Ecological Indicators 66 (2016) 275–280

Contents lists available at ScienceDirect

Ecological Indicators

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

Habitat indicators for cavity-nesters: The polypore *Phellinus pini* in pine forests

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ARTICLE INFO

Article history:
Received 10 August 2015
Received in revised form 27 January 2016
Accepted 1 February 2016

Keywords:
Heart decay fungi
Hole-nesting passerines
Pinus sylvestris
Snag
Tree cavity
Woodpecker

ABSTRACT

Foresters and arborists have long used fruit-bodies of heart-rot fungi as signs of advanced live-tree decay, but such usage has not been elaborated for forest conservation. I analysed relationships between a heart-rot fungus, tree-cavity supply, and cavity-nesting bird assemblage in wet hemiboreal Scots pine (*Pinus sylvestris*) forests in Estonia. The focal species, *Phellinus pini*, is the main heartwood decayer of live pines; it typically forms fruit-bodies at the stage of advanced decay on old trees. I found that the pine wetlands had few tree-cavities (mostly in snags) and cavity-nesting birds (woodpeckers being almost absent) despite abundant snag supply. Only one fruit-body of *P. pini* was found on cavity-tree but stand-scale abundance of the fruit-bodies correlated well with cavity-nester densities. Multifactor models indicated that cavity formation, not tree death, was the limiting process for secondary cavity-nesters, and *P. pini* could indeed be used (in combination with old-pine abundance) for assessing their habitat quality. This fungus could also serve as an educational flagship species to bridge conservation biology and forest pathology, and its fruit-bodies can signal trees to be retained at harvesting in pine forests. The conclusion is that there is hope for developing practical indicators to manage for the hidden decay processes that govern tree-cavity development.

1. Introduction

Foresters and arborists have long been interested in assessing the extent of internal decay processes in live trees and considered visible fruit-bodies of heart-rot fungi as warnings of timber losses and hazard for humans (e.g., Boyce and Wagg, 1953; Wagener, 1963). The implication of such assessments has been to fell the trees or forest stands ‘in right time’. Such practices have dramatically reduced the incidence of heart-rots and hollow trees in landscapes, and several heart-rot fungi have even become threatened (Vasaitis, 2013). A wider, accompanying conservation problem is that the rich biota inhabiting tree cavities (i.e., tree hollows with external opening) has suffered globally (Gibbons and Lindenmayer, 2002; Cockle et al., 2011; Remm and Lõhmus, 2011). The conservation concern has thus motivated an opposite movement to detect, protect and sustain cavity development in impoverished forests; however, with most research performed on cavity-excavating animals (primary cavity nesters), not tree decay (Bednarz et al., 2004). Communication between conservation biologists, forest pathologists, and arborists on heart-rot processes seems to have much unused potential for ecological research and planning of sustainable land use.

The current paper explores relationships between a heart-rot fungus, tree-cavity supply, and cavity-nesting bird assemblage in wet pine forests. Wide global distribution of pine (*Pinus* spp.) forests, combined with their relatively species-poor tree layer and (often) poor soils, makes such ecosystems attractive test grounds for describing functional links in the ‘tree-cavity networks’ (sensu Cockle et al., 2012). In simple ecosystems, it is easier to assess slow background processes rapidly by using comparative observational methods. Some pine ecosystems, such as the ponderosa pine (*Pinus ponderosa*) forests in the U.S. (Chambers and Mast, 2014), have outstandingly rich cavity-nesting wildlife. On the other hand, slow development and long natural persistence of cavities in pines (e.g., Rudolph and Conner, 1991; Wesołowski, 2011) make their dependent biota vulnerable to cavity-tree removal. For hole-nesting birds, the resulting cavity limitation can be so dominant that no additional benefits of old-growth structure are observable (Remm et al., 2008). A specific management issue in pine wetlands is their widespread artificial draining for timber production (Paavilainen and Päivänen, 1995), with undocumented impacts on cavity supply.

My broad question is whether a specialized heart-rot fungus, the polypore *Phellinus (Porodaedalea) pini*, indicates habitat quality for cavity-nesting birds. *P. pini* (Brot.) Bondartsev & Singer refers

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http://dx.doi.org/10.1016/j.ecolind.2016.02.003
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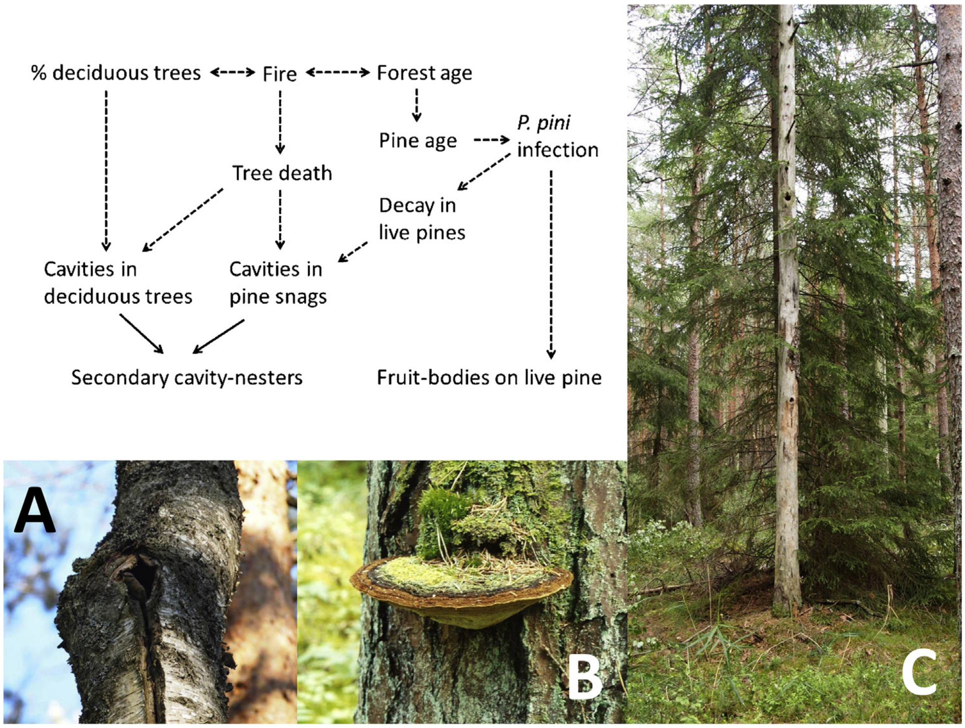

Fig. 1. Stand-scale features and processes in tree-cavity network in pine wetland. Secondary cavity nesters can benefit from the presence of decay-prone deciduous trees (A: *Phoenicurus phoenicurus* at a decay-cavity entrance in birch), while cavity development in dominant pines requires both advanced heart-rot (indicated by *Phellinus pini* fruit bodies; B) and woodpecker excavation after tree death (C). Tree death can be promoted by low-severity fires, which do not eliminate old live pines from the stand (the stand on Photo C burned in the mid-1970s).
Photos by A. Lõhmus.

to several geographically and ecologically segregated lineages (Brazee and Lindner, 2013), which are dominant heartwood decayers in several conifers, including northern pines (e.g., Scharpf and Coheen, 1993). The process from infection to hollow development takes many decades, and advanced decay and fungal fruit-bodies ('conks') may not develop until the tree is at least 50–150 years old, depending on climate and pine species (Boyce, 1961; Conner et al., 1994; Nitare, 2000; Minkevich and Ezhov, 2001; Marmolejo et al., 2011). The resulting hollow or soft heartwood provides cues to excavators, such as woodpeckers and some tits (Paridae), for completing the cavities, particularly after the tree death (Rudolph and Conner, 1991; Jusino et al., 2015). Because there are rarely other fruit-bodies on live pine trunks than those of *P. pini*, this single species could predict habitat suitability for cavity-nesting assemblages in pine forests. Moreover, its long-living fruit-bodies are observable year-round, while many northern cavity-nesters are migratory birds or bats that can only be censused during a short season. The age record of a fruit-body on pine is 100 years and 40–50 year-old fruit-bodies are frequent (Minkevich and Ezhov, 2001). Since the fruit-bodies appear mostly on old trees, they have been also proposed to indicate valuable pine-forest assemblages of less conspicuous fungi, insects, and bryophytes (Nitare, 2000; Unterseher et al., 2012). In terms of the surrogate species schemes of conservation biology (Caro, 2010), *P. pini* could thus serve as an 'ecological engineer' (a subtype of functionally important keystone species), a 'biodiversity indicator' in pine forests, an educational 'flagship species' for stimulating conservation awareness on tree-cavity networks, or a combination of these qualities.

The conceptual setup of the current study (Fig. 1) includes three sets of processes, each linked with wood decay in pine wetlands: cavity formation in live pines; in pine snags; and in the deciduous trees present. My goal was to measure, at the stand scale, the indirect relationship between *P. pini* and cavity-nester abundance, and to describe the functional links producing or confounding that relationship. I expected that, regarding cavity supply, (i) the presence of *P. pini* is more informative than simple tree-layer data (such as stand age and pine abundance), while (ii) its performance can be further modified by abundant deciduous trees and impacts of past fires. I also checked whether surveying *P. pini* fruit-bodies might be efficient due to better precision than tree cavity surveys at given study effort. I am not aware of other quantitative stand-scale analyses that link fungi and cavity-nesters; thus, this study supplements tree-scale studies on cavity networks (e.g., Conner et al., 1994; Cockle et al., 2012) with a broader indicator and management perspective.

2. Materials and methods

The approximately 70-km^2 study area (58°20′ N; 25°00′ E) was situated in the sparsely inhabited Soomaa forest-wetland complex in southwestern Estonia. The area belongs to the European hemiboreal vegetation zone. The climate is humid temperate, with mean temperatures +17 °C in July and −5.5 °C in January, and ca. 750 mm annual precipitation. Most forests are on peat soils, heavily drained for forestry, and dominated by Scots pine (*Pinus sylvestris*) and downy birch (*Betula pubescens*). The study system comprised 18 relatively homogeneous plots of drained pine wetlands (9.8–30.1 ha each; 305.5 ha in total), where the forest cover had at least partly developed secondarily after the draining in the 1960s (11 plots) or in 1980 (7 plots). One plot had pre-draining clearcut origin (67 years old at the time of the study). According to the State Forest Registry, the mean age of the overstorey (hereafter: stand age) varied between 50 and 110 years (grand mean: 78 years); the proportion of Scots pine in the overstorey – between 71% and 97% (86%); and the proportion of Scots pines >100 years old (hereafter: old pines) – between 0% and 72% (16%). The 100-year limit is highlighted here