Forest Ecology and Management 271 (2012) 98–103

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Heart rot as a key factor for cavity tree selection in the black woodpecker

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ARTICLE INFO

Article history:
Received 11 November 2011
Received in revised form 23 January 2012
Accepted 25 January 2012
Available online 1 March 2012

Keywords:
Nest site selection
Black woodpecker
Excavating
Long term process
Cavity starts
Beech

ABSTRACT

Cavity nesting birds invest considerable time and effort into the construction of nests. The investment can be particularly high for species such as the black woodpecker (*Dryocopus martius*) that selects living trees as nest substrates. However, the investment may be reduced if fungal rot is present to help soften the wood. We used Resistograph drills to objectively assess fungal decay and tested whether black woodpeckers preferred trees with heart rot as sites for cavity starts. In doing so we also examined the distribution of fungal decay across the tree radius, analysed location of cavity starts with respect to proximity to heart rot, and evaluated wood condition at fresh and old cavity starts. Heart rot was significantly more common in beeches (*Fagus sylvatica*) with cavity starts than in random reference beeches. Fungal decay was not evenly distributed across the tree radius, but was more prevalent both in the central and outer thirds than in the middle third. Distance to heart rot was smaller from cavity starts than from random drills, suggesting a preference to initiate cavities close to heart rot. Wood density at fresh cavity starts was significantly higher than at old cavity starts. Collectively, these findings imply that black woodpeckers prefer to excavate cavity starts in beeches with heart rot, which the woodpeckers can detect based on cues unavailable to humans. The decay is reducing the energy expenditure of the black woodpecker and is a part of the long time excavation strategy. The cavity starts are an important factor in the process of excavating the large black woodpecker cavities in beech that enhance biodiversity in managed forests. Future studies should attempt to uncover the mechanisms woodpeckers use in selecting the locations of cavity starts.

1. Introduction

The selection of an appropriate nest site is an important determinant of fitness in many species, putting considerable efforts into the selection and the construction of a nest. For example, many cup-nesting birds incur high nest loss rates due to predation, implying strong selection for well-concealed nest sites (Martin, 1995; Weidinger, 2002; Pasinelli and Schiegg, 2006). Species nesting in cavities generally show reduced nest predation and species excavating their own nest cavity (i.e. primary cavity nesters) enjoy increased nest survival compared to species using existing cavities or holes (i.e. secondary cavity nesters) (Martin, 1995). The construction of an elaborate nest may be important in sexual selection (Alcock, 2001), while the construction of a well-insulated nest in environments with large variability in weather conditions during the period of offspring rearing may affect nestling survival both directly or indirectly via carry-over effects during later life stages. In both contexts of sexual and natural selection, individuals investing more time and energy in nest-site selection and nest building may gain fitness benefits compared to individuals spending less effort in these endeavours.

Fungi softening the wood prior to excavation would decrease energy expenditure for tree cavity excavators, but might increase the risk of tree breakage. Tree cavity excavation thus involves compromises between energy costs during the building stage, short-term stability of the tree trunk to guarantee nestling survival and the possibility of re-using the nesting site over years. While many woodpecker species prefer to excavate nest cavities in wood showing clear signs of decay (e.g. Jackson and Jackson, 2004; Pasinelli, 2006), other species have been suggested to use sound wood. A particularly striking apparent example among the latter species is the black woodpecker (*Dryocopus martius*), the largest woodpecker species in the Palearctic. Excavation in the black woodpecker usually begins with a cavity start that may not be finished the same year (Glutz von Blotzheim and Bauer, 1980; Meyer and Meyer, 2001; Gorman, 2011). Trees as well as the immediate substrate at black woodpecker cavities look healthy from outside. However, whether the black woodpecker excavates cavities in sound wood or prefers fungus-infected trees for cavity construction has remained a subject of controversy for decades (Jamnicky, 1994; Meyer and Meyer, 2001; Mueller, 2004).

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doi:10.1016/j.foreco.2012.01.041

In this study we evaluated four hypotheses related to cavity tree selection and cavity excavation behaviour in the black woodpecker. First, we tested whether the black woodpecker selected trees with fungal rot (i.e. heart rot) by comparing trees with cavity starts to reference trees without cavity starts. If the black woodpecker selects trees with fungal rot for cavity excavation, we expected trees with cavity starts to have lower wood resistance compared to trees without cavity starts. Wood resistance as an indicator of fungal rot was measured with a Resistograph (Rinn et al., 1996; Schepps et al., 1999).

Second, in cavity start trees with signs of fungal decay, we additionally examined whether fungal rot was evenly distributed across the tree radius. Because trees with black woodpecker cavity starts and cavities, respectively, look uninfected from outside (see above), we expected fungal decay to be more prevalent in the inner than in the outer parts of the tree radius. Third, we tested whether the black woodpecker initiated cavities at sections of a tree located near heart rot. If it did, we predicted that the distance to heart rot would be less from cavity starts than from random locations. Finally, we evaluated whether wood condition at fresh and old cavity starts differed. We expected wood at fresh cavity starts to be harder than wood at old cavity starts, owing to the softening effects of fungal decay over time at the latter.

2. Methods

2.1. Study sites

The study was conducted in the continental zone of central Europe in two woodland areas of southern Germany in 2009. Elevation of the woodland areas studied ranged from 200–600 m a.s.l. Fieldwork took part in Lower Bavaria, Germany (Kelheim, Hienheimer Forst, 48°54′N, 11°48′E), where 1246 ha were surveyed, and in the biosphere reserve Swabian Jura (Baden-Wuerttemberg (48°24′N, 09°36′E) with 6600 ha. European Beech (*Fagus sylvaticus* L.) and Norway Spruce (*Picea abies* (L.) Karst.) dominated the forests. The proportion of beech ranged from 70% in the Hienheimer Forst to 80% in the biosphere reserve of Swabian Jura.

2.2. Study trees

We focused on old beech stands (100 years and older), because the black woodpecker needs large trees for cavity excavation (tree diameter at the cavity entrance >38 cm, Glutz von Blotzheim and Bauer, 1980), and beech is the most important cavity tree species in our study areas (unpublished data). In these old beech stands, we systematically searched for black woodpecker cavity starts and cavities. For this study, we restricted our analyses to trees having only cavity starts. We focused on cavity starts to examine the wood conditions that are encountered by black woodpeckers when they begin excavating. Cavity starts were defined as rounded injuries of the bark, reaching into the wood and situated at the tree trunk with signs of beak strokes visible. None of the other woodpecker species occurring in our study forests builds cavities in large beeches lacking visual evidence of fungal decay (e.g. conks) at the height of the cavity, so we could safely assume that cavity starts considered in this study were initiated by the black woodpecker.

For each tree, we recorded the following measures: tree species, social classes proposed by Kraft 1884 (cited in Burschel and Huss (1987): 1 = tree is predominant, 2 = dominant, 3 = subdominant, 4 = suppressed, 5 = understory) in the stand, diameter at breast height (dbh), diameter at the cavity start, nearest distance of the cavity start to the next branch, exposition of the cavity (main compass directions), and age of cavity starts (fresh or old). Age of cavity start was distinguished based on wood colour, which at fresh cavity starts is much lighter than at older cavity starts.

2.3. Tree drills

We examined 30 beech trees with cavity starts. These trees were climbed and wood density at the cavity starts was recorded with a special drill (IML Resistograph). A needle of 40-cm length and 4-mm diameter was horizontally drilled into the tree. Three brad points on the head of the drilling device create a triangle with the fine needle in its centre. This anchors the drill in the bark and ensures a radial motion of the needle. The average deviation of the needle from the radial direction hardly influences the measuring results (Rinn et al., 1996).

The Resistograph measures the wood resistance at the tip of the needle. Wood-decaying fungi break down lignin and cellulose. This process softens the wood, making it less resistant to the drill and resulting in a change of power consumption which is measured electronically (Rinn et al., 1996; Schepps et al., 1999). This reflects wood resistance and is plotted against drilling depth. The resulting graph resembles an ECG (electrocardiogram). We refer to this graph as drilling profile, which allows quantification of extent of decay.

Wood resistance was recorded both electronically and on a drilling profile printout, representing the whole radius to the pith of the trunk. To make sure that we had drilled into the heart of the trunk, we inspected the pattern of annual growth rings on the printout (see Fig. 1a). On the printout, wood resistance is plotted as a curve, with low values indicating weak resistance and hence decayed wood. The method provides a reliable quantitative measure of rot (e.g. Rinn et al., 1996; Schepps et al., 1999; Gruber, 2001).

Four drills were made per tree. First, we drilled into the centre of the cavity start (hereafter referred to as HCD = horizontal cavity drill). A second and third drill was made to the left and to the right, respectively, but at the same level as the cavity start (HLD = horizontal left drill and HRD = horizontal right drill). Both HLD and HRD were directed from the trunk surface to the tree heart, with the drill direction having an angle of 45° to the HCD. A fourth drill was taken 30 cm underneath the cavity start (HUD = horizontal underneath drill). These latter three reference drills were compared with the drill through the cavity start to find out if the cavity start had been placed near heart rot. For each drill, distance to heart rot was measured on the drilling profile. We defined distance to heart rot (cm) as the distance from one centimetre after the needle had left the drilling machine to heart rot, indicated by fungal decay on the drilling profile. Heart rot in this study is defined as fungal decay in the inner layers of the tree, but not in the sapwood. The tree thus resembles a tube-like structure consisting of a softened centre surrounded by a hard zone of sound wood.

If there were multiple cavity starts in one tree, we took the largest for the HCD.

2.4. Reference trees

Within 15–20 m of each beech tree with a cavity start, another beech without cavity start (or cavity) was selected, hereafter referred to as a reference tree. We recorded social class, dbh and age class for each reference tree. Each reference tree was climbed and the same four drills as for the corresponding tree with cavity start were taken with the Resistograph at a comparable height and exposition.

2.5. Statistical analyses

The graphs of the drilling profiles from the Resistograph were visually inspected and ranked by professional arborists. If a fungus had softened the wood, the wood density in the graph dropped or