Spatially-explicit impacts of climate change on habitats of a focal species in eastern boreal forest

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INTRODUCTION

Climate change is thought to strongly alter boreal forest processes, vegetation composition and age structure\textsuperscript{[1]}. As such, bird habitats should greatly change, triggering potential range shift in bird species\textsuperscript{[2]}. Most of studies projecting future bird habitats rely on species distribution models (SDM) which are mainly based on projections of where climate conditions will be similar to current species range might be expected in the future. This approach does not take into account the projected realized migration of the habitat (e.g., forest cover).

Forest landscape models (FLM) simulate stand (e.g., succession, growth) and landscape-scale processes (e.g., seed dispersal, natural and anthropogenic disturbances) allowing for more realistic projections of bird habitats.

Black-backed Woodpecker (BBW0) is found in conifer-dominated stands presenting sufficiently old dead wood, such as over-mature and old-growth forests\textsuperscript{[3, 4]} and forest stands recently disturbed by wildfire or insect outbreaks\textsuperscript{[5-7]}. Territory sizes diminish according to prey abundances (i.e. amount of recently dead wood) in habitat types, which is related with age in old forests and with disturbance severity\textsuperscript{[3, 8]}. As such BBW0 is considered an indicator species for deadwood and associated saproxylic biodiversity in the boreal forest\textsuperscript{[3, 5, 9]}.

Climate change induced decrease in conifer species productivity\textsuperscript{[11]} a concurrent increase in wildfires\textsuperscript{[12]}, coupled with a rather high logging pressure in the study area which should strongly affect the quality of the BBW0 habitat.

STUDY AREA

Coniferous tree species increase in abundance with latitude, mostly balsam fir (\textit{Picea mariana}), jack pine (\textit{Pinus banksiana}), and inversely for boreal deciduous species, such as trembling aspen (\textit{Populus tremuloides}) and white birch (\textit{Betula papyrifera})\textsuperscript{[13]}. Large and rather frequent stand-replacing fires mostly occur within this portion of boreal regions\textsuperscript{[12]} whereas recurrent spruce budworm outbreaks are the most important natural disturbances in the mixed forest portions\textsuperscript{[14]}.

METHODS

The model: LANDIS-II

Four climate scenarios considered

- Projections (3): RCP 2.6, 4.5 and 8.5 run under the CanESM2 model.

Natural disturbances

- Two natural disturbances considered: wildfire and spruce budworm (SBW) outbreaks.
- Baseline and future fire regime parameters according to models recently developed\textsuperscript{[2, 12]} and further updated for each RCP scenario\textsuperscript{[15]}. All fires were considered as severe, i.e., killing all cohorts.

Habitat quality was estimated by the number of young produced by hectare, based on known estimates of home range sizes and productivity (Nest success * number of fledglings / successful nest) per habitat types.

Habitat classification and habitat quality for BBW0

LANDIS-II outputs at the cell level were reclassified to consider five BBW0 habitat types.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Nb of pixels in a patch</th>
<th>Mean productivity (nb fledglings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Mature coniferous forest</td>
<td>23</td>
<td>1.5</td>
</tr>
<tr>
<td>2) Mature mixed forest</td>
<td>32</td>
<td>1.0</td>
</tr>
<tr>
<td>3) Recently burned mature coniferous forest</td>
<td>16</td>
<td>0.5</td>
</tr>
<tr>
<td>4) Recently burned young coniferous forest</td>
<td>42</td>
<td>0.25</td>
</tr>
<tr>
<td>5) Old burned mature coniferous forest</td>
<td>16</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Based on\textsuperscript{[7, 17]}.

DISCUSSION

Our study demonstrates that impacts of climate change are likely to be detrimental for our focal species, with decline in productivity up to 87 % in all forcing scenarios.

- Mature and old coniferous stands are predicted to greatly decline during the next century but not only due to succession and climate-induced changes in forest growth and reproduction per se, but also by increases in fire activity, coupled with forest harvesting.
- Forest succession and regeneration processes (e.g., seed dispersal, natural and anthropogenic disturbances) are strongly altered in BBW0 habitats as fire would burn younger and non coniferous forests, this being accentuated in scenarios RCP 4.5 and 8.5.
- Such proctogics suggest that biodiversity associated with dead wood and old-growth boreal forests may be greatly altered by cumulative impacts of disturbances (natural and anthropogenic) under climate change.

MANAGEMENT IMPLICATIONS

- Most of the study area became unproductive for BBW0 at the end of the century, with a latitudinal gradient where southern regions being less and less productive and this pattern progressed northward with time.
- Presence of key boreal climate refugia that are likely to remain relatively stable to climate change impacts (and less prone to wildfire) throughout time will be of greatest importance for persistence of boreal biodiversity.


\textsuperscript{[9]} Nappi, G. et al.\textsuperscript{2011}. Canadian Journal of Forest Research 41, 994-1000.

\textsuperscript{[10]} Nappi, G. et al.\textsuperscript{2011}. Canadian Journal of Forest Research 41, 994-1000.