevation	3	69.70	12.90	0.01
	Elevation + Distance to habitat edge	3	70.15	13.34	0.01
	Distance to stream + Elevation + Distance to habitat edge	4	70.63	13.82	< 0.01

[a] Model parameters represent distance to nearest road, habitat edge, and stream or river and elevation (m). Elevation based on 30-m resolution digital elevation model (U.S. Geological Survey).
[b] K = number of parameters in model.
[c] Akaike's Information Criterion adjusted for small sample size.
[d] ΔAIC_c = the difference between the AIC_c value of the top model and successive models. All models are included.
[e] w_i = Akaike model weight.

Table 3. Model averaged parameter estimates describing effects of landscape attributes influencing den-site selection by American black bears within annual and autumn home ranges, Mississippi, USA, 2005–2011

Home range	Parameter[a]	Parameter estimate	Standard error	95% Confidence limit	
				Upper	Lower
Annual	Distance to road	0.0034	0.0015	0.0063	0.0005
	Distance to habitat edge	–0.0039	0.0019	–0.0003	–0.0076
	Distance to stream	0.0002	0.0003	0.0007	–0.0003
	Elevation	0.0008	0.0095	0.0193	–0.0176
Autumn	Distance to road	0.0035	0.0014	0.0063	0.0007
	Distance to habitat edge	–0.0022	0.0015	0.0007	–0.0051
	Distance to stream	–0.0001	0.0003	0.0004	–0.0006
	Elevation	–0.0005	0.0092	0.0174	–0.0184

[a]Parameters represent distance to nearest road, habitat, and stream or river and elevation (m).

(den site = –1.2149 + 0.00390 distance to road –0.00360 distance to edge; $w_i = 0.42$) followed by distance to road only (den site = –1.6670 + 0.00281 distance to road; $\Delta AIC_c = 1.17$; $w_i = 0.23$).

Parameter estimates and 95% confidence limits suggested black bears selected den sites distant from roads within annual and autumn home ranges and selected sites near habitat edges within autumn home ranges (Table 3). Confidence intervals of remaining parameters for annual and autumn home ranges included zero.

Discussion

Black bear den-site selection suggested bears attempted to reduce disturbance by choosing sites farther from roads compared to mean distances to nearest road within annual and autumn home ranges. Avoidance of roads may reduce the likelihood of mortality by poachers, hunters, or vehicle collisions (Brody and Stone 1987; Reynolds-Hogland et al. 2007). However, bears in Mississippi likely avoid roads due to non-lethal disturbances (e.g., vehicle traffic, recreationists, timber harvest) because bear hunting is illegal and incidents of poaching and vehicle mortalities are limited (Simek et al. 2012).

Bears also denned closer to habitat edges compared to mean distance to nearest habitat edge within annual home ranges. This may be from reduced predation risk (Garneau et al. 2006) as bears in Mississippi no longer coexist with other large carnivores which have been extirpated (e.g., wolves [*Canis rufus* and *C. lupus*], cougars [*Felis concolor*]). Similarly, the black bear population size in Mississippi is likely too small to exhibit density-dependent risk from conspecifics as suggested by Polis (1981) in which intraspecific predation increases as density of bears increases. Thus, black bears may not avoid these areas as these potential threats do not exist or occur at very low levels. Additionally, bears in the southeastern United States exhibit periods of winter activity (Weaver and Pelton 1994; Waller et al. 2012) and denning closer to travel corridors (i.e., habitat edges) may increase efficiency of winter excursions to and from dens.

We found no differences in elevation of den sites and mean elevations of annual and autumn home ranges. Bears in Mississippi use tree and ground dens and typically use tree dens in areas prone to inundation which reduces risk of flooding, similar to bears in Arkansas (White et al. 2001; Waller et al. 2012). Additionally, water control levees installed along the Mississippi River and other smaller rivers (e.g., Yazoo River) prevent flooding in many low-lying areas. This allows bears to use otherwise flood-prone areas without risk of inundation. Higher-resolution and more accurate floodplain elevation data (i.e., Light Detection and Ranging [LiDAR] data) were not available for our study but would be useful for future studies.

It is necessary to identify sources of disturbance which influence habitat selection by wildlife to appropriately prescribe management regimes. Den-site selection by black bears is particularly important because parturition occurs while females den, and disturbance during this time can cause substantial energetic and litter losses (Linnell et al. 2000). Therefore, conservation of black bear denning habitat that includes minimal development of new roads is recommended. In addition, managers could consider closure of roads that traverse known denning habitat during winter to reduce disturbance risk. Because denning is energetically demanding and important for reproduction, reducing potential disturbance to black bears is critical, especially for threatened and endangered populations as occur in Mississippi.

Acknowledgments: We thank Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP); Federal Aid in Wildlife Restoration; USDA Forest Service, McIntire-Stennis; and Forest and Wildlife Research Center at Mississippi State University (MSU) for funding. The Bear Education and Restoration Group of Mississippi provided additional radiocollars and funding for flight time. We thank C. Ayers, N. Libal, M. Ihlefeld, E. Interis, C. Brazil, C. Singleton, M. Jordan, M. Bryant, C. Cooley, J. Holt, and E. O'Donnell for field assistance. We thank J. Fleming for GIS assistance. We thank the numerous individuals, private land owners, hunting clubs, MDWFP employees, USDA Forest Service employees, and US Fish and Wildlife Service employees for assistance, especially B. and O. Sumerall, H. Fordice, C. Winter, and W. Winter.

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Received 30 September 2013. Accepted 9 December 2013.