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Wildlife Research

Supplementary Material

Patterns of livestock depredation by snow leopards and effects of intervention strategies: lessons from the Nepalese Himalaya

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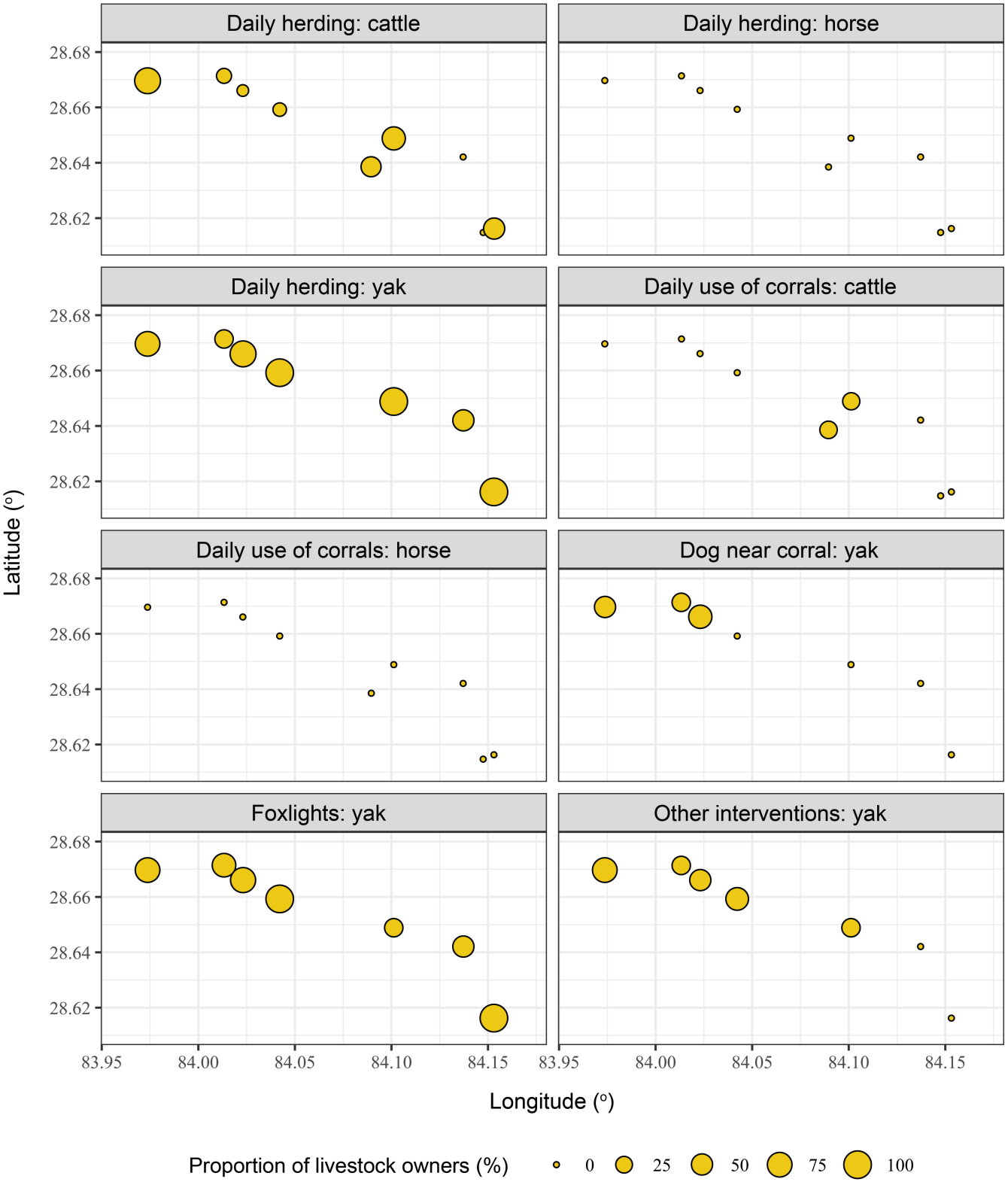
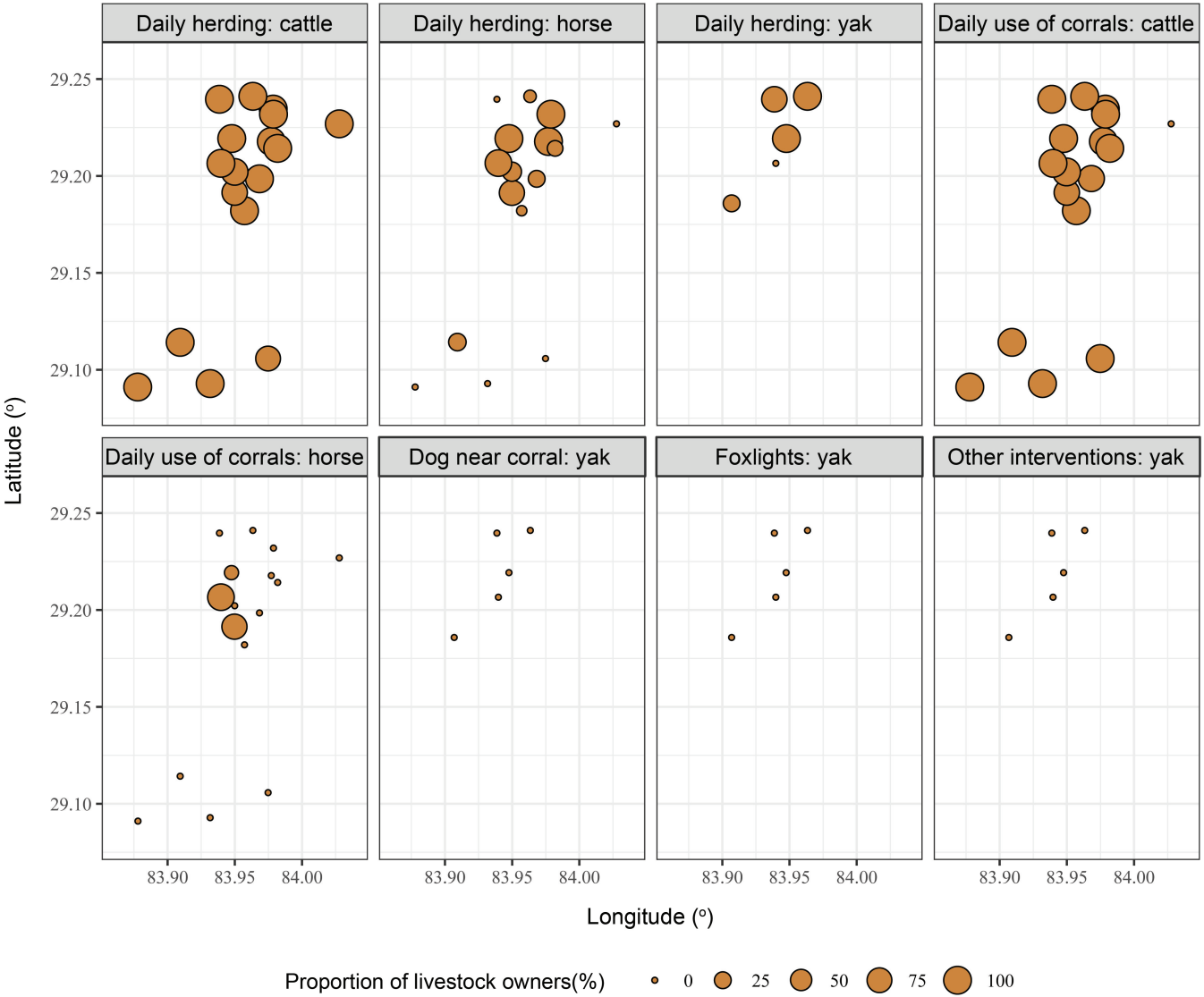

Daily herding: cattle
Daily herding: horse
Daily herding: yak
Daily use of corrals: cattle
Daily use of corrals: horse
Dog near corral: yak
Foxlights: yak
Other interventions: yak
28.68
28.66
28.64
28.62
83.95
84.00
84.05
84.10
84.15
Latitude (°)
Longitude (°)
Proportion of livestock owners (%)
0
25
50
75
100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Other interventions: yak
Latitude (°)
29.25
29.20
29.15
29.10
83.90
83.95
84.00
Longitude (°)
Proportion of livestock owners(%)
0
25
50
75
100

Table A1. Results of Mann-Whitney U tests to analyse livestock depredation attributed to snow leopards in Manang and Upper Mustang during 2018-2020.

Parameter / Comparison	Group 1			Group 2			Test statistics	
	Definition	Sample size	Mean	Definition	Sample size	Mean	U	p
Size of the livestock holding: yak	Manang	146	8.2	Upper Mustang	183	2.4	15434	< 0.001
Size of the livestock holding: cattle	Manang	146	3.2	Upper Mustang	183	4.4	8547.5	< 0.001
Size of the livestock holding: dzo	Manang	146	0.0	Upper Mustang	183	0.1	12556	0.003
Size of the livestock holding: horse	Manang	146	1.2	Upper Mustang	183	1.6	11462	0.022
Size of the livestock holding: sheep/goat	Manang	146	7.6	Upper Mustang	183	22.3	11682	0.009
Size of the livestock holding: all	Manang	146	20.2	Upper Mustang	183	30.8	10482	0.001
Number of animals killed per attack: yak	daytime	42	1.0	night-time	37	1.7	496	< 0.001
Number of animals killed per attack: cattle	daytime	11	1.0	night-time	22	1.1	110	0.332
Number of animals killed per attack: horse	daytime	5	1.0	night-time	25	1.1	57.5	0.562
Number of animals killed per attack: sheep/goat	daytime	23	1.5	night-time	41	8.0	66.5	< 0.001
Number of animals killed per attack: all	daytime	81	1.2	night-time	125	3.5	3239	< 0.001
Number of sheep/goats killed per attack in corral	stone wall hut/house	9	4.6	simple stone wall corral	26	9.4	93.5	0.381
Number of sheep/goats killed per attack in corral	stone wall hut/house	9	4.6	wire-fenced corral	3	10.0	8	0.346
Number of sheep/goats killed per attack in corral	simple stone wall corral	26	9.4	wire-fenced corral	3	10.0	31.5	0.614
Number of yaks killed per attack during daytime	shepherds present	28	1	shepherds absent	14	1.0	182	0.329
Number of yaks killed per attack during night-time	Foxlights active	14	1.6	Foxlights inactive	17	1.2	144	0.233
Number of yaks killed per attack during night-time	dogs present	4	1.3	dogs absent	27	1.4	49	0.745

Table A2. Results of χ2 tests to analyse livestock depredation attributed to snow leopards in Manang and Upper Mustang during 2018-2020.

Parameter/Comparison	Species	Sample size		Test statistics	
		Manang	Upper Mustang	χ^2	p
Differences in the composition of the livestock community between Manang and Upper Mustang	all			1478.7	< 0.001
Seasonal differences in depredation patterns in Manang	yak	74		2.92	0.404
Seasonal differences in depredation patterns in Manang	cattle	34		2.41	0.491
Seasonal differences in depredation patterns in Manang	horse	19		3.83	0.280
Seasonal differences in depredation patterns in Manang	sheep/goat	25		0.36	0.948
Seasonal differences in depredation patterns in Manang	all	152		4.10	0.251
Seasonal differences in depredation patterns in Upper Mustang	yak		7	2.85	0.415
Seasonal differences in depredation patterns in Upper Mustang	cattle		4	2.67	0.446
Seasonal differences in depredation patterns in Upper Mustang	horse		29	7.03	0.071
Seasonal differences in depredation patterns in Upper Mustang	sheep/goat		40	1.77	0.622
Seasonal differences in depredation patterns in Upper Mustang	all		80	4.35	0.226
Seasonal differences in depredation patterns between Manang and Upper Mustang	yak	74	7	7.01	0.071
Seasonal differences in depredation patterns between Manang and Upper Mustang	cattle	34	4	2.43	0.488
Seasonal differences in depredation patterns between Manang and Upper Mustang	horse	19	29	2.92	0.405
Seasonal differences in depredation patterns between Manang and Upper Mustang	sheep/goat	25	40	2.46	0.482
Seasonal differences in depredation patterns between Manang and Upper Mustang	all	152	80	4.71	0.194
Daytime differences in depredation patterns in Manang	yak	73		0.56	0.455
Daytime differences in depredation patterns in Manang	cattle	30		1.74	0.188
Daytime differences in depredation patterns in Manang	horse	15		4.97	0.026
Daytime differences in depredation patterns in Manang	sheep/goat	25		0.51	0.475
Daytime differences in depredation patterns in Manang	all	143		0.09	0.767
Daytime differences in depredation patterns in Upper Mustang	yak		6	1.78	0.182
Daytime differences in depredation patterns in Upper Mustang	cattle		3	0.00	1.000
Daytime differences in depredation patterns in Upper Mustang	horse		15	0.88	0.348

Daytime differences in depredation patterns in Upper Mustang	sheep/goat		39	7.56	0.006
Daytime differences in depredation patterns in Upper Mustang	all		63	10.64	0.001
Daytime differences in depredation patterns between Manang and Upper Mustang	yak	73	6	5.24	0.022
Daytime differences in depredation patterns between Manang and Upper Mustang	cattle	30	3	0.42	0.521
Daytime differences in depredation patterns between Manang and Upper Mustang	horse	15	15	0.96	0.327
Daytime differences in depredation patterns between Manang and Upper Mustang	sheep/goat	25	39	12.10	0.001
Daytime differences in depredation patterns between Manang and Upper Mustang	all	143	63	12.18	< 0.001

Table A3. Seasonal patterns of livestock depredation attributed to snow leopards in Manang and Upper Mustang during 2018-2020.

Season	Species	Attacks by snow leopards				Individuals depredated by snow leopards			
		Manang		Upper Mustang		Manang		Upper Mustang	
		Number	Proportion (%)	Number	Proportion (%)	Number	Proportion (%)	Number	Proportion (%)
spring	yak	27	36.5	0	0	34	38.2	0	0
	cattle	5	14.7	0	0	5	13.9	0	0
	horse	5	26.3	3	10.3	5	26.3	3	9.4
	sheep/goat	6	24	11	27.5	21	31.8	100	33.4
	all	43	28.3	14	17.3	65	31	103	28.9
summer	yak	19	25.7	1	14.3	23	25.8	2	9.5
	cattle	14	41.2	2	50	16	44.4	2	50
	horse	9	47.4	17	58.6	9	47.4	20	62.5
	sheep/goat	8	32	9	22.5	18	27.3	34	11.4
	all	50	32.9	30	37	66	31.4	59	16.5
autumn	yak	13	17.6	2	28.6	15	16.9	4	19
	cattle	8	23.5	2	50	8	22.2	2	50
	horse	4	21.1	5	17.2	4	21.1	5	15.6
	sheep/goat	5	20	14	35	8	12.1	80	26.8
	all	30	19.7	23	28.4	35	16.7	91	25.5
winter	yak	15	20.3	4	57.1	17	19.1	15	71.4
	cattle	7	20.6	0	0	7	19.4	0	0
	horse	1	5.3	4	13.8	1	5.3	4	12.5
	sheep/goat	6	24	6	15	19	28.8	85	28.4
	all	29	19.1	14	17.3	44	21	104	29.1

Table A4. Daytime patterns of livestock depredation attributed to snow leopards in Manang and Upper Mustang during 2018-2020. Depredation events at unknown times of attack and during transition times (dusk and dawn) are disregarded.

Time	**Species**	**Attacks by snow leopards**				**Number of individuals killed by snow leopards**				**Number of individuals killed per attack**		
		Manang		Upper Mustang		Manang		Upper Mustang		Manang	Upper Mustang	combined
		Number	%	Number	%	Number	%	Number	%			
daytime	yak	42	57.5	0	0.0	44	50.0	0	0.0	1.0		1.0
	cattle	9	30.0	2	66.7	9	28.1	2	66.7	1.0	1.0	1.0
	horse	1	6.7	4	26.7	1	6.7	4	23.5	1.0	1.0	1.0
	sheep/goat	16	64.0	7	17.9	25	37.9	10	3.4	1.6	1.4	1.5
	all	68	47.6	13	20.6	79	39.3	16	4.8	1.2	1.2	1.2
night-time	yak	31	42.5	6	100.0	44	50.0	18	100.0	1.4	3.0	1.7
	cattle	21	70.0	1	33.3	23	71.9	1	33.3	1.1	1.0	1.1
	horse	14	93.3	11	73.3	14	93.3	13	76.5	1.0	1.2	1.1
	sheep/goat	9	36.0	32	82.1	41	62.1	286	96.6	4.6	8.9	8.0
	all	75	52.4	50	79.4	122	60.7	318	95.2	1.6	6.4	3.5

Table A5. List of interventions applied by livestock owners in Manang and Upper Mustang during 2018-2020.

Region	Species	Households (n)	Shepherd herding during daytime grazing			Corral use during night-time			Corral type during night-time			Dogs		Foxlights	Other interventions[A]
			daily	variable	occasional	daily	variable	never	simple stone wall corral	iron/wire-fenced corral	stone wall hut/house	Daytime	Night-time		Night-time
Manang	yak	33	27	2	4	0	33	0	33	1	0	0	12	25	15
	cattle	127	36	7	84	5	122	0	0	0	127	0	0	1	0
	dzo	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	horse	94	0	0	94	0	94	0	0	0	94	0	0	0	0
	sheep/goat	26	26	0	0	26	0	0	0	0	26	1	1	0	0
Upper Mustang	yak	13	8	4	1	0	12	1	11	1	0	0	0	0	0
	cattle	172	168	0	4	160	12	0	0	0	172	0	0	0	0
	dzo	11	1	0	10	0	11	0	11	0	0	0	0	0	0
	horse	123	38	0	85	17	106	0	1	0	122	0	0	0	0
	sheep/goat	53	53	0	0	53	0	0	50	3	0	1	1	0	0

[A]including other light deterrents, music playing, flapping tapes and dung burning

Table A6. Summary of model-averaged results of the top-ranked generalised linear models (GLMs, ΔAICc < 2) describing livestock depredation attributed to snow leopards in Manang and Upper Mustang during 2018-2020.

Species	Daytime	Model type	Response variable	Predictor variable	Estimate	SE	95% CI	p
yak	daytime	total_number + proportion_juveniles + shepherds_daily + region						
		binomial	depredation yes/no	Intercept	-0.230	1.434	-3.080 – 2.619	0.874
				region_UpperMustang	-20.682	2649.5	-5365.4 – 5324.0	0.994
				shepherds_daily_yes	1.407	1.511	-1.593 – 4.407	0.358
				total_number	0.963	0.762	-0.552 – 2.478	0.213
		Poisson	number of depredation events	Intercept	-1.793	1.053	-3.914 – 0.328	0.098
				region_UpperMustang	-19.127	2334.6	-4730.5 – 4692.3	0.994
				shepherds_daily_yes	2.189	1.099	-0.024 – 4.402	0.053
				total_number	0.146	0.168	-0.188 – 0.481	0.391
				proportion_juveniles	-0.116	0.197	-0.509 – 0.276	0.561
			number of animals depredated	Intercept	-1.813	1.050	-3.929 – 0.302	0.093
				region_UpperMustang	-19.168	2320.9	-4702.7 – 4664.4	0.994
				shepherds_daily_yes	2.266	1.093	0.065 – 4.467	0.044
				total_number	0.129	0.159	-0.188 – 0.445	0.425
				proportion_juveniles	-0.119	0.195	-0.507 – 0.269	0.548
	night-time	total_number + proportion_juveniles + dogs_use + foxlights_use + other_interventions_use + region						
		binomial	depredation yes/no	Intercept	0.257	0.398	-0.542 – 1.057	0.528
				total_number	1.220	0.437	0.340 – 2.100	0.007
				proportion_juveniles	0.188	0.330	-0.469 – 0.845	0.575
				dogs_use_yes	-0.386	0.699	-1.777 – 1.005	0.586
		binomial[A]	depredation yes/no	Intercept	0.152	0.345	-0.544 – 0.848	0.668
				total_number	1.194	0.423	0.342 – 2.045	0.006
				proportion_juveniles	0.157	0.298	-0.437 – 0.751	0.605
		binomial[B]	depredation yes/no	Intercept	0.196	0.379	-0.566 – 0.958	0.615

				total_number	1.212	0.427	0.352 – 2.073	0.006
				proportion_juveniles	0.126	0.274	-0.420 – 0.671	0.652
				multiple_interventions_use_yes	-0.099	0.377	-0.853 – 0.655	0.798
		Poisson	number of depredation events	Intercept	-0.324	0.271	-0.867 – 0.219	0.243
				proportion_juveniles	0.472	0.206	0.056 – 0.888	0.026
				total_number	0.477	0.172	0.130 – 0.823	0.007
				dogs_use_yes	-0.215	0.390	-0.990 – 0.560	0.586
				region_UpperMustang	-0.271	0.446	-1.157 – 0.615	0.549
				other_interventions_use_yes	-0.097	0.284	-0.663 – 0.468	0.736
		Poisson[A]	number of depredation events	Intercept	-0.431	0.223	-0.881 – 0.019	0.060
				proportion_juveniles	0.475	0.206	0.058 – 0.891	0.025
				total_number	0.467	0.162	0.140 – 0.795	0.005
				region_UpperMustang	-0.162	0.348	-0.856 – 0.531	0.646
		Poisson[B]	number of depredation events	Intercept	-0.180	0.380	-0.932 – 0.572	0.639
				multiple_interventions_use_yes	-0.441	0.516	-1.461 – 0.579	0.397
				region_UpperMustang	-0.415	0.589	-1.579 – 0.748	0.484
				total_number	0.511	0.171	0.168 – 0.855	0.004
				proportion_juveniles	0.330	0.279	-0.222 – 0.883	0.241
		zero-inflated negative binomial	number of animals depredated	count_Intercept	0.455	0.230	0.004 – 0.906	0.048
				count_other_interventions_use_yes	-0.578	0.411	-1.383 – 0.228	0.160
				count_total_number	0.709	0.159	0.397 – 1.021	<0.001
				zero_Intercept	-1.292	0.716	-2.696 – 0.111	0.071
				count_proportion_juveniles	0.052	0.128	-0.200 – 0.303	0.686
		zero-inflated negative binomial[A]	number of animals depredated	count_Intercept	0.274	0.218	-0.153 – 0.702	0.209
				count_total_number	0.661	0.170	0.328 – 0.993	<0.001
				zero_Intercept	-1.336	0.783	-2.871 – 0.199	0.088

				count_number_of_interventions	-0.146	0.179	-0.498 – 0.206	0.415
				count_proportion_juveniles	0.085	0.164	-0.236 – 0.406	0.606
		zero-inflated negative binomial[B]	number of animals depredated	count_Intercept	0.546	0.196	0.163 – 0.930	0.005
				count_multiple_interventions_use	-0.843	0.313	-1.457 – -0.229	0.007
				count_total_number	0.722	0.141	0.445 – 0.998	<0.001
				zero_Intercept	-1.368	0.675	-2.690 – -0.046	0.043
				count_proportion_juveniles	0.084	0.156	-0.222 – 0.389	0.592
cattle	daytime	total_number + proportion_juveniles + shepherds_daily + region						
		binomial	depredation yes/no	Intercept	-2.793	0.439	-3.657 – -1.929	<0.001
				region_UpperMustang	-1.851	0.857	-3.537 – -0.165	0.031
				total_number	0.439	0.224	-0.002 – 0.880	0.051
				proportion_juveniles	-0.042	0.218	-0.471 – 0.388	0.849
				shepherds_daily_yes	0.079	0.430	-0.767 – 0.925	0.854
		Poisson	number of depredation events	Intercept	-2.731	0.397	-3.512 – -1.949	<0.001
				region_UpperMustang	-1.899	0.838	-3.549 – -0.250	0.024
				total_number	0.181	0.195	-0.202 – 0.563	0.354
				shepherds_daily_yes	0.140	0.460	-0.764 – 1.045	0.761
				proportion_juveniles	-0.031	0.171	-0.367 – 0.304	0.856
		Poisson	number of animals depredated	Intercept	-2.731	0.397	-3.512 – -1.949	<0.001
				region_UpperMustang	-1.899	0.838	-3.549 – -0.250	0.024
				total_number	0.181	0.195	-0.202 – 0.563	0.354
				shepherds_daily_yes	0.140	0.460	-0.764 – 1.045	0.761
				proportion_juveniles	-0.031	0.171	-0.367 – 0.304	0.856
	night-time	total_number + proportion_juveniles + corral_use_daily + region						
		binomial	depredation yes/no	Intercept	-1.800	0.293	-2.377 – -1.223	<0.001
				region_UpperMustang	-4.032	1.352	-6.691 – -1.373	0.003
				total_number	0.128	0.197	-0.259 – 0.515	0.517
				proportion_juveniles	0.222	0.289	-0.346 – 0.791	0.443

				corral_use_daily_yes	0.553	0.937	-1.288 – 2.394	0.556
		negative binomial	number of depredation events	Intercept	-1.767	0.263	-2.284 – -1.251	<0.001
				region_UpperMustang	-3.704	1.197	-6.059 – -1.348	0.002
				proportion_juveniles	0.115	0.213	-0.302 – 0.533	0.588
				corral_use_daily_yes	0.270	0.648	-1.004 – 1.544	0.678
				total_number	0.028	0.094	-0.156 – 0.212	0.764
		negative binomial	number of animals depredated	Intercept	-1.652	0.273	-2.190 – -1.115	<0.001
				region_UpperMustang	-3.781	1.192	-6.127 – -1.436	0.002
				proportion_juveniles	0.173	0.254	-0.326 – 0.672	0.497
				corral_use_daily_yes	0.199	0.613	-1.006 – 1.403	0.747
				total_number	0.028	0.106	-0.181 – 0.237	0.792
horse	night-time	total_number + proportion_juveniles + corral_use_daily + region						
		binomial	depredation yes/no	Intercept	-2.161	0.347	-2.844 – -1.478	<0.001
				region_UpperMustang	-0.393	0.509	-1.393 – 0.608	0.441
				total_number	0.551	0.217	0.124 – 0.977	0.011
				proportion_juveniles	0.033	0.121	-0.206 – 0.271	0.788
				corral_use_daily_yes	0.036	0.314	-0.582 – 0.654	0.908
		Poisson	number of depredation events	Intercept	-2.117	0.321	-2.748 – -1.485	<0.001
				region_UpperMustang	-0.480	0.490	-1.444 – 0.483	0.328
				total_number	0.506	0.191	0.131 – 0.881	0.008
				proportion_juveniles	0.125	0.167	-0.205 – 0.454	0.458
		Poisson	number of animals depredated	Intercept	-2.143	0.297	-2.727 – -1.559	<0.001
				proportion_juveniles	0.172	0.177	-0.176 – 0.520	0.333
				total_number	0.464	0.188	0.094 – 0.834	0.014
				region_UpperMustang	-0.283	0.404	-1.078 – 0.512	0.485
				corral_use_daily_yes	0.088	0.344	-0.589 – 0.764	0.800
sheep/ goat	daytime	total_number + proportion_juveniles + region						
		binomial	depredation yes/no	Intercept	-0.660	0.421	-1.497 – 0.178	0.123
				region_UpperMustang	-1.617	0.631	-2.874 – -0.360	0.012

				proportion_juveniles	0.101	0.226	-0.346 – 0.548	0.658
				total_number	-0.060	0.259	-0.573 – 0.454	0.820
		negative binomial	number of depredation events	Intercept	-0.507	0.342	-1.188 – 0.174	0.145
				region_UpperMustang	-1.675	0.554	-2.779 – -0.572	0.003
				proportion_juveniles	0.053	0.162	-0.267 – 0.373	0.745
				total_number	-0.045	0.215	-0.471 – 0.381	0.836
		negative binomial	number of animals depredated	Intercept	-0.061	0.428	-0.914 – 0.792	0.888
				region_UpperMustang	-1.964	0.626	-3.210 – -0.718	0.002
				total_number	-0.086	0.297	-0.675 – 0.503	0.775
	night-time	total_number + proportion_juveniles + region						
		binomial	depredation yes/no	Intercept	-0.388	0.368	-1.118 – 0.341	0.297
				total_number	0.639	0.348	-0.053 – 1.332	0.070
				region_UpperMustang	0.189	0.403	-0.608 – 0.986	0.642
				proportion_juveniles	-0.027	0.121	-0.267 – 0.214	0.827
		Poisson	number of depredation events	Intercept	-0.851	0.278	-1.403 – -0.299	0.003
				total_number	0.095	0.122	-0.146 – 0.337	0.438
				region_UpperMustang	0.150	0.306	-0.456 – 0.756	0.628
				proportion_juveniles	-0.009	0.063	-0.135 – 0.116	0.886
		zero-inflated negative binomial	number of animals depredated	count_Intercept	1.684	0.351	0.997 – 2.371	<0.001
				count_total_number	0.407	0.140	0.133 – 0.681	0.004
				zero_Intercept	0.102	0.269	-0.425 – 0.630	0.703
				count_region_UpperMustang	0.268	0.393	-0.501 – 1.038	0.494
				count_proportion_juveniles	0.035	0.088	-0.136 – 0.207	0.688

[A]total_number + proportion_juveniles + number_interventions + region

[B]total_number + proportion_juveniles + multiple_interventions_use + region