Habitat requirements of Boreal Owl (*Aegolius funereus*) and Pygmy Owl (*Glaucidium passerinum*) in mountainous populations on the Balkan Peninsula

Boris Nikolov, Stoyan Stoyanov, Thomas Groen, Iva Hristova-Nikolova, Che Elkin, Tzvetan Zlatanov
Study area

Map of Bulgaria with georeferenced image of high resolution satellite imagery of the study area from Google Earth.
Study area

Shiroka Laka Forest Enterprise in “Trigrad-Mursalitsa” Natura-2000 zone according to the Birds Directive
Study area
Studied species

Two species of boreal owls:

- glacial relics
- high conservation value (Appendix I of the Birds Directive)

Boreal Owl
(Aegolius funereus)

Pygmy Owl
(Glaucidium passerinum)
Studied species

Two species of boreal owls:

- Widely distributed in the taiga zone of Eurasia (both species) and North America (Boreal Owl);
- Balkan Peninsula holds relic mountain populations (isolated refugia?) – little is known about their habitat requirements.

Boreal Owl
(Aegolius funereus)

Pygmy Owl
(Glaucidium passerinum)
Data collection – birds

Field work performed in autumn 2012

- A total of 49.9km transects surveyed, all above 1450m altitude
- 85 point counts performed (34 points successful, which is 40%)

Target owl species recorded:

- Boreal Owl (Aegolius funereus) - 29 birds in 27 territories
- Pygmy Owl (Glaucidium passerinum) - 10 birds in 9 territories
Data collection – birds

Localities ascertained

Territories of:
- Boreal Owls
- Pygmy Owls
- Both species
Data collection – stand parameters

Field work performed in 2013 and 2014

- 85 “complexes of plots” established (85 point counts performed)
- 25 plots in each complex or a total of 2125 plots
- Predominantly spruce dominated forests, few plots dominated by Scots pine
Data collection – stand parameters

Total area sampled ~ 13 ha
Sampling intensity ~ 2%

100 m² x 25

360 m

30 m
Data collection – stand parameters

Total area sampled ~ 13 ha
Sampling intensity ~ 2%

100 m² x 25
Set of predictor variables

Growing stock [m3/ha]
Fellings ≤ 3 years old (% plots)
Fellings 4-10 years old (% plots)
Fellings ≥ 4 years old (% plots)
Canopy closure ≤ 0.3 (% plots)
Canopy closure 0.6-0.8 (% plots)
Mean canopy closure
DBH ≥ 38 / ha (# trees)
DBH ≥ 38 (% plots)
DBH ≥ 42 / ha (# trees)
DBH ≥ 42 (% plots)
DBH ≥ 50 / ha (# trees)
DBH ≥ 50 (% plots)
DBH ≥ 58 / ha (# trees)
DBH ≥ 58 (% plots)

Fallen dead wood (m3/ha)
Standing dead wood (m3/ha)
Fallen dead wood Decay stage 1 (m3/ha)
Fallen dead wood Decay stage 2 (m3/ha)
Fallen dead wood Decay stage 3 (m3/ha)
Fallen dead wood Decay stage 4 (m3/ha)
Fallen dead wood Decay stage 5 (m3/ha)
Standing dead wood Decay stage 1 (m3/ha)
Standing dead wood Decay stage 2 (m3/ha)
Standing dead wood Decay stage 3 (m3/ha)
Standing dead wood Decay stage 4 (m3/ha)
Standing dead wood Decay stage 5 (m3/ha)
Set of predictor variables

Many predictors correlated!
Selection of predictor variables

1. Univariate logistic regressions to suggest explanatory variables which could explain the significant proportion of the deviance and could be considered as important factors determining the presence of both owl species.

2. Principal component analysis to overcome the high collinearity and select variables that contain most information about the stand structure.

3. Then we fitted multivariate logistic regression model to the presence/absence data. The final set of explanatory variables to be included in the model was selected by following criteria - the variables that were related strongest to the first few principal components; those that best represent the stand structure and are not highly correlated and also made sense from the perspective of the ecology of both owl species.
Selection of predictor variables

Explanatory variables which significantly influence the presence of Boreal owl and Pygmy owl. Results from $\chi^2$ test applied to univariate logistic regression models.

<table>
<thead>
<tr>
<th>Variable Index</th>
<th>Boreal owl (Aegolius funereus)</th>
<th>Pygmy owl (Glaucidium passerinum)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AIC $\chi^2$ (df = 78)</td>
<td>P</td>
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Selection of predictor variables

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Modelling - PCA

We selected 6 principal components to explain large enough amount (at least 75%) of the variation in the set of explanatory variables.
Modelling - PCA

Strong clustering along the first two principal components with at least 4 very well distinguished clusters. **DBH ≥ 50 (% plots), Fallen dead wood (m³/ha); Canopy closure ≤ 0.3 (% plots); Fallen dead wood decay stage 4** well represented every cluster and significantly influenced the presence of both owl species.

**DBH ≥ 50 (% plots)** – represents one of the clusters; from an ecological point of view, trees with a DBH > 50 cm are expected to be more relevant for both owl species.

**Fallen dead wood (m³/ha)** – best represented one of the clusters.

**Canopy closure ≤ 0.3 (% plots)** – stands out as a variable that contains a lot of unique information.
From the standing deadwood indicators, **Standing dead wood decay stage 4&5** related most with the 3rd principal component.

For the falling deadwood indicators, **Fallen dead wood Decay stage 1 - 3** related most to the 3rd principal component, but **Fallen dead wood Decay stage 4** was more significantly related with the presence of both owl species and was selected.

For the harvesting indicators, **fellings up to 10 years old (% plots)** related most with the 4th principal component.
Modelling - the final set of predictors

The 5th and 6th principal components didn’t yield any further insights into variables to select.

The final set of predictors:

- DBH ≥ 50 (% plots)
- Fallen dead wood (m3/ha)
- Canopy closure ≤ 0.3 (% plots)
- Standing dead wood decay stage 4&5 (m3/ha)
- Fallen dead wood decay stage 4
- Fellings up to 10 years old (% plots)

The VIFs associated with these variables were well below 10.
The best parsimonious model for the Boreal owl (*Aegolius funereus*) included three explanatory variables:

<table>
<thead>
<tr>
<th>Included</th>
<th>B(SE)</th>
<th>95 % CI for odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.940 (0.583)</td>
<td></td>
</tr>
<tr>
<td>Canopy closure ≤ 0.3 (% plots)</td>
<td>-0.042 (0.018)**</td>
<td>0.922</td>
</tr>
<tr>
<td>DBH ≥ 50 (% plots)</td>
<td>0.038 (0.020)*</td>
<td>1.000</td>
</tr>
<tr>
<td>Fallen dead wood decay stage 4</td>
<td>0.175 (0.071)**</td>
<td>1.040</td>
</tr>
</tbody>
</table>

*p < 0.001. AIC = 87.261. * p < 0.1, ** p < 0.05.*

There are no issues related to the basic residual statistics for the model (leverage, studentized residuals and DFBeta values)
Best model (GLM) - Boreal Owl

- Canopy closure ≤ 0.3 (% plots)
- DBH ≥ 50 (% plots)
- Fallen dead wood Decay stage 4 (m3/ha)
Model performance

- Area under the ROC curve (ROC) statistic: 0.7 – reasonable ability of the model to discriminate between presence and absence

ROC value ranges between 0.5 and 1, where 0.5 means a discrimination which is no different than random, and a value of 1 means perfect discrimination of presence and absence

- True skill statistics (TSS): 0.4 – ability of the model to discriminate between presence and absence similar to (ROC) statistic

A TSS of 1 indicates perfect discrimination of presences and absences, and a TSS of -1 indicates an inverse result (i.e. absences are perfectly assigned as presence and vice versa)

- Kappa statistic: 0.4 – reasonably high accuracy

The Kappa statistic ranges between 0 and 1 and indicates the accuracy, corrected for the random chance of correctly assigning presences and absences
The best parsimonious model for the Pigmy owl (*Glaucidium passerinum*) included only one explanatory variable – rooting logs.

<table>
<thead>
<tr>
<th>Included</th>
<th>B(SE)</th>
<th>95 % CI for odds ratio</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Odds ratio</td>
<td>Upper</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.812</td>
<td>(0.0815)***</td>
<td></td>
</tr>
<tr>
<td>Fallen dead wood (m3/ha)</td>
<td>0.087</td>
<td>1.029</td>
<td>1.168</td>
</tr>
</tbody>
</table>

\[ p < 0.01, \text{AIC} = 47.419, \text{* p < 0.05, ** p < 0.01, *** p < 0.001.} \]

There are no issues related to the basic residual statistics for the model (leverage, studentized residuals and DFBeta values)
Model performance

• Area under the ROC curve (ROC) statistic: 0.55 – high randomness; model not able to sufficiently discriminate between presence and absence

*ROC value ranges between 0.5 and 1, where 0.5 means a discrimination which is no different than random, and a value of 1 means perfect discrimination of presence and absence*

• True skill statistics (TSS): 0.2 – ability of the model to discriminate between presence and absence similar to (ROC) statistic

*A TSS of 1 indicates perfect discrimination of presences and absences, and a TSS of -1 indicates an inverse result (i.e. absences are perfectly assigned as presence and vice versa)*

• Kappa statistic: 0.4 – reasonably high accuracy

*The Kappa statistic ranges between 0 and 1 and indicates the accuracy, corrected for the random chance of correctly assigning presences and absences*
Model robustness

**Biomod modelling**

- Generalized Linear Models (GLM)
- Random Forest (RF)
- Surface Range Envelope (SRE)
- Classification Tree Analysis (CTA)
- Multiple Adaptive regression splines (MARS)
- Flexible Discriminant Analysis (FDA)
Model robustness

Possible reasons for the relatively high randomness, especially in the Pygmy owl model

- Sampling bias, only “suitable areas” included in visited locations, therefore no “unsuitable” locations in dataset for contrast to show importance of variables.

- Very few successful observations of Pygmy owl – the species is too rare.

- Missed variables to consider (presence of other competing species, e.g. *Strix aluco*; *distance to the nearest large protected territory*)

- Low sampling intensity ~ 2%
Model robustness

Total area sampled ~ 13 ha

Sampling intensity ~ 2%

Areas not well represented
Model robustness

Total area sampled ~ 13 ha

Smaller than expected nesting territory ~ 50 ha?
Thresholds

Only plots where Boreal Owl is present are shown in the figures.
Thresholds

Canopy closure 0.3 or more

DBH 50cm or more

DBH 50cm and more

FDW total

FDW Decade stage 4

Only plots where Pigmy Owl is present are shown in the figures
Projections of bird habitat quality

Calculating a bird habitat quality based on a combination of “threshold” criteria

<table>
<thead>
<tr>
<th>Year</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature change [°C]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation change [%]</td>
<td></td>
<td></td>
</tr>
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</table>

FS model: LandClim

C1:
- DMI-HIRHAM5_BCM
- DMI-HIRHAM5_ARPEGE

C0

C1

C2

Projections based on the LF – TBD
Management implications

Both species moderately tolerant to management (less so Pigmy owl)

Continuous cover forestry (currently shelterwood)

Elements of oldgrowthness on some 10% of the territory
Thank you for your attention!

Acknowledgements:
Support for this study was provided by the project “Advanced Multifunctional Forest Management in European Mountain Ranges (ARANGE)” within the European commission’s 7th framework program, grant agreement number 289437. Colleagues who helped with the field work for the stand structure evaluation: Dimitar Angelov, Georgi P. Georgiev, Georgi Gogushev, Georgi Hinkov, Hristina Hristova, Ivaylo Velichkov, Magdalena Zlatanova.