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Identification of ecological thresholds in harvesting intensity using avian indicators

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Summary

Forestry is a major economic activity in Canada and particularly in New Brunswick, where 85% of the land surface is occupied by forest lands, mostly under intensive management. A century of highgrading and decades of conifer plantation and spruce budworm control have changed the structure and composition of forest landscapes across the province. Recently, selection systems have increasingly been used to restore the commercial value of shade-tolerant deciduous stands (mainly sugar maple and yellow birch). In this study, we examined the response of forest bird species and species assemblages to gradients in the alteration of their habitat through harvesting and other silvicultural treatments. Our specific goals were to determine (1) whether these responses exhibit clear nonlinearities, or thresholds, and (2) whether responses are similar when comparing species occurrence and reproductive activity. In the event that thresholds could be detected, we aimed to use them (3) to recommend guidelines for conservation planning at stand and landscape scales. We surveyed forest songbirds and woodpeckers at a total of 426 stations over three breeding seasons (2000-2002) in J.D. Irving Ltd's Black Brook District. These stations sampled a wide variety of stand types (conifer-dominated, mixedwood, deciduous-dominated) and silvicultural treatments (retention patches in clearcuts, selection cuts, patch cuts, 35-yr or older spruce plantations). At each station, we also recorded signs of reproductive activity by attracting birds with playbacks of Black-capped Chickadee mobbing calls. We collected vegetation data within a 80-m radius of each station, and landscape data within radii of 500 m and 1 km. Finally, we surveyed wood substrates excavated by the Pileated Woodpecker along four 100-m long transects at a subset of stations **(n=132)**.

Assemblages of woodland-dependent songbird species exhibited nonlinear responses to gradients in the alteration of their habitat, especially at the scale of forest stands. For example, a density of approximately 80 large trees (>30-cm dbh) per hectare, or a canopy closure of at least 70% were required to have a high probability of detecting the complete assemblage of species sensitive to forest harvesting. These thresholds were surprisingly consistent among stand types (coniferous, mixed or deciduous). We also found thresholds in the occurrence of individual species using a statistical method called ROC (receiver-operating characteristic) analysis. However, although these thresholds were objectively defined, few were as visually striking as those found at the level of species assemblages. Our survey of excavated substrates revealed a significant preference for American beech by foraging Pileated Woodpeckers. This woodpecker was significantly more likely to be present in stands with a basal area of American beech (≥8-cm dbh) of at least 3.5 m^2 / ha. Finally, we could not assess the effects of silvicultural (or harvesting) intensity on the viability of songbird populations, as originally proposed, owing to the difficulty of obtaining reliable estimates of reproductive success. Indeed, our index or reproductive activity tended to underestimate the actual reproductive success of songbirds at the scale of sampling stations. Nonetheless, the thresholds we found in the occurrence of forest songbirds and the Pileated Woodpecker provide useful guidelines for initial conservation planning, especially if we provide for a margin of error and consider them to be somewhat liberal. We still have to ascertain whether meeting these "occurrence thresholds" is enough to maintain viable populations at the scale of management units.

Original research questions and objectives

The general objective of this research project was to determine over what range of intensity silviculture may compromise the viability of forest bird populations. Most species of forest birds can persist and reproduce successfully in landscapes which maintain a high proportion of uncut stands; our specific question was: do breeding populations disappear relatively suddenly as silviculture is intensified and an increasing proportion of the landscape is harvested?

To answer this question, we selected forest landscapes (ca. 1-km radius circles) covering a range of silvicultural intensities and we recorded (1) the presence and abundance of forest bird species, (2) signs of reproductive activity, and (3) the presence of the Pileated Woodpecker or signs of its foraging activity. This woodpecker requires large-diameter trees for nesting, roosting, and foraging, and hence we expected that it should be sensitive to intensive silviculture. This species plays an important ecological role by excavating large cavities in trees that are also used by a variety of other animal species. Because we only sampled mature or old stands and spruce plantations that were at least 35 years old, we replaced the term "silvicultural intensity" by "harvesting intensity".

The study was conducted in J.D. Irving Ltd's Black Brook District, a 1900 km^2, privately-owned area located in northwestern New Brunswick (Figure 1).

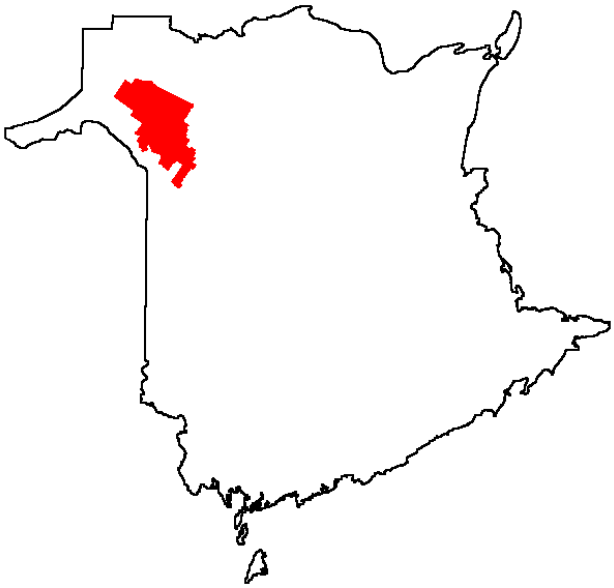

Figure 1: Location of study area, J.D. Irving Ltd's Black Brook District, in northwestern New Brunswick.

Key findings and deliverables

My students and I (1) adapted a statistical approach previously not used in ecology to objectively define thresholds (nonlinearities) in species response, (2) we determined a list of forest bird species significantly affected by intensive harvesting at either stand or landscape scales, and (3) we derived thresholds in the occurrence of these sensitive species which can either be expressed in terms of stand or landscape structure characteristics (e.g. density of large trees, percent mature/old woodland) or as points along a multivariate gradient encapsulating several aspects of forest structure and composition. The threshold values obtained represent key deliverables for our partners. Of course, these threshold values should not be used as rules-of-thumb for sustainable forest management until they are validated in other study areas, and confronted to thresholds observed in the occurrence of other taxa or even in the rates of certain key ecological processes. Nonetheless, these threshold values are a major improvement over some of the current, relatively subjective prescriptions used on public lands in some provinces and, as such, have clear applications for conservation planning in managed forest landscapes. We propose to use these thresholds as working hypotheses which require testing and validation.

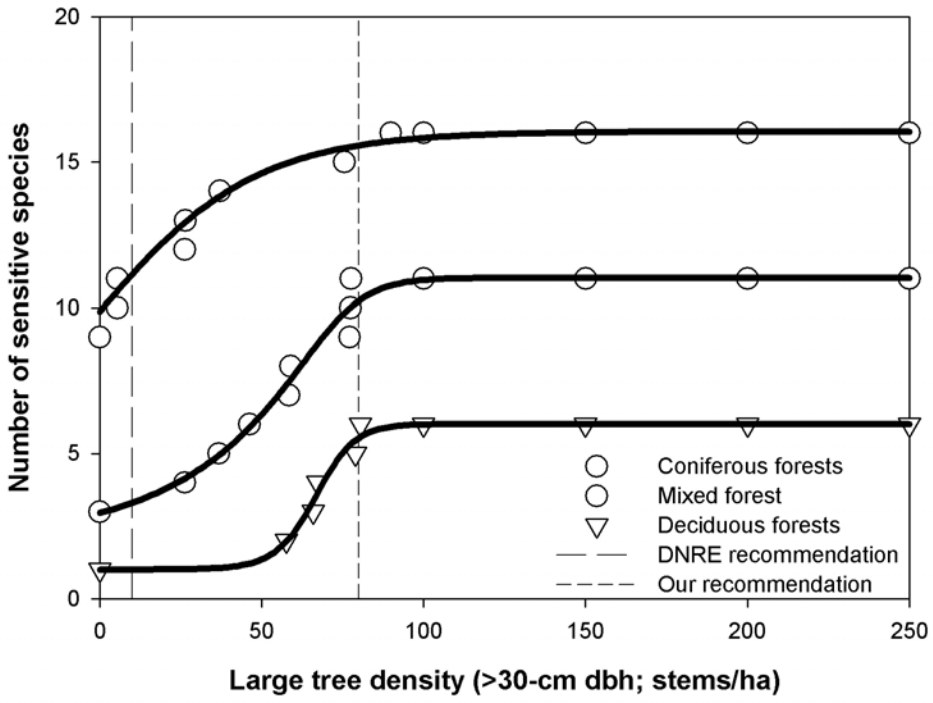

Figure 2. Relationship between the density of large trees and the cumulative richness of species responding negatively to harvesting intensity (Guénette and Villard, in prep.).

In New Brunswick, for example, our threshold for the density of large trees (Figure 2) is approximately eight times higher than that recommended in the provincial guidelines, based on the literature and expert advice (Beaudette and Makepeace, New Brunswick Dept. of Natural Resources [NB-DNR], pers. comm.). The apparent importance of American beech for Pileated Woodpecker foraging (Figure 3), and possibly for nesting, also contrasts strongly with current harvest practices aiming to actively suppress this species in favour of more commercially desirable ones (sugar maple and yellow birch). That being said, the woodpecker's attraction to beech might reflect the increasing prevalence of the bark disease sweeping northeastern North America.

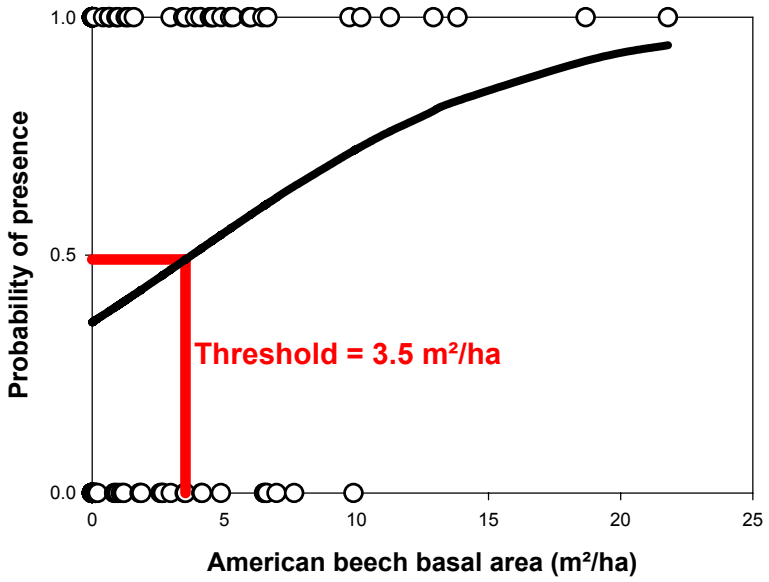

Figure 3. ROC-derived threshold in the probability of presence of the Pileated Woodpecker as a function of American beech basal area (see text for details) (Lemaître and Villard, in prep.).

We also found thresholds in the proportion of mature/old untreated woodland at the landscape scale, or in its configuration (mean area of patches), but fewer species responded to variables at that scale when controlling for stand-level habitat characteristics.

Thus, even though these thresholds were obtained by sampling a relatively small area (1900 km^2) and they have not yet been validated elsewhere, representatives of the NB-DNR have taken note of our these values as they are currently developing the new set of guidelines for the 2007-2012 Crown land management plans.

Contributions to the advancement of knowledge

The definition of quantitative targets for the conservation of biodiversity is still in its infancy. Of course, a variety of approaches have been examined to derive rules-of-thumb for management, but the validity of these approaches has either been called into question (e.g. minimum viable populations) or their accuracy has been found to be very sensitive to the quality of the parameters used in models (e.g. population viability analysis).

Most conservation studies tend to document the degree of correlation between a "dose" (e.g. harvesting intensity) and a response (e.g. probability of occurrence, abundance, reproductive success) without paying much attention to the shape of this response. M.Sc. student Jean-Sébastien Guénette actually had to adapt a method previously used in clinical medicine (Zweig and Campbell 1993) to objectively determine threshold values in the response of the target bird species. Prior to that, ROC analysis had strictly been used in ecology to assess the goodness-of-fit of logistic regression models, and even this was a rare occurrence (Manel et al. 2001). We then used the species-specific thresholds obtained using ROC analysis to plot the expected species richness of sites along gradients in harvesting intensity, which allowed us to obtain threshold values for actual species assemblages rather than individual species. We view these "assemblage-level thresholds" as even more informative for forest management because they provide a broader perspective on potential tradeoffs: they are less sensitive to extremes and we expect them to be more consistent geographically, at least within the collective ranges of the majority of the species. From the two master's theses generated by this project, two papers are currently in review (*Ecological Bulletins* and *Journal of Applied Ecology*), and two others are close to submission. A fifth manuscript is in preparation.

Benefits to partners and other organizations

The results of this project have been presented to our partners at meetings of J.D. Irving Ltd's Forest Research Advisory Committee (hereafter JDI's FRAC) and at J.D. Irving's Science Forum (Fredericton, 8 April 2003). NB-DNR was represented both at FRAC meetings and at the Science Forum. We also met with NB-DNR representatives in Fredericton on 15 April 2003 and in Moncton on 29 July 2003 to discuss our results in details, and adjustments to some of DNR's threshold values to be used for the 2007-2012 Crown land management plans. JDI's FRAC is also currently examining harvest planning scenarios for its flagship District (Black Brook) which incorporate DNR's guidelines adjusted based on this study's findings. DNR's guidelines are used to estimate the supply of wildlife habitat and, when necessary, to adjust harvest planning to maintain or increase this supply.

The basic approach and main results obtained through this work have also been summarized in a popular article published in *Elements*, New Brunswick Environmental Network's electronic newsletter (Villard 2003). In addition, my students and I gave public presentations in Edmundston as part of a regular meeting of the Madawaska Ornithology Club (10 April 2002), a workshop on hardwood forest management (8 May

2003), and a meeting organized for wildlife observers and hunters (23 May 2003). It should be noted that the audience for the workshop on hardwood management was composed of woodland managers and representatives of NB-DNR and federal agencies. These presentations have contributed to clarify perceptions on the actual effects of forest management on forest birds, and they helped to illustrate the level of commitment of the industry with regards to these effects.

Management/policy implications

As mentioned above, we hope that our results will help NB-DNR develop its criteria and indicators to assess wildlife habitat supply (e.g. densities of large trees/snags; crown closure; beech component; landscape structure). Jean-Sébastien Guénette and I were in fact invited to review DNR's focal species lists per stand type/age and the quantitative criteria for stand and landscape structure associated to each focal species at a meeting on 29 July 2003.

Acknowledgments

First of all, the work outlined above was conducted by two master's students, Jean-Sébastien Guénette and Jérôme Lemaître. Their great skills and exceptional commitment were instrumental to the success of this project. We also benefited from the long-term commitment of our industrial partner, J.D. Irving Ltd, which contributed to the NSERC Postgraduate Scholarship of JSG and provided invaluable logistical support. JDI also gave us access to the Boston Brook Camp for the duration of the study. Special thanks go to Gaétan Pelletier and Charles Neveu (JDI). We wish to thank our field assistants, whose dedication was greatly appreciated. This project benefited from the feed-back of members of JDI's FRAC and the close collaboration of Dr David MacLean, his students and research assistants. Finally, representatives of NB-DNR provided advice, information, and encouragement to push this project towards more specific applications.

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