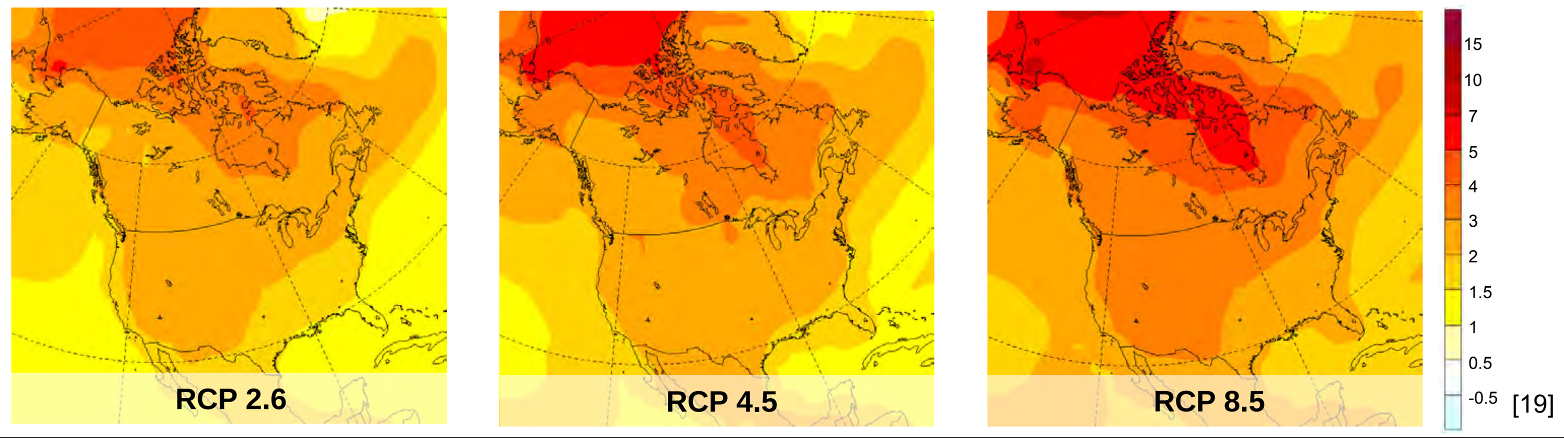
Spatially-explicit impacts of climate change on habitats of a focal species in eastern boreal forest



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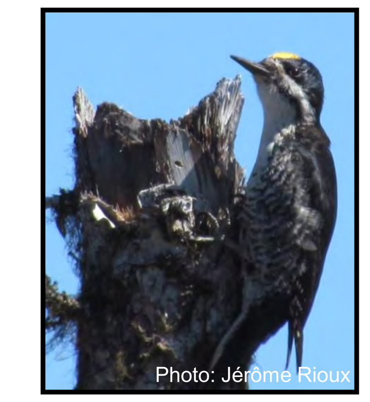


INTRODUCTION

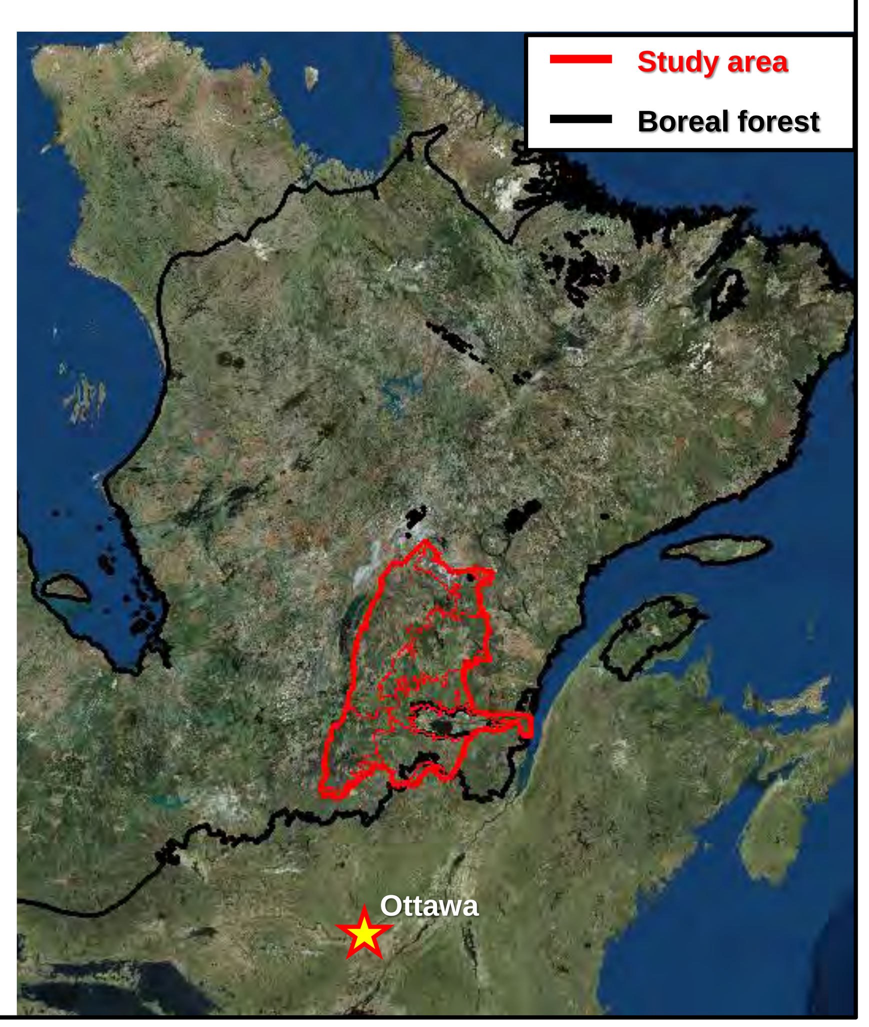
- Climate change is thought to strongly alter boreal forest processes, vegetation composition and age structure [1].
- As such, bird habitats should greatly change, triggering potential range shift in bird species [2].
- Most of studies projecting future bird habitats rely on species distribution models (SDM) which are mainly based on projections of where climate conditions within the 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 (BBWO) is found in conifer-dominated stands presenting sufficient amount of dead wood, such as over-mature and old-growth forests [3, 4] and forest stands recently disturbed by wildfire or insect outbreaks [5-7]. Territory sizes diminish accordingly with prey abundances (i.e. amount of recently dead wood) in habitat types, which is related with age in old forests and with disturbance severity [3, 8].
- As BBWO is considered an indicator species for deadwood and associated saproxylic biodiversity in the boreal forest [3, 5, 9], and a threatened species by climate change [10], it then represents a valuable focal species to understand impacts of climate change on saproxylic biodiversity.
- Climate change induced decrease in conifer species productivity [11] a concurrent increase in wildfires [12], coupled with a rather high logging pressure in the study area which should readily affect the quality of the BBWO habitat

OBJECTIVE

- Project the impacts of anthropogenic (forest harvesting) and natural (wildfire and insect outbreak) disturbances as well as climate-induced changes on forest processes on BBWO habitats in boreal forest of eastern Canada.

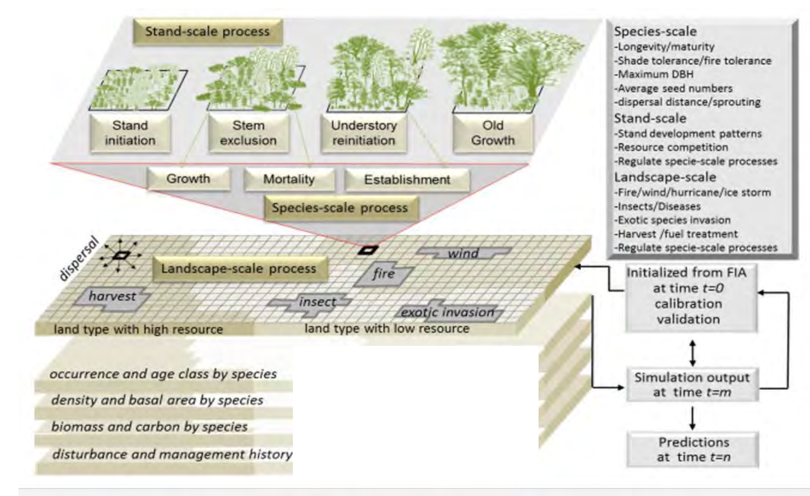
STUDY AREA

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



METHODS

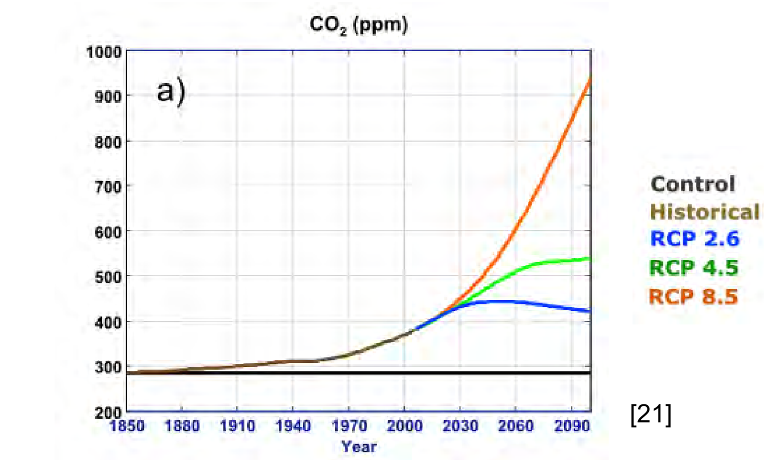
The model: LANDIS-II



Adapted from [20]

Four climate scenarios considered

- Baseline (1) : 1901-2000 climate.
- Projections (3) : RCP 2.6, 4.5 and 8.5 run under the CanESM2 model.



[21]

Forest succession

- Unique life-history attributes characterize seed dispersal, shade tolerance, reproduction etc. for each tree species.
- Growth parameters for each tree species occurring on each landtype were calibrated for all climate scenarios using a climate-sensitive gap model (i.e. PICUS).

Natural disturbances

- Two natural disturbances considered: wildfire and spruce budworm (SBW) outbreaks.
- Baseline and future fire regime parameters according to models recently developed [12] and further updated for each RCP scenario [15]. All fires were considered as severe, i.e., killing all cohorts.
- Outbreaks are simulated as probabilistic events at the cell level with probabilities and mortality being a function of site and neighborhood resource dominance (host: balsam fir and spruce species).

Forest harvesting

- Harvest data and prescriptions were retrieved from MODIS-based forest disturbance maps [16] from which the cumulative biomass harvested during the 2002-2011 was estimated at the 250-m cell level and then summarized by Forest Management Units.
- Harvest prescriptions were kept constant during simulations.

Simulations

- Five replicates were run for 100 years, starting in 2000 under each of the four climate scenario with a 5y timestep.

Habitat classification and habitat quality for BBWO

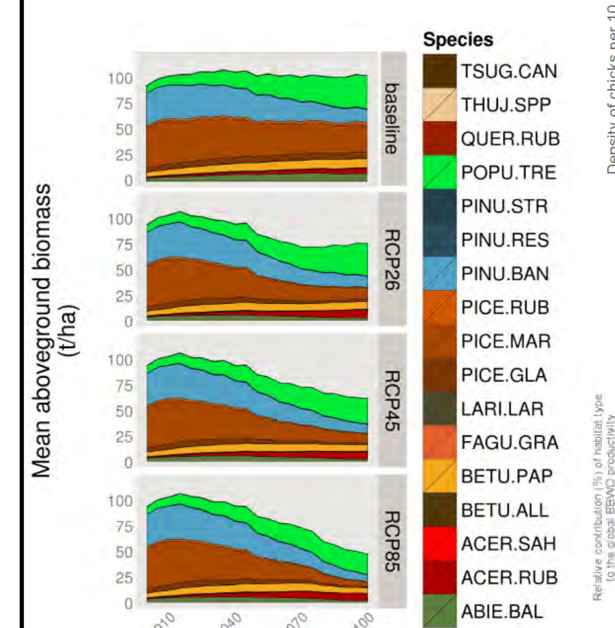
- LANDIS-II outputs at the cell level were reclassified to consider five BBWO habitat types.
- Habitat quality was estimated by the number of young produced by hectare, based on known estimates of home range sizes and productivity (Nest success * number of fledglings / successful nest) per habitat types:

Habitat type	Nb of pixels in a patch[a]	Mean productivity (nb fledlglings)[b]
1) Mature coniferous forest	20	1.5
2) Mature mixed forest	32	1.0
3) Recently[c] burned mature coniferous forest	6	1.4
4) Recently[c] burned young coniferous forest	40	0.25
5) Old[d] burned mature coniferous forest	16	0.4

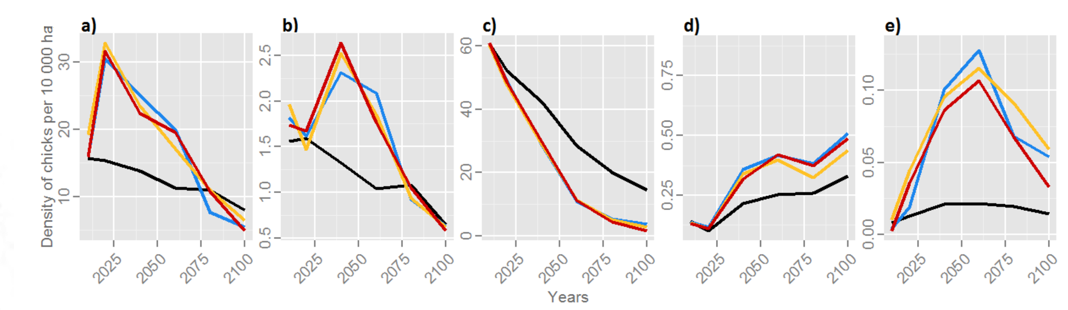
[a] Based on [3], [7,] and [17]; one pixel sized 6.25 ha. [b] Based on [7], [17], and [18]
[c] 0 to 5 year post-fire [d] 6 to 10 year post-fire.

RESULTS

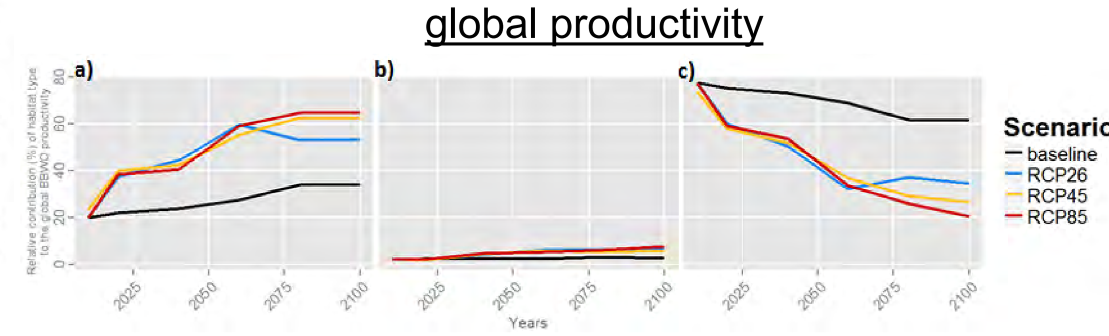
Temporal trends in landscape composition



BBWO productivity (number of fledglings/100 km^2)

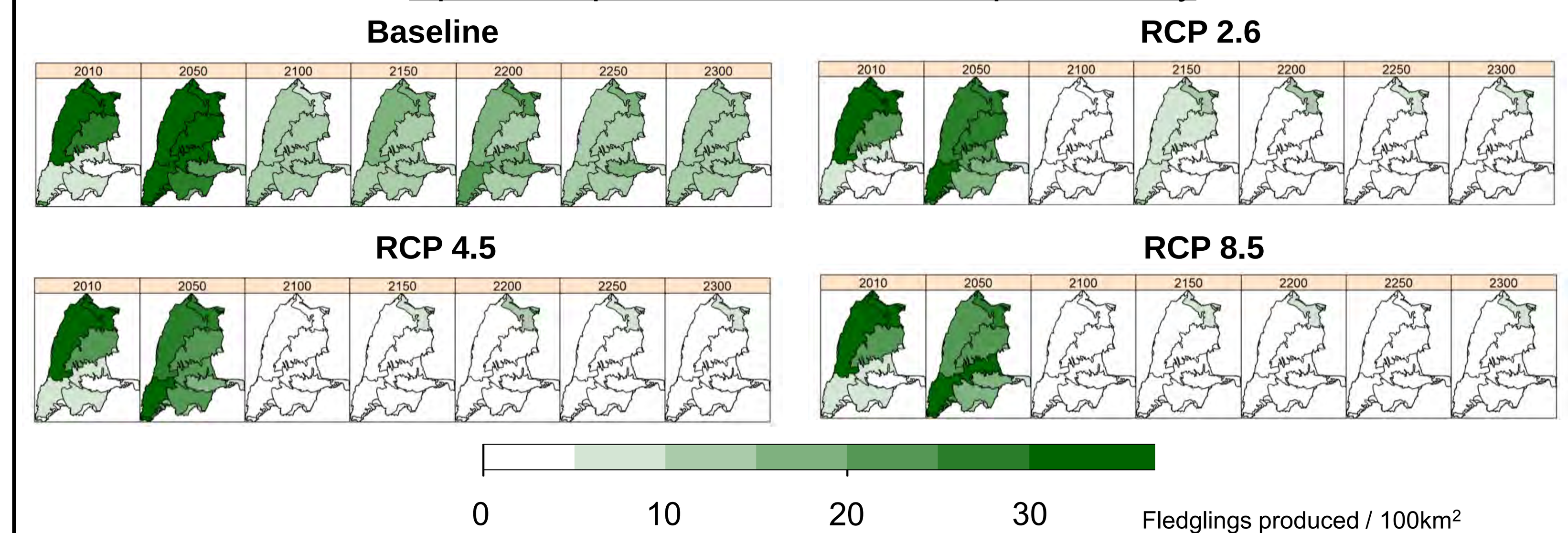


Relative contribution of principal habitat types to the global productivity



a) recently burned mature coniferous forest stands, b) old burned mature coniferous forest stands, c) mature coniferous forest stands, d) mature mixed forest stands, e) young burned coniferous forest stands

Spatiotemporal trends in BBWO productivity



DISCUSSION

- Our study demonstrates that impacts of climate change are likely to be very detrimental for our focal species, with decline in productivity above 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:
  1) Boreal coniferous tree species productivity would drop under all climate forcing scenarios favoring the establishment and growth of deciduous tree species.
  2) Increase in area burned would considerably reduce the amount of mature coniferous forest habitat. Although increase in fire would provide more high quality habitat in the short term (2050) through the burning of mature coniferous forests, further increase in area burn afterwards would strongly alter BBWO habitats as fire would burn younger and non coniferous forests, this being accentuated in scenarios RCP 4.5 and 8.5.
- Such prognostics 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 BBWO 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.

[1] Gauthier et al. 2015. Science 349, 819-822. [2] Stralberg et al. 2015. Ecological Applications 25, 52-69. [3] Tremblay et al. 2009. Avian Conservation and Ecology 4, 2. [4] Tremblay et al. 2015. Forest Ecology and Management 357, 220-227. [5] Hutto 2008. Ecological Applications 18, 1827-1834. [6] Bonnot et al. 2009. Forest Ecology and Management 259, 220-228. [7] Nappi and Drapeau 2009. Biological Conservation 142, 1381-1391. [8] Nappi et al. 2011. Canadian Journal of Forest Research 41, 994-1003. [9] Tremblay et al. 2010. Canadian journal of Forest Research 40, 991-999. [10] Langham et al. 2015. PloS one 10, e0135350. [11] Girardin et al. 2014. Global Change Biology 20, 851-866. [12] Boulanger et al. 2014. Canadian Journal of Forest Research 44, 365-376. [13] Rowe and Halliday 1972. Forest regions of Canada. [14] MacLean 1980. The Forestry Chronicle 56, 213-221. [15] Gauthier et al. 2015. Environmental Review 22, 256–285. [16] Guindon et al. 2015. Journal of Forest Research 44, 1545-1554. [17] Tremblay et al. 2016. Birds of North America 509. [18] Tremblay et al. 2015. Ecoscience 22, 145-155 [19] Environment Canada 2015. http://www.cccma.ec.gc.ca/diagnostics/cgcm4/cgcm4.shtml. [20] Arora et al. 2011. Geophysical Research Letters 38(5). [21]Wang et al. 2014. Remote Sensing of Environment 140, 60-77.