Bird response to forest disturbance size in mountain spruce forests in Central Europe

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Supplement A

**Table A1.** F-tests assessing significance of individual predictors in linear models of species richness or abundance on disturbance class and elevation. Significant values are in bold.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | *All species* | | *Specialists* | | *Generalists* | | *Canopy sp.* | | *Cavity sp.* | | *Ground/shrub sp.* | |
| *Term* | *F* | *p-value* | *F* | *p-value* | *F* | *p-value* | *F* | *p-value* | *F* | *p-value* | *F* | *p-value* |
| *Species richness* | | | | | | | | | | | | |
| Disturb. class | **4.11** | **0.008** | **6.17** | **<0.001** | **13.24** | **<0.001** | **10.73** | **<0.001** | 0.48 | 0.696 | **19.97** | **<0.001** |
| Elevation | **15.20** | **<0.001** | **7.87** | **0.006** | **8.51** | **0.004** | **7.45** | **0.007** | **12.34** | **<0.001** | 0.40 | 0.526 |
| *Abundance* | | | | | | | | | | | | |
| Disturb. class | **4.33** | **0.006** | **4.85** | **0.003** | **8.94** | **<0.001** | **13.22** | **<0.001** | 0.46 | 0.714 | **20.67** | **<0.001** |
| Elevation | **7.83** | **0.006** | **4.19** | **0.043** | **4.04** | **0.046** | 2.54 | 0.113 | **10.42** | **0.002** | 0.07 | 0.799 |

**Table A2.** Coefficients for linear models of species richness or abundances on disturbance class and elevation. SSD, LSD, NDF, and ELT, respectively, stand for “small-scale disturbance”, “large-scale disturbance”, “non-disturbed forest”, and “enclaves of live trees in large-scale disturbance areas”. Significant values are in bold.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Term* | *All species* | | |  | *Specialists sp.* | | |  | *Generalists sp.* | | |  | | *Canopy nesters* | | | |  | | *Cavity nesters* | | | |  | *Ground/shrub nesters* | | | |
| *Estimate* | *SE* | *p-value* |  | *Estimate* | *SE* | *p-value* |  | *Estimate* | *SE* | *p-value* | |  | | *Estimate* | *SE* | *p-value* | |  | | *Estimate* | *SE* | *p-value* |  | *Estimate* | *SE* | *p-value* |
| *Species richness* | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (Intercept) | **16.960** | **1.629** | **<0.001** |  | **5.868** | **1.017** | **<0.001** |  | **11.092** | **1.196** | **<0.001** | |  | | **5.642** | **1.012** | **<0.001** | |  | | **5.373** | **0.794** | **<0.001** |  | **5.692** | **0.939** | **<0.001** |
| Class: LSD | **-1.462** | **0.630** | **0.022** |  | -0.479 | 0.393 | 0.226 |  | **-0.983** | **0.463** | **0.035** | |  | | -0.718 | 0.391 | 0.069 | |  | | -0.267 | 0.307 | 0.386 |  | -0.499 | 0.363 | 0.172 |
| Class: ELT | -0.450 | 0.635 | 0.481 |  | 0.768 | 0.397 | 0.055 |  | **-1.217** | **0.467** | **0.010** | |  | | **1.115** | **0.395** | **0.005** | |  | | -0.356 | 0.310 | 0.252 |  | **-1.188** | **0.366** | **0.002** |
| Class: NDF | **-1.464** | **0.471** | **0.002** |  | **0.676** | **0.294** | **0.023** |  | **-2.139** | **0.346** | **<0.001** | |  | | **0.682** | **0.292** | **0.021** | |  | | -0.187 | 0.229 | 0.418 |  | **-1.956** | **0.271** | **<0.001** |
| Elevation | **-0.006** | **0.002** | **<0.001** |  | **-0.003** | **0.001** | **0.006** |  | **-0.004** | **0.001** | **0.004** | |  | | **-0.003** | **0.001** | **0.007** | |  | | **-0.003** | **0.001** | **<0.001** |  | 0.000 | 0.000 | 0.526 |
| *Abundance* | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (Intercept) | **18.450** | **2.063** | **<0.001** |  | **6.659** | **1.412** | **<0.001** |  | **11.789** | **1.434** | **<0.001** | |  | | **5.568** | **1.319** | **<0.001** | |  | | **6.149** | **0.981** | **<0.001** |  | **6.479** | **1.159** | **<0.001** |
| Class: LSD | **-2.591** | **0.798** | **0.002** |  | -0.874 | 0.546 | 0.112 |  | **-1.717** | **0.555** | **0.002** | |  | | **-1.232** | **0.510** | **0.017** | |  | | -0.438 | 0.380 | 0.251 |  | **-0.944** | **0.448** | **0.037** |
| Class: ELT | -0.966 | 0.804 | 0.232 |  | 0.835 | 0.551 | 0.132 |  | **-1.801** | **0.559** | **0.002** | |  | | **1.162** | **0.514** | **0.025** | |  | | -0.197 | 0.383 | 0.608 |  | **-1.912** | **0.452** | **<0.001** |
| Class: NDF | **-1.544** | **0.596** | **0.011** |  | 0.566 | 0.408 | 0.167 |  | **-2.111** | **0.414** | **<0.001** | |  | | **1.125** | **0.381** | **0.004** | |  | | -0.179 | 0.284 | 0.530 |  | **-2.488** | **0.335** | **<0.001** |
| Elevation | **-0.006** | **0.002** | **0.006** |  | **-0.003** | **0.001** | **0.043** |  | **-0.003** | **0.001** | **0.046** | |  | | -0.002 | 0.001 | 0.113 | |  | | **-0.003** | **0.001** | **0.002** |  | 0.001 | 0.001 | 0.799 |

**Table A3.** Post-hoc pairwise multiple comparisons of disturbance class differences in species richness and abundance. SSD, LSD, NDF, and ELT, respectively, stand for “small-scale disturbance”, “large-scale disturbance”, “non-disturbed forest”, and “enclaves of live trees in large-scale disturbance areas”. Significant values are in bold.

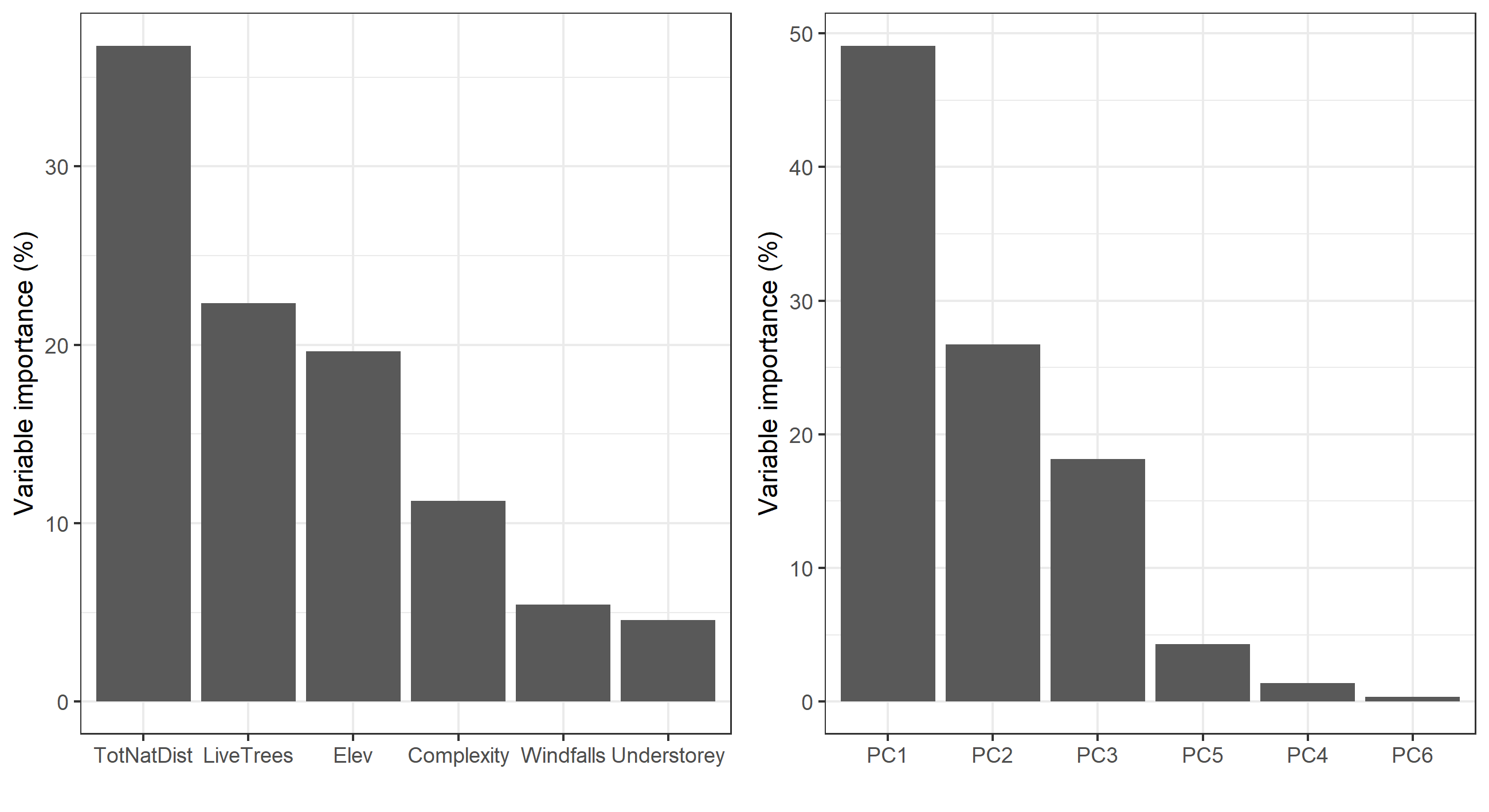
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Pair* | *All species* | | |  | *Specialists sp.* | | |  | *Generalists sp.* | | |  | *Canopy nesters* | | | |  | | *Cavity nesters* | | | |  | | *Ground/shrub nesters* | | | |
| *Diff* | *SE* | *p* |  | *Diff* | *SE* | *p* |  | *Diff* | *SE* | *p* |  | *Diff* | *SE* | *p* |  | | *Diff* | | *SE* | *p* |  | | *Diff* | | *SE* | *p* |
| *Species richness* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LSD - SSD | -1.462 | 0.630 | 0.096 |  | -0.479 | 0.393 | 0.612 |  | -0.983 | 0.463 | 0.148 |  | -0.718 | 0.391 | 0.257 |  | | -0.267 | | 0.307 | 0.818 |  | | -0.638 | | 0.290 | 0.128 |
| ELT - SSD | -0.449 | 0.635 | 0.892 |  | 0.768 | 0.397 | 0.215 |  | **-1.217** | **0.467** | **0.048** |  | **1.115** | **0.395** | **0.027** |  | | -0.356 | | 0.310 | 0.655 |  | | **-1.290** | | **0.329** | **0.001** |
| NDF - SSD | -1.464 | 0.471 | 0.012 |  | 0.676 | 0.294 | 0.101 |  | **-2.139** | **0.346** | **<0.001** |  | 0.682 | 0.292 | 0.094 |  | | -0.187 | | 0.229 | 0.846 |  | | **-1.983** | | **0.267** | **<0.001** |
| ELT - LSD | 1.013 | 0.590 | 0.314 |  | **1.247** | **0.368** | **0.005** |  | -0.234 | 0.433 | 0.948 |  | **1.833** | **0.366** | **<0.001** |  | | -0.089 | | 0.288 | 0.990 |  | | -0.652 | | 0.334 | 0.210 |
| NDF - LSD | -0.002 | 0.564 | 1.000 |  | **1.155** | **0.352** | **0.007** |  | **-1.156** | **0.414** | **0.030** |  | **1.400** | **0.350** | **<0.001** |  | | 0.081 | | 0.275 | 0.991 |  | | **-1.346** | | **0.274** | **<0.001** |
| NDF - ELT | -1.014 | 0.583 | 0.302 |  | -0.092 | 0.364 | 0.994 |  | -0.922 | 0.428 | 0.139 |  | -0.433 | 0.362 | 0.626 |  | | 0.170 | | 0.284 | 0.932 |  | | -0.693 | | 0.315 | 0.126 |
| *Abundance* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LSD - SSD | **-2.591** | **0.798** | **0.008** |  | -0.874 | 0.546 | 0.377 |  | **-1.717** | **0.555** | **0.012** |  | -1.232 | 0.510 | 0.077 |  | | -0.438 | | 0.380 | 0.653 |  | | **-1.013** | | **0.358** | **0.027** |
| ELT - SSD | -0.966 | 0.804 | 0.623 |  | 0.835 | 0.551 | 0.425 |  | **-1.801** | **0.559** | **0.008** |  | 1.162 | 0.514 | 0.111 |  | | -0.197 | | 0.383 | 0.955 |  | | **-1.962** | | **0.405** | **<0.001** |
| NDF - SSD | -1.544 | 0.596 | 0.050 |  | 0.566 | 0.408 | 0.504 |  | **-2.111** | **0.414** | **<0.001** |  | **1.125** | **0.381** | **0.019** |  | | -0.179 | | 0.284 | 0.921 |  | | **-2.502** | | **0.330** | **<0.001** |
| ELT - LSD | 1.626 | 0.747 | 0.132 |  | **1.710** | **0.511** | **0.006** |  | -0.084 | 0.519 | 0.998 |  | **2.395** | **0.477** | **<0.001** |  | | 0.241 | | 0.355 | 0.904 |  | | -0.949 | | 0.412 | 0.101 |
| NDF - LSD | 1.047 | 0.714 | 0.456 |  | **1.441** | **0.489** | **0.019** |  | -0.394 | 0.496 | 0.855 |  | **2.357** | **0.457** | **<0.001** |  | | 0.259 | | 0.340 | 0.869 |  | | **-1.489** | | **0.338** | **<0.001** |
| NDF - ELT | -0.579 | 0.738 | 0.859 |  | -0.269 | 0.505 | 0.950 |  | -0.310 | 0.513 | 0.929 |  | -0.037 | 0.472 | 0.400 |  | | 0.018 | | 0.351 | 1.000 |  | | -0.540 | | 0.338 | 0.504 |

**Table A4.** F-tests assessing significance of individual predictors in linear models of species richness and abundance on habitat characteristics (Complexity = structural complexity, LiveTrees = density of live trees, Understorey = understorey cover) and elevation (Elev). Significant values are in bold.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | *All species* | | *Specialists* | | *Generalists* | | *Canopy sp.* | | *Cavity sp.* | | *Ground/shrub sp.* | | |
| *Predictor* | *F* | *p-value* | *F* | *p-value* | *F* | *p-value* | *F* | *p-value* | *F* | *p-value* | *F* | *p-value* | |
| *Species richness* | | | | | | | | | | | | |
| Complexity | **9.03** | **<0.001** |  |  | **10.78** | **<0.001** | 3.02 | 0.052 | **3.71** | **0.027** | 1.98 | 0.142 | |
| LiveTrees |  |  | **11.33** | **<0.001** |  |  | **16.08** | **<0.001** |  |  | **4.14** | **0.018** | |
| Understorey |  |  |  |  | **5.87** | **0.004** |  |  | 2.21 | 0.114 | **12.83** | **<0.001** | |
| Elev | **12.50** | **<0.001** | **4.03** | **0.020** | **4.67** | **0.011** | **3.24** | **0.042** | **12.49** | **<0.001** |  |  | |
| *Abundance* | | | | | | | | | | | | |
| Complexity | **8.24** | **<0.001** | **4.27** | **0.016** | **5.76** | **0.004** | 2.61 | 0.078 | **4.44** | **0.014** | 2.52 | 0.084 | |
| LiveTrees | **3.33** | **0.039** | **17.33** | **<0.001** |  |  | **11.47** | **<0.001** |  |  | 1.94 | 0.148 | |
| Understorey |  |  |  |  | **3.52** | **0.032** | 2.86 | 0.061 | 2.20 | 0.115 | **12.12** | **<0.001** | |

**Table A5.** Performance metrics for classification of disturbance classes based on habitat characteristics using random forest models. SSD, LSD, NDF, and ELT, respectively, stand for “small-scale disturbance”, “large-scale disturbance”, “non-disturbed forest”, and “enclaves of live trees in large-scale disturbance areas”.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | *Original variables* | | | |  | *PCA variables* | | | |
| *Metric* | *SSD* | *LSD* | *ELT* | *NDF* |  | *SSD* | *LSD* | *ELT* | *NDF* |
| Sensitivity | 0.865 | 0.882 | 0.273 | 0.958 |  | 0.892 | 0.853 | 0.455 | 0.875 |
| Specificity | 0.904 | 0.944 | 0.983 | 0.903 |  | 0.875 | 0.953 | 0.975 | 0.935 |
| Prevalence | 0.262 | 0.241 | 0.156 | 0.340 |  | 0.262 | 0.241 | 0.156 | 0.340 |
| Detection Rate | 0.227 | 0.213 | 0.043 | 0.326 |  | 0.234 | 0.206 | 0.071 | 0.298 |
| Balanced Accuracy | 0.884 | 0.913 | 0.628 | 0.931 |  | 0.883 | 0.903 | 0.715 | 0.905 |

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**Fig. A1.** Relative importance of individual variables (left) and principal components (right) in classification of disturbance classes using random forest models. Variable importance is assessed by the corrected impurity measure, rescaled so that importance values for all variables sum to 100. Complexity = structural complexity, LiveTrees = density of live trees, Understorey = understorey cover, Windfalls = proportion of wind disturbed area, TotNatDist = total natural disturbance cover.

**Table A6:** Species recorded, their abundance (Abun), frequency (Freq), habitat specialization (Spec) as generalist (G) or specialist (S), nesting guild classification (Nest site) and Red-List classification (Red List).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** |  | **Abun** |  | **Freq (%)** |  | **Spec** |  | **Nest site** |  | **Red List** |
| *Erithacus rubecula* |  | 200 |  | 94.3 |  | G |  | Ground/Shrub |  | LC |
| *Fringilla coelebs* |  | 172 |  | 81.6 |  | G |  | Canopy |  | LC |
| *Periparus ater* |  | 156 |  | 83.7 |  | S |  | Cavity |  | LC |
| *Prunella modularis* |  | 103 |  | 66.7 |  | G |  | Ground/Shrub |  | LC |
| *Troglodytes troglodytes* |  | 85 |  | 57.4 |  | G |  | Ground/Shrub |  | LC |
| *Sylvia atricapilla* |  | 83 |  | 55.3 |  | G |  | Ground/Shrub |  | LC |
| *Certhia familiaris* |  | 76 |  | 51.1 |  | S |  | Cavity |  | LC |
| *Regulus regulus* |  | 63 |  | 40.4 |  | S |  | Canopy |  | LC |
| *Turdus merula* |  | 63 |  | 44.7 |  | G |  | Ground/Shrub |  | LC |
| *Turdus philomelos* |  | 52 |  | 35.5 |  | G |  | Canopy |  | LC |
| *Spinus spinus* |  | 49 |  | 24.1 |  | S |  | Canopy |  | LC |
| *Phylloscopus trochilus* |  | 46 |  | 31.9 |  | G |  | Ground/Shrub |  | LC |
| *Phylloscopus collybita* |  | 45 |  | 29.8 |  | G |  | Ground/Shrub |  | LC |
| *Regulus ignicapilla* |  | 34 |  | 21.3 |  | S |  | Canopy |  | LC |
| *Columba palumbus* |  | 34 |  | 21.3 |  | G |  | Canopy |  | LC |
| *Dendrocopos major* |  | 33 |  | 22.0 |  | G |  | Cavity |  | LC |
| *Pyrrhula pyrrhula* |  | 31 |  | 19.1 |  | S |  | Canopy |  | LC |
| *Anthus trivialis* |  | 26 |  | 14.2 |  | G |  | Ground/Shrub |  | LC |
| *Loxia curvirostra* |  | 25 |  | 12.8 |  | S |  | Canopy |  | LC |
| *Turdus viscivorus* |  | 22 |  | 13.5 |  | S |  | Canopy |  | LC |
| *Parus major* |  | 20 |  | 14.2 |  | G |  | Cavity |  | LC |
| *Sitta europaea* |  | 18 |  | 10.6 |  | G |  | Cavity |  | LC |
| *Garrulus glandarius* |  | 16 |  | 9.9 |  | G |  | Canopy |  | LC |
| *Phoenicurus phoenicurus* |  | 14 |  | 9.9 |  | G |  | Cavity |  | LC |
| *Picoides tridactylus* |  | 13 |  | 9.2 |  | S |  | Cavity |  | EN |
| *Dryocopus martius* |  | 12 |  | 8.5 |  | S |  | Cavity |  | LC |
| *Poecile montanus* |  | 8 |  | 4.3 |  | S |  | Cavity |  | LC |
| *Tetrastes bonasia* |  | 8 |  | 3.5 |  | S |  | Ground/Shrub |  | VU |
| *Tetrao urogallus* |  | 6 |  | 2.8 |  | S |  | Ground/Shrub |  | CR |
| *Lophophanes cristatus* |  | 6 |  | 3.5 |  | S |  | Cavity |  | LC |
| *Phylloscopus sibilatrix* |  | 6 |  | 4.3 |  | S |  | Ground/Shrub |  | LC |
| *Turdus torquatus* |  | 4 |  | 2.8 |  | G |  | Ground/Shrub |  | EN |
| *Turdus pilaris* |  | 3 |  | 2.1 |  | G |  | Canopy |  | LC |
| *Cuculus canorus* |  | 3 |  | 2.1 |  | G |  | unclassified |  | LC |
| *Fringilla montifringilla* |  | 2 |  | 1.4 |  | G |  | unclassified |  | LC |
| *Muscicapa striata* |  | 2 |  | 1.4 |  | G |  | Cavity |  | LC |
| *Acanthis flammea* |  | 1 |  | 0.7 |  | S |  | Canopy |  | NT |
| *Nucifraga caryocatactes* |  | 1 |  | 0.7 |  | S |  | Canopy |  | VU |
| *Cyanistes caeruleus* |  | 1 |  | 0.7 |  | G |  | Cavity |  | LC |
| *Coccothraustes coccothraustes* |  | 1 |  | 0.7 |  | G |  | Canopy |  | LC |