Terrestrial Ecology and Behaviour
Research Article

ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., 70 (4), 2018: 527-534

Habitat Requirements of the White-backed Woodpecker *Dendrocopos leucotos lilfordi* (Sharpe & Dresser, 1871) (Piciformes: Picidae) in Strandzha Mountain, Bulgaria

***Georgi P. Gerdzhikov*[1], *Kostadin B. Georgiev*[2], *Dimitar G. Plachiyski*[1], *Tzvetan Zlatanov*[3] & *Peter S. Shurulinkov*[1]**

[1] National Museum of Natural History – Bulgarian Academy of Sciences, 1 Tsar Osvoboditel Blvd., 1000 Sofia, Bulgaria; E-mails: georgi.gerdjikov@gmail.com, d.plachiyski@gmail.com, p.shurulinkov@googlemail.com
[2] Field Station Fabrikschleichach, Biocenter, University of Würzburg, Glashüttenstr. 5, 96181 Rauhenebrach; Bavarian Forest National Park, Freyunger Str. 2, 94481 Grafenau, Germany; E-mail: kostadin.georgiev@uni-wuerzburg.de
[3] Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Street, 1113 Sofia, Bulgaria; E-mail: tmzlatanov@gmail.com

Abstract: White-backed woodpecker (*Dendrocopos leucotos*) is an old-growth forest specialist and one of the rarest woodpeckers in Europe. The southern subspecies of the white-backed woodpecker (*Dendrocopos leucotos lilfordi*) is among the least studied. We assessed which environmental variables influence the landscape distribution of the southern white-backed woodpecker applying recursive partitioning. We carried out the study in Strandzha Mts., Bulgaria, holding one of the largest subpopulations of this subspecies in south-eastern Europe. The results indicate that the highest occurrence probability is in Oriental Beech (*Fagus orientalis*) natural stands of seed origin with average age over 140 years. There is relatively high occurrence also in the natural stands of seed origin, dominated by Oak (*Quercus* spp.) and Hornbeam (*Carpinus* spp.) and generally with high percent cover of deciduous forests. The species is rarely found in coppice stands and forest plantations. Based on the results we conclude that the white-backed woodpecker habitat requirements include extensive coverage of deciduous, high-stemmed forest stands that have reached an age that facilitates deadwood formation. We suggest that silvicultural systems such as group selection or irregular shelterwood are implemented to assure continuous forest cover with presence of older patches. We also recommend protection of patches of old-growth, at least 40–50 ha in area, covering not less than 10% of the total area of Strandzha.

Keywords: Lilford's woodpecker, habitat model, forest structural parameters, recursive partitioning, old-growth forest, oriental beech

Introduction

In Europe, two subspecies of white-backed woodpecker (*Dendrocopos leucotos*) (hereafter WbW) are widespread. The nominotypical subspecies *Dendrocopos leucotos leucotos* inhabits Central and Northern Europe. The Lilford Woodpecker *Dendrocopos leucotos lilfordi* has scattered distribution in the Pyrenees, Abruzzi, Balkan Peninsula, Asia Minor, Caucasus Mts., Georgia, Armenia and Azerbaijan (Cramp 1985, Butiev et al. 2005). The Bulgarian population is estimated at 800–1500 pairs (BirdLife International 2015), the largest subpopulation of the species in Bulgaria (ca. 200 pairs) occurs in Strandzha Mts. (Iankov 2007, Kostadinova & Gramatikov 2007) in SE Bulgaria (Fig. 1). The national conservation status of the species, according Red Data Book of the Republic of Bulgaria, is "Endangered" (Spiridonov et al. 2015).

Knowledge about processes influencing the distribution of species is of central importance in ecology and conservation (Cody 1985, Robles & Cuidad

2012). This is especially valid for rare habitat specialists like the WbW. It is an important key-stone species in mature natural deciduous forests (Roberge et al. 2008). Its population has declined in Europe due to habitat change caused by intensified forest management (Carlson 2000). In an attempt to facilitate WbW's conservation and habitat restoration, many studies in Northern and Central Europe have focused on studying its habitat selection criteria at a stand scale (Krams 1998, Pavlik 1999, Carlson & Aulén 2000, Angelstam et al. 2002, Czeszczewik 2009a). However, fewer studies have investigated the habitat preferences of the WbW at landscape scale (but see Carlson 2000, Cárcamo et al. 2014).

The WbW occupies extensive mature to old-growth natural broad-leaved or mixed mountain forests, with a large amount of dead wood (Cramp 1985, Carlson 2000, Czeszczewik &Walankiewicz 2006). The species occurs in lowlands, especially in riparian forests along river valleys (Spitznagel 1990, Wesoiowski 1995a), and in mountain forests (Cramp 1985, Butiev et al. 2005). Forest stands can be dominated by different tree species – alder, oak, birch and beech, aged no less than 60–80 years where management is minimal, often on steep slopes (Cramp 1985, Angelstam &Mikusinski 1994, Pavlik 1999, Gorman 2004). From north to south, species change preferences from multi-species broad-leaved forest (Virkkala et al. 1993, Kajtoch et al. 2013) to strong preferences of beech forest (Costantini et al. 1993, Nankinov 1993, Melletti & Penteriani 2003), with some exceptions (Handrinos & Akriotis 1997, Pavlik 1999, Shurulinkov et al. 2012). Similar changing gradient of the forest age could be observed in N-S direction – from younger (60-80 years) forests in Finland to older growth (more than 120 years) in Spain, France and the Balkans (Gorman 2004, Garmendia et al. 2006, Denac & Mihelic 2015). Garmendia et al. (2006) found that in the Pyrenees the most important factor determining the distribution of the species is the amount of large-diameter snags and trees in forest stands older than 140 years. Same study reported that WbW avoids breeding in forest patches smaller than 30 ha regardless of the other available optimal conditions. In Fennoscandia, the breeding territory of the WbW is characterized by a high proportion of deciduous trees (75-93%), rich in deadwood (average 20%) (Carlson 2000).

Main aim of the study was to evaluate the habitat requirements of the WbW in Strandzha Mts. For that purpose, we created an explanatory model to find the environmental variables that best explain the landscape distribution of the species.

Materials and Methods

Study site

The study was conducted in Strandzha Mts., South-eastern Bulgaria (Fig. 1). Outer borders of the study area overlap with borders of the "Strandzha" Nature Park and the Special Protected Area "Strandzha" (BG0002040) of NATURA 2000 network. The study area is 116 100 ha in total. Altitude varies between

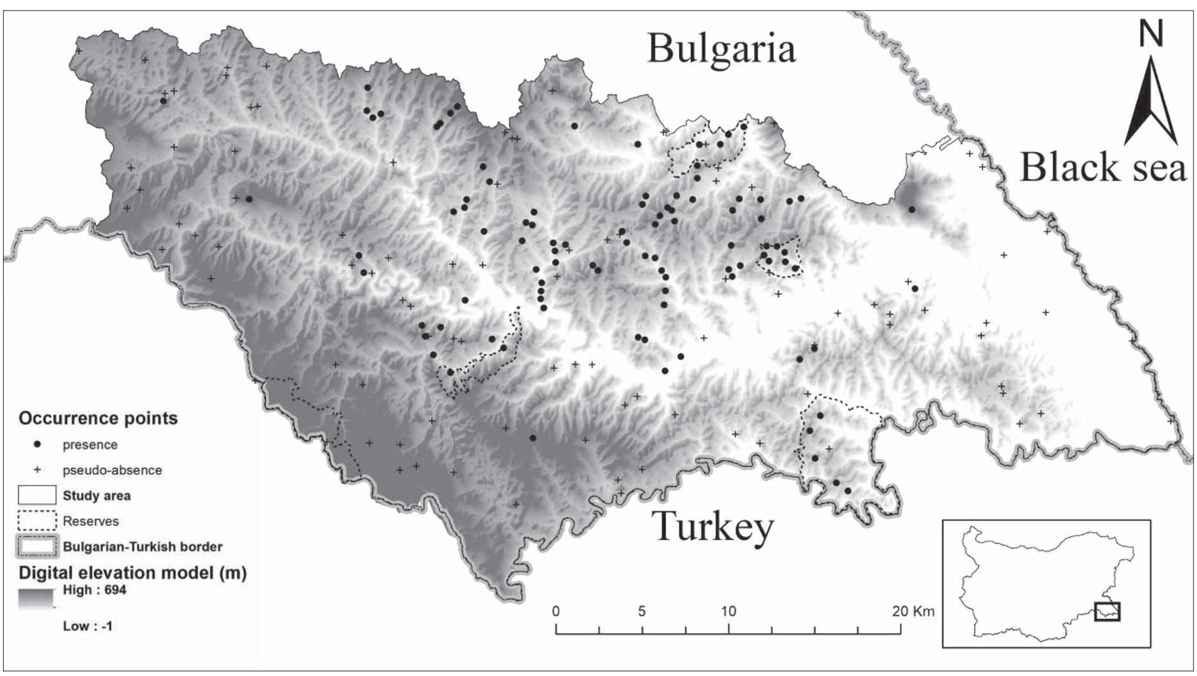

Fig. 1. Study area and presence/pseudo-absence points of the white-backed woodpecker in Strandzha Mountain.

0 and 694 m a.s.l., with forests covering about 80% of whole territory. Forests are dominated by oaks (*Quercus* spp.) and oriental beech (*Fagus orientalis*). Average forest stand age varies between 30 and 220 years. Sustainable wood production is main objective of the forest management in the core zone of the study area. Additionally, there are five strict forest reserves in the study area, with total area of 5089.6 ha.

Field data sampling

The field data (species distribution) collection was conducted during the spring/summer (March–July) and autumn (September–November) seasons in 2013–2017. As the species is non-migratory and has high site fidelity to its breeding territory it is possible to record it in its preferred habitats during the autumn as well (Gorman 2004, Shurulinkov et al. 2012). Records of juveniles were excluded from the analysis as the juveniles wander in autumn (Gorman 2004). In the study area, we conducted 65 transects with 5-15 km length. Two methods were used to establish the presence of the species – direct observation (30% from all recorded individuals, n=90) and playback survey (Johnson et al. 1981, Santis et al. 2007, Baumgardt et al. 2014). On every 500–700 m along the transects, the observer stopped and looking for/listen 5 min for the species. If the species was not registered, the observer used second method – a playback recording of territory drumming or contact calls of the species. In case of presence of the WbW, the GPS coordinates of the observation point were taken, hereafter presence point.

We used the presence/availability approach (Franklin 2010). The presence points (records of WbW) were complemented with the same number of pseudo-absences points (Zaniewski et al. 2002). The pseudo-absence points used in the analyses were generated in a random way within forests. In the modelling process, we used only points that were situated at minimum 250 m apart to avoid any possible pseudo-replication. For the final analysis, we used 90 presence and 90 pseudo-absence points, which form a representative sample of the available conditions in all forests in the study area (Fig. 1).

Environmental data

Ten explanatory variables were used to evaluate the habitat requirement of the white-backed woodpecker (Table 1). Dominant tree species (grouped in five categories), forest stand age, origin (grouped in 3 categories) and stocking rate were extracted from the GIS database of Bulgarian forests (EFA 2015) and forest database for reserves (ExEA 2017). CORINE Landcover 2012 with a resolution of 100 x 100 m was used to calculate the landscape fragmentation using the interspersion and juxtaposition-index (McGarigal & Marks 1995) and the percentage cover of deciduous forests. The calculation was per-

Table 1. Explanatory variables used to evaluate the habitat requirement of the white-backed woodpecker.

Code	Variable	Unit	Source
DEM	Digital elevation model	m a.s.l.	EU-DEM (EEA 2013)
ASP	Terrain aspect	Degrees	EU-DEM (EEA 2013)
Slope	Terrain slope	%	EU-DEM (EEA 2013)
Ruggedness	Terrain ruggedness	Index 0-150	EU-DEM (EEA 2013)
Tree.Species	Dominant tree species in stand	Grouped in five categories: *Fagus orientalis*, *Quercus* spp., *Carpinus* spp., other broad-leaved, coniferous species	Forest Database (EFA 2015, ExEA 2017)
Forest.Origin	Forest stand origin	Categories: natural stands of seed origin (natural), coppice stands (coppice), forest plantations (forest plantations)	Forest Database (EFA 2015, ExEA 2017)
Forest.Age	Average forest stand age	mean tree age in a forest stand	Forest Database (EFA 2015, ExEA 2017)
Stocking.Rate	Forest stand stocking rate	%	Forest Database (EFA 2015, ExEA 2017)
Forest.Cover	Percent cover of broad-leaved forests	%	Corine Landcover 2012 (EEA 2012)
Fragmentation	Juxtaposition and interspersion index	Index 0-100	Corine Landcover 2012 (EEA 2012)

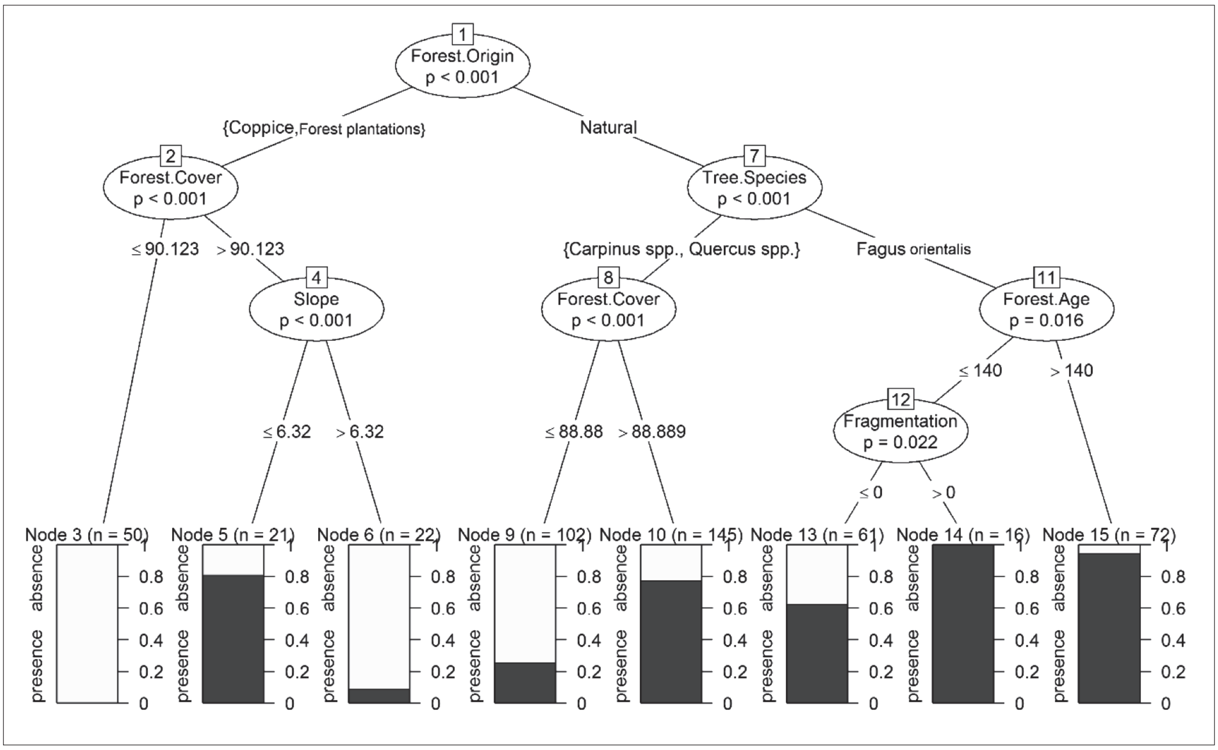

Fig. 2. Conditional inference tree visualizing the distribution of the dependent variable (presence of the WbW) according to the most influential environmental variables (see Table 1), with the significance value in each terminal node. Positive response (presence of the white-backed woodpecker (WbW)) is shown in dark grey colour, negative – in white. The relative importance of the variables is based on their order in the tree – the higher variable in the tree is more important for the distribution of the WBW.

formed with the Slicer 1.0 software (Gottschalk et al. 2008) with a moving window of 500 m. The proportion of broad-leaved forests and fragmentation were chosen as they proved to be important factors for the distribution of the species in Swedish forests (Carlson 2000). Elevation, terrain aspect, slope and terrain ruggedness were derived from the digital elevation model of Bulgaria (European Environmental Agency 2013).

Statistical analysis

To test which variables best explain the distribution of WbW, we used sophisticated recursive partitioning, i.e. conditional inference trees (Ctree) with a P value-based stopping criterion following Hothorn et al. (2006). This method embeds tree-structured regression models and allows for simultaneous variables selection and identification of variable thresholds by means of a statistical test procedure, i.e. a decision whether or not there is a relationship between the explanatory and the response variable. The model fitting results into a tree with certain number of nodes. At each node, a significance test on independence between any of the explanatory variables and the response variable is performed. A split is established when the P value, which was adjusted for multiple comparisons of the same variable, is smaller than a pre-specified nominal level. In case we started the calculation of the tree with a threshold P value < 0.001. The method and a comprehensive model comparison are described in Hothorn et al. (2006).

To evaluate the predictive accuracy of the model we estimated the area under the receiver operating characteristic (ROC) curve (AUC). We performed a cross-validation with 1000 random data splits using portions of 80 : 20 (training : testing) data. The AUC can range between 0.5 (no discrimination between presence and absence) and 1.0 (perfect discrimination; Fielding & Bell 1997).

Data preparation and statistical analyses were carried out in R version 3.0.2 (R Core Team 2013). Model fit was performed with R package ‘party’ version 1.2-3 (Hothorn et al. 2006). For visualization of the GIS data we used Quantum GIS version 2.4.0 (QGIS Development Team 2014).

Results

The model evaluation with cross-validation showed good discriminating ability (AUC = 0.744) between presence and pseudo-absence points of our model.

The results of the recursive partitioning showed that Forest Origin, Broad-leaved Forest Cover and Dominant Tree Species were the most important variables, as shown by their higher position in the conditional tree (Fig. 2). The Forest Age, Slope and Fragmentation were also selected as influential variables but the results represent lower relative importance.

The occurrence probability of the WbW was highest (ca. 95-100%) in natural stands of seed origin, oriental beech dominated stands and stands with average age of above 140 years (terminal Node 15) (Fig. 2). The occurrence probability was also high (ca. 78%) in natural stands of seed origin dominated by oak (*Quercus* spp.) and hornbeam (*Carpinus* spp.) and percent cover of broad-leaved forests higher than 88% (terminal Node 10). Forests with coppice origin and/or forest plantations, more than 90% cover of broad-leaved forests and terrain slope less than 6.32% (approximately 23 degrees) showed also high occurrence probability – 80% (terminal Node 5). The probability of finding the species was lowest in coppice stands and/or in forest plantations with percent cover of broad-leaved forests under 90% (terminal Node 3).

Discussion

In this study, we showed that the landscape distribution of the white-backed woodpecker is best explained by Forest origin, Percent cover of broad-leaved forests, Dominant tree species, Forest stand age, Slope and Forest fragmentation. Forest origin is the variable with the highest relative importance, as shown by the variable order in the conditional tree (Fig. 2). According to the model, coppice forest stands showed low importance, while natural stands of seed origin were associated with the highest occurrence probability of the WbW. This finding is in line with the findings in much of the range of the WbW, especially in Northern Europe, indicating that the species prefers natural forests of seed origin (Aulén & Aulén 1988, Carlson & Aulén 1992, Frank 2002).

The results from the analysis reveal that the probability of occurrence of the WbW is slightly higher in stands dominated by Oriental beech compared to those dominated by oak species. Oriental beech forests in Strandzha Mts. grow mainly on steep shaded slopes (Tzonev et al. 2006) where microclimate conditions favour fungi growth and deadwood formation. It is known that for its foraging the WbW is highly dependent on great amounts of deadwood in different decomposition stages (Aulén 1991, Melleti & Penteriani 2003, Czeszczewik 2009a). Forests in Strandzha Mts. have been traditionally managed under regular shelterwood system where extraction of deadwood been widely practiced (Zlatanov 2017). Deadwood extraction is generally more intensive on easily accessible terrains. Therefore, it is likely that because of the combination of steep slopes and microclimate conditions beech forests stands offer favourable conditions for deadwood formation that provides appropriate WbW nesting and foraging habitat. In Strandzha Mts., oaks are the most widely distributed tree species, covering approximately 64% of the forested area, while Oriental beech forests cover only 12% (EFA 2015).

Furthermore, our results reveal that the WbW is most likely to occur in forests older than 140 years, similar with results of Garmendia et al. (2006) in Pyrenees. Generally, forests above 140 years have developed old-growth characteristics that meet the requirements of the species, i.e. foraging and breeding substrate. Deadwood formation and accumulation is associated with higher tree age (Paletto et al. 2012). However, in Strandzha Mts., the WbW was also found in forest stands younger than 140 years but with lower occurrence probability. This is supported by the fact that in other Bulgarian mountains the WbW has been found in much younger beech (and oak) forests – 80–140 years old (Shurulinkov et al. 2012, Spiridonov et al. 2015). Therefore, forest stand age alone cannot entirely explain the occurrence of the species.

Our results about higher WbW's occurrence probability in higher percent cover of broad-leaved forests confirm the study of Pavlik (1999) who reported that in Slovakia the home range of the WbW is associated with more than 80% of oak forests coverage. Alike in Sweden and Finland, the presence of the WbW depends on a minimum amount of deciduous broad-leaved forests (75-93%) in the landscape (Carlson 2000). Nevertheless, this study was performed in boreal forests where the proportion of broad-leaved stands is naturally not significant as in Strandzha Mts. Coniferous forest stands in Strandzha Mts. are rather rare and not natural in origin (only forest plantations). In other Bulgarian mountains (Balkan Mts., Rhodopi Mts, Pirin Mts.), the species is recorded in beech-coniferous forests of natural origin (Shurulinkov et al. 2012, Spiridonov et al. 2015).

The analysis indicates that coppice forests provide less suitable habitat for the WbW, compared to the high-stem forests. The reason behind this higher selection of the high-stem forest is based on the type of management rotation. The coppice forests in Bulgaria are managed in rotations of 40–60 (80) years, hence they are harvested before they can develop old-growth characteristics that fully meet the requirements of the WbW (Stajic et al. 2009, Vacik et al. 2009). The natural high-stem forests on the other hand are managed under rotations of 140–160 years for oak and 120–140 for beech stands (Birdlife European Forest Task Force 2009), which provide suitable habitat for the breeding and foraging of the species. The analysis has indicated that the high-stem forests that have reached their final harvest age are most suitable for the WbW in Strandzha Mts. However, the objective of high-stem beech forests management in Bulgaria is wood production, even in the nature parks as "Strandzha" NP, and under these conditions, a steady degradation of the WbW habitat quality during the recent decades has been observed throughout the country.

During the double split of Forest Origin (Node 1), which is a categorical variable with three classes, the classes coppice origin and forest plantations were grouped together in one branch on the left side of the tree. Because of this grouping, the separation of the effects of the single classes becomes difficult. In our case the left hand side of the conditional tree is generally linked to low occurrence probability, with one exception in Node 5. However, based on the ecology of the species we suggest that the high occurrence probability of Node 5 is most probably associated with coppice forest stands while the low probability of Node 3 and Node 6 in associated with forest plantations.

The availability of extensive coverage of deciduous, high stemmed forests that have reached a stand age, which enhances deadwood formation, is required to provide appropriate breeding and foraging habitat for the WbW. We recommend that the silvicultural systems that should be applied in the core species habitat should mainly include group selection or irregular shelterwood cutting in order to ensure availability of continuous forest cover with presence of older patches. We also recommend protection of patches of old-growth, at least 40–50 ha in area, covering not less than 10% of the total area of Strandzha. For the benefit of species orientated forest management, the coniferous plantations should be replaced with deciduous forests of seed origin.

Acknowledgements: This study was funded through the „Support program for young scientists" of the Bulgarian Academy of the Science 2016-2017 (Project DFNP-37) of the National Museum of Natural History, Bulgaria. We are grateful to the Bulgarian Society for the Protection of Birds and the Bulgarian Biodiversity Foundation which provided data for the analysis as part of Project № 5103020-39-682 "Action plans for Capercaillie, Three-toed Woodpecker and White-backed Woodpecker", funded by Operational Programme Environment 2007–2013. We are grateful to Mikhail Illiev, Vladimir Mladenov and Ralitsa Georgieva for their support during the field surveys and Nikolay Petkov for English checking.

References

Angelstam P. & Mikusinski G. 1994. Woodpecker assemblages in natural and managed boreal and hemiboreal forest – a review. Annales Zoologici Fennici 31 (1): 157-172.

Angelstam P., Breuss M., Mikusinski G., Stenström M., Stighäll K., Thorell D., Chamberlain D. & Wilson A. 2002. Effects of forest structure on the presence of woodpeckers with different specialisation in a landscape history gradient in NE Poland. In: Chamberlain D. & Wilson A. (Eds.), Proc. of the 2002 Annual IALE (UK) Conference, pp. 25–38.

Aulén G. 1991. Increasing insect abundance by killing deciduous trees: a method of improving the food situation for endangered woodpeckers. Ecography 14 (1): 68-80

Aulén G. & Aulén G. 1988. Nest-site selection of the White-backed Woodpecker *Dendrocopos leucotos* and Great Spotted Woodpecker *D. major* in Central Sweden. Swedish University Agricultural Science Department and Wildlife Ecology, Report 14: 197-220.

Baumgardt J. A., Sauder J. D. & Nicholson K. L. 2014. Occupancy modelling of woodpeckers: Maximizing detections for multiple species with multiple spatial scales. Journal of Fish and Wildlife Management 5(2): 198-207

BirdLife European Forest Task Force. 2009. Biologically Important Forests – A Step towards Matrix Habitat Preservation in Europe.

BirdLife International. 2015. European Red List of Birds. Luxembourg: Office for Official Publications of the European Communities.

Butiev V., Zubkov N., Ivanchev V., Koblik A., Kovshar A., Kotyukov J., Lyuleeva D., Nazarov J.,Nechaev V., Priklonski S., Pukinski J., Rustamov A., Sorokin A. & Fridman V. 2005. Birds of Russia and neighbouring regions: Owls, Nightjars, Swifts, Rollers, Hoopoes and Woodpeckers. Moscow: Society of scientific press, KMK. 487 p. (In Russian).

Cárcamo S., Azkona P., Senosiain A., Fernández C. & Schwendtner O.2014. Nest tree selection by the White-backed Woodpecker (*Dendrocopos leucotos lilfordi*) and Black Woodpecker (*Dryocopus martius*) in the Western Pyrenees Navarra (Spain). In: Woodpeckers in a Changing World.7-th International Conference on Conservation and Ecology of Woodpeckers. Book of Abstracts.

Carlson A. & Aulén G. 1992. Territorial dynamics in an isolated White-backed Woodpecker (*Dendrocopos leucotos*) population. Conservation Biology 6 (3): 450-454.

Carlson A. 2000. The effect of habitat loss on a deciduous forest specialist species: the White-backed Woodpecker (*Dendrocopos leucotos*). Forest Ecology and Management 131 (1): 215-221.

Cody M. 1985. Habitat selection in birds. New York: Academic Press, 558 p.

Costantini C., Melletti M. &Papi R. 1993. Osservazioni preliminari sulla biologia riproduttiva del Picchio Dorsobianco

Picoides leucotos lilfordi in Italia Centrale. Avocetta 17: 81-83.

Cramp S. (Ed.) 1985. The Birds of the Western Palearctic. Oxford. London. New York: Oxford University Press, 960 p.

Czeszczewik D. &Walankiewicz W. 2006. Logging affects the White-backed Woodpecker *Dendrocopos leucotos* distribution in the Białowieża Forest. Annales Zoologici Fennici 43: 221-227.

Czeszczewik D. 2009a. Marginal differences between random plots and plots used by foraging White-backed Woodpeckers demonstrates supreme primeval quality of the Białowieża National Park, Poland. Ornis Fennica 86 (1): 30-37.

Denac K. &MiheličT. 2015. Status in varstvo belohrbtega detla *Dendrocopos leucotos* v Sloveniji [The status and conservation of the White-backed Woodpecker *Dendrocopos leucotos* in Slovenia]. Acrocephalus 36 (164-165): 5-20.

European Environmental Agency. 2013. EU-DEM – Metadata.

Executive Environment Agency (ExEA). 2017. Data base of Bulgarian forest reserves, Sofia. Ministry of ecology http://eea.government.bg/en

Executive Forestry Agency (EFA). 2015. Database of Bulgarian forests. Sofia: Ministry of agriculture and food.

Fielding A. H. & Bell J. F. 1997. A review of methods for the assessment of prediction errors in conservation presence / absence models. Environmental Conservation 24: 38–49.

Frank G. 2002. Habitat selection of White-backed Woodpecker *Dendrocopos leucotos* during the breeding season in comparison to Great Spotted Woodpecker *Dendrocopos major* in mountainous mixed forests of the northern Austrian Chalk Alps. Die Vogelwelt 123 (5): 225-240.

Franklin J. 2010. Mapping species distributions. Spatial inference and prediction. Cambridge, UK: University Printing House, 340 p.

Garmendia A., Cárcamo S. & Schwendtner O. 2006. Forest management considerations for conservation of Black Woodpecker *Dryocopus martius* and White-backed Woodpecker *Dendrocopos leucotos* populations in Quinto Real (Spanish Western Pyrenees). Biodiversity and Conservation 15: 339-355.

Gorman G. 2004. Woodpeckers of Europe: a study of European Picidae. London: Bruce Coleman. 192 p.

Gottschalk T. K., Bertling M., Wolters V. &Biermann J. 2008. A new MW algorithm to speed up landscape index calculation of high resolution maps. In: Schiewe J. & Michel U. (Eds.) Geoinformatics paves the highway to digital earth. University of Osnabrück, Institut für Geoinformatik und Fernerkundung, pp. 29–32.

Handrinos G. & Akriotis T. 1997. The birds of Greece. London: A & C Black. 336 p.

Hothorn T., Hornik K. & Zeileis A. 2006. Unbiased Recursive Partitioning: a Conditional Inference Framework. Journal of Computational and Graphical Statistics 15: 651–674.

Iankov P. (ed.). 2007. Atlas of breeding birds in Bulgaria. Bulgarian Society for the Protection of Birds, Conservation Series, Book 10. Sofia, BSPB, pp. 370-371.

Johnson R. R., Brown B. T., Haight L. T. & Simpson J. M. 1981. Playback recording as a special avian censuring technique. In C.J. Ralph and J.M. Scott, eds. estimating numbers of terrestrial birds. Studies in Avian Biology 6: 68–75.

Kajtoch Ł., Figarski T. &Pełka J. 2013. The role of forest structural elements in determining the occurrence of two specialist woodpecker species in the Carpathians, Poland. Ornis Fennica 90: 23-40.

Kandemir G & Kaya Z. 2009. EUFORGEN Technical guidelines for genetic conservation and use of oriental beech (*Fagus orientalis*). Roma, Italy: Bioversity International.

Kostadinova I. & Gramatikov M. (Eds.). 2007. Important Bird Areas in Bulgaria and Natura 2000. Bulgarian Society for the Protection of Birds, Conservation Series, Book 11. Sofia, BSPB, p. 252-255.

Krams I. 1998. Nest site selection of the White-backed Woodpecker *Dendrocopos leucotos* in the eastern part of Latvia. Ornis Svecica 8 (1): 11-16.

McGarigal K. & Marks B. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. General Technical Report PNW-GTR-351. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 122 p.

Melletti M. & Penteriani V. 2003. Nesting and feeding tree selection in the endangered White-backed Woodpecker, *Dendrocopos leucotos lilfordi*. The Wilson Bulletin 115 (3): 299-306.

Nankinov D. 1993. Distribution and ecological requirements of White-backed Woodpecker (*Dendrocopos leucotos*) in Bulgaria. In: National Forest protection science-technics conference. Bulgaria, Sofia 24.03.1993, pp. 58-63 (in Bulgarian).

Paletto A., Ferretti F., De Meo I., Cantiani P. & Focacci M. 2012.Ecological and environmental role of deadwood in managed and unmanaged forests. In: Diez J. J. (Ed.) Sustainable Forest Management, InTech book, pp. 219–238.

Pavlik S. 1999. Breeding ecology of the White-backed Woodpecker *Dendrocopos leucotos* in an oak forest. Biologia (Bratislava) 54: 187–194.

QGIS Development Team. 2014. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

R Core Team. 2013. R: A language and environment for statistical computing. R Found. Stat. Comput.

Roberge J-M., Mikusiński G. & Svensson S. 2008. The White-backed Woodpecker: umbrella species for forest conservation planning? Biodiversity and Conservation 17 (10): 2479-2494.

Robles H & Ciudad C. 2012.Influence of Habitat Quality, Population Size, Patch Size, and Connectivity on Patch-Occupancy Dynamics of the Middle Spotted Woodpecker. Conservation Biology 26 (2): 284-293.

Santis E., Imperio S., Fabrizi E., Campanella G., Savo E. & Cecere J. 2007. Use of playback technique for population monitoring of White-backed Woodpecker (*Dendrocopos leucotos lilfordi*) in Central Apennines. In: European Bird Census Council Meeting, Chiavenna (Italy).

Shurulinkov P., Stoyanov G., Komitov E., Daskalova G.& Ralev A. 2012. Contribution to the knowledge on distribution, number and habitat preferences of rare and endangered birds in Western Rhodopes Mts, Southern Bulgaria. Strigiformes and Piciformes. Acta Zoologica Bulgarica 64 (1): 43-56.

Spiridonov J., Georgiev D. & Zlatanov T. 2015. White-backed Woodpecker, *Dendrocopos leucotos lilfordi* (Sharp et Desser, 1871). In: Golemansky et al. 2015 Red data Book of the Republic of Bulgaria.Vol. 2, Animals, BAS & MOEW, Sofia.

Stajic B, Zlatanov T., Velichkov I., Dubravac T. & Trajkov

P. 2009. Past and recent coppice forests management in some regions of South-eastern Europe. Silva Balcanica 10 (1): 9–19.

Tzonev R., Dimitrov M., Chytry M., Roussakova V., Dimova D., Gussev C., Pavlov D., Vulchev V., Vitkova A., Gogushev G., Nikolov I., Borisova D. & Ganeva A. 2006. Beech forests communities in Bulgaria. Phytocoenologia 36 (2): 247–279.

Vacik H., Zlatanov T., Trajkov P. & Dekanic S. 2009. Role of coppice forests in maintaining forest biodiversity. Silva Balcanica 10 (1): 35–45.

Virkkala R., Alanko T., Laine T. & Tiainen J. 1993. Population contraction of the White-backed Woodpecker *Dendrocopos leucotos* in Finland as a consequence of habitat alteration. Biological Conservation 66 (1): 47-53.

Wesolowski T. 1995a. Ecology and behaviour of White-backed Woodpecker (*Dendrocopos leucotos*) in a primeval temperate forest (Biaiowieza National Park, Poland). Die Vogelwarte 38: 61-75.

Zaniewski A., Lehmann A. & Overton J. 2002. Predicting species spatial distributions using presence-only data: A case study of native New Zealand ferns. Ecological Modelling 157: 261–280.

Zlatanov T., Elkin C., Irauschek F. & Lexer M. 2017. Impact of climate change on vulnerability of forests and ecosystem service supply in Western Rhodopes Mountains. Regional Environmental Change 17: 79–91.

Received: 15.05.2018
Accepted: 26.11.2018