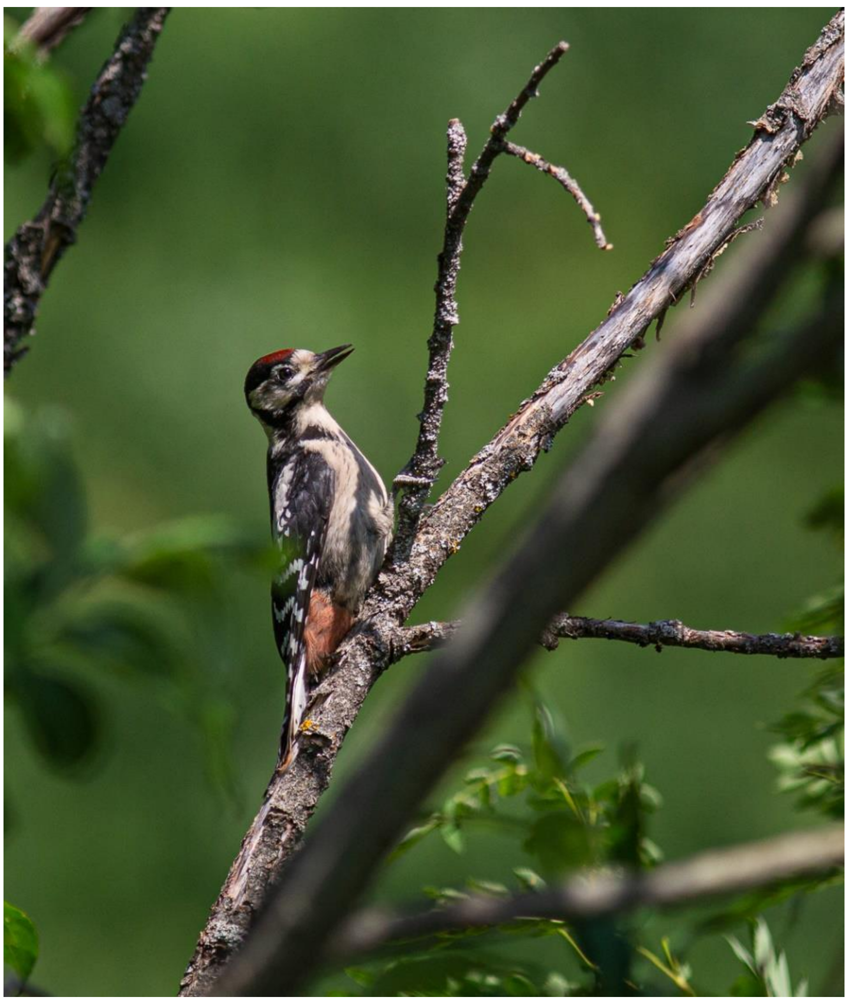
Strengthening the financial sustainability of the system of protected areas in Georgia

Monitoring of the Woodpecker community in Borjomi-Kharagauli and Pshav-Kevsureti Protected Areas.



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Introduction

Most important task of conservation biology to assess natural biodiversity and to estimate its change with time and with changing management strategies. In practice, it is very difficult to measure reliably all the components of biodiversity. One possible solution to this problem is the use of indicator species. Usually indicator species are expected to indicate the status of the landscape or habitat condition and change, or to indicate population status of a larger number of species. Existing studies used indicator species to predict species diversity and habitat quality. Researchers found that predictive value of this kind of indicator species is usually not very strong, but because of a limitation in research funding and time available for every component of biodiversity, indicator species are still used for practical conservation of biodiversity. Using indicator species as a useful short-cut in conservation planning requires thorough testing and validation of relationships between an indicator species and the objects which it tries to indicate (Mikusiński et al 2001, Virkkala 2006).

Woodpeckers have a strong association to the forests and are dependent on trees for nesting sites, foraging on trees and dead wood. Occurrence of woodpecker species indicates type of forest habitat, degree of anthropogenic influence, habitat degradation and status of other forest species (Mikusiński et al 2001, Virkkala 2006, Menon et al 2021).

With this study we explored relationship of indicator species to the forest type as well as

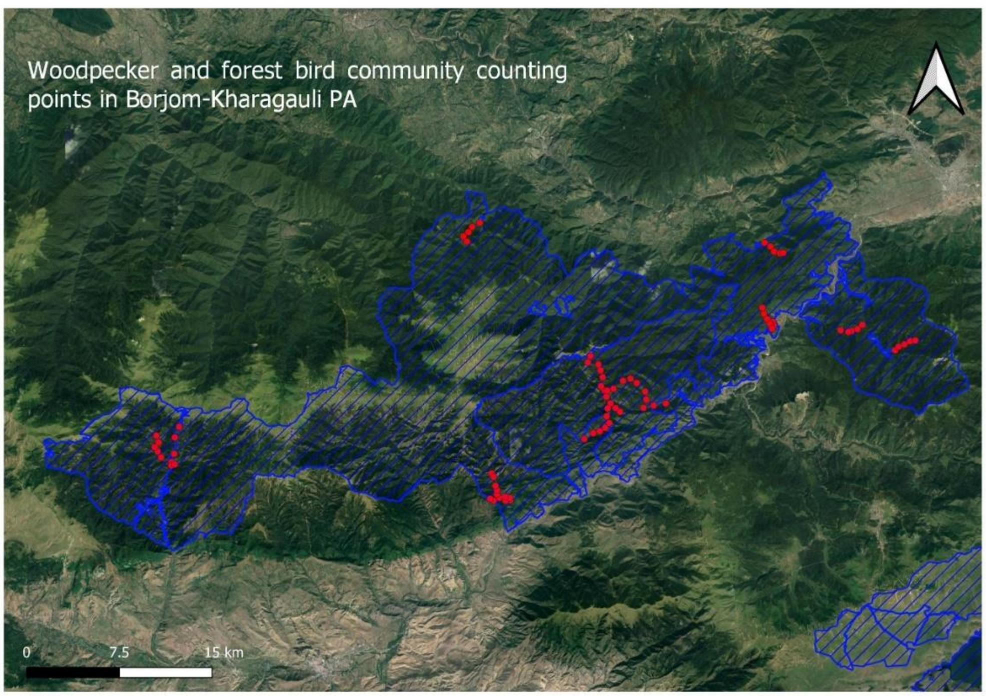
Methods

Bird Counts

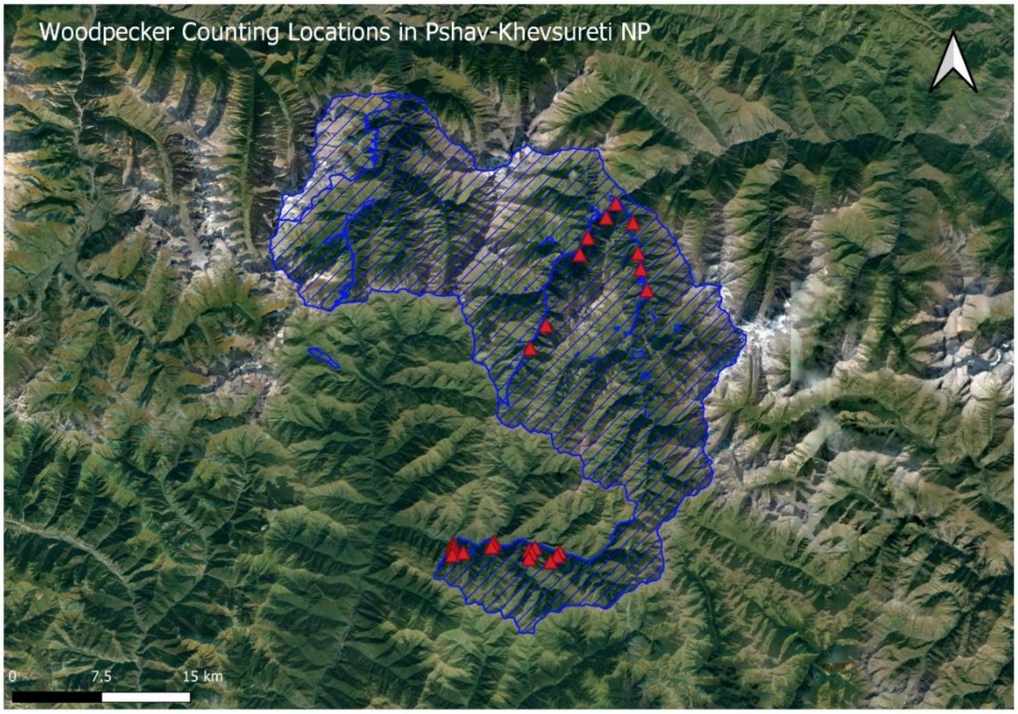
The number of breeding pairs of woodpeckers can be determined by counting pairs of the calling birds using call counts. Nest count is more time and resource consuming. Trends in increasing or decreasing populations can be detected with only call counts. Call count was conducted between period of 24 April and 17 May. Second count took place during the period of 25 June and 7 July. Call counts were starting at the sunrise and were ending 2 hours after. Counts were not taking place during rainy or windy conditions since birds are less active. Observer was walking a transect in forested habitats. Observer was stopping every 0.5 km for 5 minutes and was listening for woodpecker calls. If none were heard after 30 seconds, territorial call playback was used for five times at 30-second intervals. Results were recorded on the field forms.

During the planning phase we decided to record other bird species associated with forests in Borjomi-Kharagauli PA. Methodology of the count is mostly same for woodpeckers and other forest birds. Only difference was that territorial call playback was used only for woodpeckers. Database was respectively adjusted to accommodate information on the other species as well.

Woodpecker counts in Borjomi-Kharagauli PA were conducted on 84 counting locations (Map 1). Forests are dominating habitat in Borjomi-Kharagauli PA so selecting sampling locations and performing counts was not an issue. In contrast Pshav-Khevsureti NP is dominated by sub-alpine, alpine and sub-nival habitats. Forests are covering smaller area and are predominantly high mountain sub-alpine type. Only small areas of mixed and deciduous mountain forests are present at the northernmost territories of the NP (lower flow of Riv. Arguni and Asa) as well as small areas of beech forests are present in the southern part of the national park in river. Pshavis Aragvi gorge. Second issue is access of Khevsureti by road. Datvisjvari and Arkhoti are high mountain passes and are not opening until snow is melted during second half of May. We were able to access Khevsureti and perform counts, the beginning of June. Access to the southern (Pshavi) part of NP is easier since there are no mountain passes so we were able to conduct counts at the beginning of May. We conducted counts at 26 selected woodpecker counting locations (Map 2).



Map 1. Woodpecker and forest bird community counting points in BKNP



Map 2. Woodpecker counting locations in Phshav-Khevsureti NP

Niche-based modeling from presence-only data

We were interested in devising a model of a species' environmental requirements from a set of occurrence localities, together with a set of environmental variables that describe some of the factors that likely influence the suitability of the environment for the species (Phillips et al.2006).

Each occurrence locality is simply a latitude–longitude pair denoting a site where the species has been observed. Occurrence records have been derived from the field observation performed during the study. The goal of a modeling method is to predict environmental suitability for the species as a function of the given forest class variables.

A niche-based model represents an approximation of a species' ecological niche in the examined environmental dimensions. By definition, then, environmental conditions at the occurrence localities constitute samples from the realized niche.

For the selection of environmental variables, research goal must be considered. Climatic variables such as temperature, precipitation and topographic variables are appropriate at global and meso-scales; land-cover variables like percent canopy cover influence species distributions at the micro-scale. The choice of variables to use for modeling is important for applications such as invasive-species management and predicting the impact of climate or land use change. To improve understanding of habitat-species dependence field sampling procedures and methods must be optimized for the purpose of the study. Some factors introducing bias are often highly correlated with the nearby presence of roads, rivers or other access conduits. The location of occurrence localities may also exhibit spatial auto-correlation, sampling intensity and sampling methods might vary widely across the study area as well as number of occurrence localities may be too low to estimate the parameters of the model reliably. Determining and possibly mitigating the effects of these factors represent worthy topics of research for all presence-only modeling techniques (Phillips et al.2006).

Forest classification

For the forest classification we used following tools:

Sentinel-2 multispectral images. Sentinel-2 is a multispectral satellite developed by the European Space Agency (ESA) in the frame of Copernicus land monitoring services. Sentinel-2 acquires 13 spectral bands with the spatial resolution of 10m, 20m and 60m depending on the band.

A semi-automatic classification algorithm is an image processing technique that allows for the identification of materials in an image, according to their spectral signatures. There are several kinds of classification algorithms, but the general purpose is to produce a thematic map of the land cover. For image processing and GIS spatial analyses we used the Semi-Automatic Classification Plugin for QGIS (QGIS v 3.18.1).

Random Forest classifier was used which is a particular machine learning technique, based on the iterative and random creation of decision trees (i.e. a set of rules and conditions that define a class). Model based on the decision trees is created and used to classify all the pixels. A pixel is classified according to the majority vote of decision trees, for example a pixel is classified as class 1 if most decision trees evaluated it as class 1. Also, a confidence layer is produced, which measures the uncertainty of the model based on training data.

Maxent modeling

Maxent is a general-purpose method for making predictions or inferences from incomplete information. It is widely used as general approach for modeling the species distribution using presence-only datasets. The idea of Maxent is to estimate a target probability distribution by finding the probability distribution of maximum entropy. When Maxent is applied to presence-only species distribution modeling, the pixels of the study area make up the space on which the Maxent probability distribution is defined, pixels with known species occurrence records constitute the sample points, and the features are climatic variables, elevation, soil category, vegetation type or other environmental variables and functions thereof.

Maxent offers many advantages, and a few drawbacks for the inference of species-habitata association. Maxent is an effective tool for estimating a large number of parameters with a small sample size. It eliminates problems associated with data endogeneity and collinearity (Golan et al., 1997). The software used was Maxent v. 3.4.3 (Maxent, 2020).

Using forest density classes and grid of distance to the forest class measured at the 80 presence locations, we estimated a Maxent model. Using modeling results we assessed which species was associated with different forest class.

Results

Borjomi-kharagauli NP

We have counted woodpeckers and forest associated birds on 80 sampling locations. In total 36 breeding forest bird species was recorded on the sampling locations (Fig. 1). 5 species of woodpeckers were recorded. Black woodpecker *Dryocopus martius* was recorded at 28.75 % of sampling points, Green woodpecker *Picus viridis* was recorded at 15% of sampling sites, Great spotter woodpecker *Dendrocopus major* was recorded at 71.25% of sampling sites, White backed woodpecker *Dendrocopus leucotos* was recorded at 1.25% of sampling sites and Lesser spotted woodpecker *Dendrocopus minor* was recorded at 1.25% of sampling sites (Fig. 2). From woodpecker species most prevalent were *Dendrocopus major, Dryocopus martius* and *Picus viridis. Dendrocopus leucotos and Dendrocopus minor* were recorded relatively rarely (Fig 2). From other forest associated bird species most prevalent were: *Fringilla coelebs* 93.75 % of sampling sites, *Parus major* 88.75% of sampling sites, *Turdus merula* 77.5 % of sampling sites, *Troglodites troglodites* 73.75% of sampling sites and *Periparus ater* 57.5% of sampling sites (Fig. 1).

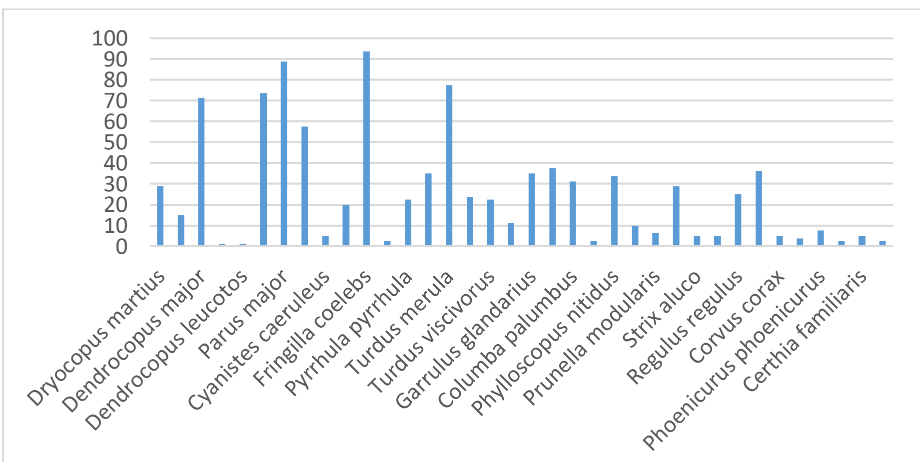


Figure 1. All forest associated bird species and their prevalence recorded at sampling locations in BKNP

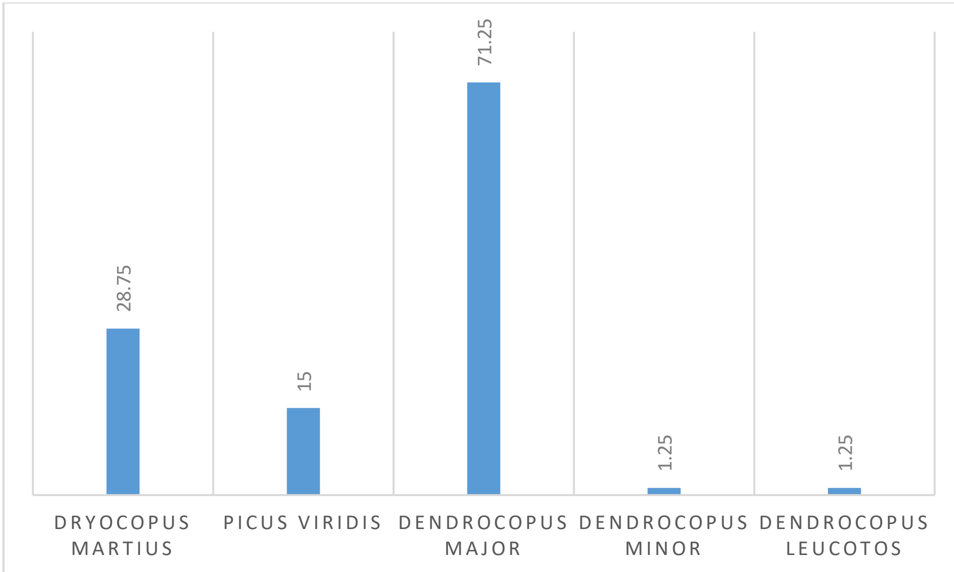


Figure 2. Prevalence of woodpecker species at sampling locations in BKNP

Pshav-Khevsureti PA

We have counted woodpeckers on 26 sampling locations. 4 species of woodpeckers were recorded. Black woodpecker *Dryocopus martius* was recorded at 7.69 % of sampling points, Green woodpecker *Picus viridis* was recorded at 3.85% of sampling sites, Great spotter woodpecker *Dendrocopus major* was recorded at 34.62% of sampling sites, White backed woodpecker *Dendrocopus leucotos* was recorded at 7.69 % of sampling sites (Fig. 3). From woodpecker species most prevalent were *Dendrocopus major, Dryocopus martius* and *Dendrocopus leucotos.* Compare to the BKNP forest cover in PKNP is relatively small. Majority of the forests are high mountain and sub-alpine forests which are not most suitable habitat for woodpeckers.

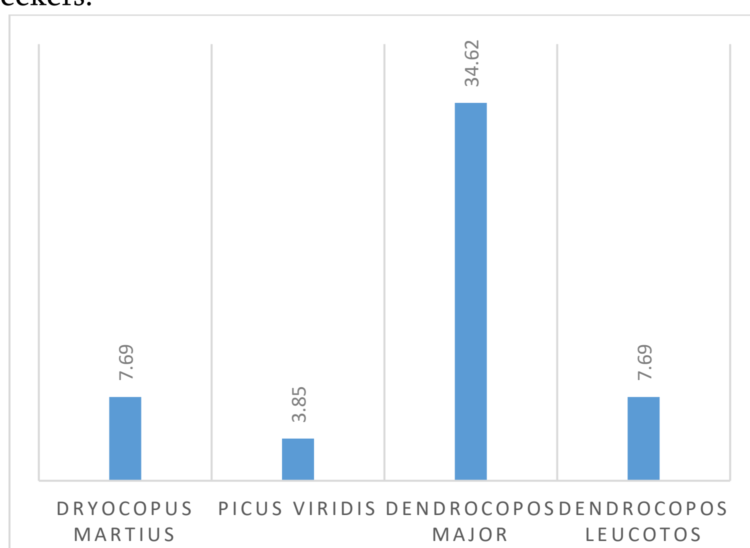
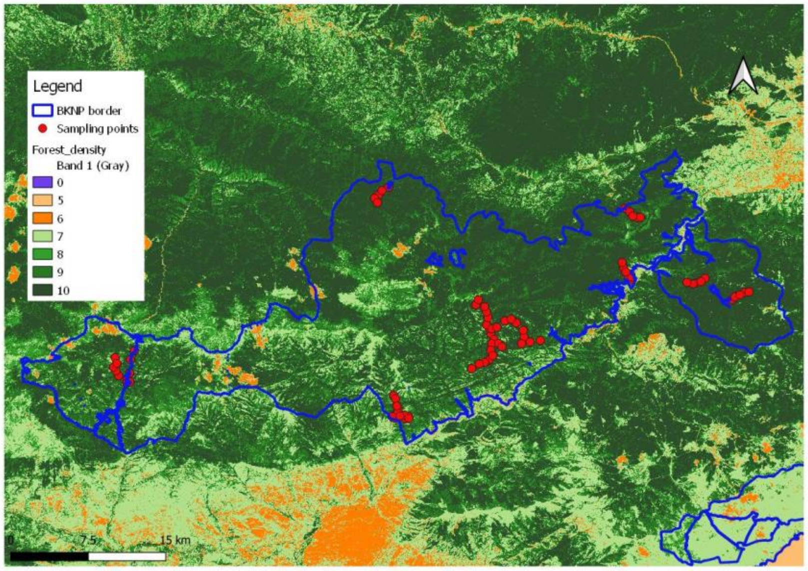


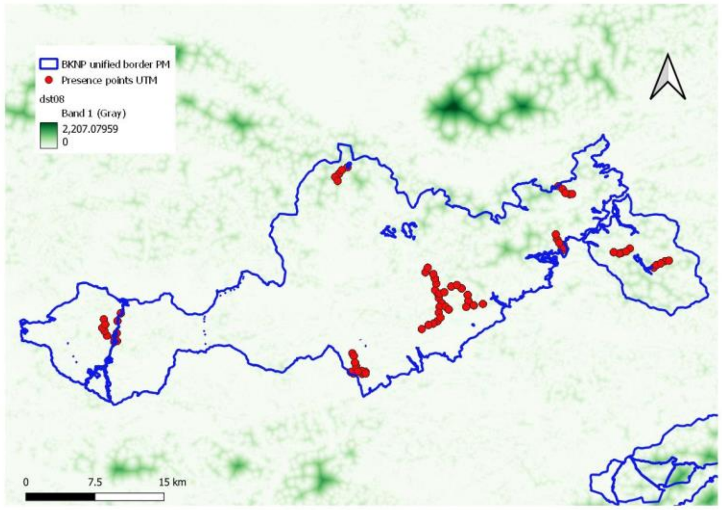
Figure 3. Prevalence of woodpecker species at sampling locations in PKNP



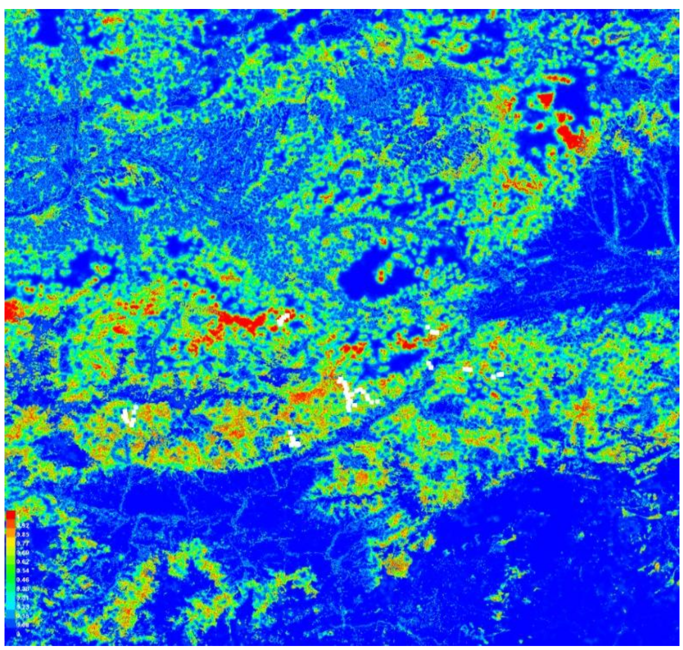
Map 3. Land cover classes and sampling locations. Class 0 – unclassified, 5 – water or clouds, 6 - Bare areas with limited vegetation, 7 – Fields/unfrosted areas, 8 – low density forests, 9 – medium density forests, 10 – high density forests.

Niche-based modeling of forest avian species

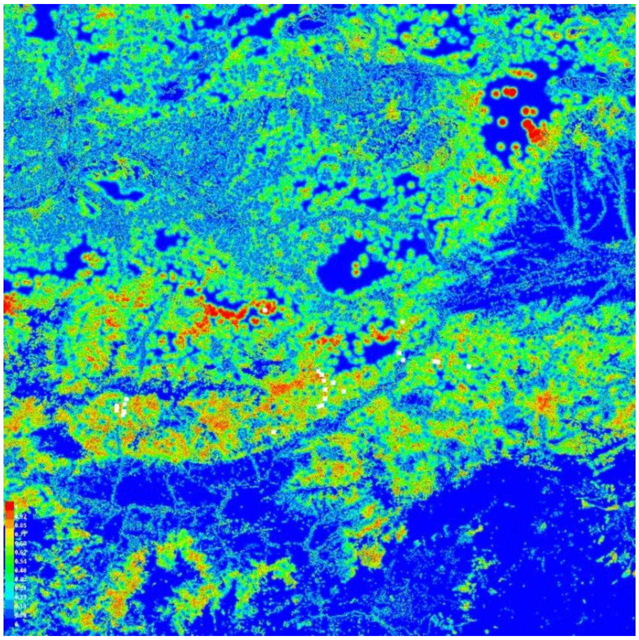
From the forest and land cover classes in QGIS we have constructed distance matrix for each forest class (Map 4). We have used this data and presence locations of each species, delivered from field sampling, to create niche models for each species. Modeling was performed in the software maxent described above. Model assesses influence of each factor (forest and land cover classes) on the probability of presence of particular species. Map of Probability of occurrence of the particular species in the study area is generated (Map 5,6,7). Maxent tests importance of the variables using jackknife test of variable importance. Algorithm selects the environmental variable with highest gain when used in isolation, which therefore appears to have the most useful information by itself. Jackknife test of variable importance also identifies the environmental variable that decreases the gain the most when it is omitted, which therefore appears to have the most information that isn't present in the other variables (Fig 4,6,8). Further we examined response of species occurrence on the particular important variable (Fig 5,7,9).
We performed this modeling to better understand realized niches of study species and if any of the species can be used as indicator species for the different type of forests.



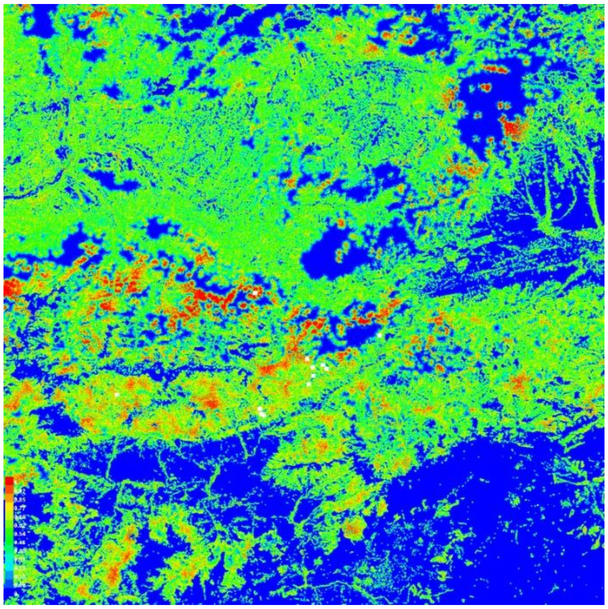
Map 4. Distance matrix of from low density forest class – 8.



Map 5. This map is a representation of the Maxent model for Dendrocopus major. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations.



Map 6. This is a representation of the Maxent model for Dryocopus martius. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations.



Map 7. This is a representation of the Maxent model for Picus_viridis. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations.

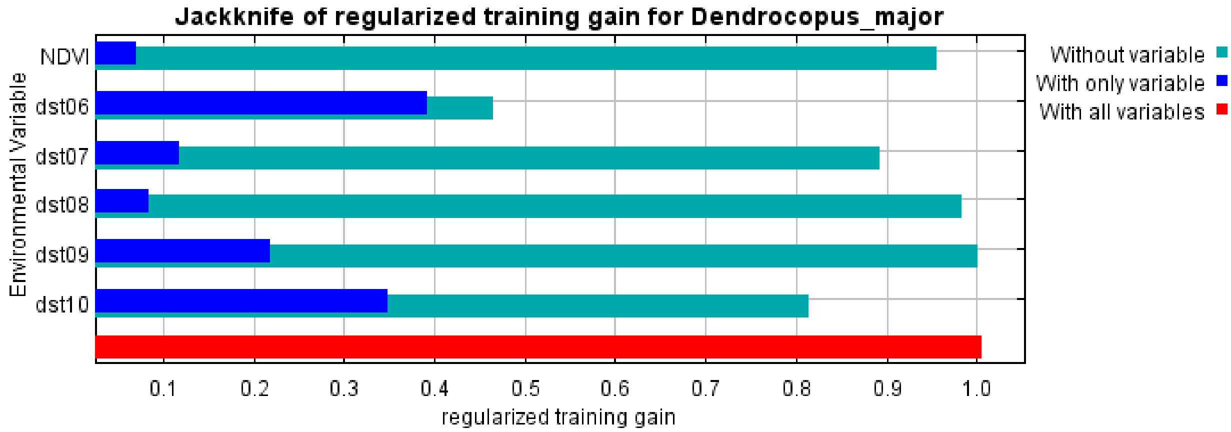


Figure 4. The following figure shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is dst06, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is dst06, which therefore appears to have the most information that isn't present in the other variables.

Jackknife test of variable importance indicates that variable distance from the land cover class 6 (bare areas with limited vegetation) is most important. Further we can see how these variable effects occurrence of the species (Fig. 5).

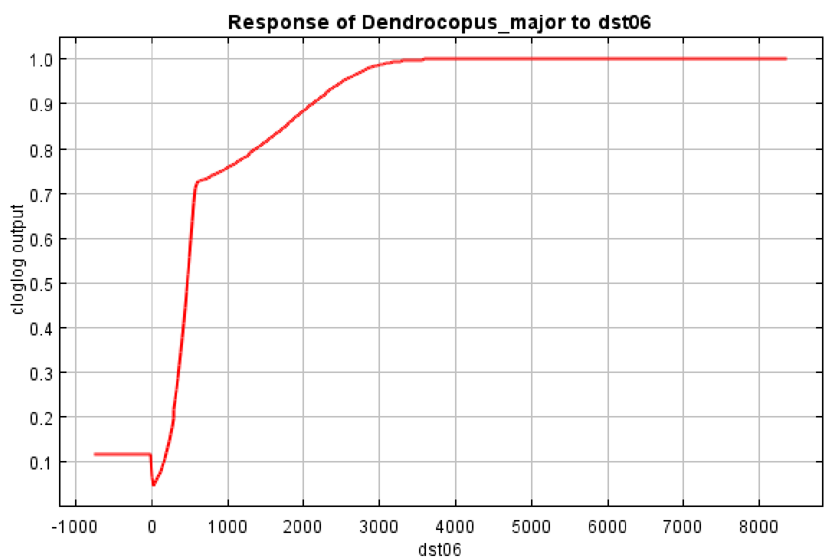


Figure 5. This curve shows how environmental variable 6 affects the Maxent prediction. The curves show how the predicted probability of presence changes as each environmental variable is varied, keeping all other environmental variables at their average sample value.

Probability of presence increases as distance from the variable grows.

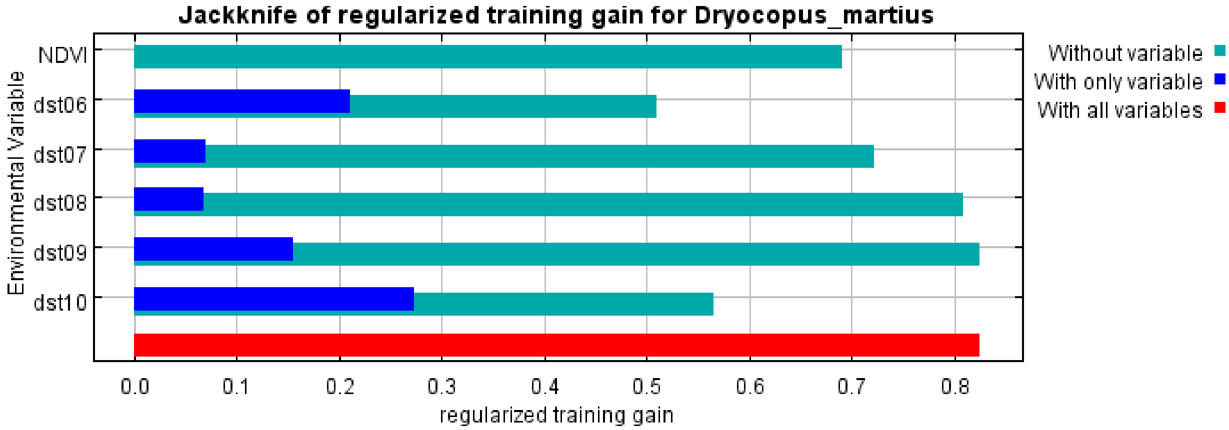


Figure 6. The following figure shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is dst10, which therefore appears to have the most useful information by itself.

Jackknife test of variable importance indicates that variable distance from the land cover class 10 (high density forest) is most important. Further we can see how this variable effects occurrence of the species (Fig. 7).

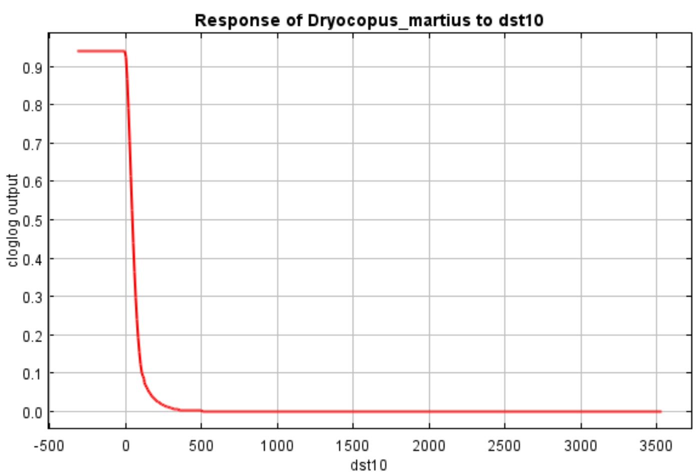


Figure 7. This curve shows how environmental variable 10 affects the Maxent prediction. The curves show how the predicted probability of presence changes as each environmental variable is varied, keeping all other environmental variables at their average sample value.

Probability of presence decreases as distance from the variable grows.

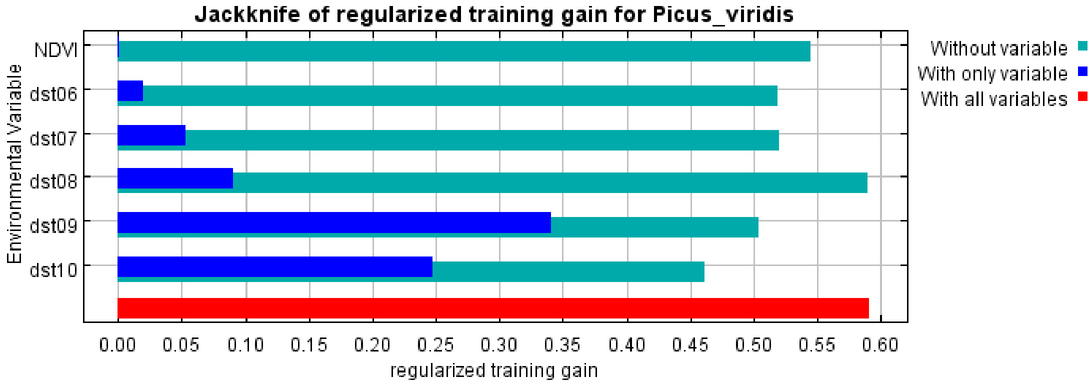


Figure 8.The following picture shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is dst09, which therefore appears to have the most useful information by itself.

Jackknife test of variable importance indicates that variable distance from the land cover class 9 (medium density forest) is most important. Further we can see how these variable effects occurrence of the species (Fig. 9).

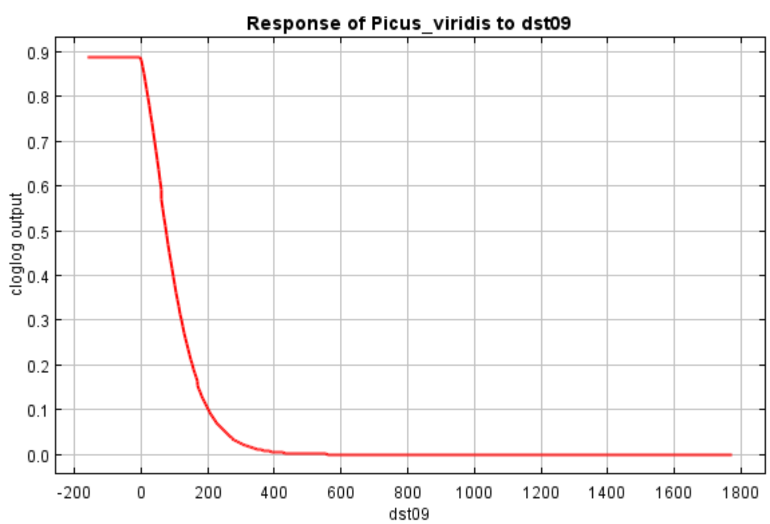


Figure 9. This curve shows how environmental variable 9 affects the Maxent prediction. The curves show how the predicted probability of presence changes as each environmental variable is varied, keeping all other environmental variables at their average sample value.

Probability of presence decreases as distance from the variable grows.

Discussion

Our results indicate that different species of woodpeckers are associated to the different forests classes. Great spotted woodpecker *Dendrocopus major* is not associated to any particular forest type but avoids areas with limited has vegetation. Probably this species will not be a good indicator for forest quality.
Black woodpecker *Dryocopus martius* is strongly associated to the high density forests and can be good indicator for those type of forests.
Green woodpecker *Picus viridis* prefers the medium density forests with openings and meadows. Therefore, can be an indicator of such type of forests as well as its appearance in high density forests can indicate forest density change.

We have performed maxent modeling for other bird species recorded during field sampling. Following species *Aegithalos caudatus, Cuculus canorus, Fringilla coelebs, Loxia curvirostra,Parus major, Periparus ater, Prunella modularis, Pyrrhula pyrrhula, Regulus regulus, Sylvia atricapilla, Troglodites troglodites, Turdus merula, Turdus viscivorus* showed some association with high density forests.
Only 2 species *Phoenicurus phoenicurus, Phylloscopus sindianus* were associated to low density forests and other species were avoiding bare areas with limited vegetation but not associated to any particular forest type.
We think that our approach for identification of bird – habitat associations might give us better, more unbiased understanding of forest indicator species. Models should be fine – tuned to provide better predictive power. This analysis was performed to demonstrate need and usefulness of more in depth understanding for unbiased selection of indicator species. It will improve monitoring scheme and will make results more interpretable.

We also discovered that due to the problems described above, monitoring of woodpeckers cannot be most useful way for the assessment of changes in Pshav-Kevsureti NP. We suggest using passive acoustic monitoring tools for the monitoring of avian communities and their change in PKNP.

Recommendations

- We recommend using passive acoustic monitoring methods for the further monitoring of forest birds in Pshav-Khevsureti NP;
- We recommend using, methodology of monitoring of forest birds, tested in this study to understand better habitat-species associations in Borjomi-Kharagauli NP;
- We recommend to develop further forest habitat models incorporating other important factors (different degradation types, different forest management strategies, coniferous or deciduous stands) affecting bird species distribution and density.

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