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Reconciling wood production with bird conservation: A regional analysis using bird distribution models and forestry scenarios in Tokachi district, northern Japan

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ABSTRACT

We examined the relationships between stand age and bird abundance in natural forests and two plantation types (larch *Larix kaempferi* and Todo fir *Abies sachalinensis*) in Tokachi district, northern Japan. Early successional species were found in 10–20-year-old larch and Todo fir plantations, as well as in older natural forests. The abundance of cavity nesters increased with stand age in all three forest types, but their abundance was consistently higher in natural forests than in plantations of the same age. We used these relationships to predict the abundance of each functional group under different forestry scenarios over a 100-year period. A scenario for optimizing larch plantations through a 100% replanting rate following clear-cuts (current replanting rate is 41%) maintained current harvest volumes over the next 100 years. One future possible scenario, in which the replanting rate was increased, resulted in higher wood production levels and a higher abundance of cavity nesters in larch plantations than the current trend scenario. Abandoned plantation clear-cuts were predicted to support large numbers of early successional species. The results also suggested that active wood production activities in natural forests would substantially decrease the abundance of cavity nesters in this region.

1. Introduction

Plantation forests have been expanding worldwide due to the increasing demand for wood. In 2010, 7% of the world's forests were plantation forests (FAO, 2010), many of which have replaced natural forests that produce relatively low volumes of wood (Puyravaud et al., 2010; Yamaura et al., 2012a). The establishment of plantation forests in place of natural forests negatively affects biodiversity not only by simplifying vegetation structure and composition but also by fragmenting natural forests (e.g., Moore and Allen, 1999; Lindenmayer et al., 2002). Because the area under plantation forests is projected to expand in the future, it is necessary to establish methods to maintain both wood production and biodiversity conservation at regional scales while taking advantage of the high productivity of plantation forests (Paquette and Messier, 2010; Yamaura et al., 2012a).

Harvesting forests decreases the abundance of many species that depend on mature forests (hereafter, mature forest species), such as cavity nesting birds (Imbeau et al., 2001; Gibson et al., 2011). Furthermore, species that depend on the early stages of forest succession (hereafter, early successional species) have recently decreased in many regions (Askins, 2001; Yamaura et al., 2009; Betts et al., 2010). In regions with relatively low levels of natural and/or anthropogenic disturbance, harvested forests are known to provide important habitats for early successional species (DeGraaf and Yamasaki, 2003; Yamaura et al., 2012b). Therefore, a demand is increasing to simultaneously maintain wood production and the populations of both mature forest species and early successional species in landscapes that contain large areas of plantation forest. This problem has become a pressing issue in Japan, where vast areas of plantation forest exist (Yamaura et al., 2012a).

Understanding the relationships between biodiversity and stand age (or total basal area) is critical for developing forest management plans that reconcile biodiversity conservation with wood production (e.g., Loehle et al., 2006; Hauer et al., 2010; Schwenk et al., 2012). These relationships have been studied in extensively managed natural forests in Europe and North America, especially with regard to bird species (e.g., Keller et al., 2003; Wilson et al., 2006; Schlossberg and King, 2009; cf. Patterson et al., 1995). However, in plantation forests, the tree species composition and stand structure that determine bird diversity are extremely simplified compared to natural forests, and therefore, bird-stand age relationships may differ between natural and plantation forests. In the current era of plantation forests, it is necessary to understand the relationships between stand age and the abundance of early

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successional and mature forest species in plantations as well as natural forests. These relationships can be used to predict bird abundance at regional scales and to prepare alternative resource management plans. In this study, we examined the relationship between stand age and the abundance of early successional species and mature forest species in three dominant forest types (natural forests, larch *Larix kaempferi* plantations, and Todo fir *Abies sachalinensis* plantations) in Tokachi district, which is currently one of the most active forestry areas in Japan. We used these relationships in multiple future forestry scenarios to assist with the production of regional resource management plans that consider both wood production and the conservation of bird diversity. Although forest birds comprise many species with varied ecological traits, we particularly focused on cavity nesters and early successional species. We additionally examined the responses of bird species preferring conifer trees because major planted trees in Japan are conifers and their responses to stand age may differ between natural forests and coniferous plantations.

Of the three dominant forest types in this study, we focused specifically on larch plantations because they produce approximately 70% of all timber products, and approximately 31% of forests in the study area (including private and prefectural forests) are larch plantations (Tokachi General Subprefectural Bureau, unpublished data; Department of Fisheries and Forestry of Hokkaido, 2011). Therefore, resource management plans for larch plantations will play an important role in determining regional wood production and biodiversity outcomes. To evaluate the larch plantations, we compared several possible future forestry scenarios with optimization scenarios. Finally, we applied each scenario to the three forest types and compared the forestry scenarios at the regional scale.

2. Methods

2.1. Study area

Our study area included all of the private and prefectural forests in Tokachi district (42°55′N, 143°12′E) in eastern Hokkaido, northern Japan. Annual precipitation in this area is 1177 mm year^{-1}, and the mean annual temperature is 7.2 °C (2012). In this district, private and prefectural forests account for 40% of the forest cover (approximately 270,000 ha) and for 85% of the annual total timber production (approximately 610,000 m^3). Natural forests, larch plantations, and Todo fir plantations comprise 55%, 31%, and 8% of these forests, respectively (Department of Fisheries and Forestry of Hokkaido, 2011; Tokachi General Subprefectural Bureau, unpublished data).

We established a total of 31 plots in young to old stands in natural forests, larch plantations, and Todo fir plantations (Appendix A). Ten plots (1–115 years old) were established in natural forests, 11 plots (1–50 years old) were set up in larch plantations, and 10 plots (5–73 years old) were located in Todo fir plantations. We established two plots in a very large and old natural forest stand that had not been disturbed by humans for approximately 300 years. Because no records of the canopy age of this stand existed, we assumed that its age was the same as the oldest forest (115 years old) among the sampled natural forests with known canopy ages.

Each plot was established in the center of each selected stand (>5 ha) except for the oldest natural forest stand (see above). In most cases, the plots (bird transects) were 300 m long and 100 m wide (3 ha). We marked the start and end points of each plot, as well as four or five additional points along the center line, using vinyl marking tape. Because we were unable to select large stands, we established two 1-ha and one 1.5-ha plot in three Todo fir plantation stands (5, 6, and 13 years old: Appendix A). We also established 1-ha and 2-ha plots in two natural forest stands (4 and 14 years old) and a 2.5-ha plot in one Todo fir plantation stand (73 years old) because their shapes were too linear for a 3-ha rectangular plot (Appendix A). All plots were spaced at least 300 m apart.

2.2. Bird survey

We visited each plot three times and identified bird species using a line-transect method (Bibby et al., 2000). We walked the center of each plot and recorded all adult individuals seen or heard within 50 m on either side of the center line. We did not include juveniles, either with or without their parents, in the analyzed data due to their low detection rate. Studies have suggested that bird detection rates within 50 m are similar even among plots that differ in vegetation structure (Schieck, 1997; Alldredge et al., 2007). On some occasions, we remained stationary while carefully searching for birds because the noise made by our shoes and the rustling of understory plants often prevented the observer from detecting birds while walking. Birds flying over or through the forests were not counted. We conducted bird surveys between sunrise and 10:00 h, and the surveys were not conducted in rain, fog, or strong wind. Each plot was visited three times on different days at different times (e.g., near the beginning and end of the daily survey period). The census period ran from May 30 to July 11, 2011 (27 plots), and from June 2 to July 7, 2012 (the remaining four plots). Each plot was visited three times during 1 of the 2 years (Appendix A), and each plot was visited twice before the end of June in that year. We accounted for variations in bird abundance that were not explained by stand age (including the year effects) using random site effects (see below). Bird identification was performed by a single person (Y.T.), and the data were recorded by an assistant.

2.3. Statistical analyses for bird abundance

For a given species on a given plot, the maximum abundance observed over the three visits was used in the analysis (e.g., Hausner et al., 2003; Yamaura, in press). We classified the bird species into early successional species and mature forest species based on the published literature (Yamaura et al., 2009). For the mature forest species, we classified them into cavity nesters and species that prefer coniferous forests (conifer species), and we used these two groups along with the early successional species group in our analysis (Yamaura et al., 2008, 2009). The coal tit (*Parus ater*) was both a cavity nester and conifer species, but we treated it only as a conifer species. With a small size and mass (8 g) the coal tit prefers conifer trees and can dominate bird communities (Yamaura et al., 2008). This species may mask the responses of other cavity nesters. We grouped other species using their foraging locations and examined their responses to stand age because foraging location is an important predictor of a bird's response to the environment (Lindenmayer et al., 2002; Yamaura et al., 2008). However, no clear relationships were observed between stand age and the abundance of these groups in specific forest types (Appendix B), and we excluded them from our prediction and subsequent simulation analysis. Although it is typically classified as an early successional species, we excluded the black-faced bunting (*Emberiza spodocephala*) from the early successional species grouping. This species prevailed over the study area and dominated the bird communities. Their abundance did not respond to stand age and masked the responses of early successional species to stand age.

To identify the relationships involving functional group, stand age, and forest type, we built generalized linear mixed models (GLMMs) using a Poisson error distribution and a log link function. The observed abundance of each functional group was used as the