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Supplementary material

Analysis of the spatial variation in the abundance of lesser rheas using density surface models

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Inspection of residual plots

As described in the article, we obtained six models as final candidates and subsequently selected the best fitting model based on the inspection of residual plots (Fig. S1 to S6). We concluded that the tweedie distribution that included the univariate smooth functions of the mean NDVI, distance to the nearest ranch building, sheep stocking rate and longitude, produced the best residual plots (Fig. S1; parametric coefficients in table S1)

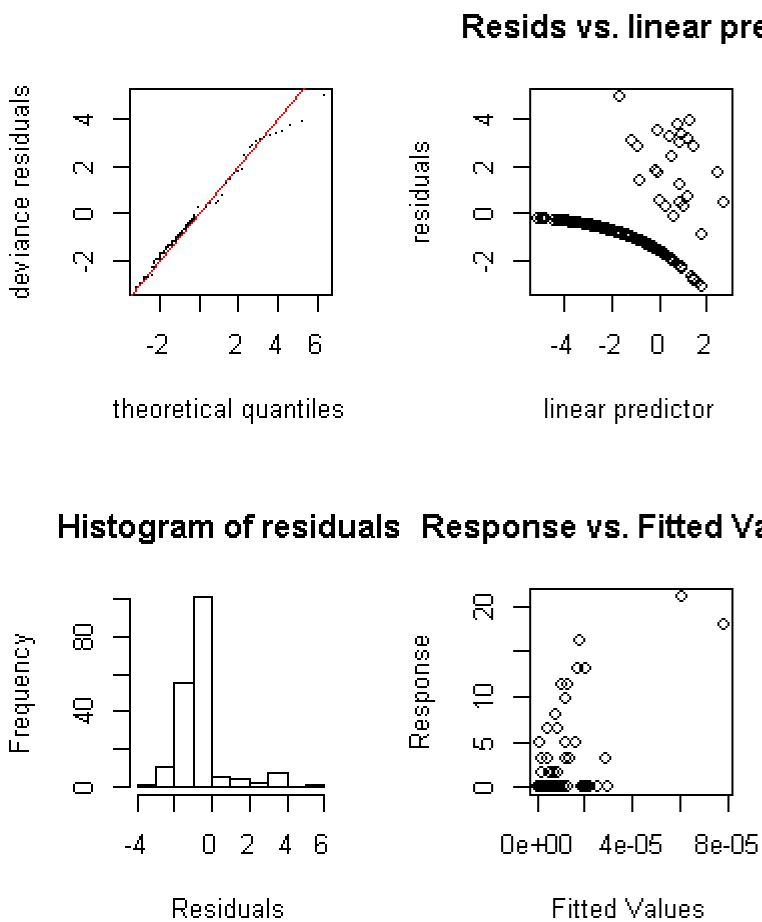

Figure S1. Model checking plot for the model using tweedie response distribution with univariate smooth functions of the mean NDVI, distance to the nearest ranch building, sheep stocking rate and longitude.

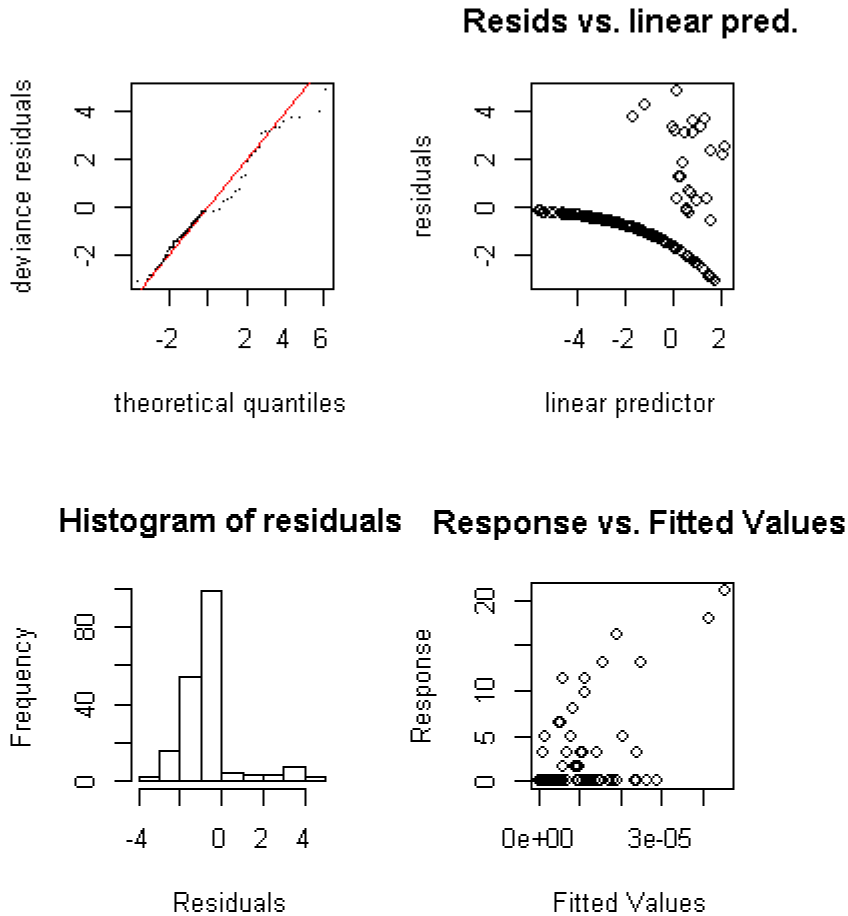

Figure S2. Model checking plot for the model using tweedie response distribution with a bivariate smooth function of the geographic covariates (latitude, longitude), and univariate smooth functions of the mean NDVI, distance to the nearest ranch building, and sheep stocking rate.

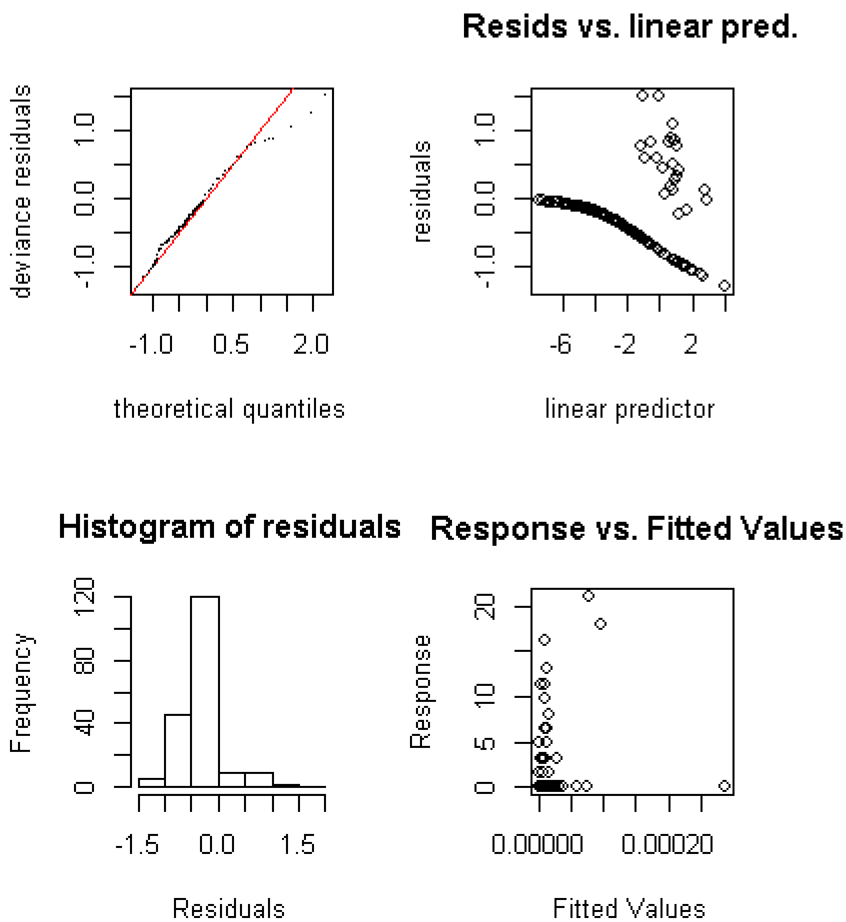

Figure S3. Model checking plot for the model using negative binomial response distribution with univariate smooth functions of the mean NDVI, distance to the nearest ranch building, sheep stocking rate, longitude and latitude.

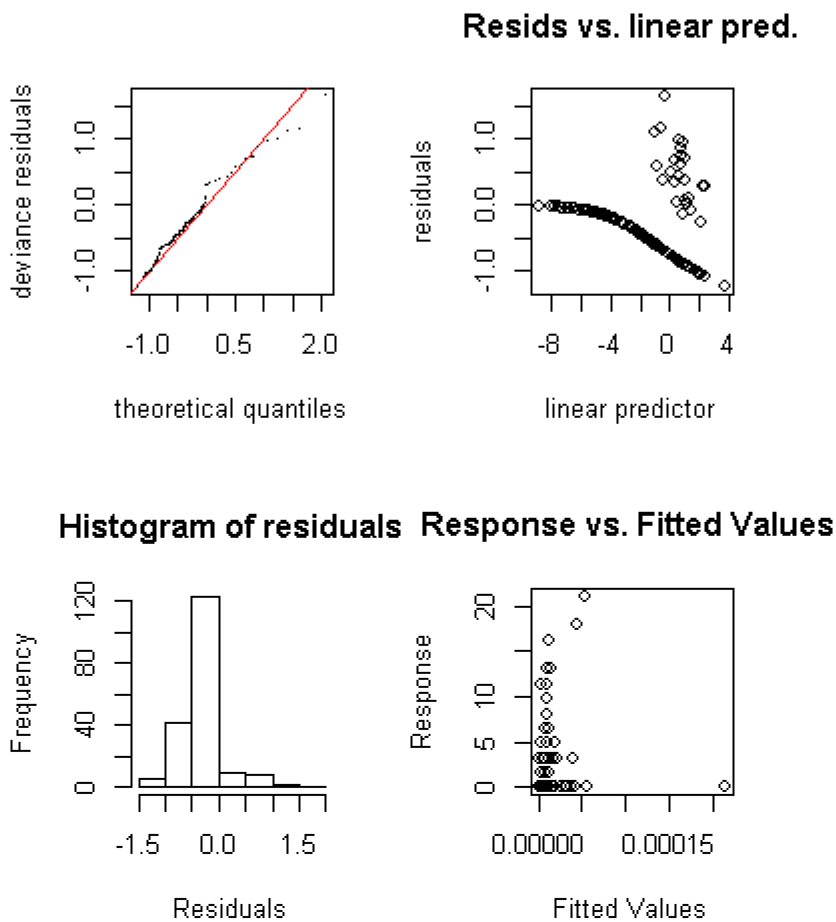

Figure S4. Model checking plot for the model using negative binomial response distribution with a bivariate smooth function of the geographic covariates (latitude, longitude), and univariate smooth functions of the mean NDVI, distance to the nearest ranch building, and sheep stocking rate.

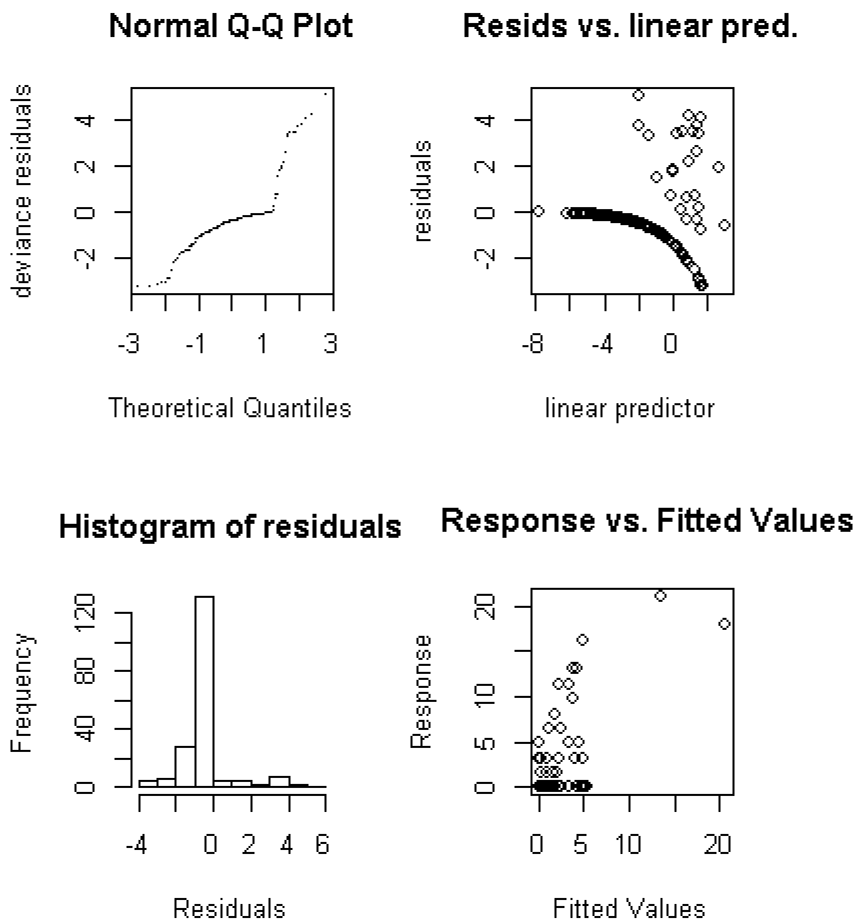

Figure S5. Model checking plot for the model using quasi-Poisson response distribution with univariate smooth functions of the mean NDVI, distance to the nearest ranch building, sheep stocking rate, longitude and latitude.

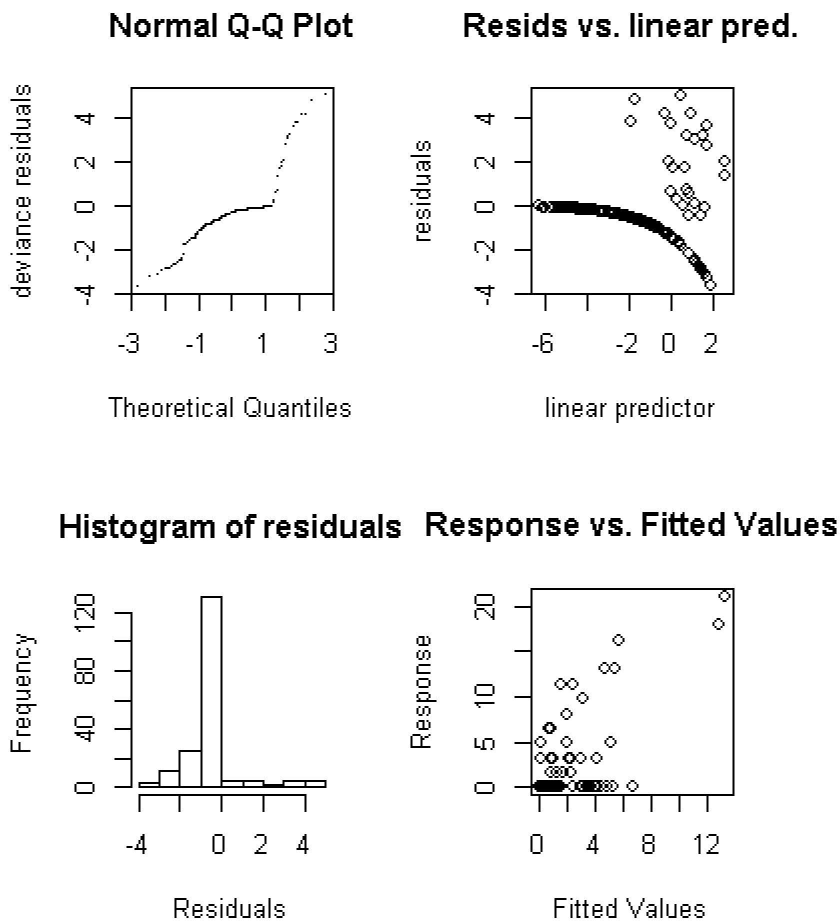

Figure S6. Model checking plot for the model using quasi-Poisson response distribution with a bivariate smooth function of the geographic covariates (latitude, longitude), and univariate smooth functions of the mean NDVI, distance to the nearest ranch building, and sheep stocking rate.

Table S1. Parametric coefficients of the best fitting model selected.

	Estimate	Std. error	t value	Pr(>|t|)
Intercept	-16.344	0.3479	-46.98	<2e-16

Table S2. Approximate significance of smooth terms of the best fitting model selected.

Smooth terms	Estimated degrees of freedom	Ref.df	F	p-value
s(mean_ndvi)	2.039	4	1.7	0.01998 *
s(ranch_dist)	1.397	4	2.06	0.00311 **
s(sheep_stock)	2.295	4	2.622	0.00419 **
s(x)	3.103	5	7.476	5.22e-09 ***

Concurvity measures between smooth terms

As we described in the article, we evaluated concurvity measures between smooth terms throughout the model fitting procedure. Here we presented the pairwise concurvity measures by three related indices (worst, observed and estimated) for the base model with univariate smooth terms and a Tweedie response distribution (Tables S3, S4 and S5), and for the final model selected (Tables S6, S7 and S8).

Table S3. Concurvity "worst measures" between each pair of univariate smooth terms of the base model with a Tweedie response distribution.

terms	worst. para	worst.s. y.	worst.s. sheep stock.	worst.s. x.	worst.s. mean ndvi.	worst.s. water dist.	worst.s. ranch dist.	worst.s. fence dist.	worst.s. paddock size.
para	1	5.46E-32	3.21E-32	4.18E-32	5.77E-30	4.95E-31	8.54E-32	7.77E-32	7.13E-32
s(y)	6.57E-32	1	0.60	0.17	0.50	0.28	0.14	0.12	0.40
s(sheep_stock)	7.15E-32	0.60	1.00	0.19	0.28	0.17	0.12	0.19	0.35
s(x)	1.65E-31	0.17	0.19	1.00	0.17	0.28	0.08	0.14	0.30
s(mean_ndvi)	4.78E-30	0.50	0.28	0.17	1.00	0.09	0.07	0.08	0.09
s(water_dist)	4.88E-31	0.28	0.17	0.28	0.09	1.00	0.22	0.09	0.11
s(ranch_dist)	4.12E-33	0.14	0.12	0.08	0.07	0.22	1.00	0.10	0.17
s(fence_dist)	5.55E-32	0.12	0.19	0.14	0.08	0.09	0.10	1.00	0.24
s(paddock_size)	1.05E-31	0.40	0.35	0.30	0.09	0.11	0.17	0.24	1.00

Table S4. Concurvity "observed measures" between each pair of univariate smooth terms of the base model with a Tweedie response distribution.

terms	observed . para	observed. s. y.	observed. s. sheep stock.	observed. s. x.	observed. s. mean ndvi.	observed. s. water dist.	observed.s . ranch dist.	observed. s. fence dist.	observed. s. paddock
para	1	1.35E-33	2.31E-32	1.97E-35	4.80E-32	2.86E-32	1.95E-32	6.64E-33	6.42E-32
s(y)	6.57E-32	1.00	0.32	0.09	0.13	0.28	0.09	0.07	0.16
s(sheep_stock)	7.15E-32	0.37	1.00	0.07	0.13	0.13	0.06	0.10	0.02
s(x)	1.65E-31	0.05	0.06	1.00	0.08	0.09	0.01	0.08	0.29
s(mean_ndvi)	4.78E-30	0.11	0.13	0.11	1.00	0.06	0.06	0.04	0.07
s(water_dist)	4.88E-31	0.10	0.06	0.06	0.07	1.00	0.11	0.02	0.09
s(ranch_dist)	4.12E-33	0.08	0.02	0.02	0.05	0.10	1.00	0.08	0.03
s(fence_dist)	5.55E-32	0.03	0.08	0.01	0.05	0.02	0.03	1.00	0.12
s(paddock_size)	1.05E-31	0.16	0.01	0.06	0.07	0.09	0.10	0.21	1.00

Table S5. Concurvity "estimated measures" between each pair of univariate smooth terms of the base model with a Tweedie response distribution.

terms	estimate. para	estimate.s. y.	estimate.s. sheep stock.	estimate.s. x.	estimate.s. Mean ndvi.	estimate.s. water dist.	estimate.s. ranch dist.	estimate.s. fence dist.	estimate.s. paddock size
para	1	1.28E-32	1.15E-32	5.35E-33	4.68E-32	1.95E-32	3.98E-33	1.17E-32	7.10E-33
s(y)	6.57E-32	1.00	0.29	0.07	0.20	0.18	0.07	0.07	0.25
s(sheep_stock)	7.15E-32	0.25	1.00	0.06	0.16	0.07	0.04	0.09	0.16
s(x)	1.65E-31	0.07	0.06	1.00	0.09	0.10	0.02	0.04	0.05
s(mean_ndvi)	4.78E-30	0.18	0.14	0.07	1.00	0.04	0.03	0.03	0.03
s(water_dist)	4.88E-31	0.13	0.05	0.06	0.06	1.00	0.10	0.02	0.04
s(ranch_dist)	4.12E-33	0.07	0.04	0.03	0.04	0.13	1.00	0.05	0.12
s(fence_dist)	5.55E-32	0.05	0.08	0.03	0.04	0.03	0.04	1.00	0.09
s(paddock_size)	1.05E-31	0.17	0.12	0.07	0.06	0.04	0.09	0.11	1.00

Table S6. Concurvity "worst measures" between each pair of univariate smooth terms of the final model selected.

terms	worst.para	worst.s. mean_ndvi.	worst.s. ranch_dist.	worst.s. sheep_stock.	worst.s.x.
para	1	5.77E-30	8.54E-32	3.21E-32	4.18E-32
s(mean_ndvi)	6.08E-30	1	0.06	0.27	0.16
s(ranch_dist)	1.08E-32	0.06	1	0.11	0.07
s(sheep_stock)	7.12E-32	0.27	0.11	1	0.18
s(x)	1.12E-31	0.16	0.07	0.18	1

Table S7. Concurvity "observed measures" between each pair of univariate smooth terms of the final model selected.

terms	observed. para	observed.s. mean_ndvi.	observed.s. ranch_dist.	observed.s. sheep_stock.	observed.s.x.
para	1	5.47E-32	1.96E-32	2.24E-32	1.08E-35
s(mean_ndvi)	6.08E-30	1	0.05	0.12	0.11
s(ranch_dist)	1.08E-32	0.05	1	0.01	0.02
s(sheep_stock)	7.12E-32	0.13	0.06	1	0.06
s(x)	1.12E-31	0.08	0.005	0.05	1

Table S8. Concurvity "estimated measures" between each pair of univariate smooth terms of the final model selected.

terms	estimate. para	estimate.s. mean_ndvi.	estimate.s. ranch_dist.	estimate.s. sheep_stock.	estimate.s. x.
para	1	4.68E-32	3.98E-33	1.15E-32	5.35E-33
s(mean_ndvi)	6.08E-30	1	0.03	0.13	0.07
s(ranch_dist)	1.08E-32	0.03	1	0.04	0.02
s(sheep_stock)	7.12E-32	0.15	0.03	1	0.06
s(x)	1.12E-31	0.09	0.02	0.06	1

Partial effects of the significant predictors on the abundance

The relative effects for each significant smooth on the abundance of lesser rheas were set on the same scale in order to facilitate visual comparisons (Figure S7).

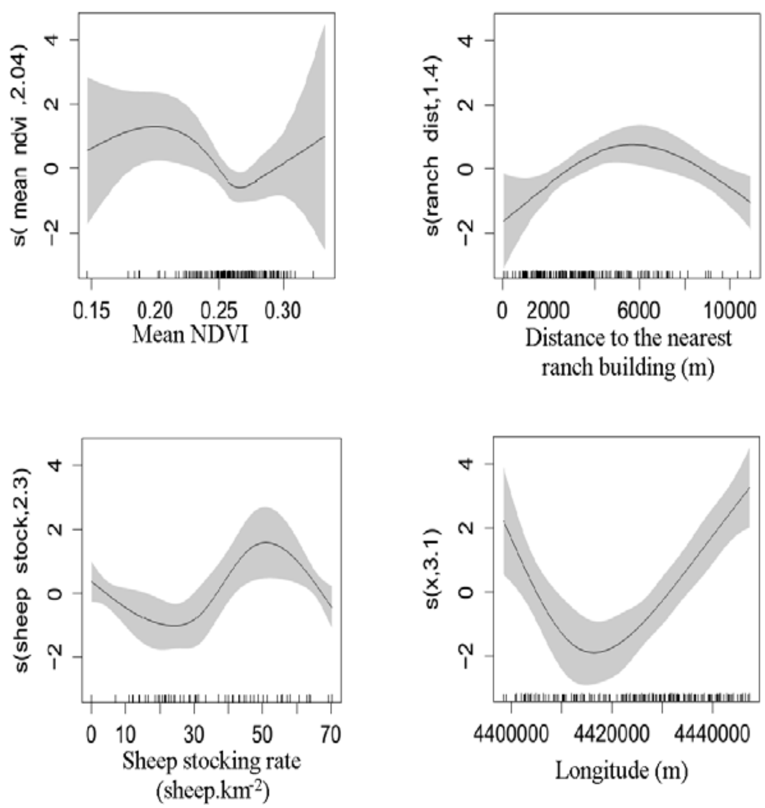

Figure S7. Partial effects of the significant predictors on the abundance of lesser rheas according to the best fitting model. The gray shading represents 95% confidence intervals for the mean effect. The rug ticks at the bottom of the plot indicate the coverage of the range of values of each variable in the survey area. The number in brackets in each “s” gives the effective degrees of freedom (a measure of flexibility) of each term.

Spatial autocorrelation in the residuals

Spatial autocorrelation in the residuals was evaluated using the 'dsm.cor' function of the'dsm' package. As described in the article, the correlogram did not show spatial autocorrelation in the residuals (Fig. S8). The confidence interval increased in width as the number of lags increased.

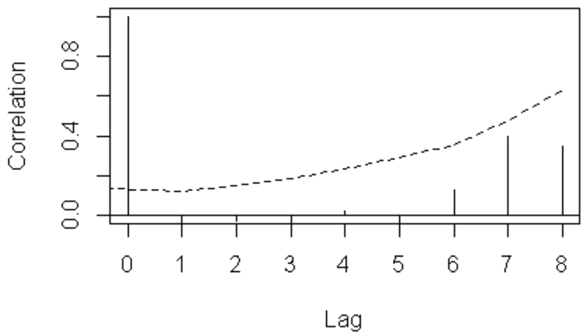

Figure S8. Autocorrelation of deviance residuals between segments (lags) for the fitted density surface model. The dashed line represents the 95% confidence interval. Lag 0 is the correlation between a segment and itself, Lag 1 between a segment and its immediate neighbours (i.e. segments that touch), Lag 2 between a segment and the segment one segment away, and so on. Correlations are only calculated within a given transect.