Assessing the Structural Connectivity of a Biological Corridor for Tiger Movements between National Parks in Bhutan

Letro

Jigme Singye Wangchuck National Park

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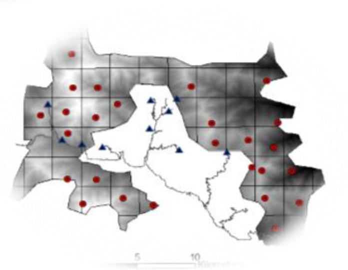
The Presentation Outline

1. **Introduction**



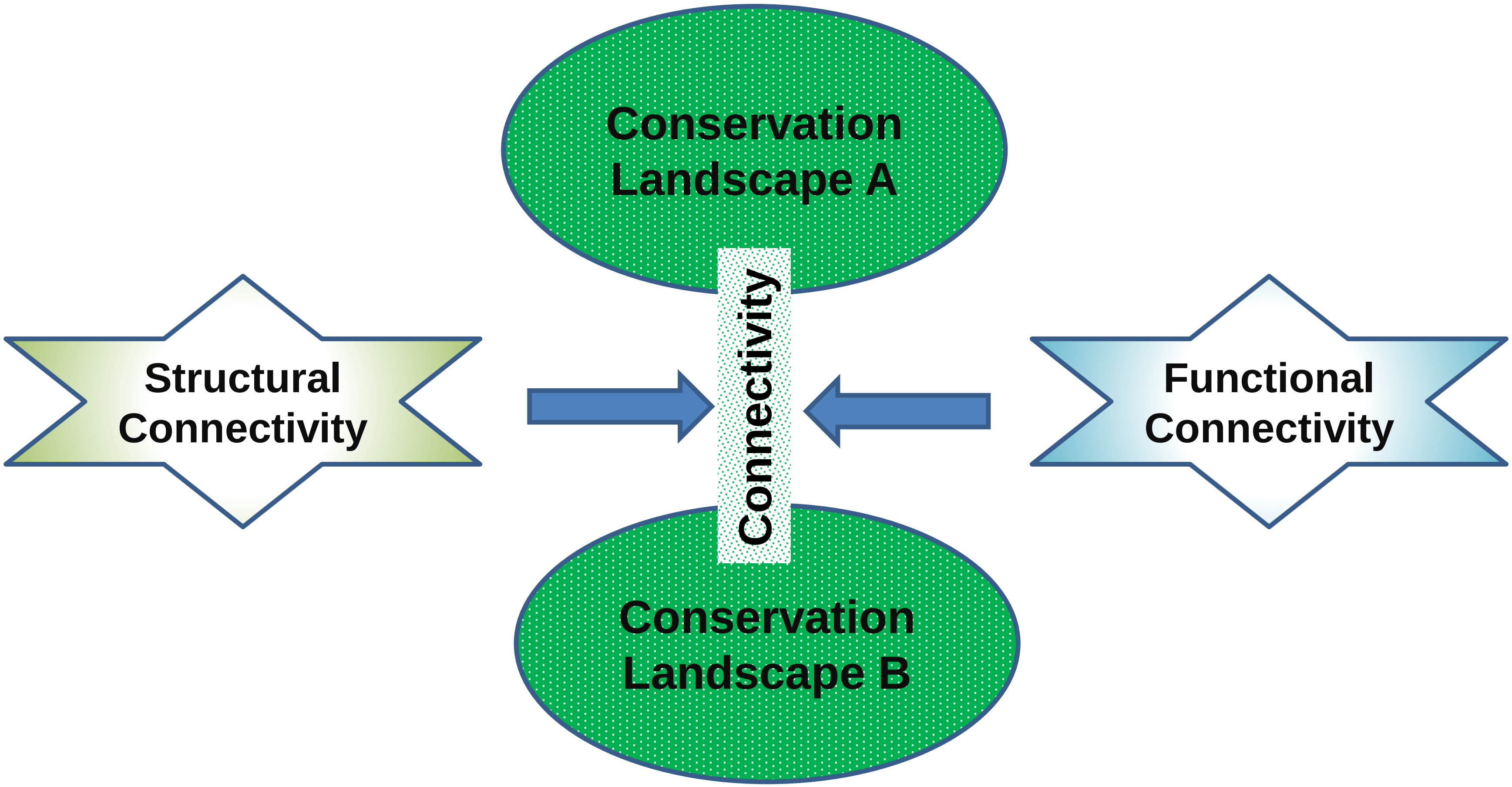
2. Materials and Methods

3. Results and Discussions

4. Conclusion and Recommendations

What are the purpose of Bridges?

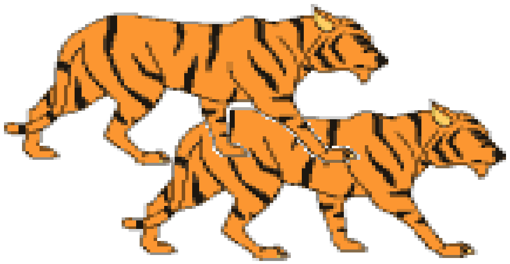
1.1. Connectivity

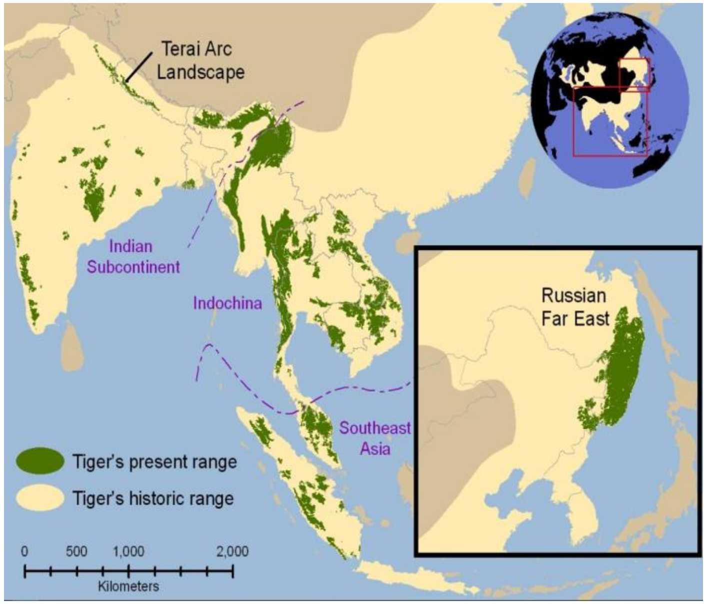


Taylor et al. 1993; Metzger & Ddcamps 1997

1.2. Global Tiger Conservation

Goal
TX2
2022

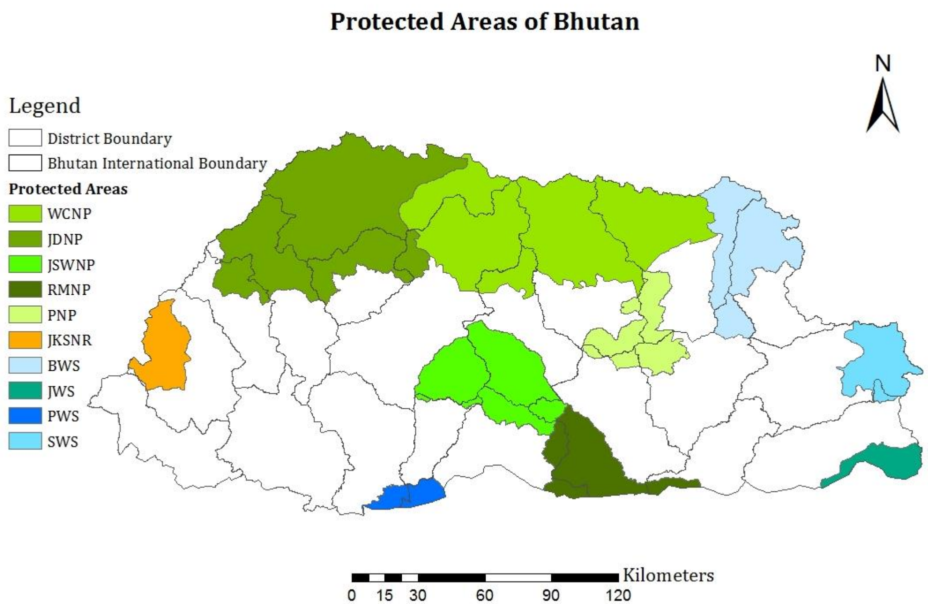




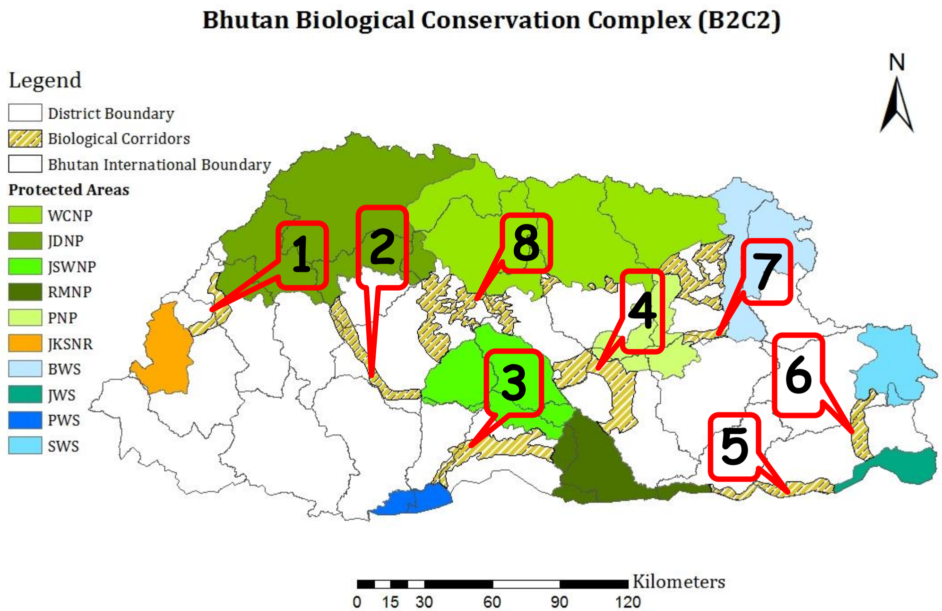
Landscape level approach to Tiger conservation

Wikramanayake et al. 2011

1.3. Bhutan Conservation Landscape



Protected Areas: 16,397 km^2 (43%)



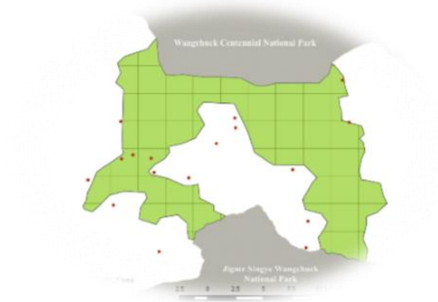
Biological Corridors (BC): 3306 km^2 (8.61%)

- Bhutan is a hotspot for wild felid diversity

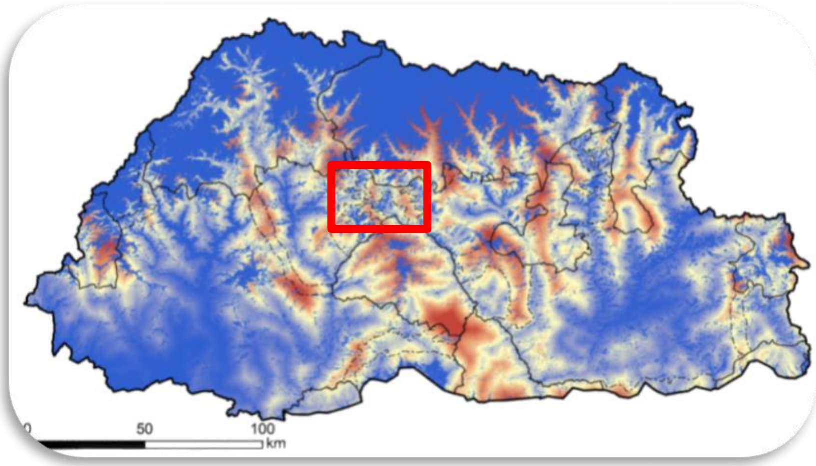
Tempa et al. 2013

1.4. Rationale

- 103 tigers,
- 0.46 tigers per 100 km^2



- BC8

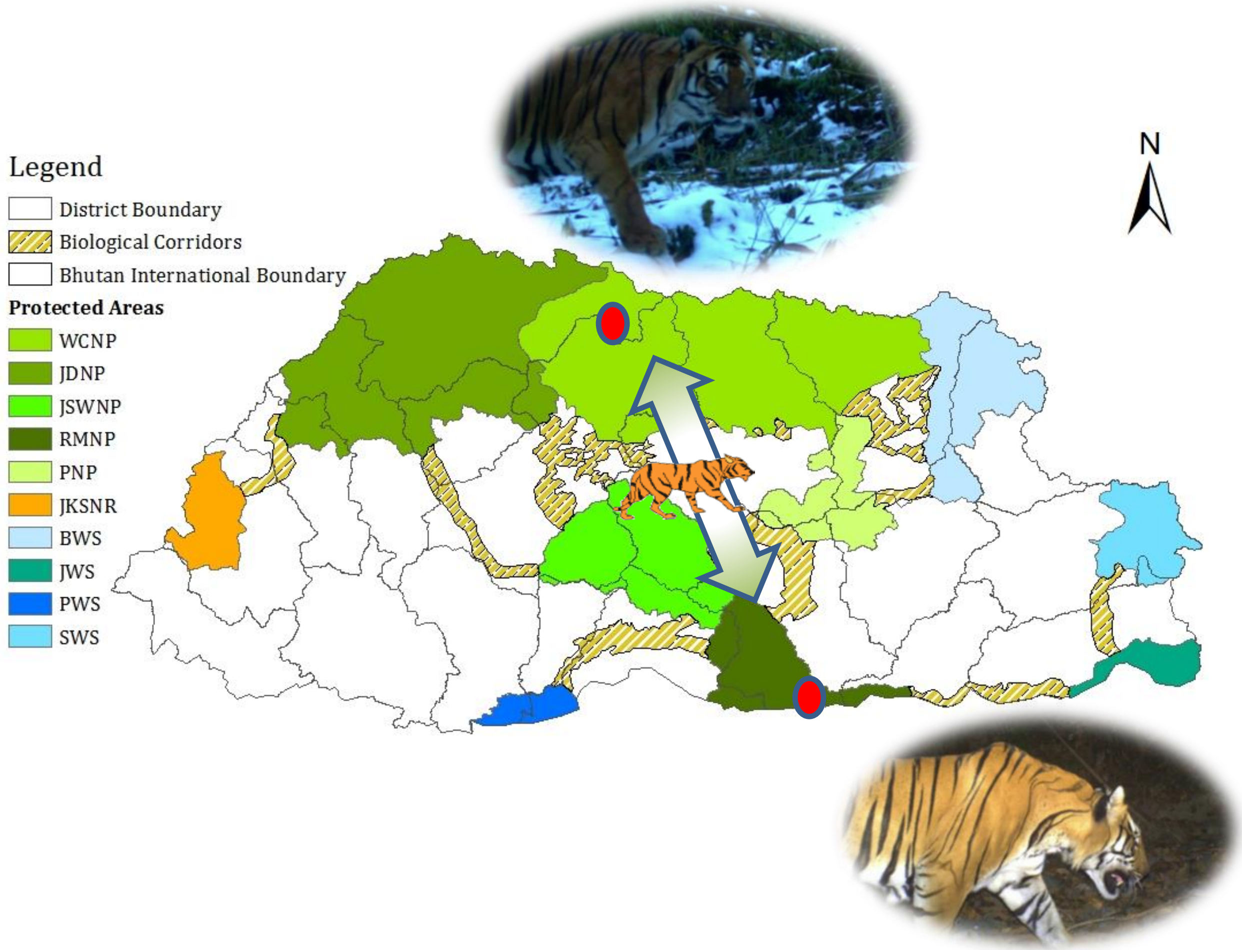


- Denser in south/central

- Human-Tiger Conflict – A Threat?

Unknown status of connectivity of the BC8.

1.5. Goal



Assess structural connectivity of Biological Corridor No. 8 (BC8) that connects JSWNP with WCNP for tiger movement.

1.6. Objectives

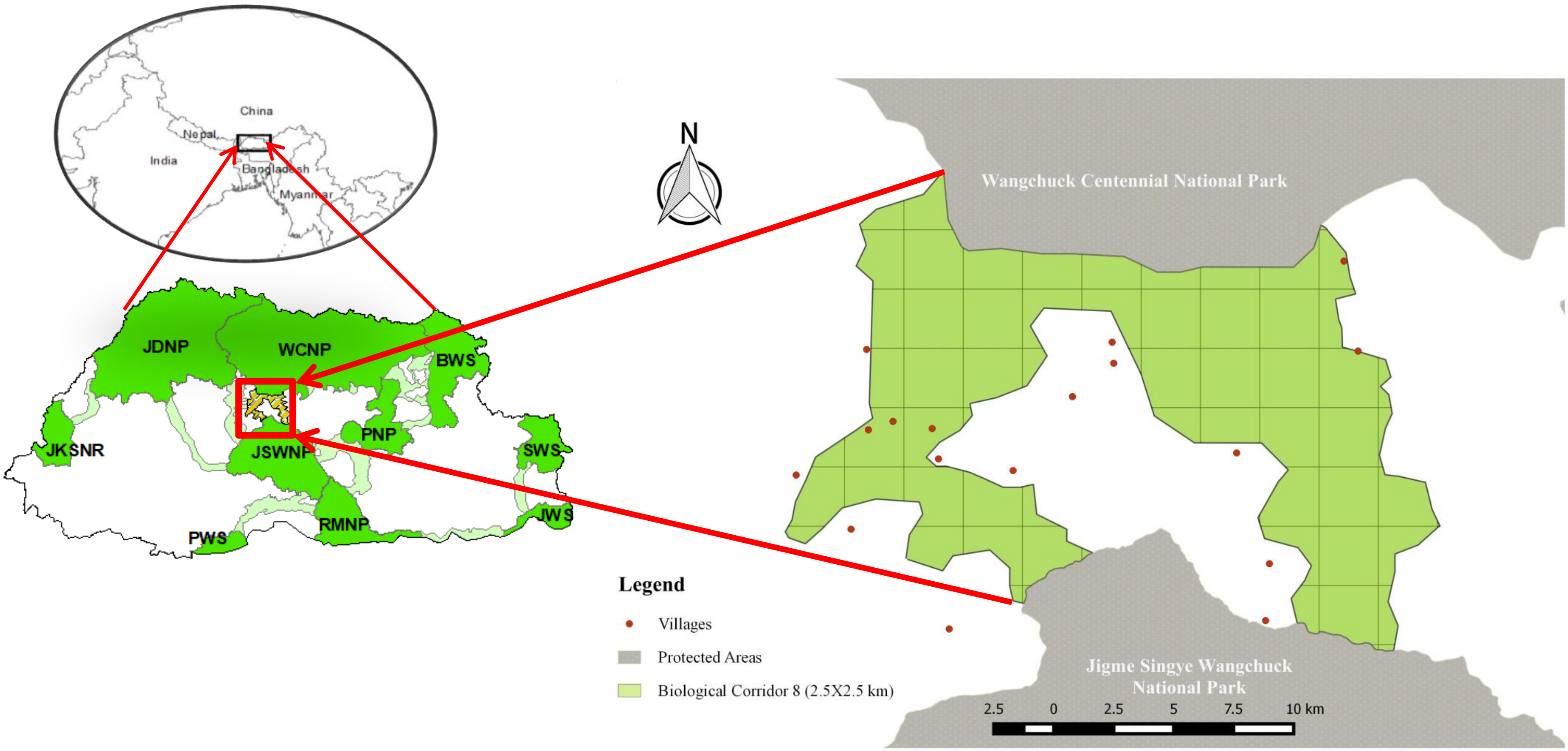
barking deer (*Muntiacus muntjak*)

sambar (*Rusa unicolor*)

wild boar (*Sus scrofa)*

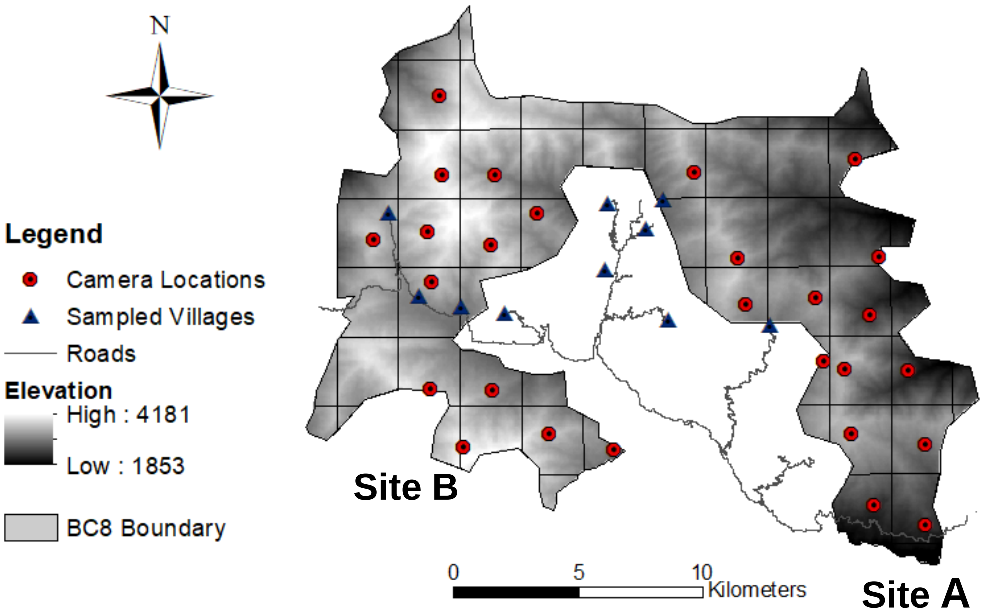
- ✓ Principal prey species occupancy pattern?
- ✓ Tiger Habitat use probability in BC8?
- ✓ HTC incidences and people's perceptions?

2.1. Study Area



- Elevation: 1853 to 4181 m, Temperature 14˚C; Rainfall: 1956 mm
- Cool Temperate Forests
- Wangdue Phodrang and Trongsa

2.2. Field survey design



i. **Wildlife survey;**

❖2.5 X 2.5 km grids, 27 grids sampled,

❖Camera trapping

❖***Site A:*** 14 Cameras

❖***Site B:*** 13 Cameras

2.3. Covariates: The landscape structure

Site Covariates: Covariates influencing site occupancy

Ecological covariates:

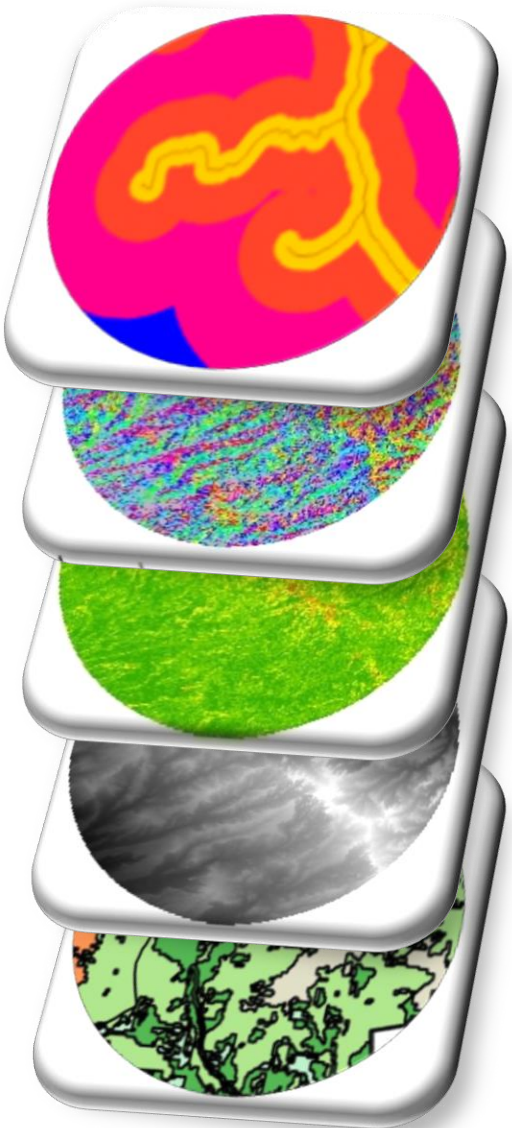
- land use types (LU): forest types
- elevation (ELE): m
- aspect (ASP): degree
- slope (SLO): degree
- distance to protected area (PA): m
- distance to the river (RIV): m

Anthropogenic covariates:

- distance to road (ROA): m
- distance to settlement (SET): m

Survey covariates: Covariates influencing detection

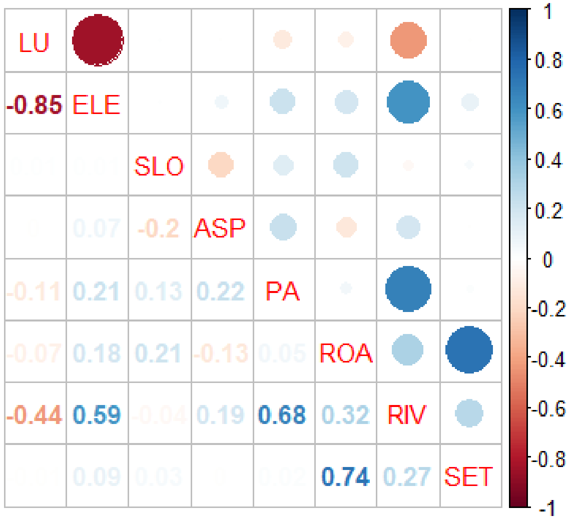
- survey areas (S. area) (site A and site B)
- camera trapping effort (Effort): No of days



2.4. Occupancy modeling

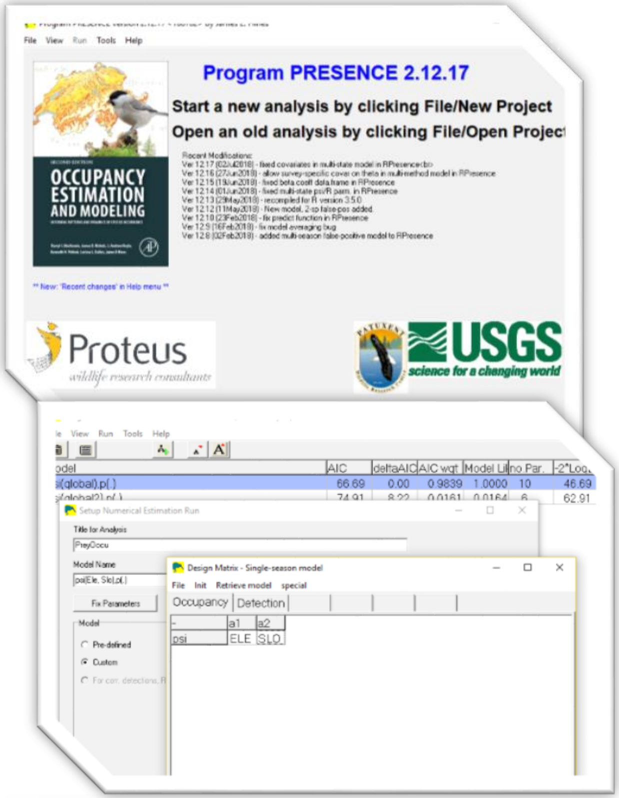
Occupancy modeling of principal prey species

- ✓ presence-absence detection history from sampling periods
- ✓ non-correlated covariates
- ✓ z-standardized values
- ✓ occupancy probability '*ψ*' (psi)
- ✓ the probability of detection '*p*'



Mackenzie et al. 2002, 2006

2.4. Occupancy modeling



Single-species single season occupancy modeling

- ✓ programme PRESENCE

Two-step process

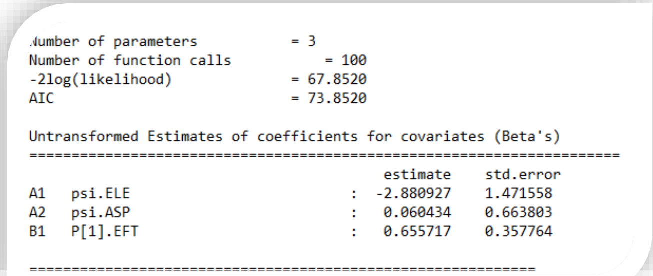
- ✓ estimate the probability of detection (*p*)
- ✓ estimate the probability of occurrence (*ψ*)

The selection of best model

- ✓ Akaike information criterion (AIC) values

The mean untransformed beta coefficient estimate

- ✓ to predict the site occupancy of the species using ArcGIS
- ✓ to measure the degree and direction of the covariate effect on the site-use probability



Hines 2006; Mackenzie et al 2006; Burnham and Anderson 2004.

2.5. Habitat use probability for tiger

Habitat use probability

- ✓ GLM with binomial function
- ✓ presence-absence at sampled sites
- ✓ z-standardized covariates

Maximum likelihood model selection

- ✓ dredge function in R package “MuMIn”
- ✓ Akaike information criterion (AIC) values

R Studio®
R.3.5.1

The coefficient estimates of various covariates

- ✓ used to generate raster pixels predicting tiger habitat use
- ✓ to measure the degree and direction of the covariate effect on the site-use probability

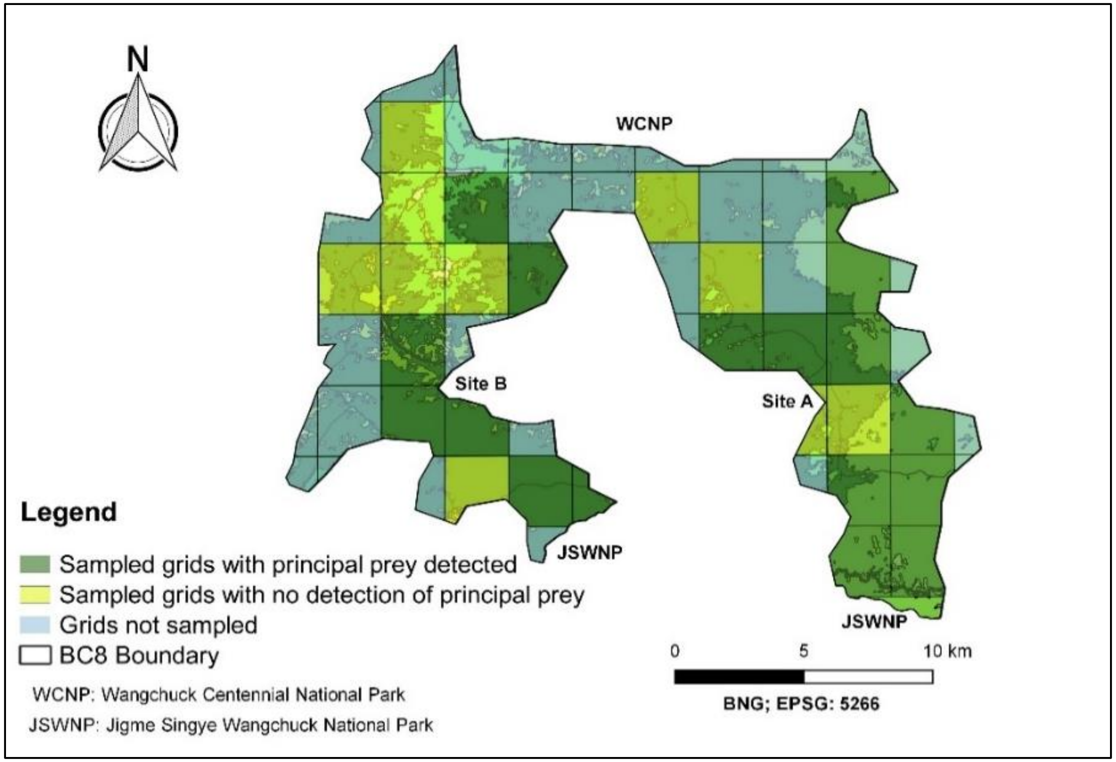
R Core Team 2018

3.1. Occupancy of principal prey species

- ✓ 26 camera traps retrieved
- ✓ total effort of 1080 trap days

- ✓ At least one principal prey species recorded in 17 camera trap locations
- ✓ 368 independent images

- ✓ sambar: 9 locations
- ✓ barking deer:11 locations
- ✓ wild boar:10 locations



3.1. Occupancy of principal prey species

Detection probability models

Species	Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2LogLik
Sambar	*p*(S. area + Effort)	76.58	0	0.326	1	4	68.58
	p(Effort)	77.17	0.59	0.239	0.744	2	73.17
	p(S. area)	77.27	0.69	0.228	0.708	3	71.27
	p(.)	77.42	0.84	0.211	0.657	2	73.42
Barking deer	*p*(Effort)	88	0	0.40	1	2	84
	p(.)	88.09	0.09	0.38	0.96	2	84.09
	p(SA)	89.91	1.91	0.15	0.38	3	83.91
	p(S. area + Effort)	91.85	3.85	0.06	0.15	4	83.85
Wild boar	*p*(Effort)	83.24	0	0.533	1	2	79.24
	p(S. area)	84.97	1.73	0.225	0.421	3	78.97
	p(S. area + Effort)	85.89	2.65	0.148	0.268	4	77.89
	p(.)	86.58	3.34	0.101	0.188	2	82.58

3.1. Occupancy of principal prey species

A. Occupancy probability of Sambar:

(ψ ± SE): 0.49 ± 0.03

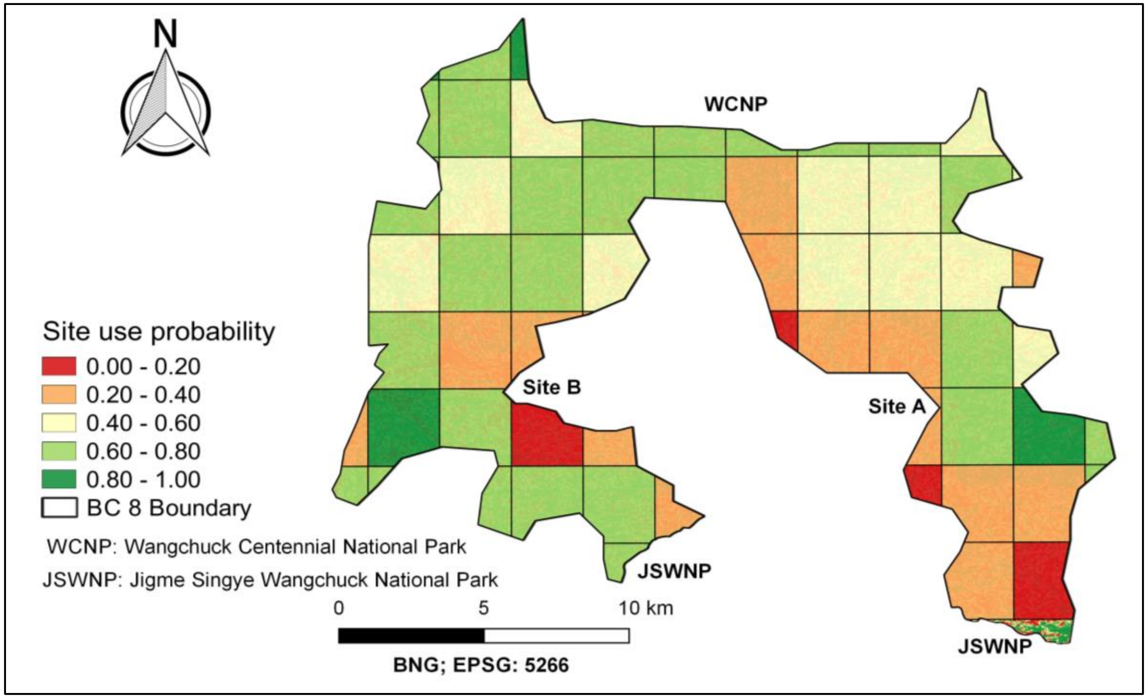
Species	Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2LogLik
Sambar	ψ (SLO+ASP+SET), p(S. area + Effort)	75.73	0	0.389	1	6	63.73
	ψ (ELE+ASP), p(S. area + Effort)	76.21	0.48	0.306	0.786	5	66.21
	ψ(ELE, SET), p(S. area + Effort)	76.31	0.58	0.2952	0.7483	5	66.31

Estimates of β-coefficient values

Species	Model	β_{SET} (SE)	β_{ASP} (SE)	β_{SLO} (SE)
Sambar	ψ (SLO+ASP+SET), p(S. area + Effort)	0.20 (0.64)	- 0.02 (0.57)	1.28 (0.74)

3.1. Occupancy of principal prey species

A. Occupancy probability of Sambar:



ψsiteA (SE) = 0.44 (0.06)

ψsiteB (SE) = 0.57(0.07)

3.1. Occupancy of principal prey species

B. Occupancy probability of Barking deer:

(ψ ± SE): 0.52 ± 0.09

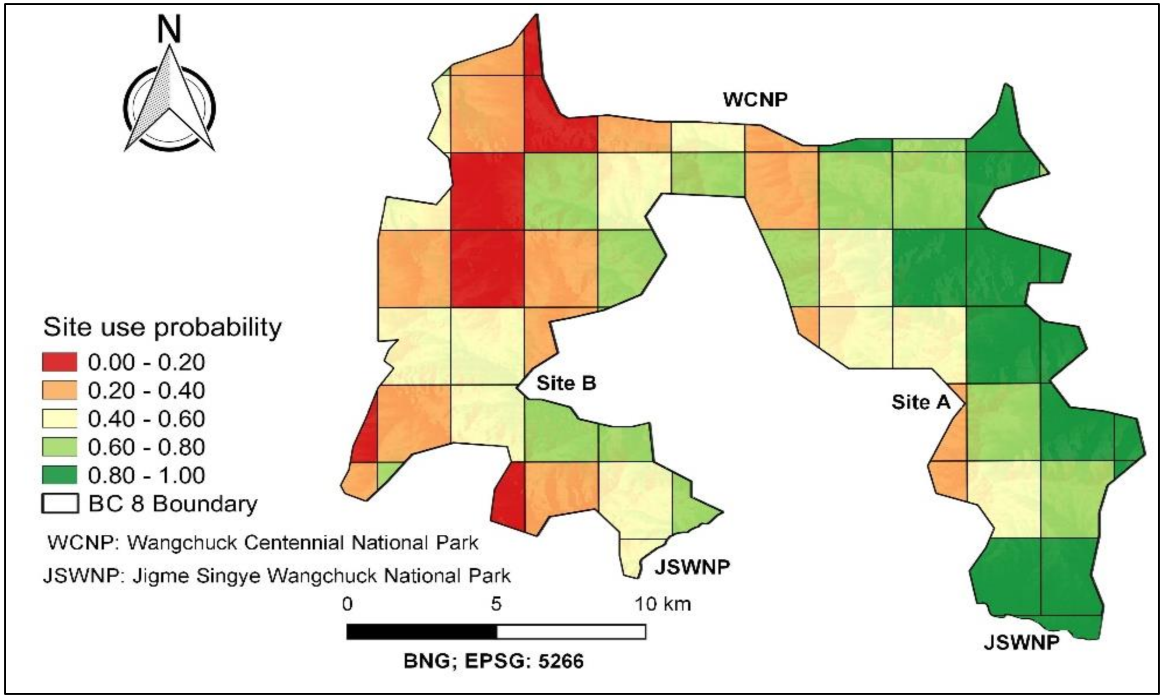
Species	Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2LogLik
	ψ (ELE+ASP), *p*(Effort)	83.64	0	0.4388	1	3	77.64
Barking deer	*ψ* (ELE+ROA), *p*(Effort)	84.48	0.84	0.2883	0.657	3	78.48
	ψ (ELE+RIV), p(Effort)	84.59	0.95	0.2729	0.6219	3	78.59

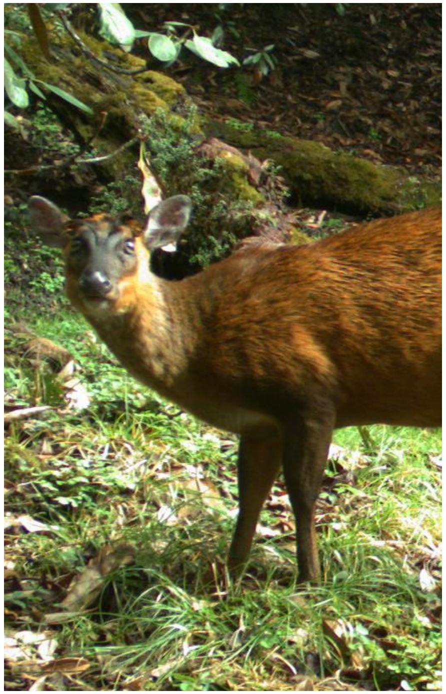
Estimates of β-coefficient values

Species	Model	β_{ELE} (SE)	β_{ASP} (SE)
Barking deer	ψ (ELE+ASP), p(Effort)	-1.54 (0.96)	-0.59 (0.58)

3.1. Occupancy of principal prey species

B. Occupancy probability of Barking deer:





ψsiteA (SE) = 0.62 (0.06)

ψsiteB (SE) = 0.35(0.07)

3.1. Occupancy of principal prey species

C. Occupancy probability of Wild boar:

(ψ ± SE): 0.45 ± 0.07

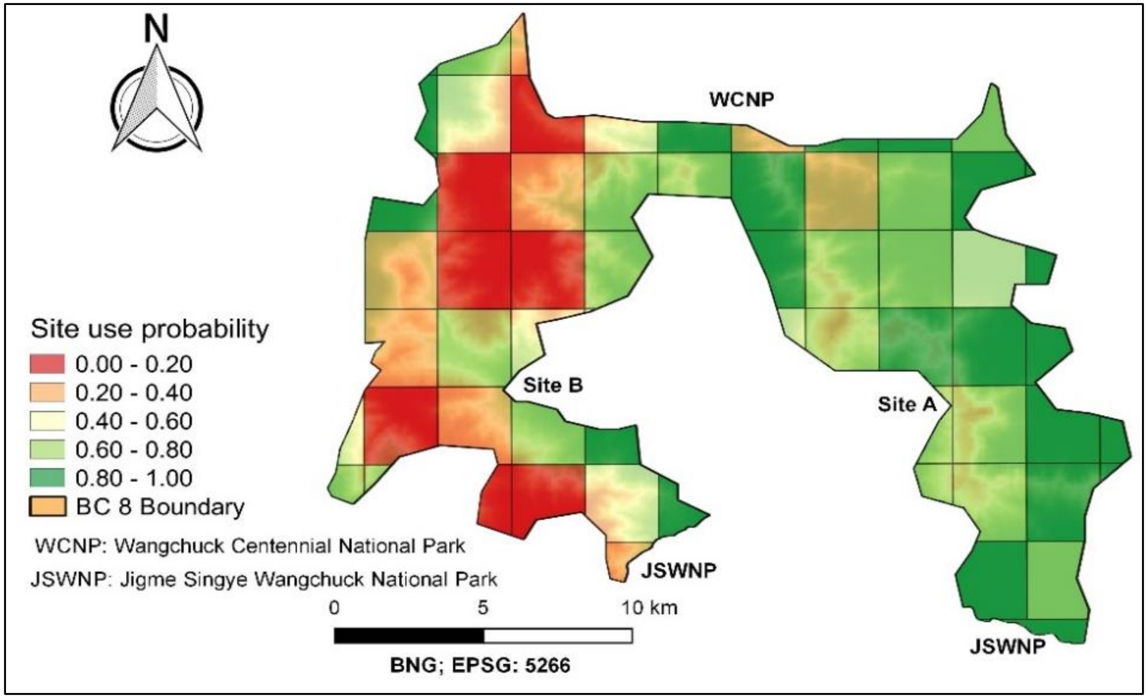
Species	Model	AIC	ΔAIC	AIC wt	Model Likelihood	K	-2LogLik
Wild boar	*ψ* (ELE+RIV), *p*(Effort)	72.98	0	0.247	1	3	66.98
	ψ (ELE+SLO), *p*(Effort)	73.17	0.19	0.225	0.909	3	67.17
	ψ (ELE+ROA), p(Effort)	73.6	0.62	0.1814	0.733	3	67.6

Estimates of β-coefficient values

Species	Model	β_{ELE} (SE)	β_{RIV} (SE)
Barking deer	ψ (ELE+RIV), p(Effort)	-2.64 (1.6)	-0.73 (0.83)

3.1. Occupancy of principal prey species

C. Occupancy probability of Wild boar:



ψsiteA (SE) = 0.64(0.09)

ψsiteB (SE) = 0.24 (0.08)

3.1. Occupancy of principal prey species

All three species have preference towards lower limit of the elevation.

- Tempa 2017

Easterly and southerly aspects have positive influence to sambar and barking deer occupancy.

- Forsyth et al. 2009

Wild boar prefers forests and shrubs surrounding water holes, swamps, marshes.

- Graves 1984

Influence of forest types on species is weaker than elevation, probably attributed to the adaptation of species to wide-ranging vegetation types.

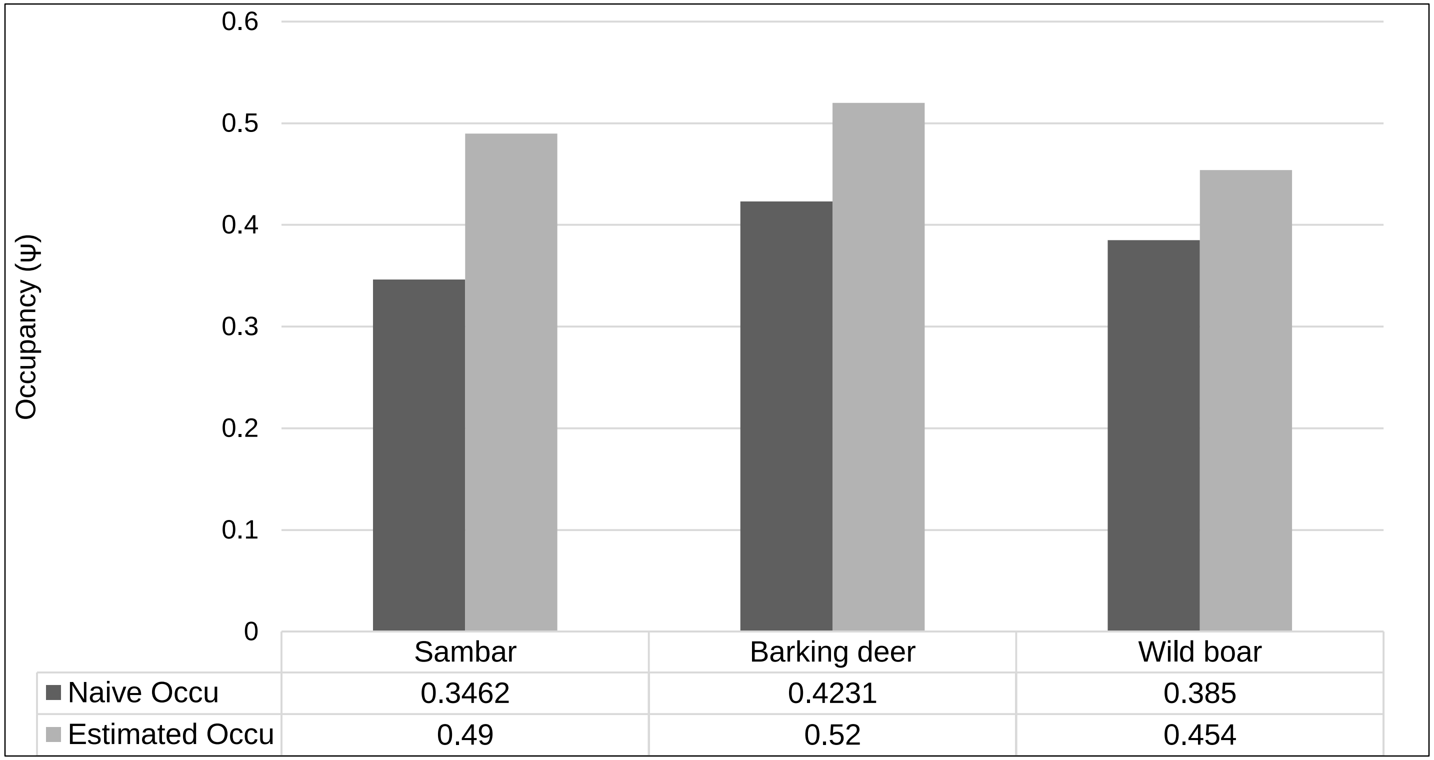
- Timmins et al. 2015, 2016

No strong signature of human disturbance on prey species in Bhutan.

- Tempa 2017

3.1. Occupancy of principal prey species

Occupancy of principal prey species



- Occupancy: Accounting imperfect detections and inclusion of covariates

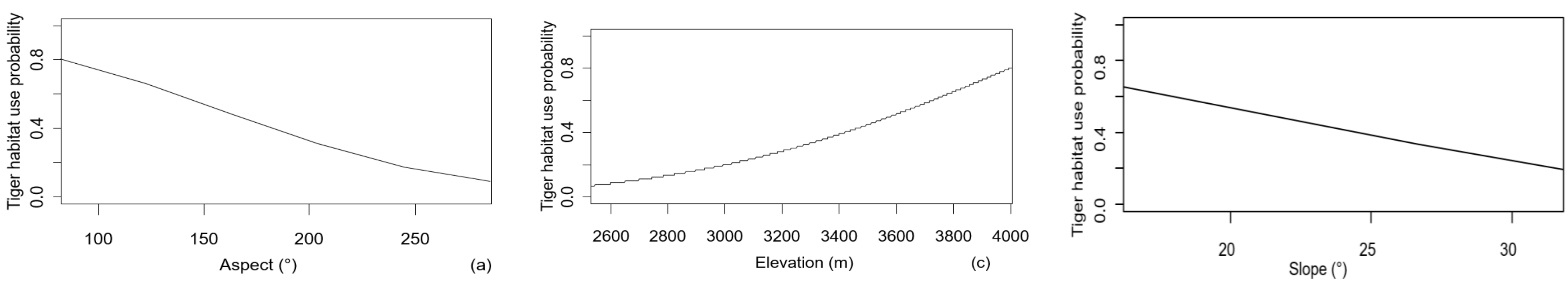
  - Karanth et al. 2011

3.2. Habitat use probability for tiger

- Tiger uses BC8

Intercept	ASP	ELE	SLO	f	logLik	AIC_c	ΔAIC_c	weight
-2.73	-0.02	0.004	-0.23	4	-11.94	33.8	0	0.35
-7.98	-0.01	0.003	-	3	-13.41	33.9	0.13	0.33
-9.25	-	0.002	-	2	-15.19	34.9	1.12	0.20
-6.95	-	0.003	-0.14	3	-14.34	35.8	1.98	0.13

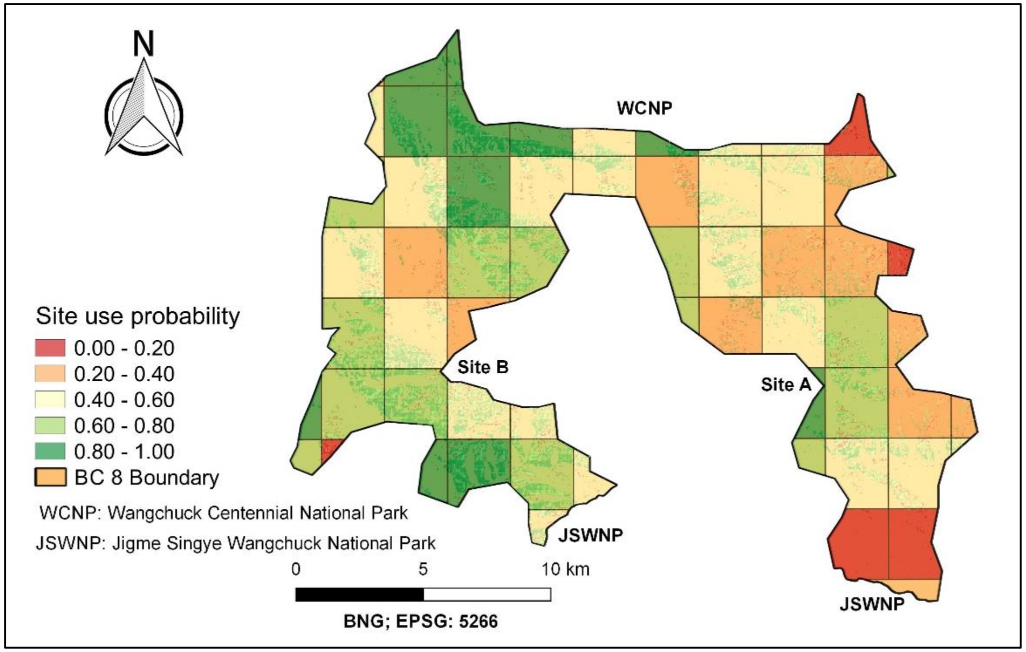
- Aspect (ASP), Elevation (ELE) and Slope (SLO) major predictors



Tempa et al. 2017; Sunarto et al. 2012

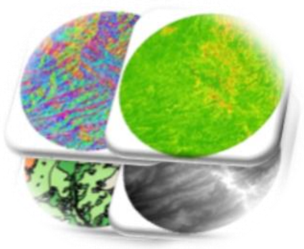
3.2. Habitat use probability for tiger

- ❖ Site B have better suitability as compared to site A

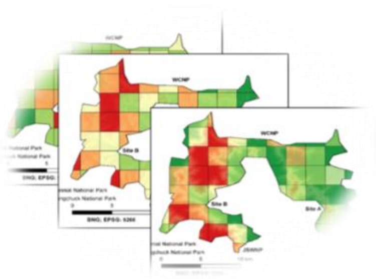


Tempa et al. 2017; Linkie et al. 2006

4.1. Conclusion



- ✓ The ecological covariates are important predictor than anthropogenic influences.
- ✓ Occupancy patterns indicates niche partitioning of species, that enabled better connectivity.



- ✓ Prey occupancy is likely to enhance tiger movement between national parks.

- ✓ High incidences of livestock depredation by tiger induces negative attitudes towards tiger conservation.
- ✓ Mitigating HTC and increasing awareness programme will strengthen conservation.

4.2. Recommendations

1. Management plan for BC8
2. Habitat improvement and management
3. Safeguarding wildlife through patrolling
4. Mitigating HTC and increasing awareness programme
5. Assessing functional connectivity

Healthy Corridor – A Bridge of Connectivity

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Questions?

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