**Appendix S3: Supplementary analyses tables**

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Ecological effects of wolves in anthropogenic landscapes: potential for trophic cascades is context-dependent

*Frontiers in Ecology and Evolution*

**Table S1**: Additional analyses using general linear mixed models to assess the effect of wolf presence, forest age stages (forest stage), distance from forest (Forest roads) and main (Main roads) roads, pine proportion and RAWO presence on **moose presence** in Sweden between 2003 and 2016. Wolf presence is a four-category variable where the parameter estimate is the difference in moose presence/absence probability for inside an observed territory, inside an average territory and inside a maximum territory compared to outside a wolf territory (intercept). This was included to account that the true borders of wolf territories are unknown and the wolf territories obtained from the monitoring scheme in most cases only represent a portion of the whole territory. Average and maximum wolf territory size were calculated according to the study of Mattisson et al. (2013) (average: radius 18.0 km, area = 1017 km2; maximum: radius 23.0 km, area = 1661 km2). For each model, degrees of freedom (df), difference in AIC relative to the highest-ranked model (ΔAIC), and AIC weights (wi) are shown. Only the three top-ranked models (lowest ΔAIC; red square), univariate models, and intercept-only models are shown.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Top ranked models** | | | **Univariate models** | | | | | | |
|  | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **M7** | **M8** | **M9** | **M10** |
| **Response variable** |  |  |  |  |  |  |  |  |  |  |
| Moose presence | X | X | X | X | X | X | X | X | X | X |
| **Fixed effects** |  |  |  |  |  |  |  |  |  |  |
| Wolf presence | X | X | X |  |  | X |  |  |  |  |
| Forest age | X | X | X | X |  |  |  |  |  |  |
| Forest roads | X | X | X |  |  |  | X |  |  |  |
| Main roads |  | X |  |  |  |  |  |  | X |  |
| Pine proportion | X | X | X |  | X |  |  |  |  |  |
| RAWO presence |  |  | X |  |  |  |  | X |  |  |
| Interaction1 |  |  |  |  |  |  |  |  |  |  |
| **Intercept** |  |  |  |  |  |  |  |  |  | X |
| **Random effects** |  |  |  |  |  |  |  |  |  |  |
| Year of inventory | X | X | X | X | X | X | X | X | X | X |
|  |  |  |  |  |  |  |  |  |  |  |
| **Model criteria** |  |  |  |  |  |  |  |  |  |  |
| df | 10 | 11 | 11 | 5 | 3 | 6 | 3 | 3 | 3 | 2 |
| ΔAIC | **0\*** | 1.39 | 1.88 | 29.14 | 223.7 | 279.85 | 282.8 | 290.6 | 291.7 | 296.2 |
| wi | **0.53** | 0.26| | 0.21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| \* = best model | | | | | | | | | | |
| 1 = interaction between wolf presence and forest age stage | | | | | | | | | | |

**Table S2**: Model averaged parameter estimates with standard error (SE) and z value for each variable retained in the best models (∆AIC < 2) in Table S1. Moose presence was the response variable and was defined as a two-category variable (presence or absence of moose pellet counts).

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Standardized coefficients** | | |
| **Variables** | **B** | **Std.error** | **z** |
| **Intercept** | -2.03 | 0.05 | 37.04 |
| **Forest roads** | 0.14 | 0.03 | 5.11 |
| **Forest age\_Clearcut** | -0.17 | 0.12 | 1.47 |
| **Forest age\_Mature** | -0.5 | 0.07 | 7.39 |
| **Forest age\_Thinned** | -0.05 | 0.06 | 0.97 |
| **Pine proportion** | 0.07 | 0.03 | 2.89 |
| **Wolf presence\_Av** | 0.06 | 0.06 | 1.17 |
| **Wolf presence\_Max** | -0.10 | 0.07 | 1.4 |
| **Wolf presence\_Obs** | 0.18 | 0.06 | 2.90 |
| **Main roads** | 0.02 | 0.02 | 0.33 |
| **RAWO presence\_Absent** | -0.01 | 0.01 | 0.15 |

**Table S3**: Additional analyses using general linear mixed models used to assess the effect of wolf presence, forest age stages (forest stage), distance from forest (Forest roads) and main (Main roads) roads, pine proportion and RAWO presence **o**n **moose abundance** (no. pellet counts) in Sweden between 2003 and 2016. Wolf presence is a four-category variable where the parameter estimate is the difference in moose presence/absence probability for inside an observed territory, inside an average territory and inside a maximum territory compared to outside a wolf territory (intercept). This was included to account that the true borders of wolf territories are unknown and the wolf territories obtained from the monitoring scheme in most cases only represent a portion of the whole territory. Average and maximum wolf territory size were calculated according to the study of Mattisson et al. (2013) (average: radius 18.0 km, area = 1017 km2; maximum: radius 23.0 km, area = 1661 km2). For each model, degrees of freedom (df), difference in AIC relative to the highest-ranked model (ΔAIC), and AIC weights (wi) are shown. Only the three top-ranked models (lowest ΔAIC; red square), univariate models, and intercept-only models are shown. Zi(X) corresponds to zero-inflated (X) and indicates that the explanatory variable was only important in the zero-inflated part of the model, whereas X+ Zi(X) indicates that the explanatory variable was important in both the conditional and zero-inflated parts of the model.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Top ranked models** | | | | | **Univariate models** | | | | | | |
|  | **M1** | **M2** | **M3** | **M5** | **M6** | | **M7** | **M8** | **M9** | **M10** | **M11** |
| **Response variable** | |  |  |  |  | |  |  |  |  |  |
| Moose abundance | X | X | X | X | X | | X | X | X | X | X |
| **Fixed effects** | |  |  |  |  | |  |  |  |  |  |
| Wolf presence | X | X | X |  |  | |  | X |  |  |  |
| Forest age | X | X | X | X |  | |  |  |  |  |  |
| Forest roads | X + Zi(X) | X + Zi(X) | X |  | X | |  |  |  |  |  |
| Main roads |  | X | X |  |  | | X |  |  |  |  |
| Pine proportion | Zi(X) | Zi(X) | Zi(X) |  |  | |  |  |  |  | X |
| RAWO presence |  | X | X |  |  | |  |  |  | X |  |
| Interaction1 |  |  |  |  |  | |  |  |  |  |  |
| **Intercept** |  |  |  |  |  | |  |  | X |  |  |
| **Random effects** | |  |  |  |  | |  |  |  |  |  |
| Year | X | X | X | X | X | | X | X | X | X | X |
|  |  |  |  |  |  | |  |  |  |  |  |
| **Model criteria** | |  |  |  |  | |  |  |  |  |  |
| df | 13 | 14 | 13 | 3 | 3 | | 3 | 3 | 3 | 3 | 2 |
| ΔAIC | **0\*** | 0.78 | 1.56 | 48.7 | 184.3 | | 203.1 | 276 | 253.6 | 267.8 | 277 |
| wi | **0.28\*** | 0.18 | 0.14 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| \* = best model | | | | | | | | | | | | |
| 1 = interaction between wolf presence and forest age stage | | | | | | | | | | | | |
| Zi(X) = variable in the zero-inflated part of the model | | | | | | | | | | | | |
| X + Zi(X) = variable in both the conditional and zero-inflated parts of the model | | | | | | | | | | | | |

**Table S4**: Model averaged parameter estimates with standard error (SE) and z value for each variable retained in the best models (∆AIC < 2) in Table S3. Moose abundance was the response variable and was defined as the number of moose pellet counts.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Standardized coefficients** | | |
| **Variables** | **B** | **Std.error** | **z** |
| **Intercept** | -2.17 | 0.08 | 33.5 |
| **Forest roads** | 0.16 | 0.03 | 5.44 |
| **Forest age\_Clearcut** | -0.15 | 0.14 | 1.33 |
| **Forest age\_Mature** | -0.54 | 0.08 | 7.49 |
| **Forest age\_Thinned** | -0.03 | 0.04 | 0.86 |
| **Pine proportion** | 0.71 | 0.04 | 3.01 |
| **Wolf presence\_Av** | 0.09 | 0.05 | 1.20 |
| **Wolf presence\_Max** | -0.07 | 0.08 | 1.01 |
| **Wolf presence\_Obs** | 0.13 | 0.05 | 3.04 |
| **Main roads** | -0.03 | 0.02 | 0.28 |
| **RAWO presence\_Absent** | -0.01 | 0.03 | 0.19 |

**Table S5:** Additional analyses using general linear mixed models used to assess the effect of wolf presence, moose abundance, distance from forest roads (Forest roads) and main roads (Main roads), pine proportion, RAWO presence on **browsing damage presence** (Damage presence) in Sweden between 2003 and 2016. Wolf presence is a four-category variable where the parameter estimate is the difference in moose presence/absence probability for inside an observed territory, inside an average territory and inside a maximum territory compared to outside a wolf territory (intercept). This was included to account that the true borders of wolf territories are unknown and the wolf territories obtained from the monitoring scheme in most cases only represent a portion of the whole territory. Average and maximum wolf territory size were calculated according to the study of Mattisson et al. (2013) (average: radius 18.0 km, area = 1017 km2; maximum: radius 23.0 km, area = 1661 km2).For each model, degrees of freedom (df), difference in AIC relative to the highest-ranked model (ΔAIC), and AIC weights (wi) are shown. Only the three top-ranked models (lowest ΔAIC; red square), univariate models, and intercept-only models are shown.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Top ranked models** | | | **Univariate models** | | | | | | | |
|  | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **M7** | **M8** | **M9** | **M10** | **M11** |
| **Response variable** | |  |  |  |  |  |  |  |  |  |  |
| Damage presence | X | X | X | X | X | X | X | X | X | X | X |
| **Fixed effects** | |  |  |  |  |  |  |  |  |  |  |
| Wolf presence |  |  |  |  |  |  |  |  |  |  | X |
| Moose abundance | X | X | X |  | X |  |  |  |  |  |  |
| Forest roads |  |  |  |  |  |  |  | X |  |  |  |
| Main roads | X | X | X |  |  | X |  |  |  |  |  |
| Pine proportion |  |  | X |  |  |  |  |  |  | X |  |
| RAWO presence | X |  | X |  |  |  |  |  | X |  |  |
| Previous browsing | X | X | X | X |  |  |  |  |  |  |  |
| **Intercept** |  |  |  |  |  |  | X |  |  |  |  |
| **Random effects** | |  |  |  |  |  |  |  |  |  |  |
| Year | X | X | X | X | X | X | X | X | X | X | X |
|  |  |  |  |  |  |  |  |  |  |  |  |
| **Model criteria** | |  |  |  |  |  |  |  |  |  |  |
| df | 6 | 5 | 7 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 |
| ΔAIC | **0\*** | 0.24 | 1.27 | 5.37 | 20.38 | 29.17 | 30.01 | 30.25 | 30.44 | 31.31 | 40.13 |
| wi | **0.2** | 0.19 | 0.11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| \* = best model | | | | | | | | | | | |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Standardized coefficients** | | |
| **Variables** | **B** | **Std.error** | **z** |
| **Intercept** | -2.48 | 0.19 | 13.07 |
| **Forest roads** | 0.02 | 0.06 | 0.25 |
| **Pine proportion** | -0.02 | 0.08 | 0.27 |
| **Main roads** | 0.17 | 0.13 | 1.27 |
| **Moose pellet counts** | 0.33 | 0.10 | 3.23 |
| **Previous browsing** | 0.5 | 0.09 | 5.06 |
| **RAWO presence\_Absent** | -0.12 | 0.01 | 0.78 |

**Table S6:** Model averaged parameter estimates with standard error (SE) and z value for each variable retained in the best models (∆AIC < 2) in Table S5. Browsing damage presence was the response variable and was defined as a two-category variable (presence or absence of freshly browsed trees).

**Table S7**: Additional analyses using general linear mixed models used to assess the effect of wolf presence, forest age stages (forest stage), distance from forest (Forest roads) and main (Main roads) roads, pine proportion and RAWO presence on **browsing damage intensity** (Damage intensity) in Sweden between 2003 and 2016. Wolf presence is a four-category variable where the parameter estimate is the difference in moose presence/absence probability for inside an observed territory, inside an average territory and inside a maximum territory compared to outside a wolf territory (intercept). This was included to account that the true borders of wolf territories are unknown and the wolf territories obtained from the monitoring scheme in most cases only represent a portion of the whole territory. Average and maximum wolf territory size were calculated according to the study of Mattisson et al. (2013) (average: radius 18.0 km, area = 1017 km2; maximum: radius 23.0 km, area = 1661 km2). For each model, degrees of freedom (df), difference in AIC relative to the highest-ranked model (ΔAIC), and AIC weights (wi) are shown. Only the three top-ranked models (lowest ΔAIC; red square), univariate models, and intercept-only models are shown. Zi(X) corresponds to zero-inflated (X) and indicates that the explanatory variable was only important in the zero-inflated part of the model, whereas X+ Zi(X) indicates that the explanatory variable was important in both the conditional and zero-inflated parts of the model.

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|  | **Top ranked models** | | | **Univariate models** | | | | | | | |
|  | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **M7** | **M8** | **M9** | **M10** | **M11** |
| **Response variable** | |  |  |  |  |  |  |  |  |  |  |
| Damage intensity | X | X | X | X | X | X | X | X | X | X | X |
| **Fixed effects** | |  |  |  |  |  |  |  |  |  |  |
| Wolf presence |  | X | X |  |  |  |  | X |  |  |  |
| Moose abundance | X + Zi(X) | X + Zi(X) | X + Zi(X) |  | X |  |  |  |  |  |  |
| Forest roads | X | X | X |  |  |  | X |  |  |  |  |
| Main roads | X | X + Zi(X) |  |  |  |  |  |  | X |  |  |
| Pine proportion | X + Zi(X) |  |  |  |  |  |  |  |  | X |  |
| RAWO presence | X | X | X |  |  | X |  |  |  |  |  |
| Previous browsing | X + Zi(X) | X | X + Zi(X) | X |  |  |  |  |  |  |  |
| **Intercept** |  |  |  |  |  |  |  |  |  |  | X |
| **Random effects** | |  |  |  |  |  |  |  |  |  |  |
| Year of inventory | X | X | X | X | X | X | X | X | X | X | X |
|  |  |  |  |  |  |  |  |  |  |  |  |
| **Model criteria** | |  |  |  |  |  |  |  |  |  |  |
| df | 11 | 12 | 13 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 |
| ΔAIC | **0\*** | 1.11 | 1.39 | 17.6 | 29.6 | 178.5 | 183.2 | 201.4 | 224.4 | 241.3 | 256.7 |
| wi | **0.14** | 0.08 | 0.07 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| \* = best model | | | | | | | | | | | |
| Zi(X) = variable in the zero-inflated part of the model | | | | | | | | | | | |
| X + Zi(X) = variable in both the conditional and zero-inflated parts of the model | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Standardized coefficients** | | |
| **Variables** | **B** | **Std.error** | **z** |
| **Intercept** | -1.24 | 0.17 | 7.10 |
| **Forest roads** | 0.27 | 0.10 | 2.66 |
| **Pine proportion** | -0.10 | 0.11 | 0.90 |
| **Wolf presence\_Av** | -0.005 | 0.15 | 0.35 |
| **Wolf presence-Max** | -0.025 | 0.24 | 1.02 |
| **Wolf presence\_Obs** | 0.26 | 0.22 | 1.15 |
| **Main roads** | 0.13 | 0.09 | 1.35 |
| **Moose pellet counts** | 0.26 | 0.08 | 3.10 |
| **Previous browsing** | 0.97 | 0.11 | 8.97 |
| **RAWO presence\_Absent** | -0.27 | 0.10 | 2.64 |
| **Zi(Pine proportion)** | -0.36 | 7.6+04 | 0 |

**Table S8:** Model averaged parameter estimates with standard error (SE) and z value for each variable retained in the best models (∆AIC < 2) in Table S7. Browsing damage intensity was the response variable and was defined as the number of trees with fresh browsing damage.