SYLWAN 166 (9): 566-578, September 2022
https://doi.org/10.26202/sylwan.2022064
Journal homepage: https://sylwan-journal.pl

ORIGINAL PAPER

Nest trees selected by the grey-headed woodpecker in northeastern Poland

Dorota Zawadzka[(1)]✉, Grzegorz Zawadzki[(2)]

[(1)] Department of Forest Sciences, Branch in Tomaszów Mazowiecki, University of Łódz, Konstystucji 3 Maja 65/67, 97-200 Tomaszów Mazowiecki, Poland

[(2)] Institute of Forest Sciences, Warsaw University of Life Science, Nowoursynowska 159, 02-776 Warszawa, Poland

ABSTRACT

Woodpeckers Picinae are recognised as important keystone species in forest ecosystems because many species of animals find shelters or breeding places in cavities woodpeckers excavate. We evaluated the nest tree preference of a European species, the grey-headed woodpecker (GHW), *Picus canus* Gmel., in the semi-boreal Augustów Forest in northeast Poland, an extensive forest complex covering 114 000 ha, dominated by fresh and mixed fresh coniferous forest. Nest trees made by the GHW were sought within areas identified by the playback of territorial vocalisations and drumming in spring. We found 35 cavities on 31 trees. Twenty-one of these cavities were made in trees of poor health and 14 in dead trees. Only deciduous trees were selected for excavation, specifically aspen *Populus tremula* L., silver birch *Betula pendula* Roth., and black alder *Alnus glutinosa* (L.) Gaertn. Alder was chosen most frequently, but according to Ivlev's electivity index, the most preferred species was aspen. We found important differences between forest sites used by the grey-headed woodpecker. Most cavities were found in alder forest, with fewer in broadleaf fertile forest, mixed broadleaf forest, and mixed pine forest. Cavity trees were on average 83-years-old (ranging from 45 to 127 years). The average diameter of cavity trees used by the grey-headed woodpecker was 47.4 cm (ranging from 30 to 67 cm), of which the most numerous were trees with diameters between 30 and 40 cm. All cavities were excavated in trunks. Cavity entrances were located at an average height of 8.2 metres (4.5-14 m). The mean height of the first branch on excavated trees was 10.2 metres above ground and was higher than the average height of the cavity entrance. Cavities in birch were placed higher than in other tree species. A linear mixed model explaining cavity height above ground showed important effects for first branch height, which allows for higher placement of the cavities, and tree species, because cavities in aspen and alder were excavated significantly lower than in birch. The GHW preferentially placed cavity entrances on southern and eastern exposures, with entrance aspect related to cavity height above the ground. Our results underline the importance of aspen to GHW and indicate the need to maintain this tree species in managed forests.

KEY WORDS

aspen, cavity trees, cavity entrance orientation, habitat preferences, *Picus canus*

✉e-mail: dorota.zawadzka@uni.lodz.pl

Received: 6 Oktober 2022; Revised: 1 December 2022; Accepted: 4 December 2022; Available online: 25 January 2023

Introduction

Woodpeckers (family *Picidae*) are important keystone species in forest ecosystems due to their role in excavating cavities in trees. Cavities created by woodpeckers provide shelter and breeding or resting places for many secondary users, *e.g.*, other birds, mammals and social insects (Mikusiński *et al.*, 2018; Zawadzka, 2018; Requier *et al.*, 2019). Thus, tree cavities are considered globally important forest ecological structures (Cockle *et al.*, 2011; Remm and Lõhmus, 2011). The ten species of woodpeckers found in Poland have been studied to varying degrees. One of the less recognised species is the grey-headed woodpecker (hereafter GHW), *Picus canus* Gmel. The range of this species in Poland includes mainly the southern, central, and northeastern parts of the country (Sikora and Kosiński, 2015), with a total national population estimated at 3-5 thousand breeding pairs, which has been slightly increasing (Chodkiewicz *et al.*, 2015).

The GHW inhabits mainly deciduous and mixed forests. It prefers old and not intensively managed forest stands, but its habitat preferences vary greatly across Europe (Gorman, 2004). This species is found in beech *Fagus sylvatica* L. forests and, outside the range of beech, in riparian and oak forests. It is more numerous in forested river valleys (Sikora and Kosiński, 2015). According to Gorman (2004), breeding habitat of the GHW should contain large, old deciduous trees with some decay for nesting, and some clear-cuts, young plantation, or meadows as foraging areas. This woodpecker species excavates cavities almost exclusively in deciduous trees, and exceptionally in coniferous species (Cramp, 1985; Gorman, 2019; Pakkala *et al.*, 2020).

The GHW is listed in Annex I of the EU Birds Directive and its habitat is subject to special conservation measurements. Specific requirements for nesting trees are not well studied in Europe. Pakkala *et al.* (2020) showed that, in Finland, GHW made cavities in five tree species, most often in aspen *Populus tremula* L. In Lower Saxony, on the other hand, cavities were most abundant in beech and less frequent in oak (*Quercus* spp.) (Südbeck, 2009). The only data on tree cavities for this species in Poland comes from the Greater Poland region, where GHW was exclusively observed nesting in beech (Kosiński and Kempa, 2007). Data from Pakkala *et al.* (2021) show that abandoned cavities are used for breeding by at least 10 bird species. According to Gorman (2004), birds occupying GHW cavities include the pygmy owl *Glaucidium passerinum* L., roller *Coracias garrulus* L., swift *Apus apus* L., nuthatch *Sitta europaea* L., redstart *Phoenicurus phoenicurus* L., tits (*Paridae*), and flycatchers (*Muscicapidae*), among others.

In our study, we examined nesting tree requirements of the GHW in the Augustów Forest (AF). This is a large forest complex dominated by Scots pine *Pinus sylvestris* L., located in northeastern Poland. Previously in this area, we assessed nest tree preferences of the black woodpecker *Dryocopus martius* L. (Zawadzka and Zawadzki, 2017). Since GHW is a target species in the Special Protection Aarea for Birds in Natura 2000 network PLB200002 'Puszcza Augustowska', nest tree preferences would be useful for conservation management of this bird species. We hypothesized that the height of cavity placement is related to nest tree species. Based on a previous study of nest tree preferences of the black woodpecker in this forest complex (Zawadzka and Zawadzki, 2017), we also tested the hypothesis that cavity entrance orientation of these co-occurring woodpecker species is similar.

Materials and method

STUDY AREA. The Polish part of the AF is in northeast Poland (23°15'E, 53°54'N) and extends over some 1140 km^2. The climate is relatively cold, with mean annual temperature of 6.5°C, a 135-day growing season, and snow cover typically present for around 100 days annually (Sokołowski, 2010). Tree stands are dominated by Scots pine (76%), black alder (9%), Norway spruce *Picea abies* (L.) H.Karst. (7%), silver birch *Betula pendula* Roth. (6%), and pedunculate oak *Quercus robur* L. (2%). Small admixtures (<1%) also occur with aspen, small-leaved lime *Tilia cordata* Mill., hornbeam *Carpinus betulus* L., Norway maple *Acer platanoides* L., sycamore *Acer pseudoplatanus* L., European ash *Fraxinus excelsior* L., and crack willow *Salix fragilis* L. Forest cover is around 93%, while lakes account for a further 6% of the area. The average age of tree stands is 65 years, but stands over 100 years old account for about 15% of the overall forest area (Sokołowski, 2010).

Among forest site types, mesic pine forest accounts for almost 40% of the area, while 27% is mesic mixed/coniferous forest. Some 7% of the forest area is wet forest (BULiGL, 2012, 2013, 2014, 2015a, b; Zawadzka, 2014). Protected areas (part of Wigry National Park and 14 nature reserves) cover 16.8% of the entire forest complex. The Wigry National Park covers 150.8 km^2 in the western part of the AF (Sokołowski, 2010). The study area is included in Europe's *Natura 2000* network as a Special Protection Area (SPA) for Birds, PLB200002 'Puszcza Augustowska', and the GHW is one of the target species in this SPA (Zawadzka *et al.*, 2011). Nevertheless, most of the area comprises commercial forest stands managed by six forest districts of Poland's State Forests National Forest Holding (Sokołowski, 2010).

Data collection. The study was conducted in the Augustów Forest in 2018-2022. Searches for GHW cavity trees were conducted in areas identified by playback of territorial vocalisations and drumming during the mating period (Sikora and Kosiński, 2015). The size of cavity trees was measured and their surroundings characterised. Data on the following features were collected: tree species, tree health (healthy – live with no visible signs of fungal infection and full foliage; decaying live tree with visible signs of rot caused by fungi, with loss of some foliage and the presence of dying or dead branches; dead – no foliage or live branches); tree age (from the Forest Data Bank; BDL, 2022); height above ground of the cavity; tree height; height to the lowest branch; diameter at breast height (DBH); forest habitat type; cavity entrance exposure; canopy closure; stand age; percentage of understory formed by young trees; and percentage of shrub cover. We distinguished the following forest habitat types: mixed pine forests (MPF) – stands dominated by pines admixed with spruces and birches; mixed broadleaved forest (MBF) – stands where birch, aspen and oak predominated but with significant components of spruce and pine; fertile broadleaved forest (FBF) – stands dominated by deciduous tree species (mainly birch, oak, aspen, elm, alder and maple); and alder forest (ALF) – stands dominated by alder admixed with birch and spruce. All height measurements were made using the application Measureheight (Bijak and Sarzyński, 2015). Tree diameter (DBH) was measured at breast height using calipers.

Statistical analysis. Statistical analyses were carried out using R (version 4.0.3) statistical software (R Core Team, 2020). The Kruskal-Wallis (KW) test was used to test relationships between DBH and tree height with cavities among different tree species, growing in different forest habitat types and with different exposures. *Post-hoc* pairwise comparisons were performed with the Wilcoxon test to further identify statistically significant differences. Analyses and plots were made using the library ggpubr (Kassambara, 2020). Preferences for forest sites and cavity tree species were assessed using Ivlev's electivity index, D, where $D=(r-p)/(r+p-2rp)$, and r is the percentage share of a given cavity tree species in the total known cavity trees and p is the proportion of the cavity species among all species in the study area (Jacobs, 1974). These data were calculated for the entire forest complex, using data of the share of tree species in all forest compartments in AF provided by the forest data bank (BDL, 2022).

To investigate differences in cavity height above ground for different tree species, a generalized linear model (GLM) for a normal distribution was used to identify factors affecting cavity excavation height using the lme4 package (Bates *et al.*, 2015). Continuous variables used in the analysis were DBH, cavity height, tree height, height of the lowest branch, tree age, canopy closure, shrub groundcover, and understory cover. Categorical variables used were forest habitat type, tree health, and tree species. The rank of tree species was determined based on woodpecker species preferences (lowest rank for the species least desirable for cavities), while habitat type was determined based on the habitat fertility scale.

Results

CAVITY TREES SPECIES AND FOREST SITES. We found a total of 35 cavities excavated by the GHW in 31 trees in the AF. Five cavity trees were found in the unmanaged forests of Wigry National Park, the others in managed forests. In four cases, woodpeckers excavated a second cavity in a tree in which there was already a cavity. All cavities were excavated at the beginning of the breeding season. We found only two cases of nesting in old cavities. Twenty-one (60%) of cavities were made in decaying trees and 14 (40%) were in dead trees, including 8 with stems that were damaged or broken (snags). Fungus was visible on the trunks of almost 90% of nesting trees. Woodpeckers selected three deciduous species for breeding: aspen, birch, and black alder. Among nest trees, alder was most frequently chosen, but the most preferred tree species based on Ivlev's electivity index was aspen (D=0.997) compared with alder (D=0.806) and birch (D=0.398).

GHW nest trees were observed in four forest types: alder (ALF), fertile broadleaved (FBF), mixed broadleaved (MBF), and mixed pine (MPF). No cavity trees were found in pine stands on dry or wet sites. Important differences existed between forest types used by the GHW. Most cavities were found in ALF (43%), with fewer cavities excavated in FBF (23%), MBF (20%) and MPF (14%). The share of forest types used by GHW showed a significant difference in relation to the percentage in the whole AF (χ^2=17.1, df=9, p=0.05).

Tree species composition of ALF differed from that of other forest types (Fig. 1A). In ALF, cavities were located almost exclusively in alder (14) and only one was in birch, but in other forest types, the main cavity species was aspen, with three birch and two alder cavity trees. Trees chosen by the GHW in ALF and FBF had larger diameters than those in poorer forest sites (MPF and MBF). There were no significant differences between the size of cavity trees in MPF and MBF or between FBF and ALF (Fig. 1B). Cavity trees selected by the GHW were placed higher in trees in the FBF (Fig. 1C), whereas cavities in trees in the ALF and MPF were lower than in MBF and FBF. Selection of cavity trees was not related to tree age (KW=18.29, p=0.22, df=19). Stand age was variable among forest types. Trees growing in MPF were older than those in other forest types (Fig. 1D). Canopy closure differed with forest type, with MPF and FBF denser than ALF and the MBF (Fig. 1E). There was less understory cover in MPF than ALF, but understory cover was not significantly different in other forest types (Fig. 1F). Stand age in which cavity trees were present ranged from 6 to 178 years, with the youngest stand having an 80-year-old alder with a cavity.

CAVITY TREE CHARACTERISTICS. Although all cavity trees grew in the interior of stands, 60% were near the stand edge. Trees used by GHW for cavities averaged 83-years-old. Most cavity trees (about 70%) were 70- to 100-years-old (Fig. 2A). The tallest cavity tree was an aspen 30 m in height, while the shortest were aspen and birch with broken tops (12.5 meters and 14.5

meters tall, respectively). Most nest trees (63%) were between 23 and 28 meters high. The average DBH of trees selected for cavities by GHW was 47.4 cm (ranging from 30-67 cm), with most between 30 and 40 cm (Fig. 2B). All cavities were excavated in trunks. Cavity entrances were located at heights of from 4.5 to 14 meters, averaging 8.2 meters, but most often (60%) were

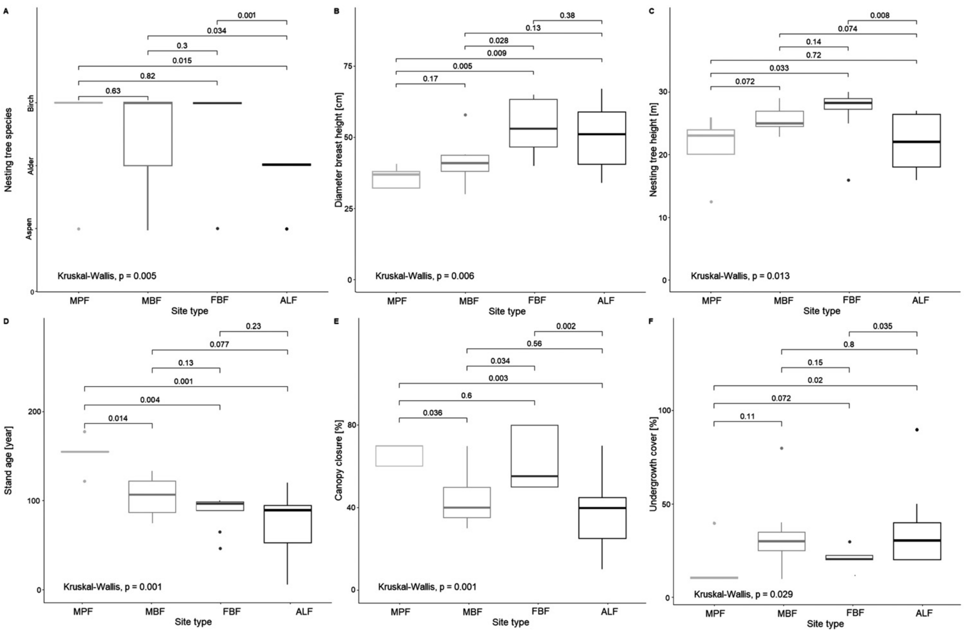
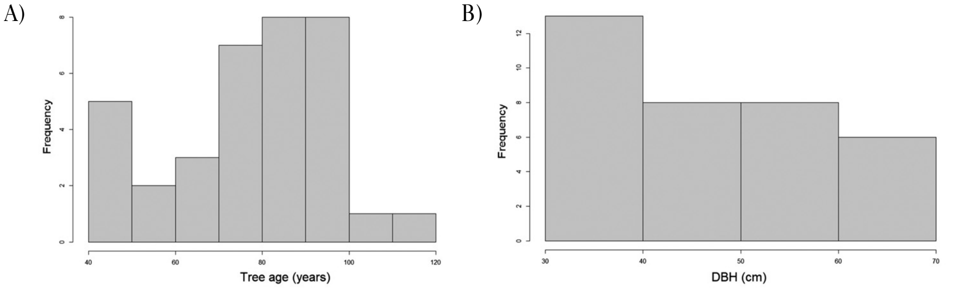


Fig. 1.

Differences among cavity trees selected by the grey-headed woodpecker in different forest types (horizontal line – median, box – interquartile range, vertical line – values within 1.5 times the interquartile range, dots – values between 1.5 and 3 times the interquartile range)



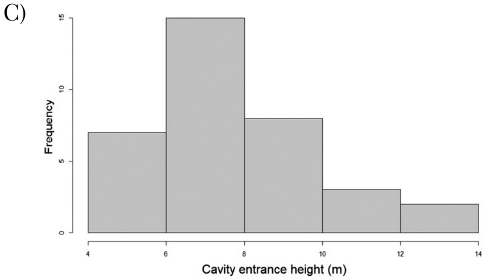


Fig. 2.

The ages (A) and diameters distributions (B) of cavity trees and heights distribution of grey-headed woodpecker cavity entrances (C) between 6 and 8 meters above the ground (Fig. 2C). The mean height of the first branch of cavity trees was 10.2 meters above the ground and was higher than the mean height of cavity entrances (Table 1).

Cavities excavated in aspen were placed higher than in other tree species (Fig. 3A). Cavities in alder were located mainly in ALF (Fig. 4B), while in birch and aspen they were found in all other forest types. Alders chosen by GWH for excavating cavities were younger than aspen and birch cavity trees (Fig. 3C). Aspen and birch with cavities were of similar ages. Canopy cover around nesting alders was lower than around other cavity tree species (Fig. 3D). There was significantly less understory cover beneath aspen cavity trees than beneath birch cavity trees (Fig. 3E).

Cavity height was not related to tree height, diameter and age. However, cavity height was significantly related to first-branch height, which allows for higher placement of the cavities. Tree species was also related to cavity height, with excavations in aspen averaging 2.8 m above-

Table 1.

Grey-headed woodpecker nest tree and stand attributes

	Min	Max	Mean	SD	Median
Tree age [years]	45	127	80.5	19.3	82
Stand age [years]	6	178	96.8	35.5	97
DBH [cm]	30	67	47.4	10.9	44
Tree height [m]	12.5	30	23.7	4.5	25
Cavity height [m]	4.5	14	8.2	2.3	8
Branch height [m]	5	15	10.2	2.8	11
Canopy cover [%]	10	80	49	18	50
Shrub [%]	10	90	29	17	30
Understory cover [%]	0	70	22	11	20

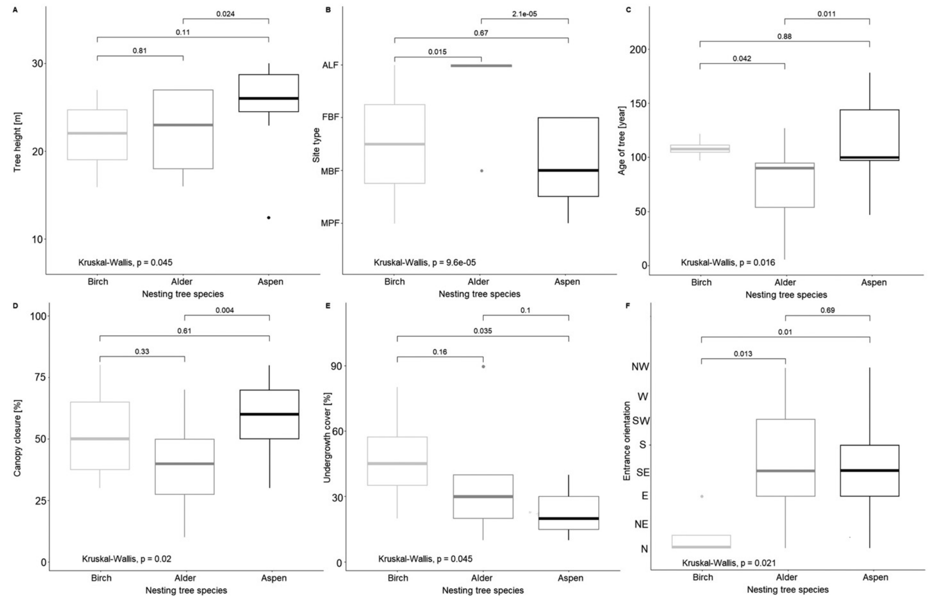


Fig. 3.

Features of cavity trees of different species selected by the grey-headed woodpecker ground and alder 5.2 m, significantly lower than in birch. A denser shrub cover was related to a lower cavity excavation height. Our model also showed influences of forest type on cavity height as, in ALF, cavities were significantly higher (Table 2).

An alder with a broken top had two cavities. For one cavity, depth was 30 cm, inner dimensions were 11×12 cm, and entrance size 6.5 (vertical) ×7 (horizontal) cm. The other cavity had

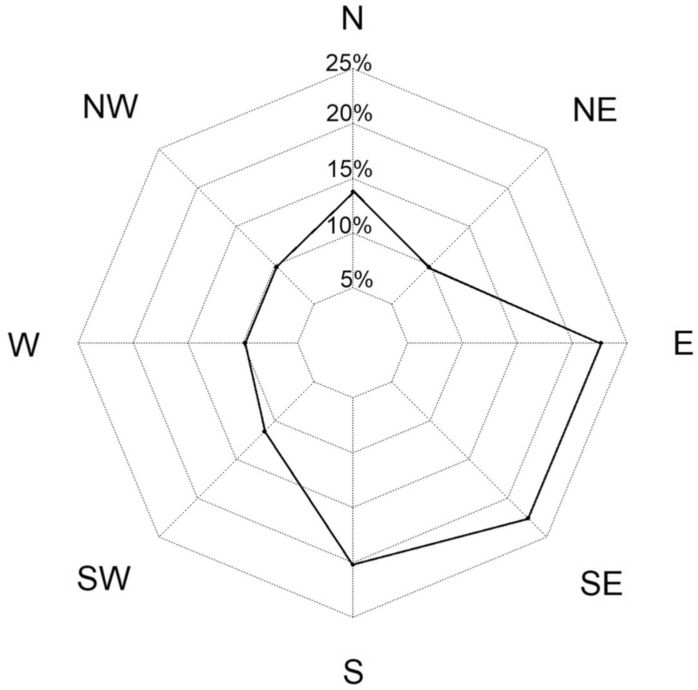


Fig. 4.
Cardinal directions of cavities excavated by the grey-headed woodpecker

Table 2.
Relationships of habitat and tree features to cavity height excavation by grey-headed woodpecker

Fixed effect parameter	Estimate	Std. error	*t*-value	*P*
Intercept	7.586	2.97	2.553	0.018
DBH	0.009	0.042	0.207	0.838
Tree height	–0.103	0.112	–0.92	0.369
Branch height	0.412	0.136	3.035	0.006
Canopy closure	–2.609	2.577	–1.013	0.322
Tree age	0.021	0.023	0.878	0.390
Alder	–5.202	1.575	–3.302	0.003
Aspen	–2.822	1.285	–2.197	0.039
Health status	0.775	0.971	0.799	0.433
Shrub cover	–0.621	2.652	–2.341	0.029
MBF	2.748	1.343	2.045	0.052
FBF	1.885	1.234	1.528	0.141
ALF	4.54	1.97	2.308	0.031
AIC	151.79			

the same total depth and entrance size as the first, but inner dimensions were slightly larger (14×14 cm).

Cavity entrance orientation. South- and east-facing cavity entrances were preferred by the GHW. Most cavities were directed towards the east (8 cavities), south-east (8), and south (7). However, cavities excavated in birch faced mainly north (75%), with other cardinal orientations in birch avoided (Fig. 3F).

The only other variable that was significantly related to cavity orientation was the height above ground of the cavity. Cavities on the northern side of trees were excavated significantly higher than those facing other directions (Fig. 5). North-facing cavities were placed mainly in birch (Fig. 3F), whereas cavities in alder and aspen had similar (non-north) cardinal orientations.

Discussion

The grey-headed woodpecker in the Augustów Forest nested in four forest types, from mixed pine forests and mixed broadleafed forest to fertile broadleafed forest and alder forest. Tree species chosen for nesting changed in different habitats, indicating the ecological plasticity of this woodpecker species. In Poland, GHW nests mainly in old, beech-dominated or mixed deciduous forests (Kosiński and Ciach, 2013) found in the regions of Pomerania (Sikora, 2006), Greater Poland (Kosiński and Kempa, 2007), and the Carpathian Foothills (Krasoń and Michalczuk, 2018). In the Świętokrzyskie Mountains, GHW inhabits old stands dominated by beech and alder (Dębowski *et al.*, 2021) and, in SE Poland, GHW occupies alder forests (Wojton and Krasoń, 2017). In southern Finland, GHW inhabits a variety of forest types, including fresh coniferous, deciduous, and mixed swamp forests (Pakkala *et al.*, 2020).

In the AF, GHW only used deciduous trees belonging to three species to excavate cavities, selected from at least nine tree species in the study area. The most preferred species was aspen, followed by alder. Preference for aspen was most evident in stands with varied tree species composition. We found no woodpecker cavities in pine, despite the extensive presence of this tree species in stands within the study area. According to Cramp (1985), the tree species

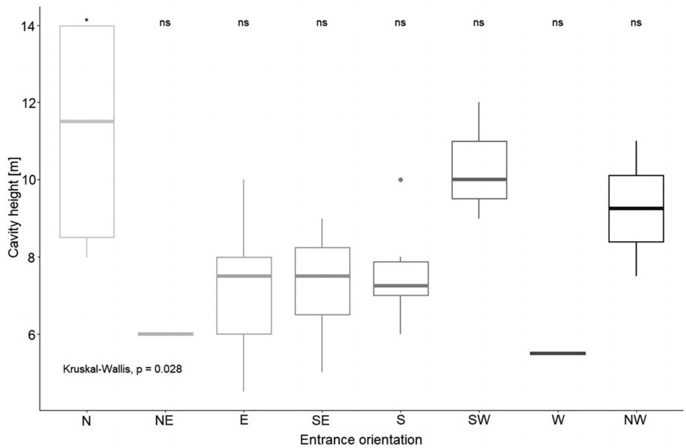


Fig. 5.

Orientation of cavity entrances excavated by the grey-headed woodpecker in relation to height above the ground

* $p<0.05$; ns – non significant; horizontal line – median, box – interquartile range, vertical line – values within 1.5 times the interquartile range, dots – values between 1.5 and 3 times the interquartile range)

most chosen by the GHW for cavity excavation include aspen, beech, oak, lime, and sometimes willow and pine. In the boreal forests of southern Finland, the GHW uses 5 tree species, including the most common, aspen, with cavities occasionally made in alder, birch, and pine (Pakkala *et al.*, 2020). In the Niray valley in Romania, a preference for aspen as a GHW nesting tree was also documented (Domokos and Cristea, 2014), and in Hungary, GHW cavities were found in six different deciduous tree species, with 50% in beech and 23% in hornbeam (Gorman, 2019). In Wielkopolska (Poland), the GHW also preferred beech for its cavities (Kosiński and Kempa, 2007), as was likewise the case in Lower Saxony, where beech was the most common GWH cavity tree and the second most common tree species used by GWH was pedunculate oak (Südbeck, 2009). Beech does not occur in the AF, except as a minor admixture in stand understory or shrub layers. Our results confirm the highly diverse selection of tree species used by this woodpecker species. In AF, the most important tree species for GHW was aspen, which was preferred mainly in mixed and deciduous stands. Aspen is a fast-growing species, reaching large dimensions suitable for excavating a cavity when as young as about 60-years-old. In addition, aspen has soft wood and frequently experiences stem rot, which makes cavity excavation easier (Tomanek and Witkowska-Żuk, 1996). The importance of aspen for the GHW was also emphasised by Pakkala *et al.* (2020). Aspen is also important for other woodpecker species, *e.g.*, in Białowieża Forest (Walankiewicz and Czeszczewik, 2005; Hebda *et al.*, 2017). Birch, although rarely selected by the GWH in other study areas, was used as a nesting tree in the AF, although this occurred mainly in coniferous stands.

The GHW excavated cavities where there was moderate canopy cover. Almost all cavity trees were either decaying with visible signs of fungus, or dead. There are probably few such trees in managed stands, which can cause difficulties for woodpeckers when they wish to choose a tree suitable for excavating a cavity. Our data parallels the preference towards decaying or dead trees noted in Romania, Hungary and Finland (Domokos and Cristea, 2014; Gorman, 2019; Pakkala *et al.*, 2020). In contrast, in the Wielkopolska region, cavities made by the GHW were found in healthy trees that did not have visible stem rot (Kosiński and Kempa, 2007).

In the AF, the GHW nested in trees aged 45- to 127-years-old, with the average age 83--years-old. Different ages of nest trees indicate that the GHW selects neither the oldest nor the largest diameter trees. Comparing the dimensions of cavity trees we observed in AF with those from other study areas shows that excavated trees in AF had a larger diameter (47.4 cm) than those in Finland, Hungary and Romania, where the average diameters were respectively 37.2 cm, 23 cm, and 34.6 cm (Domokos and Cristea, 2014; Gorman, 2019; Pakkala *et al.*, 2020), but were slightly smaller than excavated trees observed in Greater Poland (56 cm diameter) (Kosiński and Kempa, 2007). Thus, tree health appears to be more important than diameter of the tree selected for cavity excavation.

The average height of cavity placement above the ground in the AF (8.2 m) was similar to that in Finland (7.8 m) (Pakkala *et al.*, 2020) and Wielkopolska (9.3 m) (Kosiński and Kempa, 2007), but was higher than in the Niray valley in Romania (5.8 m) (Domokos and Cristea, 2014) and in Hungary (6.6 m) (Gorman, 2019). Our study indicated that cavity height was dependent on tree species and was highest in birch. Similarly, variations in cavity height among tree species were observed by Pakkala *et al.* (2020). Our model shows that height above ground of the cavity entrance was significantly related only to the height of the first branch above the ground. No other tree attributes were related to cavity height above the ground. Therefore, we conclude that height of the cavity above the ground is influenced by the tree canopy, and that the woodpecker will select trees with higher crowns so they can prepare higher cavities that are less easily detected by predators (Kosiński *et al.*, 2010).

Landler *et al.* (2014) show that woodpecker cavity entrance orientation is typically non-random but is selected. Based on the hypothesis that yearly mean temperatures influence cavity entrance orientation, it might be expected that northern woodpecker populations would orient entrances more toward the south than would southern woodpecker populations (Landler *et al.* 2014). In AF, cavity entrances made by the GHW usually faced south. Only cavities in birch trees faced north, and these cavities were also placed higher, which may indicate a connection between height and cavity orientation for this tree species. In Hungary, entrances of GHW cavities most often faced south and southwest (Gorman, 2019). The predominant orientation of GHW entrances in the AF is different from the main orientation of black woodpecker cavities in the same area; the black woodpecker strongly prefers pine as its nest tree, and its cavities are oriented mainly north, north-east, and east (Zawadzka and Zawadzki, 2017). Comparing GHW cavity entrance orientation between the AF and Hungary, as well as between the GHW and black woodpecker where they co-occur in AF, shows that differences do not fit the pattern described by Landler *et al.* (2014). Our data suggest that the cardinal direction of cavities is determined not only by geographic and environmental conditions, such as the direction of the prevailing wind, the local environment , or the proportion of understory, but also by the species of the tree. Knowing the factors affecting the direction of GHW cavities is important for an effective inventory of cavity trees and for GHW protection in managed forests.

Conclusion

The grey-headed woodpecker in the Augustów Forest inhabited a variety of forest types, from mixed coniferous to mixed deciduous and alder forest. In each habitat, it preferred different tree species for nesting, indicating the ecological plasticity of this woodpecker. The GHW selected only deciduous trees belonging to three species for its cavities. The most preferred species was aspen, but alder was also important. Maintaining aspen in managed stands is therefore important for the conservation of the GHW. All cavity trees utilized by the GHW were dead or decaying. For the GHW, the condition of a tree was more important than the tree's dimensions. The height to the cavity (on average 8.2 m above the ground) depended on the height to the first branch above the ground, and this branch's height was always higher than the cavity entrance. In addition, the height to the cavity depended on tree species. Cavities usually faced south, except for those in birch, which faced north. Birch cavities were also placed higher than those in other tree species. The cardinal direction of the cavity opening may be influenced not only by geographic and habitat conditions, but also by tree species.

Authors' contributions

D.Z. – study concept, field research, methodology, data analyses, manuscript preparation, review and editing; G.Z. – study concept, field research, methodology, statistical analyses, preparing figures, manuscript preparation, review and editing.

Conflict of interests

The authors declare no conflicts of interest.

Funding source

The research was financed from the authors' own funds.

Acknowledgements

We wish to express our gratitude to Dr Joanna Harmuszkiewicz for providing us with unpublished field data and her help collecting data.

References

Bates, D., Mächler, M., Bolker, B., Walker, S., 2015. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67 (1): 1-48. DOI: https://doi.org/10.18637/jss.v067.i01.

BDL, 2022. htps://www.bdl.lasy.gov.pl/portal/mapy-en [accessed: 21.09.2022].

Bijak, S., Sarzyński, J., 2015. Accuracy of smartphone applications in the field measurements of tree height. *Folia Forestalia Polonica*, *Seria A*, 57: 240-244. DOI: https://doi.org/10.1515/ffp-2015-0025.

BULiGL, 2012. Plan Urządzenia Gospodarstwa Leśnego Nadleśnictwa Głęboki Bród na okres 01.01.2012-31.12.2021. Białystok: BULiGL.

BULiGL, 2013. Plan Urządzenia Gospodarstwa Leśnego Nadleśnictwa Pomorze na okres 01.01.2013-31.12.2022. Białystok: BULiGL.

BULiGL, 2014. Plan Urządzenia Gospodarstwa Leśnego Nadleśnictwa Szczebra na okres 01.01.2013-31.12.2022. Białystok: BULiGL.

BULiGL, 2015a. Plan Urządzenia Gospodarstwa Leśnego Nadleśnictwa Augustów na okres 01.01.2015-31.12.2024. Białystok: BULiGL.

BULiGL, 2015b. Plan Urządzenia Gospodarstwa Leśnego Nadleśnictwa Płaska na okres 01.01.2015-31.12.2024. Białystok: BULiGL.

Chodkiewicz, T., Kuczyński, L., Sikora, A., Chylarecki, P., Neubauer, G., Ławicki, Ł., Stawarczyk, T., 2015. Ocena liczebności populacji ptaków lęgowych w Polsce w latach 2008-2012. *Ornis Polonica*, 56 (3): 149-189.

Cockle, K.L., Martin, K., Wesołowski, T., 2011. Woodpeckers, decay, and the future of cavity-nesting vertebrate communities worldwide. *Frontiers in Ecology and the Environment*, 9: 377-382. DOI: https://doi.org/10.1890/110013.

Cramp, S., ed. 1985. Handbook of the birds of Europe, the Middle East and North Africa.Vol. 4. Oxford: Oxford Univ. Press, 923 pp.

Dębowski, P., Dukała, J., Wachecki, M., Szczepaniak, W., Stojek, G., Staśkowiak, A., Maślikowski, Ł., 2021. Liczebność dzięciołów Picidae w lasach wyżynnych Lasów Suchedniowskich. *Ornis Polonica*, 62 (2): 101-112.

Domokos, E., Cristea, V., 2014. Effects of managed forest structure on woodpeckers (*Picidae*) in the Niraj valley (Romania): Woodpecker populations in managed forests. *North-western Journal of Zoology*, 10 (1): 110-117.

Gorman, G., 2004. Woodpeckers of Europe. A study of the European Picidae. Chalfont St. Peter: Bruce Coleman, 192 pp.

Gorman, G., 2019. Characteristics of Grey-headed Woodpecker (*Picus canus*) cavities in Hungary. *Aquila*, 126: 33-39.

Jacobs, J., 1974. Quantitative measurements of food selection; a modification of the forage ratio and Ivlev's electivity index. *Oecologia*, 14: 27-36.

Kassambara, A., 2020. Ggpubr: 'ggplot2' Based Publication Ready Plots. R package version 0.4.0. https://CRAN.R-project.org/package=ggpubr

Kosiński, Z., Ciach, M., 2013. Dzięcioł zielonosiwy *Picus canus*. In: D. Zawadzka, M. Ciach, T. Figarski, Ł. Kajtoch, Ł. Rejt, eds. *Materiały do wyznaczania i określania stanu zachowania siedlisk ptasich w obszarach specjalnej ochrony ptaków Natura 2000*. Warszawa: GDOŚ, pp. 94-102.

Kosiński, Z., Kempa, M., 2007. Density, distribution and nest-sites of woodpeckers *Picidae*, in a managed forest of western Poland. *Polish Journal of Ecology*, 55 (3): 519-533.

Krasoń, K., Michalczuk, J., 2018. Dzięcioły Picidae obszaru Natura 2000 „Las nad Braciejową" i boru koło Przecławia. *Chrońmy Przyrodę Ojczystą*, 74 (4): 255-266.

Landler, L., Jusino, M.A, Skelton, J., Walters, J.R., 2014. Global trends in woodpecker cavity orientation: latitudinal and continental effects suggest regional climate influence. *Acta Ornithologica*, 49 (2): 257-266. DOI: https://doi.org/10.3161/173484714X687145.

Mikusiński, G., Roberge, J.M., Fuller, R.J., eds. 2018. Ecology and conservation of forest birds. Cambridge: Cambridge University Press, 552 pp.

Pakkala, T., Tiainen, J., Pakkala, H., Piha, M., Kouki, J., 2020. Nest tree characteristics of Grey-headed Woodpeckers (*Picus canus)* in boreal forest. *Ornis Fennica*, 97 (3): 89-100.

Pakkala, T., Tiainen, J., Pakkala, H., Piha, M., Kouki, J., 2021. Dynamics of the cavities of Grey-headed Woodpeckers *Picus canus* reveal their long- and short-term ecological roles in boreal forest. *Acta Ornithologica*, 56 (2): 199-208. DOI: https://doi.org/10.3161/00016454AO2021.56.2.006.

Remm, J., Lõhmus, A., 2011. Tree cavities in forests – The broad distribution pattern of a keystone structure for biodiversity. *Forest Ecology and Management*, 262 (4): 579-585. DOI: https://doi.org/10.1016/j.foreco.2011.04.028.

Requier, F., Paillet,Y., Laroche, F., Rutschmann, B., Zhang, J., Lombardi, F., Svoboda, M., Steffan--Dewenter, I., 2019. Contribution of European forest to safeguard wild honeybee populations. *Conservation Letters:* e12693. DOI: https://doi.org/10.1111/conl.12693.

Sikora, A., 2006. Rozmieszczenie i liczebność dzięcioła zielonosiwego *Picus canus* na Wysoczyźnie Elbląskiej i jego ekspansja na Warmii i Mazurach. *Notatki Ornitologiczne*, 47 (1): 32-42.

Sikora, A., Kosiński, Z., 2015. Dzięcioł zielonosiwy *Picus canus*. In: P. Chylarecki, A. Sikora, Z. Cenian, T. Chodkiewicz, eds. *Monitoring ptaków lęgowych. Poradnik Metodyczny*. Warszawa: GIOŚ, pp. 485-490.

Sokołowski, A., 2010. Puszcza Augustowska. Warszawa: CILP, 292 pp.
Südbeck, P., 2009. Beitrag zur Höhlenökologie des Grauspechts *Picus canus*. *Osnabrücker Naturwissenschaftliche Mitteilungen*, 35: 263-274.
Tomanek, J., Witkowska-Żuk, L., 1996. Botanika leśna. Warszawa: PWRiL, 506 pp.
Walankiewicz, W., Czeszczewik, D., 2005. Wykorzystanie osiki *Populus tremula* przez ptaki w pierwotnych drzewostanach Białowieskiego Parku Narodowego. *Notatki Ornitologiczne*, 46 (1): 9-14.
Wojton, A., Krasoń, K., 2017. Wykorzystanie płatów drzewostanów liściastych przez stenotopowe gatunki dzięciołów w lasach z dominacją sosny w południowo-wschodniej Polsce. *Sylwan*, 161 (11): 940-948. DOI: https://doi.org/10.26202/sylwan.2017052.
Zawadzka, D., 2014. Popularny plan ochrony Wigierskiego Parku Narodowego. Wigierski Park Narodowy, Krzywe, 174 pp.
Zawadzka, D., 2018. Dziuple w ekosystemach leśnych: formowanie, rozmieszczenie, znaczenie ekologiczne i wskazania ochronne. *Sylwan*, 162 (6): 509-520. DOI: https://doi.org/10.26202/sylwan.2018030.
Zawadzka, D., Zawadzki, G., 2017. Charakterystyka drzew gniazdowych dzięcioła czarnego w Puszczy Augustowskiej. *Sylwan*, 161 (12): 1002-1009. DOI: https://doi.org/10.26202/sylwan.2017104.
Zawadzka, D., Zawadzki, J., Zawadzki, G., Zawadzki, S., 2011. Wyniki inwentaryzacji ornitologicznej na terenie OSO PLB20002 Puszcza Augustowska w 2010 roku. *Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej*, 13 (27): 89-104.

STRESZCZENIE

Wybór drzew gniazdowych przez dzięcioła zielonosiwego w północno-wschodniej Polsce

Dzięcioły Picinae są uznawane za gatunki kluczowe w ekosystemach leśnych, ponieważ w wykuwanych przez nie dziuplach znajduje schronienie lub miejsca lęgowe wiele gatunków zwierząt. Jednym z najsłabiej poznanych europejskich gatunków jest dzięcioł zielonosiwy *Picus canus* Gmel. Preferencje drzew gniazdowych tego gatunku badano w Puszczy Augustowskiej. Jest to rozległy kompleks leśny o powierzchni 114 000 ha, zdominowany przez siedliska boru świeżego i mieszanego świeżego. Drzewa gniazdowe dzięcioła zielonosiwego były wyszukiwane w obrębie terytoriów rozpoznanych na podstawie odtwarzania głosów terytorialnych oraz werbli wiosną. Zebrano dane dotyczące następujących parametrów: gatunek drzewa, stan zdrowotny drzewa (zdrowe, osłabione, martwe), wiek drzewa, wysokość dziupli, wysokość drzewa, wysokość najniższej gałęzi, pierśnica, typ siedliskowy lasu, ekspozycja wejścia do dziupli, zwarcie drzewostanu, wiek drzewostanu oraz pokrycie podszytu i podrostu. Na 31 drzewach znaleziono 35 dziupli wydrążonych przez dzięcioła zielonosiwego. Czterokrotnie dzięcioł wykuł drugą dziuplę w tym samym drzewie. W drzewach osłabionych znajdowało się 21 (60%) dziupli, w drzewach martwych 14 (40%), w tym w złamanych 8 dziupli. Prawie 90% drzew gniazdowych miało widoczne na pniu owocniki hub. Dzięcioł wybierał do lęgów wyłącznie drzewa liściaste: osikę, brzozę i olszę czarną. Wśród drzew gniazdowych najczęściej wybierana była olcha, ale najsilniej preferowanym gatunkiem drzewa była osika. Stwierdzono istotne różnice pomiędzy siedliskami leśnymi wykorzystywanymi przez dzięcioła zielonosiwego. Najwięcej dziupli znajdowano w olsie, a w dalszej kolejności na siedlisku lasu świeżego, lasu mieszanego oraz boru mieszanego (ryc. 1).

Drzewa dziuplaste miały średnio 83 lata (zakres od 45 do 127) (ryc. 2A). Najwyższymi drzewami dziuplastymi były osiki (do 30 m), najniższymi – złamane osiki i brzozy (odpowiednio 12,5 i 14,5 m). Większość drzew gniazdowych miała wysokość od 23 do 28 m. Średnia pierśnica drzew dziuplastych dzięcioła zielonosiwego wynosiła 47,4 cm, z czego najliczniejsze były drzewa o pierśnicy od 30 do 40 cm (ryc. 2B). Wszystkie dziuple były wydrążone w pniach. Otwory wlotowe do dziupli znajdowały się na wysokości od 4,5 do 14 m, średnio 8,2 m (ryc. 2C). Średnia

wysokość pierwszej gałęzi wynosiła 10,2 m i była wyższa od średniej wysokości otworu dziupli (tab. 1). W brzozach dziuple były umieszczone wyżej niż w innych gatunkach drzew (ryc. 3A). Dziuple w olchach znajdowały się tylko w olsach (ryc. 3B), a w brzozach i osikach na wszystkich siedliskach (ryc. 3C). Zwarcie koron wokół olch z dziuplami było niższe niż wokół brzóz i osik (ryc. 3D). Pokrycie podrostu wokół olch było niższe niż wokół brzóz (ryc. 3E).

Model liniowy dla wybranych parametrów wykazał, że większość cech drzewa nie była istotna przy lokalizacji dziupli. Istotne różnice związane były z wysokością pierwszej gałęzi nad ziemią, która pozwala na wyższe umiejscowienie dziupli, oraz gatunkiem drzewa, gdyż dziuple w osice i olszy były drążone znacznie niżej niż w brzozie (tab. 2). Wysokość położenia dziupli różniła się w zależności od gatunku drzewa gniazdowego. Dzięcioł zielonosiwy preferował południową i wschodnią ekspozycję wejścia do dziupli (ryc. 4). Kierunek geograficzny otworu był związany z wysokością dziupli nad ziemią (ryc. 5). Orientację północną miały najczęściej dziuple w brzozach (ryc. 3F). Uzyskane wyniki podkreślają znaczenie osiki dla dzięcioła zielonosiwego i wskazują na konieczność ochrony tego gatunku drzewa w lasach gospodarczych.