Project Update: October 2013

Since the beginning of the project we have completed the digitisation of all the paper based reports of livestock attacks by carnivores in Bhutan reported to the department of Forests and Park Services. Please see the attached Access database which was completed in February 2013. A new Access database input form is already in place to record future reports electronically. The inclement weather did not permit the extraction of coordinates for the records where only a vague location name was used until May, at which time the database was ready for analysis. In June-July 2013, in collaboration with the project partners at the Wildlife Conservation Research Unit (University of Oxford), we commenced the modelling of the potential spatial-distribution of carnivore attack sites on livestock for tigers.

A total of 326 confirmed tiger attacks on livestock was available for analysis (Figure 2), spanning from January 2003 to October 2012, and across 15 of the 20 administrative districts (dzongkhags) of Bhutan (Figure 1). In total, tigers killed 295 cattle, 49 horses and mules, and 22 yaks (Table 1), with a mean of 1.13 animals per event (1.13±0.62). There was a significant difference in the number of kills per season (Wilcoxon's rank-sum test W=11, p = 0.002) with nearly 70% of the attacks occurring in the rainy season (April to October).

Following consultation with Sam Cushman, a world leader in wildlife spatial modelling, we adopted a multi-scale approach for the analysis of habitat relationships with tiger attacks as opposed to a more traditional single-scale (on site) approach, in order to incorporate also the influence of scale of different predictors when evaluating their predictive value for livestock attack risk by each predator. We developed GIS raster layers for a total of 13 parameters representing anthropic, topographic and land-use characteristics of the Bhutanese landscape (Table 2), the majority of which were considered at 1, 2, 4, 8, and 16 km radius from the centre of each raster cell. We then conducted both single-scale and multi-scale maximum entropy models of livestock risk maps for tiger attack for the entire country using non-correlated variables only, and found that a) the data permitted very good models (Area Under the Curve (AUC) >0.9) and b) that multi-scale models performed better than single scale models (Table 3). Models took into account at least one variable for: a) landscape configuration, which depict spatial distribution and physical connectedness of the habitat; b) landscape composition, which elucidates the amount and quality of habitat; c) landscape edge contrast, which describes the edge effects between different land-cover types; and d) human disturbance.

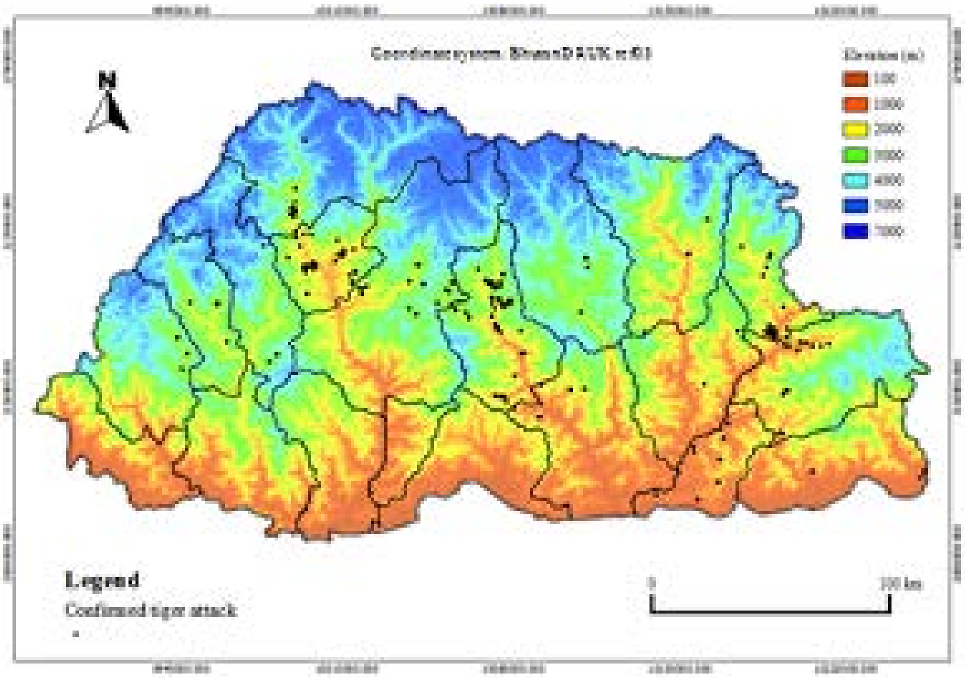

Figure 1. Map of Bhutan showing confirmed tiger attacks on livestock reported to the Nature Conservation Division between 2003-2012 (n=326).

Table 1. Overall livestock loss caused by tiger attacks reported from January 2003 to October 2012 throughout Bhutan. These data only come from households that experienced livestock losses to tigers.

Livestock	Cattle	Yak	Horses/mules
Owned	2401	254	221
Killed	295	22	49
Total loss (%)	**12.29**	**8.66**	**22.17**

Table 2. Independent variables considered for analysing tiger's livestock depredation-risk

Covariate	Short name	Type	Native Spatial Resolution (m)	Metrics calculated*	Scale (km)	Resolution MaxEnt (km)	Produced with/Generated in	Source
Corridors	C	Land cover	100	Percentage of landscape (PLAND)	1, 2, 4, 8, 16	1	FRAGSTATS 4.1	WCD
Elevation ASTER GDEM 30 m	E	Topographic	30	Focal mean (FM)	1, 2, 4, 8	1	r.neighbors/GRASS v.6.4	http://asterweb.jpl.nasa.gov/gdem.asp
Global Human Influence Index	HII	Anthropic	1000	Focal mean (FM)	1, 2, 4, 8, 16	1	r.neighbors/GRASS v.6.4	http://sedac.ciesin.columbia.edu/data/set/wildareas-v2-human-influence-index-geographic
Forest Loss	FL	Land cover	200	Percentage of landscape (PLAND)	1, 2, 4, 8, 16	1	FRAGSTATS 4.1	Generated in GRASS v.6.4
				Radius of Gyration Area-Weighted Mean (GYRATE_AM)				
Landcover Class-Level: Forest (F), Agriculture (A), Meadows (M), Urban (U)	LCL	Land cover	100	Clumpiness (CLUMPY)	1, 2, 4, 8, 16	1	FRAGSTATS 4.1	
				Percentage of landscape (PLAND)	1, 2, 4, 8, 16	1	FRAGSTATS 4.1	
Landcover Landscape-Level:	LLL	Land cover	100	Contagion (CONTAG)	1, 2, 4, 8, 16	1	FRAGSTATS 4.1	
				Contrast-weighted edge effect (CWED)		1	FRAGSTATS 4.1	
				Patch density (PD)		1	FRAGSTATS 4.1	
				Shannon Diversity Index (SHDI)		1	FRAGSTATS 4.1	
				Radius of Gyration Area-Weighted Mean (GYRATE_AM)		1	FRAGSTATS 4.1	WCD
Protected Areas	PA	Land cover	100	Percentage of landscape (PLAND)	1, 2, 4, 8, 16	1	FRAGSTATS 4.1	
Rivers-streams density	RSD	Land cover	100	Focal mean (FM)	1, 2, 4, 8, 16	1		
Road density	RD	Anthropic	100	Focal mean (FM)	1, 2, 4, 8, 16	1	v.kernel (250 m)-r.neighbors/GRASS v.6.4	
Settlement density	SD	Anthropic	100	Focal mean (FM)	1, 2, 4, 8, 16	1		
Slope	S	Topographic	30	Focal mean (FM)	1, 2, 4, 8	1		Derived from ASTER GDEM 30 m
Terrain Ruggedness Index	TRI	Topographic	30	Focal mean (FM)	1, 2, 4, 8	1	r.neighbors/GRASS v.6.4	Derived from ASTER GDEM 30 m
Vegetation Continuous Fields	VCF	Land cover	250	Focal mean (FM)	1, 2, 4, 8, 16	1		http://glcf.umd.edu/data/vcf/

Table 3. AUC values for the different models tested. The selected model is highlighted in grey.

(a)

Single-scale model

Model	AUC	A-LCL	C	E	FL	F-LCL	HII	LLL-CONTAG	LLL-CWED	LLL-GYRATE	LU	M-LCL	PA	LLL-PD	RD	RSD	S	SD	LLL-SHDI	TRI	U-LCL	VCF
		Variable used																				
A1	0.96	□	□	□	□		□	□	□	□	□	□	□		□	□	□	□			□	
A2	0.96		□	□		□	□	□			□	□	□	□	□	□		□	□	□	□	□
B1	0.93	□		□	□				□								□	□				
B2	0.94			□									□				□	□	□			□
C1	0.87	□			□													□				
C2	0.86				□													□				
D1	0.90			□					□								□					
D2	0.93			□									□				□		□			□

(b)

Multi-scale model

Model	AUC	A-LCL	C	E	FL	F-LCL	HII	LLL-CONTAG	LLL-CWED	LLL-GYRATE	M-LCL	PA	LLL-PD	RD	RSD	S	SD	LLL-SHDI	TRI	U-LCL	VCF
		Variable used																			
A1	0.98	□	□	□	□	□	□	□	□	□	□	□	□		□	□	□			□	□
A2	0.98	□	□	□	□			□			□	□	□	□	□		□	□	□	□	□
B1	0.95	□		□					□		□						□			□	□
B2	0.95	□		□							□	□				□	□				□
C1	0.92	□									□						□			□	
C2	0.91	□									□						□				
D1	0.91			□					□			□									□
D2	0.90			□								□				□					□

Of all the variables considered in the best performing model, density of settlements and elevation were the features that contributed most to the model of tiger attacks on livestock (Figure 2; Table 4). Percentage of land cover by meadows was also an important feature, while the percentage of land cover by agriculture

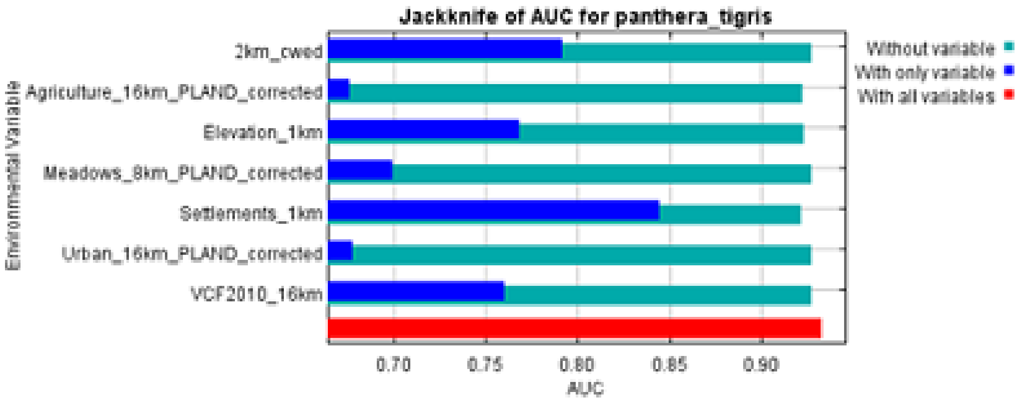

Figure 2. Jack-knife test of variable importance for multi-scale (1-16 km) models. The plots show the area under the ROC curve (AUC) of the selected variables (i.e. uncorrelated, best performing and with over 5% contribution in the global model).

Table 4. Selected model variables and their percent of contribution.

Variable – scale	Percent contribution (%)
Settlements density (1 km)	42.2
Elevation (1 km)	14.1
Percentage of land covered by meadows (8 km)	12.5
Vegetation Continuous Fields (16 km)	8.9
Percentage of land covered by agricultural lands (16 km)	8.5
Contrast-weighted edge effect (2 km)	8.2
Percentage of land covered by urban areas (16km)	5.6

Generating a Bhutan-wide predictive livestock risk attack map by tigers using the best performing model, vulnerability to tiger attack is higher in locations ranging from 1,000 to 3,000 m, with a high settlement density, a percentage of land cover up to 15% by meadows, a cover between 35 and 55% of trees, in places with low percentage of land covered by urban areas and with edges per unit area of approximately 10 to 35% (Figure 5).

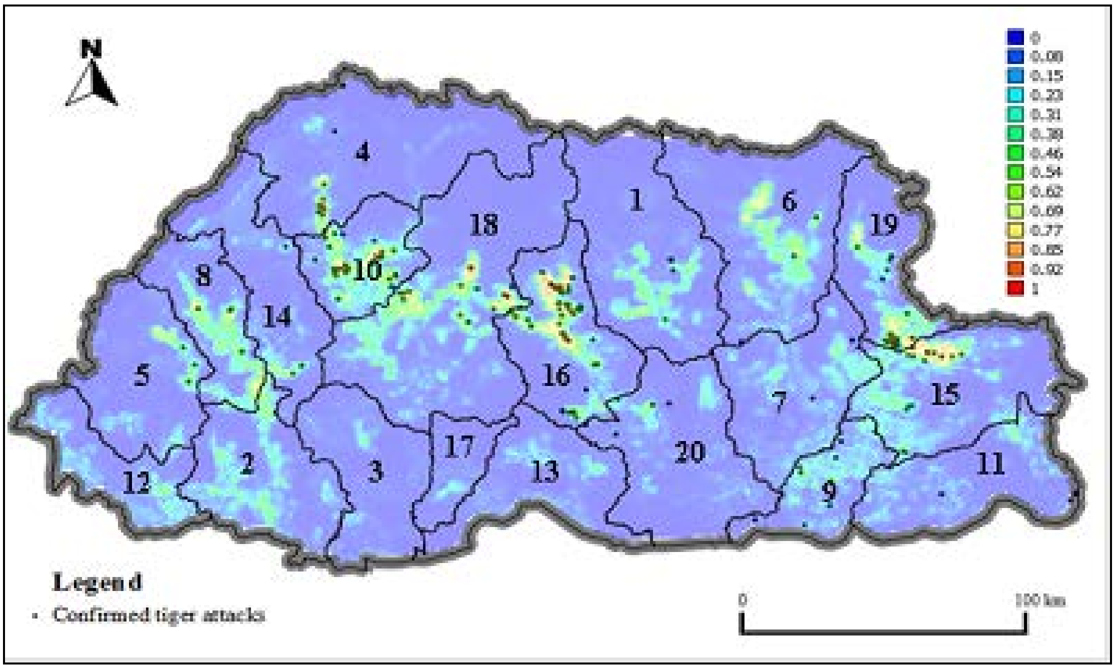

Figure 3. Map of the potential distribution of tiger attack on livestock across Bhutan. The colour gradient indicates attack vulnerability, with warmer colours representing the areas in which attacks are most likely to occur. The risk of predation is shown for the different administrative districts: 1 Bumthang, 2 Chhukha, 3 Dagana, 4 Gasa, 5 Haa, 6 Lhuentse, 7 Monggar, 8 Paro, 9 Pemagatshel, 10 Punakha, 11 Samdrupjongkhar, 12 Samtse, 13 Sarpang, 14 Thimphu, 15 Trashigang, 16 Trongsa, 17 Tsirang, 18 Wangduephodrang, 19 Trashiyangste, 20 Zhemgang.

Project actions remaining

We are currently in the process of conducting the same analysis for the common leopard and a third one for all carnivore attacks regardless of species involved. Species-specific analyses for other species will not be possible because there are not sufficient data. Upon completion of these models, we will share our findings with the department of Forests and Parks Services, Bhutan in order to gain their feedback as to the most appropriate format that they could use the results in their decision making. Then, we will develop region specific risk maps so that they can be shared with the appropriate local branches of parks and territorial forest divisions. Finally, we need to organise the final workshop where the data analysis and interpretation processes will be discussed with the final end users and mitigation measures – based on the findings of our analyses – will be discussed. Tentatively, the date for this final workshop will be in January-February 2013 (within the frame of time extension requested).

We remain excited about this project and the potential human-wildlife mitigation opportunities that it creates in Bhutan, and look forward with anticipation for the feedback from the end users. Plans for sharing of our tiger/leopard findings with the international conservation community are already in place, with a peer-reviewed publication currently being drafted.

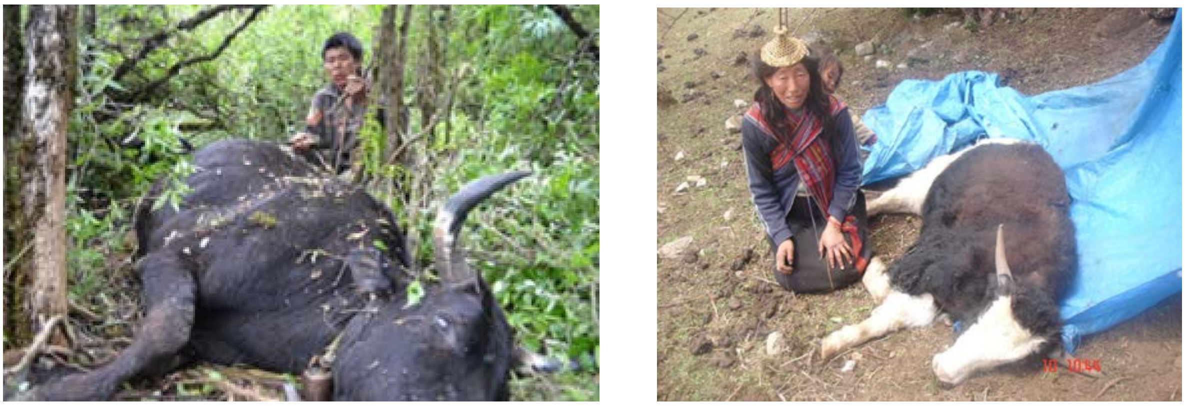

Figure 4. Owner with their cattle killed by wild predators

Figure 5. Verifying the kill site using the GPS.