Supplementary Materials

Investigating Carnivore Guild Structure: Spatial and Temporal Relationships amongst Threatened Felids in Myanmar

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Table S1. Survey information and camera trap locations used for space use analysis in Htamanthi Wildlife Sanctuary during 2014-2018.

Survey Periods	2014-15	2015-16		2016-17		2017-2018	
Survey Name	WildCRU1	WildCRU2	IUCN1	Sun Bear	IUCN2	WildCRU3	IUCN3
Survey Area	Nam Pa Gon	Nam E Zu	Nam Yan Yin	Nam E Zu	Nam Yan Yin	Nam Pa Gon	Nam Phi Lin & Nam Yan Yin
Target Species	Clouded Leopard	Clouded Leopard	Tiger	Malayan Sun Bear	Tiger	Clouded Leopard	Tiger
Spacing (km)	1-1.5	1-1.5	2-3	1 station per 2 km² grid	2-3	1-1.5 km	2-3
No. Days Operational	14452	14116	3151	2682	6238	15868	7613
Total Trap Days	7226	7226	1632	2682	3155	7934	3855
No. Trap Locations	82	80	50	60	75	80	100
No. Trap Locations (Working)	80	79	46	60	73	80	99
Trap Locations used for Space use analysis	-	79	-	60	33	80	36

Method S1

Single-species occupancy modeling and covariate selection

 Covariates

In our analysis, we considered a simple set of covariates that are ecologically informative and have been found to be important to those species. Thus, seven environmental and anthropogenic covariates are selected: (1) elevation, (2) terrain ruggedness, (3) density of small streams and main rivers within a radius of 2 km of camera stations, (4) distance to main stream which are used by trespassing boats, (5) per cent tree cover, (6) Euclidean distance to park boundary, and (7) disturbance expressed as the number of poaching detections, trespassing and livestock trafficking activities recorded by each camera trap station, which was standardized by total trap nights across all surveys. The elevation raster layer (30-meter resolution) was obtained from the LOCA website, an online platform for updated GIS information for the WCS Myanmar program (available at https://myanmar-geotools.appspot.com), and based on this raster we calculated terrain ruggedness. For forest cover, we used Hansen global forest cover layer for the year 2000 as the base of analysis [1]. Then, the corresponding year data were obtained by calculating forest cover using forest gain and loss for respective years from 2014 to 2016. The analysis is of focal mean values of forest which does not use a threshold for defining forest and non-forest. The mean values of tree cover percentage, elevation, and stream density were extracted from 2km focal mean representing average site characteristics around each camera station, using zonal statistics in SAGA plug-in in QGIS software [2]. The digitized park boundary and stream data were obtained from the WCS Myanmar GIS team. The Euclidean distance to park boundary and streams was calculated in QGIS. We then extracted the values of each covariate at each camera trap location and calculated Pearson correlations between the covariates (Figure S1). We assumed the correlation was strong if $|r| > 0.7$. Since the variation in sampling duration across different surveys can affect detection probability, we included survey effort as an observation level covariate.

Space use estimation

We binned the daily detection histories into 10 days per sampling occasion to increase temporal independence and reduce over-dispersion of data [3]. Our sampling effort ranged from 29 to 109 days among survey grids, and to maximize accuracy and precision of occupancy estimation we set sampling occasions at 10 days, thus resulting in at least three occasions for each grid [4].

To estimate the probability of space use for each species independently, we ran separate occupancy models using our predetermined covariates for each species. Firstly, we checked the importance of effort to detection probability. Using AIC ranking, we chose model with effort when they are in top model or when there is low variation in model performance (i.e. delta AIC < 2). Then, using non-correlated site covariates we created a global model and checked the model fitness by bootstrapping with 10,000 samples as suggested by MacKenzie & Bailey (2004). We used the "dredge" function from package "MuMIn" [6], which runs models for all combinations of the predictor variables. We then selected all covariates present in the best ranked models (i.e. models with the delta AICc and QAIC < 2 [7]. The model averaging was done for best ranked models and beta parameter estimates and confidence intervals are obtained (Table 1). We also extracted overall predictions for occupancy and detection probability for each

species using respective pairs of covariates used during model averaging. The analysis was conducted in R [8] using package "unmarked" [9].

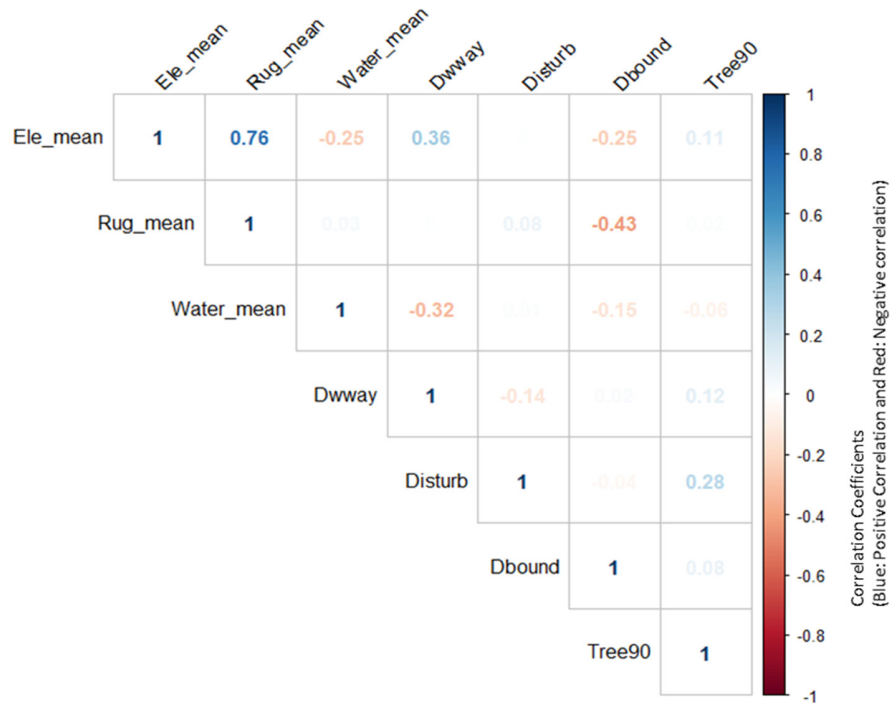**Figure S1.** Correlation test of covariates affecting occupancy of four cat species for single-species single-season occupancy modelling where Ele_mean= Mean elevation, Rug_mean= mean terrain ruggedness, Water_mean=Mean water density, Dwway= Distance to accessible streams, Dbound=Distance to nearest park boundary, Disturb=Frequency of human and livestocks detected by camera traps, Tree90=Percent tree cover with 90% threshold

Table S2. Beta parameter estimates for occupancy (**Ψ**), detection probability (**P**) and Standard errors (SE) from model averaging results for each felids species

	Model averaged Beta Parameter	Estimate	SE
Ψ	Intercept	-1.358	0.469
	Distance to Boundary	0.325	0.402
	Disturbance	1.802	0.919
	Mean Elevation	1.137	0.485
	Tree cover	-0.423	0.456
P	Intercept	-2.519	0.431
	Effort	-0.005	0.037
Ψ	Intercept	0.817	0.509
	Disturbance	2.633	1.437
	Stream density	0.033	0.112
	Tree cover	0.029	0.111
	Mean Elevation	0.082	0.303
	Distance to main streams	-0.147	0.199
	Distance to boundary	-0.075	0.199
P	Intercept	-2.884	0.663
	Effort	0.104	0.067
Ψ	Intercept	-0.154	0.277
	Disturbance	1.277	0.91
	Stream density	0.003	0.055
	Tree cover	0.105	0.244
	Mean Elevation	0.108	0.347
	Distance to main streams	0.034	0.115
	Distance to boundary	0.031	0.109
P	Intercept	-2.887	0.767
	Effort	0.116	0.077
Ψ	Intercept	-0.741	0.250
	Disturbance	0.029	0.099
	Stream density	0.025	0.098
	Tree cover	0.036	0.119
	Mean Elevation	0.040	0.153
	Distance to main streams	0.011	0.073
	Distance to boundary	-0.019	0.086
P	Intercept	-4.937	1.516
	Effort	0.295	0.152
Ψ	Intercept	-0.768	0.158
	Disturbance	0.066	0.164
	Stream density	0.027	0.093
	Tree cover	0.095	0.214
	Mean Elevation	0.008	0.064
	Distance to main streams	-0.001	0.046
	Distance to boundary	0.009	0.055
P	Intercept	-2.532	0.697
	Effort	0.143	0.070

Table S3. Model selection for single-species occupancy modeling ranked by delta AICC < 2 and QAIC < 2 where EFF= Effort, Dbound= Distance to boundary, Disturb= Disturbance(the number of poaching detections, trespassing and livestock trafficking activities recorded by each camera trap station), Dwway = Distance to main streams, Ele_mean = mean elevation, Tree90 = Tree cover, Water_mean = Mean stream density. Tiger and

Models	P (Int)	Psi (Int)	P (EFF)	Psi (Dbound)	Psi (Disturb)	Psi (Dwway)	Psi (Ele_mean)	Psi (Tree90)	Psi (Water_mean)	R^2	df	logLik	AICc/QAIC	delta	Weight
Tiger															
Psi(Dbound+Disturb+Ele-mean+Tree90)	-2.561	-1.419		0.616	1.952		1.32	-0.729		0.131	6	-160.126	332.6	0	0.314
Psi(Disturb+Ele_mean+Tree90)	-2.593	-1.202			1.955		1.008	-0.501		0.122	5	-161.559	333.3	0.78	0.213
Psi(Disturb+Ele_mean)	-2.584	-1.309			1.563		0.9278			0.116	4	-162.623	333.4	0.84	0.207
Psi(Dbound+Disturb+Ele_mean)	-2.557	-1.462		0.3902	1.477		1.077			0.12	5	-161.936	334.1	1.53	0.146
P(Eff), Psi(Dbound+Disturb+Ele_mean+Tree90)	-2.125	-1.430	-0.045	0.6209	1.945		1.322	-0.7241		0.131	7	-160.025	334.5	1.90	0.121
Clouded leopard															
P(Eff),Psi(Disturb)	-2.879	0.817	0.1034		2.681					0.064	4	-538.209	1084.6	0.00	0.291
P(Eff),Psi(Disturb+Water_mean)	-2.906	0.822	0.106		2.620				0.1991	0.067	5	-537.735	1085.7	1.12	0.166
P(Eff),Psi(Disturb+Tree90)	-2.842	0.729	0.1004		2.434			0.1951		0.0665	5	-537.823	1085.9	1.30	0.152
P(Eff),Psi(Disturb+Ele_mean)	-2.918	0.862	0.1059		2.582		0.5735			0.0662	5	-537.881	1086.0	1.42	0.144
P(Eff),Psi(Disturb+Dwway)	-2.873	0.843	0.1029		2.769	-0.1469				0.0658	5	-537.940	1086.1	1.53	0.135
P(Eff),Psi(Dbound+Disturb)	-2.893	0.838	0.1046	-0.07528	2.699					0.0645	5	-538.137	1086.5	1.93	0.111
Asiatic golden cat															
P(Eff), Psi(Disturb)	-2.857	-0.1123	0.1153		1.710					0.1138	4	-462.564	107.2	0.00	0.251
P(Eff)	-3.042	-0.2015	0.1254							0.0112	3	-478.342	108.5	1.31	0.130
P(Eff), Psi(Disturb+Dwway)	-2.863	-0.1657	0.116		1.587	0.3149				0.1231	5	-461.051	108.9	1.68	0.108
P(Eff), Psi(Disturb+Ele_mean)	-2.957	0.0365	0.1215		1.802		1.005			0.1230	5	-461.068	108.9	1.69	0.108
P(Eff), Psi(Dbound+Disturb)	-2.792	-0.196	0.1098	0.296	1.638					0.1214	5	-461.330	108.9	1.74	0.105
P(Eff), Psi(Disturb+Tree90)	-2.802	-0.2171	0.1109		1.433			0.3146		0.1212	5	-461.359	108.9	1.75	0.105
P(Eff), Psi(Tree90)	-2.918	-0.3184	0.1148					0.7175		0.0583	4	-471.310	109.0	1.84	0.100
P(Eff), Psi(Disturb+Water_mean)	-2.863	-0.1080	0.1158		1.715				0.0283	0.1139	5	-462.552	109.2	2.00	0.092
Marbled cat															
P(Eff)	-4.942	-0.7448	0.2956							0.0241	3	-305.609	59.5	0.00	0.299
P(Eff),Psi(Tree90)	-4.854	-0.8330	0.2889					0.2999		0.0321	4	-304.431	61.3	1.80	0.121
P(Eff),Psi(Disturb)	-0.889	-0.7878	0.2910		0.2412					0.0313	4	-304.548	61.3	1.82	0.120
P(Eff),Psi(Ele_mean)	-4.949	-0.7378	0.2959				0.342			0.0301	4	-304.724	61.3	1.85	0.119
P(Eff),Psi(Water_mean)	-4.996	-0.7560	0.2998						0.219	0.0282	4	-305.002	61.4	1.90	0.116
P(Eff),Psi(Dbound)	-4.981	-0.7436	0.2985	-0.1719						0.0268	4	-305.216	61.4	1.93	0.114
P(Eff),Psi(Dwway)	-4.949	-0.7456	0.2959			0.0978				0.0249	4	-305.487	61.5	1.98	0.111
Leopard cat															
P(Eff)	-2.549	-0.7448	0.1442							0.0178	3	-510.979	117.3	0.00	0.260
P(Eff),Psi(Tree90)	-2.495	-0.8330	0.1405					0.5293		0.0571	4	-505.090	118.0	0.74	0.180
P(Eff), Psi(Disturb)	-2.488	-0.7878	0.1390		0.4166					0.0492	4	-506.296	118.3	1.00	0.158
P(Eff), Psi(Water_mean)	-2.580	-0.7378	0.1466						0.2464	0.0267	4	-509.656	119.0	1.72	0.110
P(Eff), Psi(Dbound)	-2.534	-0.7560	0.1429	0.1011						0.0193	4	-510.748	119.3	1.95	0.098
P(Eff), Psi(Ele_mean)	-2.555	-0.7436	0.1447				0.0865			0.0185	4	-510.867	119.3	1.98	0.097
P(Eff), Psi(Dwway)	-2.548	-0.7456	0.1440			-0.0152				0.0178	4	-510.974	119.3	2.00	0.096

clouded leopard are ranked by AICc and Asiatic golden cat, marbled cat and leopard cat were ranked by QAIC.

Table S4. Naïve occupancy, detection probability and occupancy estimate of tiger, clouded leopard, golden cat and marbled cat and beta estimates for effect of covariates from top models with standard errors under maximum likelihood framework selected based on AICc and QAIC.

Species	Naïve Occupancy	Detection Probability	Probability of Space use	Model Averaged Beta Parameters					
				Elevation	Water density	Tree cover	Disturbance	Boundary	Distance to water
Tiger	0.108	0.072 (SE±0.018)	0.226 (SE±0.076)	1.137 (SE±0.485)	-	-0.423 (SE±0.454)	1.801 (SE±0.919)	0.325 (SE±0.401)	-
Clouded leopard	0.34	0.129 (SE±0.015)	0.56 (SE±0.12)	0.082 (SE±0.302)	0.033 (SE±0.112)	0.029 (SE±0.111)	2.632 (SE±1.437)	-0.075 (SE±0.199)	-0.147 (SE±0.199)
Asiatic golden cat	0.278	0.143 (SE±0.016)	0.425 (SE±0.09)	0.108 (SE±0.347)	0.002 (SE±0.055)	0.104 (SE±0.244)	1.277 (SE±0.909)	0.031 (SE±0.109)	0.034 (SE±0.115)
Marbled cat	0.181	0.11 (SE±0.02)	0.32 (SE±0.11)	0.040 (SE±0.153)	0.025 (SE±0.098)	0.036 (SE±0.119)	0.029 (SE±0.099)	-0.019 (SE±0.085)	0.011 (SE±0.073)
Leopard cat	0.26	0.24 (SE±0.02)	0.31 (SE±0.077)	0.008 (SE±0.064)	0.027 (SE±0.092)	0.095 (SE±0.214)	0.065 (SE±0.164)	0.01 (SE±0.055)	-0.001 (SE±0.047)

Table S5. Models with 300,000 iterations and 50,000 burn-ins with thinning rate of 5 for two-species single-season occupancy modeling with effects of covariates to each species (Where cl= clouded leopard, gc= Asiatic golden cat, mc=marbled cat, lc=leopard cat, Dbound=Distance to boundary, Disturb=Disturbance, Dwway=Distance to accessible main streams, Ele=Mean elevation, Water=Density of streams, effort=Effort, tree=Tree cover)

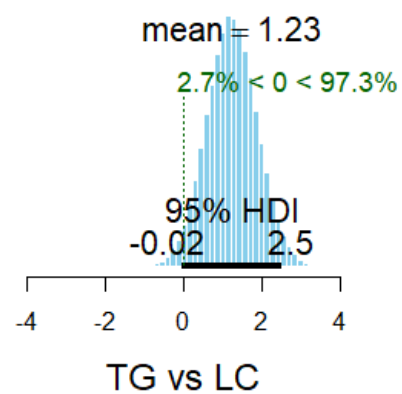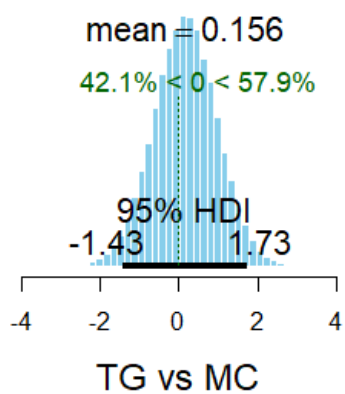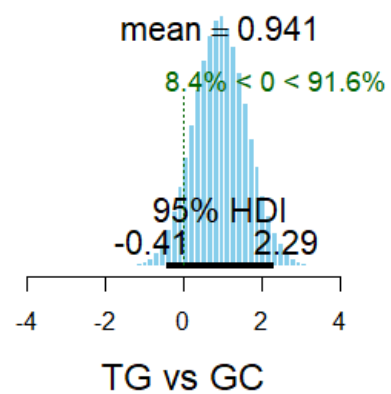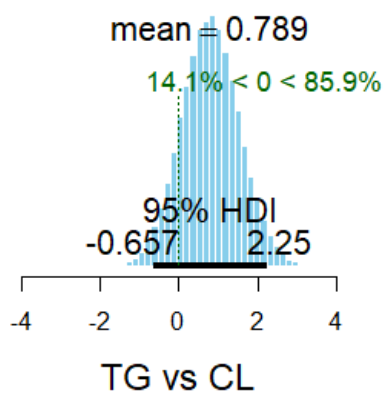| Parameters	mu.vect	sd.vect	2.50%	25%	50%	75%	97.50%	Rhat	n.eff
alpha.p.cl	-2.018	0.162	-2.371	-2.115	-2.011	-1.91	-1.722	1.002	4300
alpha.p.gc	-2.017	0.156	-2.331	-2.121	-2.014	-1.911	-1.717	1.001	61000
alpha.p.lc	-1.289	0.145	-1.576	-1.387	-1.288	-1.191	-1.009	1.001	36000
alpha.p.mc	-2.581	0.344	-3.21	-2.843	-2.571	-2.334	-1.925	1.004	940
alpha.p.tg	-2.679	0.272	-3.246	-2.849	-2.668	-2.496	-2.178	1.001	43000
alpha.psi.cl	1.336	1.215	-0.26	0.598	1.132	1.815	3.81	1.009	1900
alpha.psi.gc	-0.245	0.738	-1.547	-0.728	-0.301	0.169	1.426	1.001	13000
alpha.psi.lc	-3.371	0.706	-4.865	-3.817	-3.333	-2.885	-2.095	1.001	13000
alpha.psi.mc	2.185	3.155	-1.867	-0.111	1.353	3.668	9.517	1.005	650
alpha.psi.tg	-0.532	0.79	-1.851	-1.073	-0.601	-0.077	1.167	1.001	6900
beta.Dbound.psi.cl	-0.145	0.386	-0.863	-0.317	-0.116	0.072	0.457	1.008	2100
beta.Dbound.psi.gc	0.326	0.271	-0.199	0.145	0.324	0.505	0.867	1.001	64000
beta.Dbound.psi.lc	0.042	0.242	-0.441	-0.118	0.045	0.205	0.512	1.001	110000
beta.Dbound.psi.mc	-0.185	0.928	-2.756	-0.381	-0.05	0.24	1.156	1.008	1200
beta.Dbound.psi.tg	0.774	0.479	-0.025	0.478	0.749	1.034	1.663	1.004	10000
beta.Disturb.psi.cl	3.32	2.321	-0.149	1.627	2.943	4.67	8.862	1.001	22000
beta.Disturb.psi.gc	2.377	1.479	0.52	1.371	2.039	2.985	6.418	1.001	18000
beta.Disturb.psi.lc	-0.404	0.239	-0.878	-0.56	-0.401	-0.244	0.055	1.001	14000
beta.Disturb.psi.mc	4.299	2.926	-0.327	2.031	4.325	6.566	9.555	1.002	3900
beta.Disturb.psi.tg	4.576	1.894	1.66	3.127	4.312	5.765	8.936	1.001	9500
beta.Dwway.psi.cl	-0.216	0.493	-0.845	-0.42	-0.241	-0.065	0.382	1.026	1400
beta.Dwway.psi.gc	0.404	0.249	-0.061	0.236	0.396	0.564	0.92	1.001	120000
beta.Dwway.psi.lc	-0.01	0.256	-0.509	-0.181	-0.011	0.159	0.499	1.001	38000
beta.Dwway.psi.mc	-0.282	1.012	-2.347	-0.664	-0.211	0.105	1.816	1.009	46000
beta.Ele.psi.cl	0.49	0.894	-0.877	-0.069	0.417	1.005	2.252	1.002	2800
beta.Ele.psi.gc	1.187	0.719	-0.225	0.721	1.189	1.645	2.633	1.001	34000
beta.Ele.psi.lc	-0.538	0.381	-1.309	-0.781	-0.53	-0.291	0.2	1.001	44000
beta.Ele.psi.mc	1.671	1.845	-0.327	0.461	1.125	2.32	6.982	1.004	930
beta.Ele.psi.tg	1.831	0.674	0.738	1.349	1.763	2.233	3.307	1.001	15000
beta.Water.psi.cl	0.215	0.338	-0.335	0.012	0.192	0.379	0.868	1.007	2400
beta.Water.psi.gc	0.323	0.25	-0.154	0.155	0.318	0.486	0.831	1.001	98000
beta.Water.psi.lc	0.25	0.233	-0.204	0.093	0.248	0.405	0.712	1.001	140000
beta.Water.psi.mc	0.469	0.856	-0.659	0.049	0.326	0.672	2.762	1.007	1600
beta.effort.p.cl	0.091	0.13	-0.16	0.002	0.089	0.177	0.351	1.001	11000
beta.effort.p.gc	0.319	0.145	0.042	0.22	0.317	0.415	0.611	1.001	53000
beta.effort.p.lc	0.234	0.145	-0.049	0.136	0.234	0.332	0.52	1.001	62000
beta.effort.p.mc	-0.229	0.164	-0.537	-0.341	-0.235	-0.123	0.11	1.001	11000
beta.effort.p.tg	-0.219	0.205	-0.611	-0.359	-0.222	-0.083	0.191	1.001	140000
beta.psi.WithCL.gc	0.672	0.608	-0.492	0.268	0.662	1.064	1.91	1.001	19000
beta.psi.WithCL.lc	0.934	0.577	-0.173	0.548	0.925	1.309	2.094	1.001	37000
beta.psi.WithCL.mc	0.458	0.801	-1.224	-0.049	0.493	0.996	1.959	1.001	6300
beta.psi.WithGC.lc	1.543	0.522	0.541	1.189	1.536	1.888	2.59	1.001	24000
beta.psi.WithGC.mc	-0.136	0.717	-1.537	-0.607	-0.142	0.327	1.309	1.001	23000
beta.psi.WithMC.lc	1.257	0.679	-0.131	0.823	1.269	1.707	2.562	1.002	3700
beta.psi.WithTG.cl	0.789	0.738	-0.644	0.291	0.784	1.282	2.261	1.001	200000
beta.psi.WithTG.gc	0.941	0.688	-0.392	0.477	0.934	1.398	2.315	1.001	120000
beta.psi.WithTG.lc	1.228	0.642	-0.024	0.794	1.223	1.658	2.496	1.001	88000
beta.psi.WithTG.mc	0.156	0.806	-1.437	-0.385	0.16	0.701	1.724	1.001	12000
beta.tree.psi.cl	0.123	0.466	-0.691	-0.09	0.145	0.378	0.876	1.01	1700
beta.tree.psi.gc	-0.144	0.313	-0.753	-0.353	-0.146	0.063	0.48	1.001	60000
beta.tree.psi.lc	0.401	0.273	-0.14	0.22	0.402	0.582	0.939	1.001	23000
beta.tree.psi.mc	1.022	1.612	-0.679	0.244	0.601	1.397	5.33	1.007	1000
beta.tree.psi.tg	-0.961	0.606	-2.111	-1.252	-0.906	-0.594	-0.056	1.004	31000
deviance	3344.859	62.417	3226.059	3300.902	3344.064	3387.972	3467.087	1.003	1100
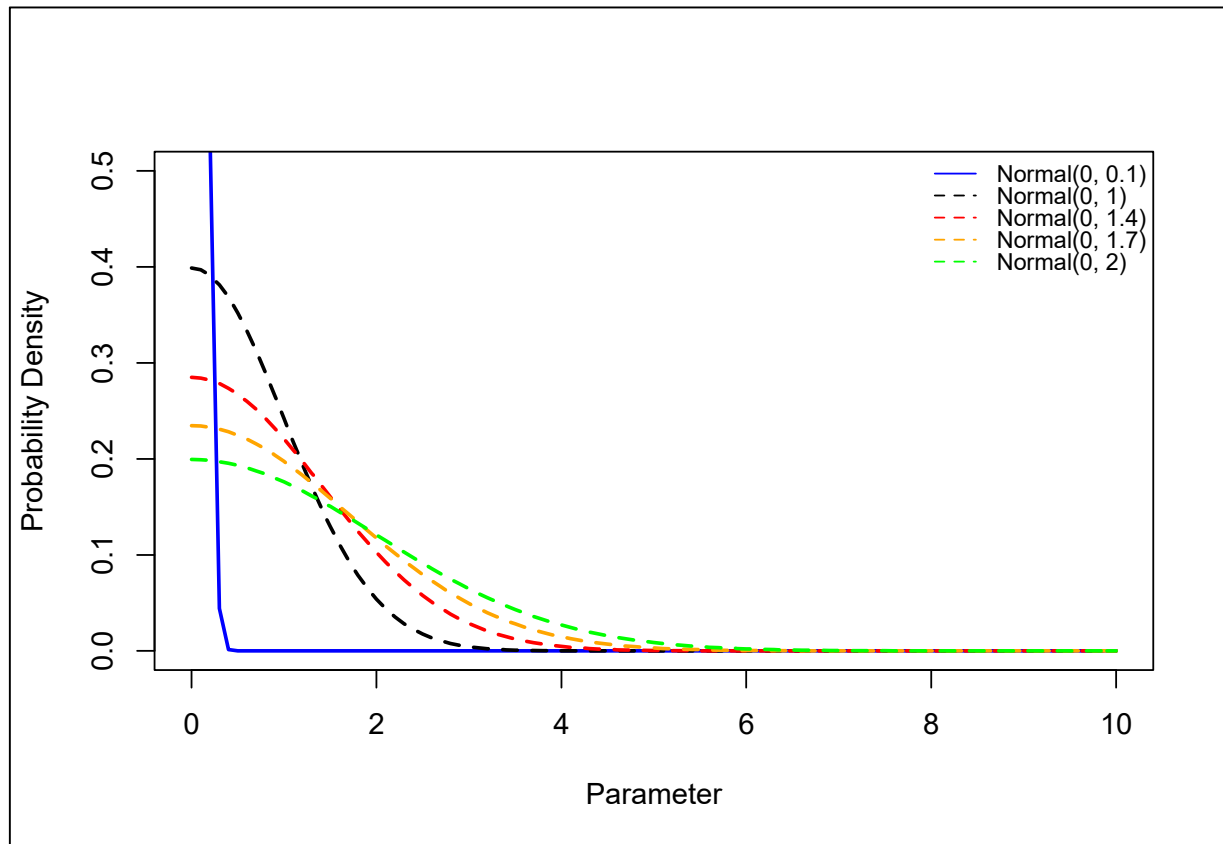
Figure S2. Sensitivity testing of priors using different standard deviation (SD) values for two-species single-season occupancy modeling

mean = 0.789

14.1% < 0 < 85.9%

95% HDI
-0.657   2.25

-4 -2   0   2   4

TG vs CL

mean = 0.941

8.4% < 0 < 91.6%

95% HDI
-0.41   2.29

-4 -2   0   2   4

TG vs GC

mean = 0.156

42.1% < 0 < 57.9%

95% HDI
-1.43   1.73

-4 -2   0   2   4

TG vs MC

mean = 1.23

2.7% < 0 < 97.3%

95% HDI
-0.02   2.5

-4 -2   0   2   4

TG vs LC

mean = 0.672

13% < 0 < 87%

95% HDI
-0.515   1.88

-4 -2   0   2   4

CL vs GC

mean = 0.458

26.9% < 0 < 73.1%

95% HDI
-1.19   1.99

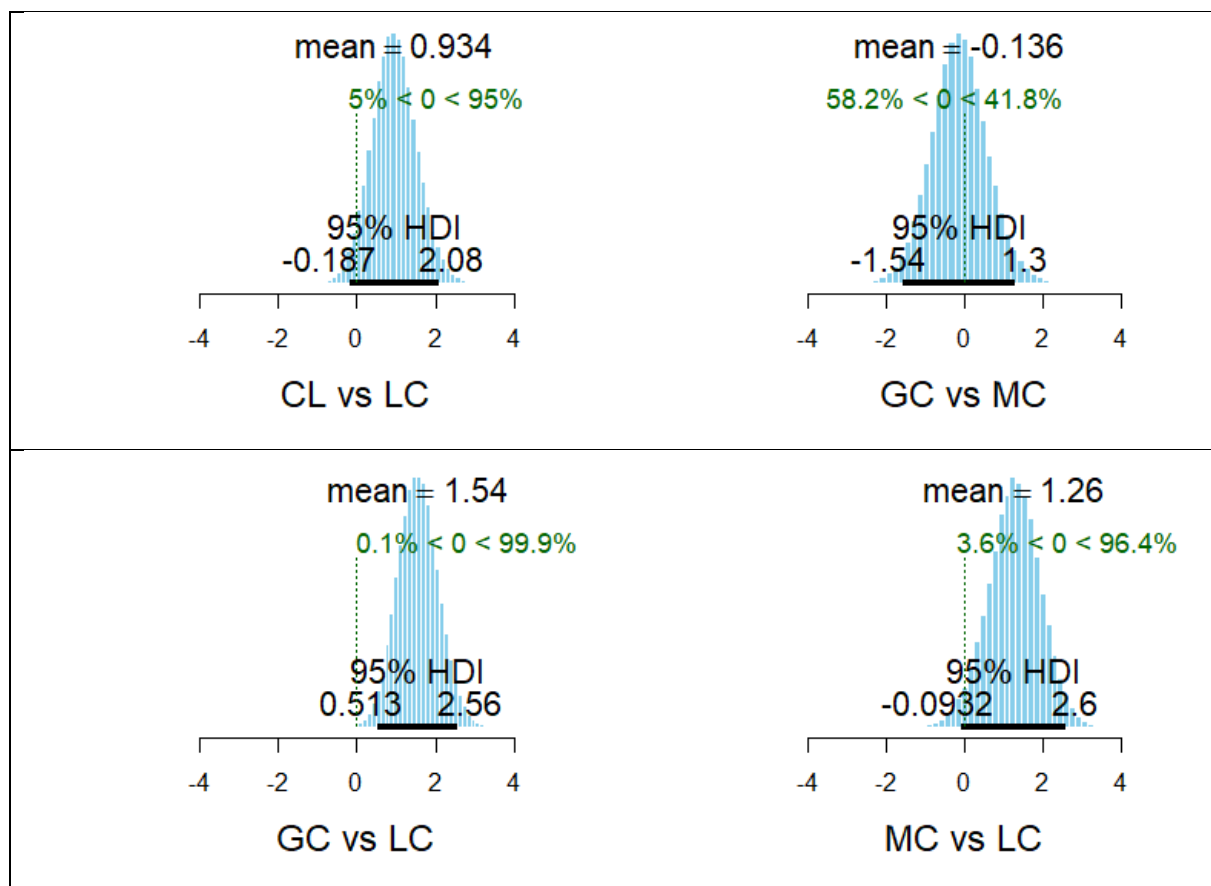-4 -2   0   2   4

CL vs MC
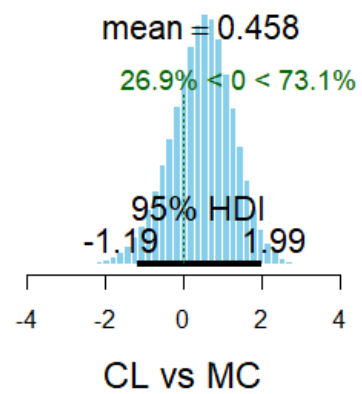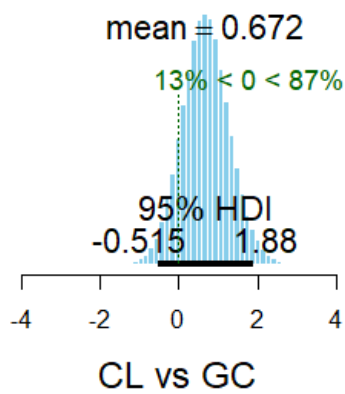
Figure S3. Overlap in two species occupancy modeling with the 95% credible density interval of the mean of posterior distribution of parameter estimates where TG=Tiger, CL= Clouded leopard, GC=Asiatic golden cat, MC=Marbled cat, LC=Leopard cat

Table S6. Comparison of Bootstrapped means for smoothing using different bandwidth values (c=1, c= 0.1 and c=0.5) to check sensitivity of smoothing effect derived for both sample sizes (n=1344 and n=823) for activity pattern overlap. Overall dataset (n=1344) and default value (c=1) is used for final interpretation. (where Tg=Tiger, Cl=Clouded leopard, Mc=Marbled cat, Gc=Asiatic golden cat, Lc=Leopard cat)

| Species-pair	Mean Overlap & 95% CI comparison (n=1344)			Mean Overlap & 95% CI comparison (n=823)		
	1 (default)	0.1	0.5	1 (default)	0.1	0.5
TgCl	0.564 (0.447-0.633)	0.564 (0.446-0.631)	0.564 (0.449-0.631)	0.624 (0.485-0.716)	0.624 (0.485-0.719)	0.624 (0.486-0.715)
TgMc	0.847 (0.808-0.974)	0.847 (0.807-0.974)	0.848 (0.806-0.974)	0.821 (0.769-0.968)	0.820 (0.772-0.967)	0.819 (0.769- 0.967)
TgGc	0.692 (0.593-0.762)	0.691 (0.593-0.761)	0.692 (0.595-0.759)	0.691 (0.573-0.785)	0.691 (0.572-0.789)	0.691 (0.574-0.788)
TgLc	0.402 (0.275-0.446)	0.402 (0.279-0.448)	0.402 (0.277-0.449)	0.407 (0.2570-0.476)	0.407 (0.257- 0.477)	0.407 (0.257-0.477)
ClMc	0.511 (0.412-0.557)	0.511 (0.412-0.556)	0.511 (0.413-0.558)	0.549 (0.441-0.613)	0.549 (0.440-0.614)	0.550 (0.441-0.612)
ClGc	0.805 (0.724-0.853)	0.805 (0.723-0.854)	0.805 (0.723-0.854)	0.833 (0.755-0.900)	0.833 (0.755-0.900)	0.833 (0.754-0.899)
CLLc	0.794 (0.745-0.851)	0.793 (0.745-0.850)	0.794 (0.745-0.851)	0.730 (0.656-0.793)	0.730 (0.665-0.791)	0.730 (0.657-0.792)
McGc	0.631 (0.541-0.672)	0.631 (0.538-0.672)	0.631 (0.537-0.672)	0.615 (0.512-0.674)	0.614 (0.509-0.674)	0.615 (0.5112-0.674)
McLc	0.338 (0.240-0.359)	0.338 (0.239-0.359)	0.337 (0.239-0.359)	0.314 (0.205-0.349)	0.314 (0.202-0.347)	0.314 (0.202- 0.347)
GcLc	0.678 (0.609-0.719)	0.678 (0.609-0.719)	0.678 (0.607-0.719)	0.658 (0.572-0.709)	0.658 (0.571- 0.709)	0.657 (0.571-0.711)
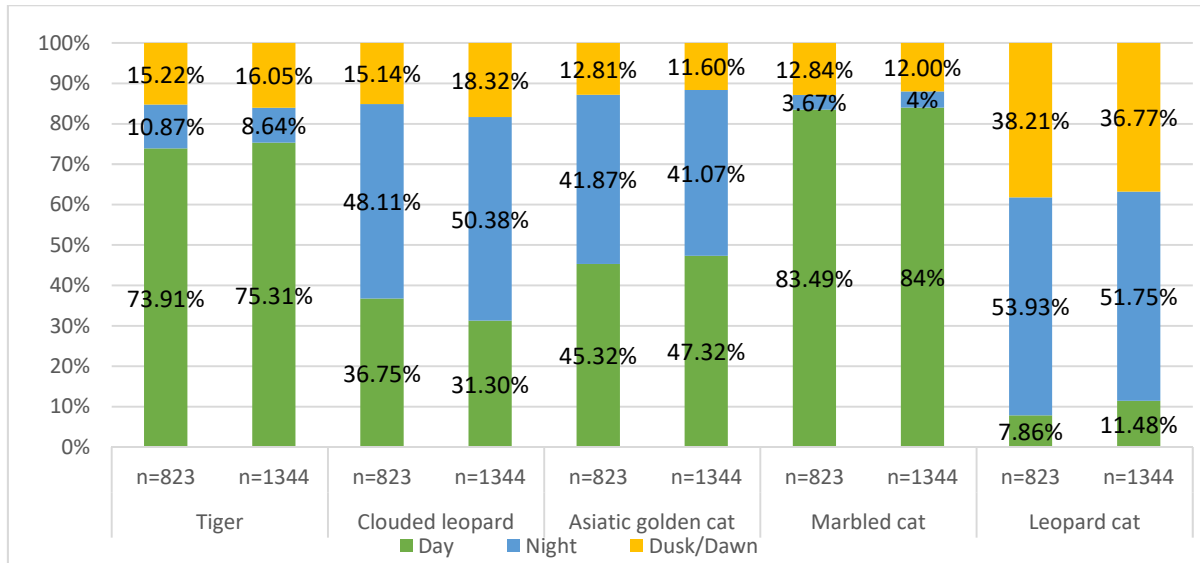
Figure S4. Diel activity of tiger, clouded leopard, Asiatic golden cat, marbled cat and leopard cat (n= 823 represent dataset used for space use and interaction, n=1344 represent combination of all camera trap data surveyed during 2014-2018)
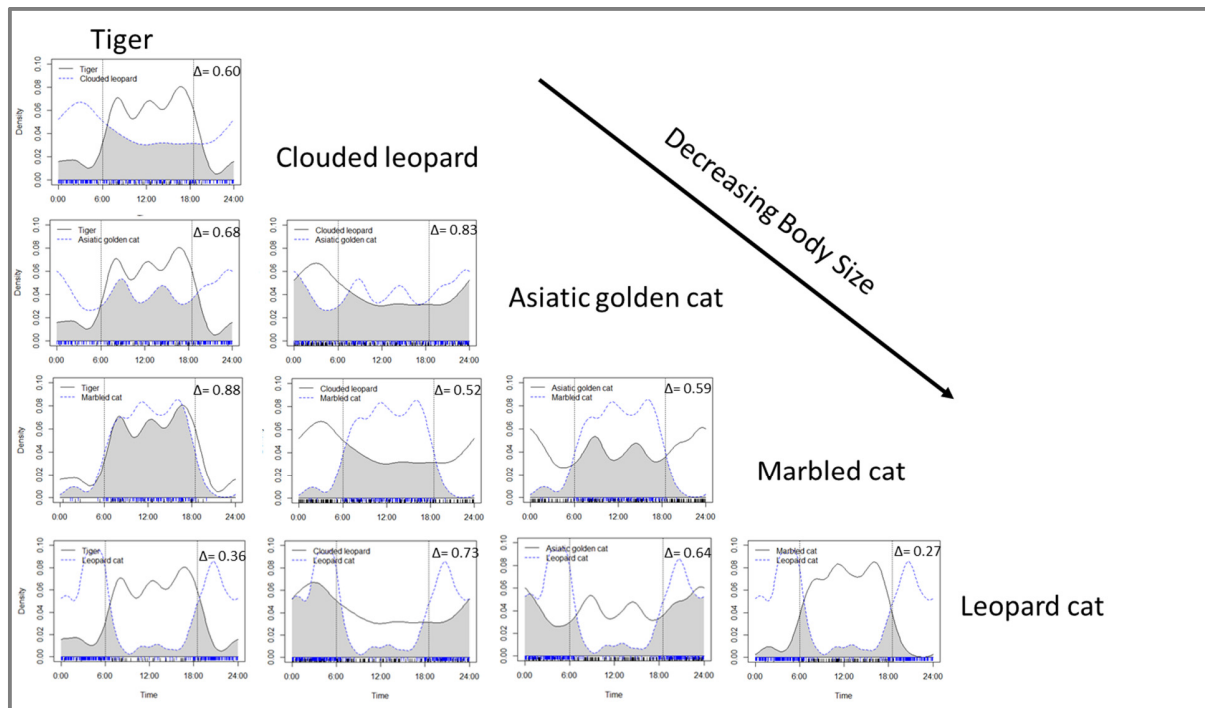

Figure S5. Activity overlap of tiger, clouded leopard, marbled cat and Asiatic golden cat from occupancy survey data (n=823). Dotted vertical lines at 06:00 and 18:00 hour represents the approximate dawn and dusk. Activities detected for each species are represented by blue and black coloured rugs on x axes.

Table S7. Observed temporal activity of tiger, clouded leopard, Asiatic golden cat, marbled cat and leopard cat in Htamanthi Wildlife Sanctuary and comparison to findings around Southeast Asia region

Site	Dial Activity	Source
Tiger		
Htamanthi WS (Myanmar)	**73% to 75% Diurnal**	**This study**
Sundarban (Bangladesh)	Nocturnal and Crepuscular	[10]
Thailand	57% Diurnal	[11]
Jerangau (Peninsular Malaysia)	37% Diurnal	[12]
Kerinci-Seblat(Sumatra)	62% Diurnal	[13]
Clouded leopard		
Htamanthi WS (Myanmar)	**31% to 37% Diurnal**	**This study**
Dampha (India)	40% Diurnal	[14]
Thailand	27% Diuranl	[11]
Jerangau (Peninsular Malaysia)	25% Diurnal	[12]
Kerinci-Seblat(Sumatra)	36.1% Diurnal	[15]
Sabah (Borneo)	23.9% (male) and 26.3% (female) Diurnal	[16]
Senbangau (Borneo)	24% Diurnal	[17]
Asiatic golden cat		
Htamanthi WS (Myanmar)	**45% to 47% Diurnal**	**This study**
Dampha (India)	67% Diurnal	[14]
Thailand	58% Diurnal	[11]
Jerangau (Peninsular Malaysia)	62% Diurnal	[12]
Kerinci-Seblat(Sumatra)	62% Diurnal	[15]
Marbled cat		
Htamanthi WS (Myanmar)	**83% to 84% Diurnal**	**This study**
Dampha (India)	83.4% Diurnal	[14]
Thailand	100% Diurnal	[11]
Johor (Penensular Malaysia)	82% Diurnal	[18]
Sabah (Borneo)	62% Diurnal	[16]
Sebangau (Borneo)	50% Diurnal	[17]
Leopard cat		
Htamanthi WS (Myanmar	**7% to 11% Diurnal**	**This study**
Sabangau peat-swamp (Indonesian Borneo)	65% Nocturnal	[17]
Thailand	85% Nocturnal	Lynam et al., 2013)
Jerangau (Peninsular Malaysia)	77% Nocturnal	[12]

Note: The activity patterns were compiled in the table as diurnal (except leopard cat) regarding the crepuscular activities as part of nocturnal activity. Please refer to original source for detail

Table S8. Model metrices for Mantel test evaluating the support for each hypothesis where h= hypothesis, size = difference in body size, space = spatial overlap between a pair of species, time = temporal overlap between a pair of species, both = spatio-temporal overlap index

h1	Tiger	Clouded leopard	Asiatic golden cat	Marbled cat	leopard
Tiger	0	-10	-8	-6	0
Clouded leopard	-10	0	0	0	0
Asiatic golden cat	-8	0	0	0	0
Marbled cat	-6	0	0	0	0
Leopard cat	0	0	0	0	0

h2	Tiger	Clouded leopard	Asiatic golden cat	Marbled cat	leopard
Tiger	0	-10	10	10	0
Clouded leopard	-10	0	0	0	0
Asiatic golden cat	10	0	0	0	0
Marbled cat	10	0	0	0	0
Leopard cat	0	0	0	0	0

h3	Tiger	Clouded leopard	Asiatic golden cat	Marbled cat	leopard
Tiger	0	0	0	0	0
Clouded leopard	0	0	-10	-5	0
Asiatic golden cat	0	-10	0	0	0
Marbled cat	0	-5	0	0	0
Leopard cat	0	0	0	0	0

h4	Tiger	Clouded leopard	Asiatic golden cat	Marbled cat	leopard
Tiger	0	0	0	0	0
Clouded leopard	0	0	0	-10	0
Asiatic golden cat	0	0	0	0	0
Marbled cat	0	-10	0	0	0
Leopard cat	0	0	0	0	0

h5	Tiger	Clouded leopard	Asiatic golden cat	Marbled cat	leopard
Tiger	0	0	0	0	0
Clouded leopard	0	0	0	0	0
Asiatic golden cat	0	0	0	-10	0
Marbled cat	0	0	-10	0	0
Leopard cat	0	0	0	0	0

size	Tiger	Clouded leopard	Asiatic golden cat	Marbled cat	leopard
Tiger	0	-4	-3	-2	-1
Clouded leopard	-4	0	-4	-3	-2
Asiatic golden cat	-3	-4	0	-4	-3
Marbled cat	-2	-3	-4	0	-4
Leopard cat	-1	-2	-3	-4	0

Space	Tiger	Clouded leopard	Asiatic golden cat	Marbled cat	leopard
Tiger	0	0.86	0.92	0.58	0.97

Clouded leopard	0.86	0	0.87	0.73	0.95
Asiatic golden cat	0.92	0.87	0	0.42	1
Marbled cat	0.58	0.73	0.42	0	0.96
Leopard cat	0.97	0.95	1	0.96	0

Time	Tiger	Clouded leopard	Asiatic golden cat	Marbled cat	leopard
Tiger	0	0.54	0.068	0.89	0.36
Clouded leopard	0.54	0	0.79	0.48	0.8
Asiatic golden cat	0.068	0.79	0	0.6	0.66
Marbled cat	0.89	0.48	0.6	0	0.29
Leopard cat	0.36	0.8	0.66	0.29	0

Both	Tiger	Clouded leopard	Asiatic golden cat	Marbled cat	leopard
Tiger	0	0.46	0.63	0.52	0.35
Clouded leopard	0.46	0	0.69	0.35	0.76
Asiatic golden cat	0.63	0.69	0	0.25	0.66
Marbled cat	0.52	0.35	0.25	0	0.28
Leopard cat	0.35	0.76	0.66	0.28	0

Table S9. Ranking supports for joint niche separation hypotheses across spatial, temporal and combined dimensions. Hypotheses are ranked in order of Mantel correlation between niche overlap and the model matrix for each hypothesis. Space – hypotheses tested for spatial partitioning; Time – hypotheses tested for temporal partitioning, Both – hypotheses tested for the joint portioning of Space*Time

	Space		Time		Both
h6	0.744	h521	0.250	h56	0.559
h61	0.701	h52	0.243	h561	0.553
h56	0.690	h21	0.211	h563	0.479
h561	0.679	h2	0.203	h5631	0.471
h562	0.654	h5621	0.184	h6	0.469
h5621	0.641	h562	0.183	h61	0.455
h642	0.573	h621	0.134	h5632	0.401
h62	0.569	h62	0.128	h63	0.399
h5642	0.569	h51	0.113	h65132	0.396
h621	0.560	h5	0.093	h631	0.393
h64	0.559	h5321	0.082	h5621	0.385
h65412	0.551	h1	0.078	h562	0.381
h6421	0.540	h532	0.075	h5643	0.326
h641	0.532	h65132	0.049	h65431	0.326
h564	0.506	h5421	0.047	h51	0.317
h5641	0.502	h321	0.046	h531	0.316
h65132	0.281	h5632	0.042	h53	0.308
h5632	0.274	h32	0.037	h6321	0.298
h654321	0.259	h542	0.035	h632	0.297
h5631	0.259	h561	0.033	h5641	0.287
h65432	0.253	h56	0.016	h564	0.279
h563	0.248	h6321	0.013	h5	0.277
h51	0.229	h65412	0.009	h654321	0.277
h65431	0.226	h632	0.003	h65432	0.276
h6321	0.220	h421	-0.003	h6413	0.259
h5643	0.216	h5642	-0.005	h643	0.257
h61432	0.213	h42	-0.022	h621	0.227
h632	0.209	h531	-0.026	h5321	0.224
h521	0.208	h15432	-0.033	h31	0.221
h6432	0.205	h61	-0.039	h532	0.213
h631	0.205	h53	-0.040	h62	0.210
h1	0.198	h5432	-0.045	h3	0.208
h63	0.191	h6421	-0.046	h65412	0.208
h6413	0.186	h5631	-0.052	h5642	0.196
h5	0.176	h654321	-0.057	h61432	0.194
h643	0.174	h563	-0.067	h641	0.190

h52	0.172	h642	-0.071	h6432	0.188
h5421	0.169	h6	-0.072	h64	0.174
h542	0.143	h65432	-0.072	h5431	0.173
h541	0.138	h4321	-0.074	h1	0.172
h54	0.107	h31	-0.078	h543	0.161
h21	0.102	h432	-0.092	h321	0.116
h421	0.094	h541	-0.092	h15432	0.112
h41	0.060	h631	-0.098	h521	0.111
h42	0.056	h61432	-0.099	h32	0.097
h2	0.056	h3	-0.099	h5432	0.096
h4	0.007	h54	-0.113	h431	0.084
h15432	-0.008	h63	-0.118	h52	0.076
h5321	-0.012	h6432	-0.119	h6421	0.075
h5431	-0.034	h5641	-0.120	h43	0.064
h5432	-0.034	h5431	-0.126	h541	0.056
h532	-0.042	h543	-0.143	h642	0.046
h531	-0.044	h65431	-0.144	h54	0.025
h543	-0.061	h564	-0.144	h4321	0.011
h53	-0.078	h5643	-0.163	h432	-0.013
h4321	-0.081	h431	-0.187	h5421	-0.036
h321	-0.091	h6413	-0.198	h542	-0.070
h431	-0.114	h41	-0.214	h21	-0.083
h432	-0.116	h43	-0.214	h2	-0.134
h32	-0.128	h641	-0.215	h41	-0.146
h31	-0.141	h643	-0.226	h4	-0.220
h43	-0.154	h64	-0.266	h421	-0.225
h3	-0.190	h4	-0.268	h42	-0.290

References

1. Hansen, M.C.; Potapov, P. V.; Moore, R.; Hancher, M.; Turubanova, S.A.; Tyukavina, A.; Thau, D.; Stehman, S.V.; Goeta, S.J.; Loveland, T.R.; et al. High-resolution global maps of 21st-century forest cover change. *Science* **2013**, *342*, 850–853, doi:10.1126/science.1244693.

2. QGIS Development Team QGIS Geographic Information System 2017.

3. Penjor, U.; Tan, C.K.W.; Wangdi, S.; Macdonald, D.W. Understanding the environmental and anthropogenic correlates of tiger presence in a montane conservation landscape. *Biol. Conserv.* **2019**, *238*, 108196, doi:10.1016/j.biocon.2019.108196.

4. MacKenzie, D.I.; Nichols, J.D.; Lachman, G.B.; Droege, S.; Royle, A.A.; Langtimm, C.A. Estimating site occupancy rates when detection probabilities are less than one. *Ecology* **2002**, *83*, 2248–2255, doi:10.1890/0012-9658(2002)083[2248:ESORWD]2.0.CO;2.

5. MacKenzie, D.I.; Bailey, L.L. Assessing the fit of site-occupancy models. *J. Agric. Biol. Environ. Stat.* **2004**, *9*, 300–318, doi:10.1198/108571104X3361.

6. Barton, K. MuMIn: Multi-model inference 2019.

7. Anderson, D.R. *Model based inference in the life sciences: a primer on evidence*; Springer Science & Business Media, 2007;

8. R Core Team R: A Language and Environment for Statistical Computing 2013.

9. Fiske, I.; Chandler, R. unmarked: An R package for fitting hierarchical models of wildlife occurrence and abundance. *J. Stat. Softw.* 2011, *43*, 1–23.

10. Naha, D.; Jhala, Y. V.; Qureshi, Q.; Roy, M.; Sankar, K.; Gopal, R. Ranging, activity and habitat use by tigers in the mangrove forests of the Sundarban. *PLoS One* **2016**, *11*, e0152119, doi:10.1371/journal.pone.0152119.

11. Lynam, A.J.; Jenks, K.E.; Steinmetz, R.; Reed, D.H. Terrestrial activity patterns of wild cats from camera-trapping. *Raffles Bull. Zool.* **2013**, *61*, 407–415.

12. Azlan, J.M.; Sharma, D.S.K. The diversity and activity patterns of wild felids in a secondary forest in Peninsular Malaysia. *Oryx* **2006**, *40*, 1–6, doi:10.1017/S0030605306000147.

13. Linkie, M.; Ridout, M. Assessing tiger-prey interactions in Sumatran rainforests. *J. Zool.* **2011**, *284*, 224–229, doi:10.1111/j.1469-7998.2011.00801.x.

14. Singh, P.; Macdonald, D.W. Populations and activity patterns of clouded leopards and marbled cats in Dampa Tiger Reserve, India. *J. Mammal.* **2017**, *98*, 1453–1462, doi:10.1093/jmammal/gyx104.

15. Haidir, I.A.; Macdonald, D.W.; Linkie, M. Assessing the spatiotemporal interactions of mesopredators in Sumatra's tropical rainforest. *PLoS One* **2018**, *13*, e0202876, doi:10.1371/journal.pone.0202876.

16. Hearn, A.J.; Cushman, S.A.; Ross, J.; Goossens, B.; Hunter, L.T.B.; Macdonald, D.W. Spatio-temporal ecology of sympatric felids on Borneo. Evidence for resource partitioning? *PLoS One* **2018**, *13*, e-0200828, doi:10.1371/journal.pone.0200828.

17. Cheyne, S.M.; MacDonald, D.W. Wild felid diversity and activity patterns in Sabangau peat-

swamp forest, Indonesian Borneo. *Oryx* **2011**, *45*, 119–124, doi:10.1017/S003060531000133X.

18.   Gumal, M.; Salleh, A.B.B.M.; Yasak, M.N.; Horng, L.S.; Lee, B.P.Y.-H.; Pheng, L.C.; Hamzah, H.; Kong, D.; Magintan, D.; Yung, D.T.C.; et al. Small-medium wild cats of Endau Rompin landscape in Johor, Peninsular Malaysia. *Cat News, Spec. Issue* **2014**, 10–18.