Abundant Natural Cavities in a Deciduous Forest Leads to a Lack of Nest-box Occupancy by Northern Saw-whet Owls

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Abstract - Nest boxes are commonly used for species that utilize tree cavities, including small owls. Boxes were installed in 2011 to facilitate study of Northern Saw-whet Owls in Pennsylvania. We checked the 11 boxes that remained in 2020 after a hiatus of 8 years and found 3 rodent nests, but no evidence of owl usage. Playbacks revealed owls were present at 8 of 11 boxes checked. Cavity surveys yielded an average of 7.7 large cavities within 50 m of each box; extrapolation of cavity densities to a minimal territory size of 150 ha suggested that suitable cavities are an abundant, non-limiting resource here. Cavity abundance was likely a consequence of beech bark disease complex having recently top-killed most large American Beech trees locally, providing abundant resources for excavating woodpeckers. Assessing cavity abundance should be an essential first step for any management project involving cavity-nesting birds, and nest boxes should be used only in situations where cavities appear to be limited.

Introduction

Tree cavities are critical resources in forests, providing shelter and breeding sites for a wide variety of birds, mammals, and other animals (Edworthy et al. 2018). Tree cavities may result from decay processes, branch breakage, or from active excavation by woodpeckers and similar species (Remm and Lõhmus 2011). Under some conditions, such as in heavily managed or young forests, a paucity of cavities can limit populations of hole-nesting species (Newton 1994) but there is little experimental evidence of cavity limitation in old, unmanaged forests (Wiebe 2011).

Nest boxes are a popular tool for increasing the availability of cavities for hole-nesting birds and mammals, particularly where human activities have reduced the abundance of natural cavities (Bock and Fleck 1995, East and Perrins 1988, Edworthy et al. 2018). Nest boxes have been effective in helping to manage hole-nesting species of concern, including various ducks (e.g., Corrigan et al. 2011, Malanchuk and Straub 2020), raptors (e.g., Katzner et al. 2005, Korpimäki 1984, Liébana et al. 2013, Marti et al. 1979) and bats (Ritzi et al. 2005, Rueegger 2016). Alternatively, nest boxes can facilitate research and monitoring of species by providing known, fixed locations and facilitating access via cameras or data loggers that would be much more difficult with natural cavities (e.g., Franzreb and Hanula 1995, Stoleson and Beissinger 1999, Zárybnická et al. 2016). Therefore, there is temptation for researchers to install nest boxes rather indiscriminately, despite potential limitations to the interpretability of data from nest-box studies (Møller 1992).

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As obligate cavity nesters and nocturnal predators, most owls (families Strigidae and Tytonidae) pose particular logistical challenges to in-depth study; nest boxes have proven especially useful for facilitating research on these taxa (e.g., Hayward et al. 1992, Johnson 1987, Korpimäki 1984). Among the species documented to use nest boxes, *Aegolius acadicus* (Gmelin) (Northern Saw-whet Owl, hereafter also Saw-whets) remains poorly known despite being one of the most widespread owls in North America (Priestley et al. 2005, Rasmussen et al. 2020). Most of our understanding of Saw-whet biology comes from studies conducted in conifer forests of the Rockies, far north, or the high Appalachians (e.g., Cannings 1987, Domahidi et al. 2020, Hinam and Clair 2008, Milling et al. 1997); to date, little work has been done in deciduous forests. Although Saw-whets were once thought to be rare and local within Pennsylvania's deciduous forests, focused surveys during the second state Breeding Bird Atlas project revealed them to be fairly common in the more northern and higher-elevation areas (McWilliams and Brauning 2000, Weidensaul 2012). In 2011, a colleague installed a network of nest boxes ostensibly to facilitate research on the breeding biology of Northern Saw-whet Owls in deciduous forests of Pennsylvania. We rechecked those boxes in 2020 to characterize nest-box use by Saw-whets and other vertebrates and determine their efficacy as a management tool in mature forests. We predicted that if cavities were limiting in these eastern deciduous forests, then we would find a high rate of box usage by Northern Saw-whet Owls and other vertebrates.

Field-site Description

This study was conducted on the Allegheny National Forest (ANF) in northwestern Pennsylvania. The ANF lies within the Allegheny High Plateau physiographic region and is characterized by broad plateau tops dissected by steep-sided valleys, with elevations varying from 370 to 650 m asl. Land cover is extensively forested (>90%), primarily by mature (>80 yr) Allegheny and northern hardwoods (USDA 2007). Dominant tree species include *Prunus serotina* Ehrh. (Black Cherry), *Acer rubrum* L. (Red Maple), *A. saccharum* Marsh. (Sugar Maple), *Fagus grandifolia* Ehrh. (American Beech), and *Tsuga canadensis* (L.) Carr. (Eastern Hemlock), with lesser amounts of *Betula lenta* L. (Black Birch), *B. alleghaniensis* Britton (Yellow Birch), *Liriodendron tulipifera* L. (Tupliptree), *Magnolia acuminata* L. (Cucumbertree), *Fraxinus americana* L. (White Ash), *Quercus rubra* L. (Northern Red Oak), and *Populus grandidentata* Michx. (Bigtooth Aspen). In the 1990s and early 2000s, the killing front of the beech bark disease complex (Morin et al. 2007) passed through this region, leaving mature beech trees top-killed or dying and stimulating the growth of dense thickets of root suckers ("beech brush": Cale et al. 2013).

Methods

The nest boxes in this study were built following specifications for Northern Saw-whet Owls (Cornell Lab of Ornithology 2011), filled with about 5 cm of wood shavings, and placed along 4 transects within the ANF (centroid: 41°42′40″N,

78°50′50″W). Sixteen boxes were attached to trees in mature second growth (90–110 yrs of age) forest >35 m from low-use forest roads, ~4–5 m above the ground, and within 50 m of a stream. Boxes were spaced >800 m apart based on published average territory size (Rasmussen et al. 2020). After being checked in 2012, logistical issues precluded further checks until 2020.

During the summer of 2020, we searched for and checked all extant nest boxes to determine whether they had been used and if so, by what species. Because owls build no actual nest structure, we considered as evidence of owl use the presence of feathers, feces, pellets, eggshells or prey remains in the box. Nesting by passerines (e.g., *Myiarchus crinitus* L. [Great Crested Flycatcher]) or ducks (e.g., *Lophodytes cucullatus* (L.) [Hooded Merganser]) would be indicated by a cup-shaped nest of plant materials (Passerine) or downy feathers (ducks), and small-mammal use would be indicated by globe-shaped nests of leaves (squirrels) or grass (mice).

We estimated the abundance and size distribution of tree cavities around nest boxes by visually searching for and recording all cavities in trees within a 50-m radius of each nest box. Cavities were categorized as either natural or woodpecker-excavated and either large or small. We defined large cavities as those with entrance holes ≥6 cm in diameter, and all others as small. Large cavities represented potential nesting sites for Saw-whet Owls and included those excavated by *Dryocopus pileatus* L. (Pileated Woodpecker) and *Colaptes auratus* L. (Northern Flicker) and equivalent-sized natural openings. Size classes of natural cavities were estimated; when unsure, we designated cavities as small to avoid overestimating numbers available to owls. We acknowledge that some natural cavities with large entrance holes may have been insufficiently deep to accommodate nesting owls and therefore inappropriate, and we may have missed some higher cavities hidden by foliage. Additionally, we recorded the species of each tree with a cavity and whether it was dead or alive.

To determine whether Northern Saw-whet Owls were actually present, we conducted playback surveys within 50 m of each box, using the protocol developed for the second Pennsylvania Breeding Bird Atlas (Lanzone and Mulvihill 2006), which consists of alternating periods of listening and playing Saw-whet calls, including advertising calls, whines, and meows. We conducted surveys once at each nest box location from early July through the first of August, beginning well after local sunset (21:35–22:57 EDT).

Results

During surveys in the summer of 2020, we relocated 11 nest boxes; several had been destroyed by windfall, timber harvest, or perhaps vandalism. We found evidence of prior occupancy in just 3 of the extant boxes: 2 grass nests of mice (probably *Peromyscus* sp.) and 1 sciurid leaf nest, most likely *Glaucomys volans* L. (Southern Flying Squirrel) based on nest size. None of these were occupied at the time. The remaining 8 boxes (73%) showed no sign of use by owls or any other vertebrates in 9 years.

We counted 159 cavities within a 50-m radius of the 11 nest boxes (hereafter referred to as a nest-box area), for an average density of 18.4 cavities per ha. Of those, slightly over half (53%) we classified as large, and therefore potentially suitable for Saw-whets. Nest-box areas averaged 9.8 ± 3.3 (SD) large (min–max = 5.1–19.1) and 6.7 ± 3.0 (5.1–16.6) small cavities per ha. A disproportionate number of cavities (34%) were located in American Beech, despite beech comprising just 6% of the woody stems over 13 cm dbh in the north-central portion of Pennsylvania (Albright et al. 2017). Another 33% of cavities occurred in Red Maple and unidentified snag species; almost all of the latter had lost their bark, but were likely beeches (Fig. 1). Woodpeckers were responsible for 44% of large cavities and 76% of small cavities. About two-thirds of all cavities of both sizes were located in dead trees (Fig. 1).

Northern Saw-whet Owls responded to playback by calling at 6 of the 11 nest-box points. Of those 6 responses, 2 included visual sightings of an owl flying in to approach the caller. In addition, we had visual confirmation of owls in 2 nest-box areas where no vocalizations were heard.

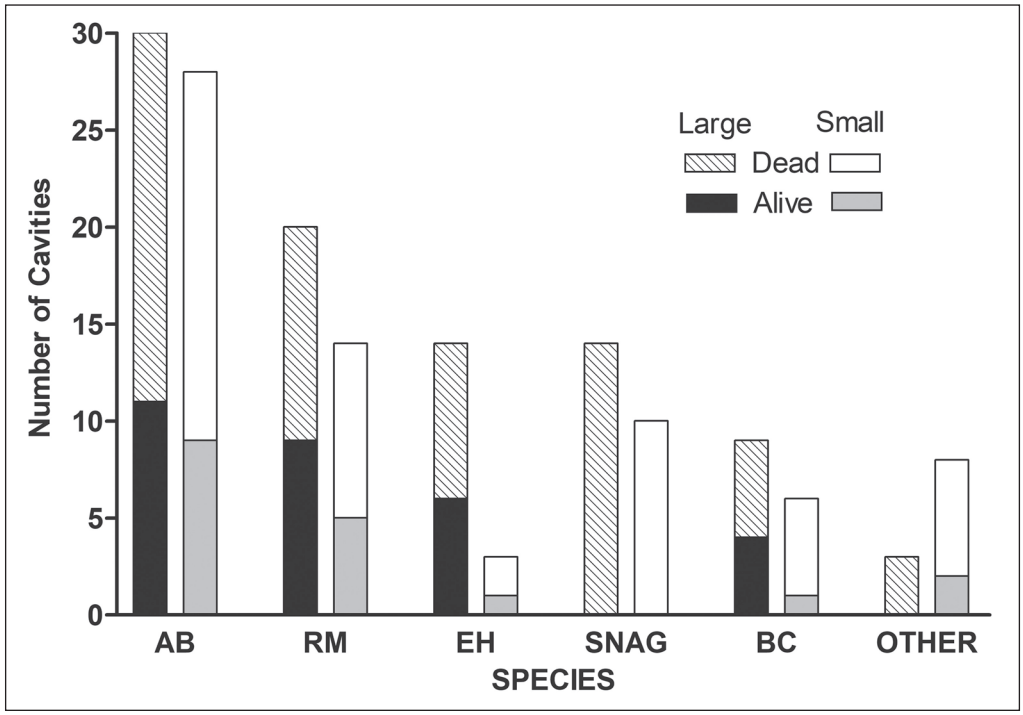

Figure 1. Substrates of 159 cavities located within 50 m of 11 nest boxes installed in the Allegheny National Forest, northwestern Pennsylvania, to facilitate the study of Northern Saw-whet Owls. Bars indicate overall counts by tree species and whether tree was live (solid) or dead (barred/white); AB = American Beech, BC = Black Cherry, EH = Eastern Hemlock, RM = Red Maple, SNAG = unidentified snag, and OTHER = other hardwood species: White Ash, Sugar Maple, Tuliptree, Basswood, Black Birch, and Yellow Birch. We classified cavities with a diameter ≥6 cm as large and all others as small.

Discussion

Despite being present in the forest for 9 years, 8 of the nest boxes appeared to have never been used. The 3 boxes that showed signs of any occupation had been used at some point by rodents. We found no evidence that Northern Saw-whet Owls (or the slightly larger *Macroscops asio* L. [Eastern Screech Owl]) had ever used the boxes for breeding or roosting. This lack of box use can be explained by 3 non-mutually exclusive hypotheses: (1) no Northern Saw-whet Owls actually occurred in the vicinity of the nest boxes; (2) there was an abundance of natural cavities in the area such that any owls present were not cavity-limited; or (3) owls did not prefer the boxes or find them suitable for nesting.

The vocal responses and sightings of owls during nocturnal surveys demonstrated that owls were present on at least 8 of 11 sites with nest boxes. This is a minimum estimate of occupancy because it is based on a single playback survey only. Sites where we detected no response might also have supported owls if the birds were out of earshot of the caller during the survey, or if they responded vocally but were too distant to be heard by the surveyor, or if the owls responded without vocalizing and remained unseen. Although owl surveys were conducted relatively late in the season, the birds detected likely were breeders still on territory and caring for fledglings. In the closest studied populations south of the ANF in Maryland and West Virginia, egg laying begins from mid- to late April (Brinker and Dodge 1993). Given an average 27-day incubation period and 33-day nestling period (Rasmussen et al. 2020), fledging should occur locally from mid- to late June, followed by another 5–8 weeks of dependence on parents (Rasmussen et al. 2020). Thus, in this region, young owls should still be cared for by parents through at least July; anecdotal observations on the ANF are consistent with this breeding phenology (S.H. Stoleson, unpubl. data).

Clearly, Northern Saw-whet Owls were present at most of our box locations. Our owl survey results are consistent with those of the Pennsylvania Breeding Bird Atlas, which found Saw-whets to be widespread and common breeders in this region of the state (Weidensaul 2012). Thus, our hypothesis that the lack of use of nest boxes was due to an absence of owls is not supported.

Cavity abundance

The density of cavities we counted in the vicinity of our nestboxes (18.4 cavities/ha) is close to the cavity density reported for another mature hardwood forest in New York (25 cavities/ha; Kenefic and Nyland 2007) with a disproportionate number in American Beech. The preponderance of cavities in beech in this region results from beech bark disease complex, which top-kills most trees, making them prone to decay, fungal infection, and woodpecker excavation (Witter et al. 1983). Woodpeckers are known to preferentially excavate nest cavities in diseased trees (Conner et al. 1976, Gunn and Hagan 2000).

Estimates of the home-range size of Saw-whets remain poorly understood, but 1.5 km^2 has been reported as being at the low end of estimates for the Appalachians (Rasmussen et al. 2020). Assuming our cavity-survey numbers are

representative of the entire area, by extrapolation each Saw-whet territory of 1.5 km^2 around a box would average approximately 1470 usable cavities available for owls, with a potential of 764 to 2866 cavities per territory based on our observed variance. It seems unlikely that cavities are limiting for saw-whets or other cavity-dependent vertebrates in this area.

Why then were our boxes never used? Many cavity-nesting bird species have been shown to prefer nest boxes over natural cavities, including several raptor species (e.g., Bortolotti 1994, Korpimäki 1984, Petty et al. 1994), but nest-site selection by Saw-whets remains poorly known. Very few published studies report nest-box occupancy rates by Northern Saw-whet Owls, but those that exist suggest our results may not be unusual for mature forest sites. Two separate studies conducted in mature conifer forests in Alberta found Saw-whets used only 5 of 50 boxes (Priestley et al. 2005), and 4 of 169 boxes (Domahidi et al. 2020). Unfortunately, neither study reported the relative abundance of natural cavities on their study sites. In contrast, of 25 nest boxes in a young hybrid poplar (*Populus* sp.) plantation in Oregon, 9 were used by Saw-whets in the first year; these young trees were too small to support natural cavities (Moser 2002). In a nest-box system in shrub-steppe of Idaho where very few trees of any size occur, all 9 Saw-whet nests found were in boxes (Marks et al. 2015). These conflicting occupancy rates suggest that Saw-whets may readily choose nest boxes for breeding, but only in habitats where natural cavities are sparse or absent.

A possible mechanism for apparent nest-box avoidance was suggested by Brawn (1988). In his study of cavity nesters in managed pine forests of Arizona, Brawn showed that most species preferred nest boxes over cavities in thinned areas where boxes were more abundant than natural cavities. In nearby uncut forests with abundant cavities, boxes were mostly ignored. Brawn attributed this apparent paradox to birds developing a search image for nest sites based on the most frequently encountered type of cavity. In our study, natural cavities far outnumbered nest boxes on the ANF, so such a mechanism may have functioned here. However, our data do not allow us to differentiate non-use from actual avoidance of nest boxes.

Management implications

Nest boxes at our field site failed to attract any breeding Northern Saw-whet Owls over the course of 9 years, despite the species apparently being quite common in the area. In fact, our boxes were essentially ignored by almost all vertebrates, likely because natural cavities were abundant in these mature forests. That abundance is likely due at least in part to this region having recently experienced the killing front of the beech bark disease complex, leaving most American Beech trees dead or dying and prone to cavity creation by decay or woodpeckers. Our finding of almost no use of nest boxes in mature forests suggest that any program intending to study or manage cavity-nesting species first conduct an assessment of cavity abundance in the targeted forest system before investing time and resources into nest boxes, as has been suggested by previous authors (Waters et al. 1990, Wiebe 2011).

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