10.1071/WR20059_AC

Supplementary Material: *Wildlife Research*, 2021, 48(2), 163–174.

Red deer allocate vigilance differently in response to spatio-temporal patterns of risk from human hunters and wolves

Nathan J. Proudman[A,C,D], *Marcin Churski*[A], *Jakub W. Bubnicki*[A], *Jan-Åke Nilsson*[B] *and Dries P. J. Kuijper*[A]

[A]Mammal Research Institute, Polish Academy of Sciences, ul. Stoczek 1 17-230 Białowieża, Poland.

[B]Department of Biology, Lund University, Sölvegatan 37, 223 62 Lund, Sweden.

[C]Present address: Oklahoma State University, 305 Noble Research Center, Stillwater, OK 74075, USA.

[D]Corresponding author. Email: nathan.j.proudman@okstate.edu

Table S1. All red deer observations used in final analysis (*n* = 157) by year during open and closed hunting season

Hunting season	2009	2012	2013	2014	2016
Closed	0	8	10	12	0
Open	10	64	49	3	1
Total	*10*	*72*	*59*	*15*	*1*

Table S2. Variables eliminated from analyses, based on Pearson correlation coefficient (*r*-value)

Table shows eliminated variables' correlation with variables used in final analysis

Eliminated variable	Correlated variable	Correlation value	*P*-value
Distance to publicly available roads	Distance to human settlements	$r = 0.440$	<0.001
Distance to publicly available roads	Probability of wolf encounter	$r = 0.699$	<0.001
Distance to forest edge	Distance to human settlements	$r = 0.898$	<0.001
Elevation	Probability of wolf encounter	$r = -0.489$	<0.001

Table S3. Predictor variables, including six interaction terms, used in competing GAMLSS models during model selection

Predictor variable
Probability of wolf encounter
Distance to human settlements
Hunting season
Time of day
Sex/age group
Canopy height
Canopy openness
Probability of wolf encounter × sex/age group
Probability of wolf encounter × time of day
Distance to human settlements × hunting season
Distance to human settlements × time of day
Density of non-hunting reserves × hunting season
Density of non-hunting reserves × time of day

Table S4. Best competing models (ΔAICc < 2) for explaining vigilance patterns in red deer

Table shows AICc, ΔAICc and AICc weights for each model

Model	AICc	ΔAICc	AICc weights
Hunting season + Density of non-hunting reserves + Time of day + Density of non-hunting reserves × Time of day	661.879	0.000	0.36
Hunting season + Canopy openness + Density of non-hunting reserves + Time of day + Density of non-hunting reserves × Time of day	662.818	0.939	0.23
Hunting season + Density of non-hunting reserves + Time of day + Density of non-hunting reserves × Time of day + Density of non-hunting reserves × Hunting season	663.7543	1.876	0.14
Hunting season + Probability of wolf encounter + Density of non-hunting reserves + Time of day + Density of non-hunting reserves × Time of day	663.805	1.926	0.14
Hunting season + Canopy height + Density of non-hunting reserves + Time of day + Density of non-hunting reserves × Time of day	663. 828	1.950	0.14

Table S5. Importance of predictor variables to red deer vigilance, based on model averaging of competing GAMLSS models ΔAICc <2

Table shows predictor variables elected in competing models, with the sum of AICc weights and percentage of competing models with which they were selected

Predictor variable	Sum of AICc weights	% containing models
Density of non-hunting reserves × Time of day	1	100.00
Hunting season	1	100.00
Time of day	1	100.00
Density of non-hunting reserves	1	100.00
Canopy openness	0.23	20.00
Density of non-hunting reserves × Hunting season	0.14	20.00
Probability of wolf encounter	0.14	20.00
Canopy height	0.14	20.00

Table S6. Model-averaged coefficient estimates, standard error, *z*-values and *P*-values for competing (ΔAICc <2; n = 5) GAMLSS models

Mu and sigma intercepts are shown. ****P* ≤ 0.01; ***P* ≤ 0.05; **P* ≤ 0.1

Model-averaged coefficient	Estimate	s.e.	*z*-value	*P*-value
(Mu intercept)	–2.212	1.182	1.872	0.061*
(Sigma intercept)	0.389	0.163	2.385	0.017**
Hunting season: open	1.024	0.733	1.397	0.162
Density of non-hunting reserves	0.048	1.504	0.032	0.975
Time of day: night	–1.884	0.642	2.932	0.003***
Density of non-hunting reserves × Time of day: night	4.085	1.460	2.798	0.005***
Canopy openness	–0.676	1.813	0.373	0.709
Density of non-hunting reserves × hunting season: open	–0.311	1.248	0.250	0.803
Probability of wolf encounter	–0.289	1.686	0.171	0.864
Canopy height	0.007	0.044	0.165	0.869

Table S7. Supplementary analysis results from night-only observations

GAMLSS model outputs for top model (ΔAICc = 0.000), and of models within 2ΔAIC of the top model with significant vigilance responses to predictor variables (Models 1–4), are shown. Table shows 'density of non-hunting reserves' as sole significant ($\alpha < 0.001$) predictor of red deer vigilance during night hours. ***$P \leq 0.001$; *$P \leq 0.1$

Parameter	Estimate	s.e.	*t*-value	*P*-value
Top model (ΔAICc = 0.000)				
(Intercept)	–9.926	5.328	–1.863	0.066*
Hunting season: open	7.173	5.346	1.342	0.183
Density of non-hunting reserves	17.985	10.902	1.650	0.103
Hunting season: open × density of non-hunting reserves	–14.619	10.944	–1.336	0.185
Model 1 (ΔAICc = 0.478)				
(Intercept)	–2.984	0.478	–6.244	<0.001***
Density of non-hunting reserves	3.723	0.997	3.735	0.0003***
Model 2 (ΔAICc = 1.136)				
(Intercept)	–3.733	0.840	–4.443	<0.001***
Density of non-hunting reserves	3.623	0.996	3.637	<0.001***
Hunting season: open	0.879	0.778	1.129	0.262
Model 3 (ΔAICc = 1.547)				
(Intercept)	–2.674	0.556	–4.806	<0.001***
Canopy openness	–4.398	4.354	–1.010	0.315
Density of non-hunting reserves	3.712	0.993	3.740	<0.001***

Table S8. Supplementary analysis results from day-only observations

GAMLSS model output for top models (ΔAICc = 0.000), and all other models within 2ΔAIC of top model (Models 1, 2) are shown. Table shows hunting season as sole significant (α = 0.1) predictor of red deer vigilance during night hours. ***$P \leq 0.001$; *$P \leq 0.1$

Parameter	Estimate	s.e.	*t*-value	*P*-value
Top model (ΔAICc = 0.000)				
(Intercept)	–2.192	0.490	–4.474	<0.001***
Hunting season: open	0.884	0.528	1.674	0.099*
Model 1 (ΔAICc = 1.940)				
(Intercept)	–2.002e+00	5.48E–01	–3.656	<0.001***
Distance to human settlements	–5.23E–05	1.23E–04	–0.427	0.6707
Hunting season: open	9.00E–01	5.38E–01	1.673	0.099*
Model 2 (ΔAICc = 1.975)				
(Intercept)	–2.099	0.521	–4.026	<0.001***
Canopy openness	–1.866	3.580	–0.521	0.604
Hunting season: open	0.932	0.535	1.741	0.087*

Table S9. Best competing models (ΔAICc < 2) for explaining vigilance patterns in red deer, when deployment year is used as predictor variable in place of hunting season

Table shows AICc and ΔAICc values for each model. Table shows deployment year disparities do not have large effects on model selection

Model	AICc	ΔAICc
Density of non-hunting reserves × Time of day	663.937	0.0000
Canopy openness + Density of non-hunting reserves × Time of day	665.195	1.258
Deployment year + Density of non-hunting reserves × Time of day	665.843	1.907

Table S10. Supplementary analysis results when deployment year is used as predictor variable in place of hunting season

GAMLSS model outputs for top model (ΔAICc = 0.000), and all models within 2ΔAIC of the top model are shown (Models 1, 2). Table shows deployment year disparities do not have large effects on results. ***$P \le 0.001$; **$P \le 0.01$; *$P \le 0.05$; †$P \le 0.1$

Parameter	Estimate	s.e.	*t*-value	*P*-value
Top model (ΔAICc = 0.000)				
(Intercept)	–1.145	0.4517	–2.535	0.012*
Density of non-hunting reserves	–0.6622	1.0305	–0.643	0.521
Time of day: night	–1.9743	0.6372	–3.099	0.002**
Density of non-hunting reserves **× night**	4.5555	1.4235	3.200	0.002**
Model 1 (ΔAICc = 1.258)				
(Intercept)	–0.9165	0.512	–1.790	0.075†
Canopy openness	–2.564	2.7698	–0.926	0.356
Density of non-hunting reserves	–0.7954	1.0394	–0.765	0.445
Time of day: night	–2.0149	0.6389	–3.154	0.002**
Density of non-hunting reserves **× night**	4.6752	1.4265	3.277	0.001***
Model 2 (ΔAICc = 1.907)				
(Intercept)	–143.435	297.2249	–0.483	0.630
Density of non-hunting reserves	–0.65807	1.11408	–0.591	0.556
Time of day: night	–2.00798	0.64902	–3.094	0.002**
Deployment year	0.07069	0.14765	0.479	0.633
Density of non-hunting reserves **× night**	4.77233	1.48798	3.207	0.002**

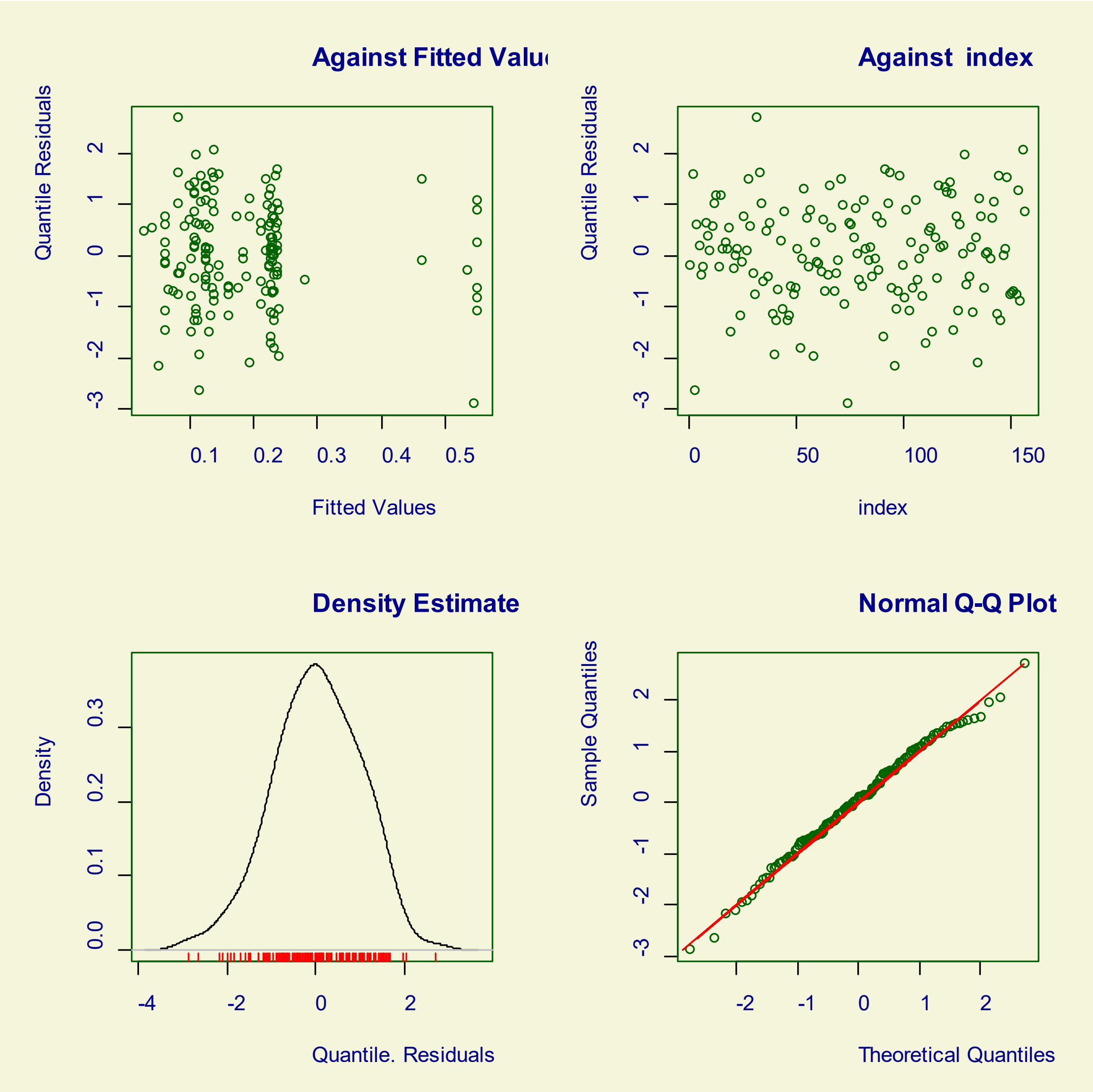

Fig. S1. Diagnostic plots for best (ΔAICc = 0.00) GAMLSS model explaining red deer vigilance patterns in response to predictor variables. Plots show the quantile residuals against the fitted values (top left), quantile residuals (top right), density of quantile residuals (bottom left), and theoretical quantiles against sample quantiles (normal Q-Q; bottom right), using plot() function in the gamlss package (Rigby and Stasinopoulos 2005) in R (R Core Team 2017).

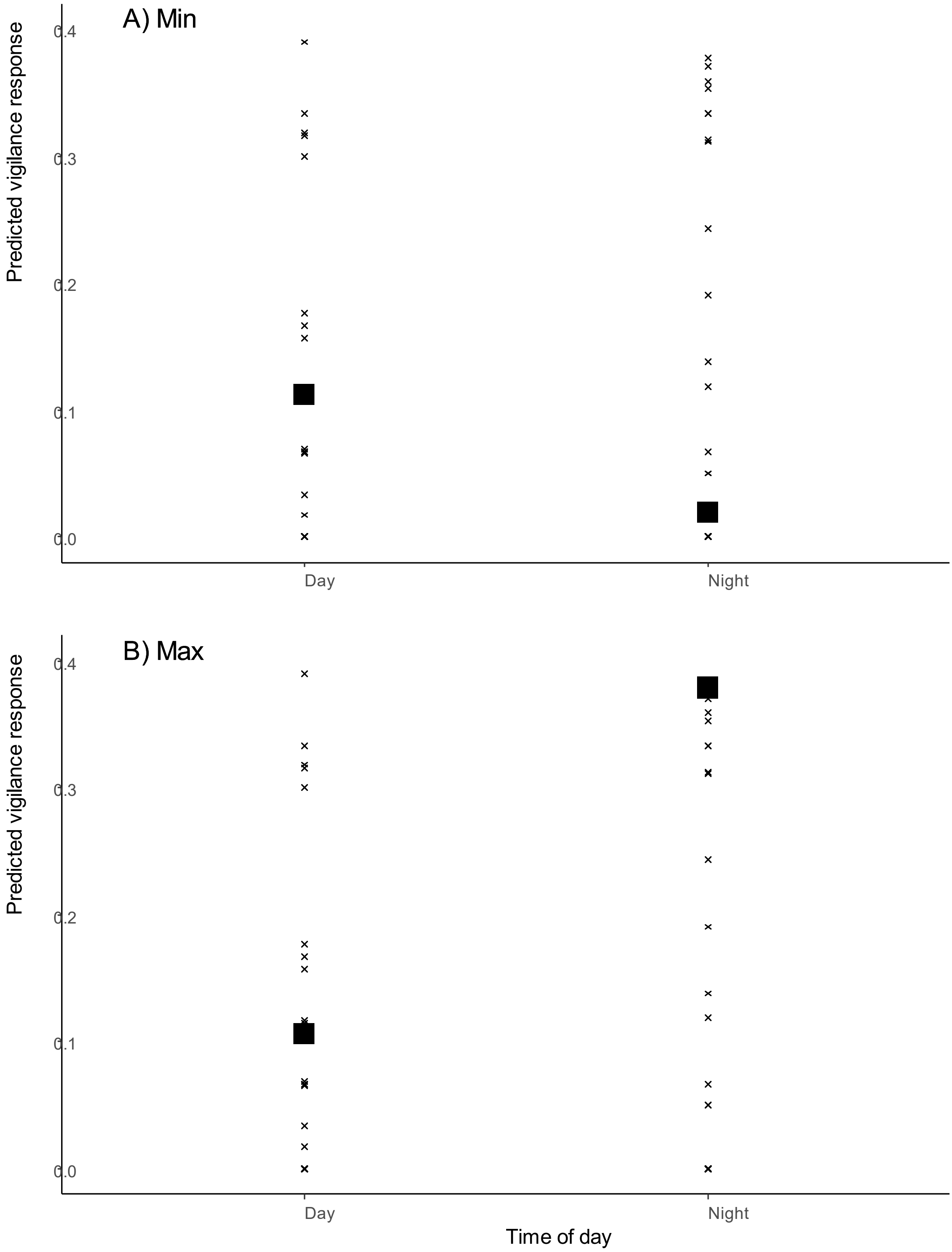

Fig. S2. Predicted values (black squares) in vigilance behaviour of red deer (*Cervus elaphus*) during day and night hours, when A) density of protected areas and reserves is set to minimum value, and B) density of protected areas and reserves is set to maximum value, based on model-averaging of best GAMLSS models. Other predictor variables in the model were set to mean or model intercept values for continuous and categorical variables, respectively. Data points (X) are also shown.