Suitable habitat for recolonizing large carnivores in the midwestern USA

JULIA B. SMITH, CLAYTON K. NIELSEN and ERIC C. HELLGREN

SUPPLEMENTARY MATERIAL 1 Survey of potential black bear *Ursus americanus* habitat in the Midwestern United States. An identical survey was used to assess potential wolf *Canis lupus* habitat.

Objective

The objective of this survey is to gather expert opinion about black bear habitat in the Midwest by asking wildlife biologists to rank certain factors important to bear habitat. Experts will use pair-wise comparisons and the Analytic Hierarchy Process (AHP; Saaty, 1980) to make these comparisons. This survey was adapted from that developed by LaRue & Nielsen (2008, 2011) for cougars *Puma concolor* in the Midwest.

I wish to identify potential habitat for black bears in the midwestern United States (Fig. S1). To do this it is necessary to understand the factors that determine the suitability of bear habitat. Five habitat variables were identified (cover type, distance to roads, human density, distance to water, and slope) and will be ranked in order of importance by experts in bear ecology and/or midwestern habitats. These surveys will be analysed at the Cooperative Wildlife Research Laboratory at Southern Illinois University Carbondale using multi-criteria evaluation (Saaty, 1980), and implemented in a geographical information system (GIS) to produce a map of potential habitat suitability for black bears in the Midwest.

Model structure

Table S1 includes all variables to be ranked in order of importance for potential habitat suitability for black bears in the Midwest. These variables were chosen based on previous studies elsewhere. Variables will be scored within each habitat factor as well as among factors (i.e. variables within 'cover type' will be scored against each other, and cover type will be scored against distance to roads, human density, distance to water, and slope). Upon receipt of all completed surveys, investigators will determine the mean weight of each factor, using multi-criteria evaluation (Saaty, 1980; Clevenger et al., 2002). These weights will be applied in a GIS to produce a map of potential habitat suitability for black bears in the Midwest.

Table S1 Habitat factors and variables within each factor to be considered in a model of bear habitat.

Cover type	Developed/barren & open water
	Deciduous forest
	Evergreen forest
	Mixed forest
	Shrubland
	Grassland
	Agricultural land

	Wetland
Distance to roads (km)	Low (< 0.25)
	Medium (0.25–0.5)
	High (> 0.5)
Human density (persons per km^2)	Low (≤ 4)
	Low–Medium (5–10)
	Medium–High (10–19)
	High (≥ 20)
Distance to water (km)	Short (< 1)
	Medium (1–5)
	Long (> 5)
Slope (°)	Gentle (0–5)
	Moderate (5–15)
	Steep (> 15)

Survey instructions

On a scale of 1/9 to 9, as a pair-wise comparison of variables, rank the importance of each variable relative to another. Think of each comparison in terms of two 30 m x 30 m pixels, comparing the two pixels relative to their importance to black bear habitat in the Midwest.

Scoring scheme

1/9	1/7	1/5	1/3	**1**	3	5	7	9
Extremely	Very strongly	Strongly	Moderately	**Equally**	Moderately	Strongly	Very strongly	Extremely

Less important More important

Example

The tables below represent an example scoring scheme using the Saaty (1980) pair-wise comparison matrix method (Clevenger et al., 2002). They illustrate the progression of filling out a hypothetical survey regarding habitat suitability for black bears in the Midwest. Pair-wise comparisons are made by working your way across rows, comparing the importance of the variable in a given row to the variable in the associated column. A variable in comparison to itself receives a score of 1, meaning it is equally important (i.e. 'Open' compared relatively to 'Open' is equally important).

The expert begins with the column titled Deciduous and compares the importance of a 30 m^2 tract of deciduous cover type relative to a 30 m^2 tract of open cover type, which may be 5 (strongly more important). In other words, Deciduous is strongly more important, or five times as important as Open.

	Open	Deciduous	Coniferous	Agriculture	Grasslands
Open	1				
Deciduous	**5**	1			
Coniferous			1		
Agriculture				1	
Grasslands					1

The expert next works down to the row titled Coniferous and compares this cover type to Open (A), using the same scoring scheme.

	Open	Deciduous	Coniferous	Agriculture	Grasslands
Open	1				
Deciduous	5	1			
Coniferous	**A**		1		
Agriculture				1	
Grasslands					1

Moving across the Coniferous row, the expert compares Coniferous to Deciduous (B), again using the scoring scheme.

	Open	**Deciduous**	Coniferous	Agriculture	Grasslands
Open	1				
Deciduous	**5**	1			
Coniferous	A	**B**	1		
Agriculture				1	
Grasslands					1

The expert will continue thus until the lower portion of the matrix is complete. A completed survey may look like this:

	Open	Deciduous	Coniferous	Agriculture	Grasslands
Open	1				
Deciduous	5	1			
Coniferous	7	3	1		
Agriculture	3	1/5	1/7	1	
Grasslands	3	1/3	1/5	3	1

The matrix is symmetric, so only the lower half needs to be filled in; the upper half will contain reciprocals of the lower half.

Note that comparisons between two different variables may also be given a score of 1 (meaning they are equally important relative to each other). Also note that you will only compare two variables at a time; e.g. when rating cover type vs. human density you should not also consider one of the other variables, even if you believe the variables are correlated.

Please begin the survey. If you have any questions or concerns, call (618) 453-6947 or email julia.smith.b@siu.edu.

Expert survey on black bear habitat: Part 1 of 2

Scoring scheme

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very strongly	Extremely

Less important More important

Cover Type

Please score these variables according to relative importance to potential black bear habitat in the Midwest. Use the land cover definitions attached and the above scoring scheme. Consider the importance of the cover types to a bear in a 30 m block of this habitat. These land cover data will be analysed using a raster (pixel-based) dataset with a resolution of 30 m.

	Barren/developed & open water	**Deciduous forest**	**Evergreen forest**	**Mixed forest**	**Shrubland**	**Grassland**	**Agricultural land**	**Wetland**
Barren/developed & open water	1							
Deciduous forest		1						
Evergreen forest			1					
Mixed forest				1				
Shrubland					1			
Grassland						1		
Agricultural land							1	
Wetland								1

Distance to roads (km)

Please use the scoring scheme to score these variables according to relative importance to potential black bear habitat in the Midwest. These categories were determined from the literature (Maehr et al., 2003; Unger et al., 2008).

	Low	**Medium**	**High**
Low	1		
Medium		1	
High			1

Low, < 0.25 km; Medium, 025–0.5 km; High, > 0.5 km

Human density (km^{-2})

Please use the scoring scheme to score these variables according to relative importance to potential black bear habitat in the Midwest. These categories were determined from the literature (Woodroffe, 2000).

	Low	**Medium–Low**	**Medium–High**	**High**
Low	1			
Medium–Low		1		
Medium–High			1	
High				1

Low, ≤ 4 km^{-2}; Medium–Low, 5–10 km^{-2}; Medium–High, 11–19 km^{-2}; High, ≥ 20 km^{-2}

Distance to Water (km)

Please use the scoring scheme to score these variables according to relative importance to potential black bear habitat in the Midwest. These categories were determined by the investigators.

	Short	**Medium**	**Long**
Short	1		
Medium		1	
Long			1

Short, < 1 km; Medium, 1–5 km; Long, > 5 km

Slope (°)

Please use the scoring scheme to score these variables according to relative importance to potential black bear habitat in the Midwest. These categories were determined by the investigators.

	Gentle	**Moderate**	**Steep**
Gentle	1		
Moderate		1	
Steep			1

Gentle, 0–5°; Moderate, 5–15°; Steep, > 15°

Score among variables

Please use the scoring scheme to score each habitat factor relative to the others in relation to its importance to potential black bear habitat in the Midwest.

	Cover type	**Distance to roads**	**Human density**	**Distance to water**	**Slope**
Cover type	1				
Distance to roads		1			
Human density			1		
Distance to water				1	
Slope					1

Definitions of land cover types

These are the definitions you will use when evaluating differences between cover types. These data were obtained from the Multi-Resolution Land Characteristics Consortium of the United States Geological Survey (MRLC, 2006) and represent reclassifications of land cover provided by the MRLC. Data are from 2006 satellite imagery, and the resolution to be analysed will be 30 m.

Barren/developed and open water: Areas characterized by a high percentage (≥ 20%) of constructed materials or by bare rock, gravel, or sand, with relatively little or no green vegetation present, and areas of open water with < 25% vegetation.

Deciduous forest: Areas dominated by trees where ≥ 75% of trees lose foliage simultaneously in response to seasonal change.

Evergreen forest: Areas dominated by trees where ≥ 75% of trees retain their leaves all year. Canopy is never without green foliage.

Mixed forest: Areas dominated by trees where neither deciduous nor evergreen species represent > 75% of the cover.

Shrubland: Areas dominated by shrubs (including true shrubs and young/stunted trees), with shrub canopy typically > 20% of total vegetation.

Grassland: Areas dominated by graminoid or herbaceous vegetation, generally > 80% of total vegetation. These areas are not subject to intensive management but can be utilized for grazing.

Agricultural land: Areas planted with grasses or legumes for livestock grazing or production of seed or hay crops. Also, areas used for production of annual crops, such as corn and soybeans, and orchards and vineyards. Crop vegetation accounts for > 20% of total vegetation.

Wetland: Areas where the soil or substrate is periodically saturated with or covered with water. Forest or shrubland account for 20–100% of the cover, or perennial herbaceous vegetation accounts for 80–100% of the cover.

Fig. S1 States to be included in the analysis of potential black bear habitat in the midwestern United States.

SUPPLEMENTARY MATERIAL 2 Area and percentage of suitable habitat for black bears *Ursus americanus*, cougars *Puma concolor* and grey wolves *Canis lupus* (expert-assisted scores ≥75%) in the states of the Midwestern USA, and area and percentage of contiguous habitat.

State	Species	Area of suitable habitat (km^2)	% suitable habitat	Area of contiguous suitable habitat (km^2)	% of contiguous suitable habitat
Arkansas	Black bear	63,908	46.4	52,831	38.4
	Cougar	41,044	29.8	31,970	23.2
	Wolf	67,489	49.0	61,733	44.8
Illinois	Black bear	21,450	14.7	3,551	2.4
	Cougar	9,631	6.6	0	0.0
	Wolf	20,282	13.9	2,315	1.6
Indiana	Black bear	12,659	13.5	4,682	5.0
	Cougar	1,969	2.1	0	0.0
	Wolf	11,252	12.0	3,081	3.3
Iowa	Black bear	20,696	14.2	1,098	0.8
	Cougar	7,433	5.1	0	0.0
	Wolf	20,842	14.3	633	0.4
Kansas	Black bear	32,391	15.2	704	0.3
	Cougar	12,147	5.7	0	0.0
	Wolf	86,945	40.8	61,187	28.7
Kentucky	Black bear	39,769	38.0	28,838	27.6
	Cougar	10,152	9.7	906	0.9
	Wolf	30,560	29.2	16,704	16.0
Louisiana	Black bear	43,546	32.1	25,516	18.8
	Cougar	16,686	12.3	301	0.2
	Wolf	46,259	34.1	39,202	28.9
Michigan	Black bear	54,965	36.6	48,517	32.3
	Cougar	31,537	21.0	25,761	17.2
	Wolf	55,115	36.7	49,320	32.8
Minnesota	Black bear	87,754	40.2	70,414	32.2
	Cougar	40,179	18.4	37,306	17.1
	Wolf	87,966	40.3	72,158	33.0
Missouri	Black bear	65,355	36.2	41,291	22.9
	Cougar	36,650	20.3	20,128	11.1
	Wolf	64,453	35.7	43,073	23.9
Nebraska	Black bear	36,059	18.0	3,745	1.9
	Cougar	15,225	7.6	0	0.0
	Wolf	115,390	57.6	102,128	51.0
N. Dakota	Black bear	37,170	20.3	7,424	4.1
	Cougar	12,268	6.7	4,724	2.6
	Wolf	78,181	42.7	53,367	29.1

Ohio	Black bear	18,056	16.9	7,044	6.6
	Cougar	1,816	1.7	0	0.0
	Wolf	12,821	12.0	4,134	3.9
Oklahoma	Black bear	51,233	28.3	23,465	13.0
	Cougar	33,673	18.6	13,270	7.3
	Wolf	85,993	47.5	68,949	38.1
S. Dakota	Black bear	41,344	20.7	13,540	6.8
	Cougar	21,970	11.0	4,791	2.4
	Wolf	118,040	59.1	109,994	55.1
Tennessee	Black bear	37,658	34.5	24,734	22.7
	Cougar	13,862	12.7	1,936	1.8
	Wolf	32,309	29.6	19,006	17.4
Texas	Black bear	335,883	48.3	306,384	44.0
	Cougar	300,422	43.2	286,686	41.2
	Wolf	422,109	60.7	414,272	59.6
Wisconsin	Black bear	58,691	40.4	44,805	30.8
	Cougar	30,943	21.3	19,237	13.2
	Wolf	55,059	37.9	43,176	29.7
Entire region	Black bear	1,058,587	31.6	708,594	21.2
	Cougar	637,607	19.1	447,206	13.4
	Wolf	1,411,065	42.1	1,164,432	34.8

SUPPLEMENTARY MATERIAL 3 Overlap of contiguous areas of suitable habitat (expert-assisted scores ≥75%) for black bears, cougars and grey wolves in the states of the Midwestern USA in 2012.

State	Species	Total area of habitat overlap (km^2)	% suitable habitat for given species	% overlap*		
				Bear	Cougar	Wolf
Arkansas	Black bear/cougar	28,010	20.3	53.0	87.6	
	Black bear/wolf	49,132	35.7	93.0		79.6
	Cougar/wolf	30,394	22.1		95.1	49.2
	All species	27,697	20.1	52.4	86.6	44.9
Illinois	Black bear/cougar	0	0.0	0.0	0.0	
	Black bear/wolf	2,017	1.4	56.8		87.1
	Cougar/wolf	0	0.0		0.0	0.0
	All species	0	0.0	0.0	0.0	0.0
Indiana	Black bear/cougar	0	0.0	0.0	0.0	
	Black bear/wolf	2,654	2.8	56.7		86.1
	Cougar/wolf	0	0.0		0.0	0.0
	All species	0	0.0	0.0	0.0	0.0
Iowa	Black bear/cougar	0	0.0	0.0	0.0	
	Black bear/wolf	426	0.3	38.8		67.3
	Cougar/wolf	0	0.0		0.0	0.0
	All species	0	0.0	0.0	0.0	0.0
Kansas	Black bear/cougar	0	0.0	0.0	0.0	
	Black bear/wolf	687	0.3	97.6		1.1
	Cougar/wolf	0	0.0		0.0	0.0
	All species	0	0.0	0.0	0.0	0.0
Kentucky	Black bear/cougar	872	0.8	3.0	96.2	
	Black bear/wolf	14,407	13.8	50.0		86.2
	Cougar/wolf	853	0.8		94.2	5.1
	All species	843	0.8	2.9	93.0	5.0
Louisiana	Black bear/cougar	279	0.2	1.1	92.7	
	Black bear/wolf	22,238	16.4	87.2		56.7
	Cougar/wolf	296	0.2		98.3	0.8
	All species	278	0.2	1.1	92.4	0.7
Michigan	Black bear/cougar	23,795	15.8	49.0	92.4	
	Black bear/wolf	43,777	29.1	90.2		88.8
	Cougar/wolf	24,589	16.4		95.5	49.9
	All species	23,450	15.6	48.3	91.0	47.5
Minnesota	Black bear/cougar	33,122	15.1	47.0	88.8	
	Black bear/wolf	65,737	30.1	93.4		91.1
	Cougar/wolf	34,545	15.8		92.6	47.9
	All species	32,727	15.0	46.5	87.7	45.4
Missouri	Black bear/cougar	18,223	10.1	44.1	90.5	
	Black bear/wolf	36,511	20.2	88.4		84.8
	Cougar/wolf	18,842	10.4		93.6	43.7
	All species	17,992	10.0	43.6	89.4	41.8
Nebraska	Black bear/cougar	0	0.0	0.0	0.0	
	Black bear/wolf	3,731	1.9	99.6		3.7

	Cougar/wolf	0	0.0		0.0	0.0
	All species	0	0.0	0.0	0.0	0.0
N. Dakota	Black bear/cougar	3,697	2.0	49.8	78.3	
	Black bear/wolf	7,356	4.0	99.1		13.8
	Cougar/wolf	4,600	2.5		97.4	8.6
	All species	3,677	2.0	49.5	77.8	6.9
Ohio	Black bear/cougar	0	0.0	0.0	0.0	
	Black bear/wolf	3,604	3.4	51.2		87.2
	Cougar/wolf	0	0.0		0.0	0.0
	All species	0	0.0	0.0	0.0	0.0
Oklahoma	Black bear/cougar	11,470	6.3	48.9	86.4	
	Black bear/wolf	21,863	12.1	93.2		31.7
	Cougar/wolf	12,408	6.9		93.5	18.0
	All species	11,382	6.3	48.5	85.8	16.5
S. Dakota	Black bear/cougar	4,508	2.0	33.3	94.1	
	Black bear/wolf	13,468	6.7	99.5		12.2
	Cougar/wolf	4,645	2.3		97.0	4.2
	All species	4,051	2.0	29.9	84.6	3.7
Tennessee	Black bear/cougar	1,835	1.7	7.4	94.8	
	Black bear/wolf	16,349	15.0	66.1		86.0
	Cougar/wolf	1,767	1.6		91.3	9.3
	All species	1,731	1.6	7.0	89.4	9.1
Texas	Black bear/cougar	254,548	36.6	83.1	88.8	
	Black bear/wolf	301,271	43.3	98.3		72.7
	Cougar/wolf	277,126	39.8		96.7	66.9
	All species	253,595	36.5	82.8	88.5	61.2
Wisconsin	Black bear/cougar	17,656	12.2	39.4	91.8	
	Black bear/wolf	39,190	27.0	87.5		90.8
	Cougar/wolf	18,258	12.6		94.9	42.3
	All species	17,406	12.0	38.8	90.5	40.3
Entire region	Black bear/cougar	397,565	11.9	56.1	88.9	
	Black bear/wolf	644,418	19.3	90.9		55.3
	Cougar/wolf	428,323	12.8		95.8	36.8
	All species	394,829	11.8	55.7	88.3	33.9

*Percentage of suitable habitat for listed carnivore overlapped by habitat suitable for other focal carnivore(s).