Brown Bear RSF for Kenai Peninsula ALCES^{TM} Project

27 February 2006

AUTHORS

Dawn Magness
211A Irving I
EWHALE Lab/Resilience & Adaptation Program
Biology & Wildlife Department
University of Alaska
Fairbanks, AK 99775
dawn.magness@uaf.edu
907.474.7568

John M. Morton
Kenai National Wildlife Refuge
U.S. Fish & Wildlife Service
P.O. Box 2139
Soldotna, AK 99669
john_m_morton@fws.gov
907.260.2815

Lowell H. Suring
Terrestrial Wildlife Ecology Unit
Aquatic Sciences Laboratory
USDA Forest Service
322 East Front Street, Suite 401
Boise, Idaho 83702
lsuring@fs.fed.us
208.373.4351

JUSTIFICATION

The Alaska Landscape Cumulative Effects Simulator (ALCES) is being developed to model the cumulative effects of natural processes and anthropogenic disturbances on the Kenai Peninsula. An ALCES consortium was formally established among 11 partners with the signing of a Memorandum of Understanding in 2004 (http://www.kenaiwatershed.org/alces.html). As a strategic planning tool, ALCES is capable of showing landscape change in response to alternative future scenarios of management and development. The brown bear (and moose) was chosen by the ALCES stakeholders group as an indicator species that would likely be responsive to landscape change, and is of significant economic and ecological significance on the Kenai Peninsula.

ALCES can incorporate indicator species as either habitat suitability index or resource selection function (RSF) models. We chose to build an RSF (Manley et al. 2002) for brown bear habitat on the Kenai Peninsula.

Suring et al. (in press) developed several similar RSFs to model the effects of landscape change on brown bear females on the Kenai Peninsula. However, they chose to segregate models by litter size and season. Their RSFs also included spatially-explicit variables which ALCES cannot incorporate. ALCES is a spatial hybrid model; it accepts spatial data as input, which can be stratified, but produces aspatial data within stratum. The purpose of this current effort is to develop a single model that incorporates litter size and season as covariates, and does not incorporate spatially-explicit parameters.

METHODS

A logistic regression model was built using 8,247 locations (Fig.1) of female brown bears. This dataset of telemetered locations was collected by the IBBST but was subsequently edited by Lowell Suring. The dataset includes locations from 49 female bears monitored from 1995 through 1998. This dataset also includes information about whether cubs were with individual females. The random points for the RSF were distributed across the extent of the Kenai Peninsula with the assumption that individual bears have equal access to all locations (Fig.1). One random point was generated for each bear location using Hawth's Analysis Tools.

We generated the prediction variables within a GIS (Table 1). All layers were formatted in a transverse mercator projection (NAD 1983, State Plane Alaska 4, FIPS 5004). Elevation was derived from a digital elevation model. The digital elevation model was projected from a NAD 1983, UTM Zone 5N spatial reference to match the other layers. A vegetation layer with 16 categories)was developed from a supervised classification of LandSAT 7 images using eCognition (L. O'brien, pers. comm.). The vegetation layer was converted from a categorical variable to 15 binomial variables (1 for each vegetation types).

Road density (ROAD), anadromous stream density (STR), and human settlement density (HUMAN) were calculated for the 1-km^2 circular area surrounding bear and random locations. A layer with all logging roads (10m wide), minor roads (15m wide), and state roads (35m wide) was compiled for the Kenai Peninsula to populate the ALCES model (Stephanie Simms, pers. comm.). We converted the road layer from a shapefile to a 5m raster using conversion tools in ArcMap. The road raster was converted to a point layer (1 point in the center of each pixel) using conversion tools in order to make a point density surface using spatial analyst. The point density surface represented the number of points per hectare for the 1km^2 circular area around each 30m pixel. We chose to model road density as m^2/ha rather than km/ha because different road types have different widths; consequently, road density is weighted by surface area.

The anadromous stream density and human settlement density variables were created using the same process as the road density; except the shapefiles were converted to a 10m raster instead of a 5m raster in the initial step. The anadromous streams were mapped for ALCES using the state designation. Human settlement density included areas designated as towns, rural residential, hotels or camps for ALCES. Road, anadromous stream, and human settlement density were chosen because of their significance in other models of brown bear habitat on the peninsula (Suring et al. 2006). We compared our variables for road, anadromous stream, and development density to the spatial correlates used by Suring et al. (2006) and to other aspatial correlates developed independently for their analysis. Season was defined by criteria in Suring et al. (2006).

We used a forward stepwise logistic regression to select the top three binomial vegetation variables for inclusion in the model selection process. The stepwise regression evaluated the vegetation variables given that the six other variables (elevation, roads, streams, human development, cubs, and season) and individual bears as a random effect were included. Ice, lentic, and black spruce were the top vegetation variables. Models for all possible combinations of the base model with the three vegetation variables were ranked using AIC (Boyce et al. 2002, Burnham and Anderson 1998). In addition, the candidate models with elevation excluded were also evaluated because elevation was correlated with the vegetation variables. The four top ranked models were evaluated with interactions (Table 2). Individual bears were included as a random effect in all models. We ran all models using PROC MIXED in SAS 9.1 with the glimmix macro.

We developed a model that included all significant vegetation categories because vegetation change is an important driver in ALCES future scenarios (Table 2 and 3; labeled VEG Model). We used a backward stepwise logistic regression to select significant vegetation variables given that roads, streams, human development, cubs, season and individual bears (random effect) were included in the model. Note that vegetation is expressed as a categorical variable in which the coefficient references the non-value; consequently, a negative coefficient for a vegetation class *positively* influences the probability of sow occurrence.

Model used

$$Prob(Y_{ij} = 1| x_{ij}) = e^{\beta 0 + \beta j\, xij} / 1 + e^{\beta 0 + \beta j\, xij}$$

TABLE 1. Variables included in candidate models for Kenai Peninsula brown bear RSF.

Variable	Unit	Notes / Description
Elevation	(m)	From DEM.
Vegetation	Binomial	16 categorical vegetation types converted into 16 binomial variables
Alder		
Alpine		
Anadromous Lotic		
Black Spruce		
Coastal Marine		
Hardwood		
Hemlock		
Herbaceous		
Ice		
Lentic		
Non-anadromous Lotic		
Rock		
Sedge Peatland		
Shrubby Peatland		
White/Lutz/Sitka Spruce		
Willow		
Road density (ROAD)	(m^2 / ha)	Calculated for 1 km^2 area surrounding each location.
Anadromous stream density (STR)	(m^2 / ha)	Calculated for 1 km^2 area surrounding each location.
Human settlement density (HUMAN)	(m^2 / ha)	Calculated for 1 km^2 area surrounding each location.
Cubs	Binomial	0 = No cubs 1 = Cubs
Season	Categorical	Season 1 (den emergence to 15 June) Season 2 (15 June to den entrance)

RESULTS

Prediction variable summary

TABLE 2. Number of locations in each vegetation category.

	Random Locations						Random Location Total	All Location Total
	Season 1		Season 1 Total	Season 2		Season 2 Total		
	No Cubs	Cubs		No Cubs	Cubs			
Alder	87	170	257	307	326	633	890	1865
Alpine	56	220	276	276	455	731	1007	1686
Anadromous Lotic	0	14	14	27	56	83	97	375
Black Spruce	28	176	204	160	171	331	535	2038
Coastal Marine	7	5	12	51	48	99	111	113
Hardwood	107	152	259	478	332	810	1069	3280
Hemlock	14	45	59	43	96	139	198	490
Herbaceous	5	20	25	43	81	124	149	204
Ice	106	352	458	698	684	1382	1840	1892
Lentic	24	92	116	140	79	219	335	433
Non-anadromous Lotic	4	1	5	24	10	34	39	96
Rock	35	72	107	196	69	265	372	421
Sedge Peatland	14	105	119	145	170	315	434	763
Shrubby Peatland	10	8	18	25	29	54	72	168
White/Lutz/Sitka Spruce	80	191	271	458	351	809	1080	2564
Willow	11	30	41	76	82	158	199	466
	Bear Locations						**Bear Location Total**	
	Season 1		**Season 1 Total**	**Season 2**		**Season 2 Total**		
	No Cubs	**Cubs**		**No Cubs**	**Cubs**			
Alder	72	217	289	312	374	686	975	
Alpine	60	141	201	169	309	478	679	
Anadromous Lotic	13	12	25	159	94	253	278	
Black Spruce	111	321	432	558	513	1071	1503	
Coastal Marine	0	0	0	1	1	2	2	
Hardwood	148	396	544	881	786	1667	2211	
Hemlock	23	59	82	112	98	210	292	
Herbaceous	7	11	18	13	24	37	55	
Ice	1	8	9	31	12	43	52	
Lentic	6	22	28	36	34	70	98	
Non-anadromous Lotic	6	6	12	30	15	45	57	
Rock	3	19	22	14	13	27	49	
Sedge Peatland	20	70	90	118	121	239	329	
Shrubby Peatland	7	16	23	45	28	73	96	
White/Lutz/Sitka Spruce	95	319	414	568	502	1070	1484	
Willow	16	36	52	100	115	215	267	

Model selection

TABLE 3. Models organized by AIC ranking.

Model	Variables	AIC	∆ AIC
9	STR + ROAD + HUMAN	73911	0
11	STR + ROAD + HUMAN + LENTIC	74102	191
22	Model 9 + STR*CUB	74248	337
23	Model 9 + STR*SEASON	74254	344
25	Model 11 + STR*CUB	74380	469
26	Model 11 + STR*SEASON	74479	568
12	STR + ROAD + HUMAN + BKSP	74520	610
24	Model 9 + STR*CUB + STR*SEASON	74591	680
15	STR + ROAD + HUMAN + LENTIC + BKSP	74682	771
27	Model 11 + STR*CUB + STR*SEASON	74777	866
29	Model 12 + STR*SEASON	74820	909
28	Model 12 + STR*CUB	74842	931
1	ELE + STR + ROAD + HUMAN	75158	1247
18	Model 1 + ELE*SEASON	75159	1248
30	Model 12 + STR*CUB + STR*SEASON	75172	1261
17	Model 1 + ELE*CUB	75190	1279
4	ELE + STR + ROAD + HUMAN + BKSP	75416	1506
20	Model 1 + STR*SEASON	75446	1535
19	Model 1 + STR*CUB	75452	1541
3	ELE + STR + ROAD + HUMAN + LENTIC	75458	1547
7	ELE + STR + ROAD + HUMAN + LENTIC + BKSP	75680	1770
21	Model 1 + ELE*CUB + STR*CUB + STR*SEASON	75791	1880
10	STR + ROAD + HUMAN + ICE	77799	3888
2	ELE + STR + ROAD + HUMAN + ICE	77842	3931
6	ELE + STR + ROAD + HUMAN + ICE + BKSP	78038	4127
14	STR + ROAD + HUMAN + ICE + BKSP	78046	4135
13	STR + ROAD + HUMAN + ICE + LENTIC	78075	4164
5	ELE + STR + ROAD + HUMAN + ICE + LENTIC	78144	4233
16	STR + ROAD + HUMAN + ICE + LENTIC + BKSP	78298	4388
8	ELE + STR + ROAD + HUMAN + ICE + LENTIC + BKSP	78304	4393
VEG	STR + ROAD + HUMAN + Alpine + Black Spruce + Hardwood + Herbaceous + Ice + Lentic + Rock + Sedge Peatland	78871	4960

TABLE 4. Summary of the four top model coefficients. Standard error is in parenthesis and the asterisks indicate the p-value (* <0.05, ** <0.01, *<0.001, **** <0.0001).**

Variable		Model 9	Model 11	Model 22	Model 23	VEG Model
Intercept		-0.2811 (0.03313) ****	-1.6438 (0.1271) ****	-0.2402 (0.03465) ****	-0.3207 (0.03283) ****	-7.4598 (0.3727) ****
Road		-0.00095 (0.000253) ***	- 0.004567 (0.000253) ****	-0.00097 (0.000254) ****	-0.00101 (0.00258) ****	-0.00178 (0.000254) ****
Stream		0.004549 (0.00013) ****	0.004567 (0.000131) ****	0.003754 (0.000174) ****	0.005190 (0.000151) ****	0.003476 (0.000133) ****
Human		-0.00014 (0.000027) ****	-0.00014 (0.000027) ****	-.00013 (0.000027) ****	-0.00014 (0.000027) ****	-0.00016 (0.000026) ****
Cubs	NO	-0.07323 (0.04064)	-0.07890 (0.03780)*	-0.1685 (0.04429) ****	-0.07278 (0.04017)	-0.05193 (0.05524)
	YES	0	0	0	0	0
Season	1	0.1584 (0.03854) ****	0.1682 (0.03841) ****	0.1491 (0.03888) ****	0.2935 (0.04067) ****	0.1145 (0.04255) **
	2	0	0	0	0	0
Lentic	0		1.3905 (0.1250) ****			1.3902 (0.1233) ****
	1		0			0
Stream *Cubs	0			0.001648 (0.00025) ****		
	1			0		
Stream *Season	1				-0.00308 (0.000291) ****	
	2					
Alpine	0					0.6227 (0.06067) ****
	1					0
Black Spruce	0					-1.0346 (0.06321) ****
	1					0
Hardwood	0					-0.7233 (0.05136) ****
	1					0
Herbaceous	0					1.0930 (0.1643) ****
	1					0
Ice	0					3.6476 (0.1432) ****
	1					0
Rock	0					2.1381 (0.1555) ****
	1					0
Sedge Peatland	0					0.4118 (0.08243) ****
	1					0

DISCUSSION & RECOMMENDATIONS

The modeling approaches we used strongly suggest that brown bear distribution on the Kenai Peninsula is determined by stream density. This relationship is modified by the anthropogenic footprint as measured by road and human settlement density. The most parsimonious model is clearly Model 9 in which the probability of female brown bear occurrence is positively influenced by STR, and negatively influenced by ROAD and HUMAN (Table 3).

However, Model 9 is not sensitive to change in landscape types that are modeled by ALCES. For example, vegetative responses to wildfire or global climate change will not affect brown bear distribution. Consequently, we forced all vegetation class variables into the model and conducted a backward stepwise selection that sequentially eliminated nonsignificant vegetation variables. The final VEG model indicates that sow occurrence is positively influenced by black spruce and hardwood, and negatively influenced by the presence of alpine, herbaceous, sedge peatland, rock and ice (Table 4).

We recommend that the VEG model be adopted for inclusion in ALCES where *Lentic, Alpine, BlackSpruce, Hardwood, Herbaceous, Ice, Rock*, and *SedgePeatland* are the proportions of landscape in each landcover type. *NoCubs* weights the importance of females with cubs versus females without cubs; we suggest 0.5 as the default value but this value could be user-defined in ALCES. *Season1* is the proportion of summer considered Season 1 versus Season 2; we suggest 0.33 as the default value, but this value could be user-defined in ALCES as well.

$$IndexOfBrownBearOccurrence = \frac{e^{BrownBearEquation}}{1 + e^{BrownBearEquation}}$$

$$\begin{aligned}
BrownBearEquation = {} & -7.4598 + (-0.00178 * Road) + (0.003476 * Stream) + \\
& (-0.00016 * Human) + (-0.05193 * NoCubs) + (0.1145 * Season1) + [1.3902 * (1 - Lentic)] + \\
& [0.6227 * (1 - Alpine)] + [-1.0346 * (1 - BlackSpruce)] + [-0.7233 * (1 - Hardwood)] + \\
& [1.0930 * (1 - Herbaceous)] + [3.6476 * (1 - Ice)] + [2.1381 * (1 - Rock)] + [0.4118 * (1 - SedgePeatland)]
\end{aligned}$$

Future work

- This dataset has potential biases in bear locations because bears did not have an equal probability of being collared across the entire Kenai Peninsula. In the future, the brown bear RSF should be evaluated using a sampling design where the peninsula is split into grids with an equal number of collared bears in each grid section.

- Furthermore, telemetry data should be edited to ensure a more balanced temporal and seasonal distribution.

- Vegetation variables should be evaluated as continuous variables that represent the percent of the 1 km^2 circular area surrounding each location.

- The predictive ability of the RSF should be assessed using an independent validation dataset.

- Year should be included as a random effect.

LITERATURE CITED

Boyce, M.S., P.R. Vernier, S.E. Nielsen, and F.K.A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling: 281-300.

Burnham, K.P. and D.R. Anderson. 1998. Model Selection and Inference: A Practical Information – Theoretic Approach. Springer, New York.

Manley, B.F.J., L.L. McDonald, D.L. Thomas, and W.P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Second Edition. Kluwer Academic Publishers, Boston, Massachusetts.

Suring, L.H., S.D. Farley, G.V. Hilderbrand, M.I Goldstein, S. Howlin, and W.P. Erickon. 2006. Patterns of landscape us by female brown bears on the Kenai Peninsula, Alaska. J. Wildl. Manage. 00:000.

FIGURE 1. Brown bear and random locations on the Kenai Peninsula used to generate RSF.