Effects of industrial sectors on species abundance in Alberta

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SUMMARY

- Transformation of native habitat by human activity is the main cause of global biodiversity loss. Humans have visibly transformed 27% of Alberta to date.
- The effects of these changes depend on the species, and the nature and extent of the human activities in question. The ABMI collects data and produces information that helps to tease apart these factors.
- We present the example of the Boreal Chickadee from northern Alberta to illustrate how various types of industrial development influence a species. Forestry had the largest effect on Chickadee relative abundance, followed by energy and agriculture.

KEY MESSAGES

- ABMI data, freely available at species.abmi.ca, can help managers understand how activities by each industrial sector affect habitat suitability for each species.
- Sector effect estimates take into account not only the amount of footprint, but also what habitat types the sector's footprint impacts the most. These estimates thus provide tools for exploring alternative management options in land-use planning.

INTRODUCTION: HUMAN ACTIVITIES ALTER NATIVE HABITATS

Transformation of native habitat by human activity is the major cause of biodiversity loss[1]. To date, 27% of Alberta's land base has been visibly altered by this transformation, which the Alberta Biodiversity Monitoring Institute (ABMI) refers to as human footprint (see definition box). This process is ongoing, with 2% of the province converted during the last decade[2]. Data on how species respond to human footprint are vital to supporting evidence-based land-use decision-making and sustainable resource management.

Species' responses to human footprint depend on the footprint type, where the footprint occurs, and on how common that footprint type is in the environment. For example, one sector might have a positive effect on a species' abundance in a particular region, while another sector has a negative effect. These effects might cancel out, resulting in no observed change in the species' regional abundance.

DEFINITION:
Human footprint
We define human footprint as the temporary or permanent transformation of native ecosystems to industrial, residential or recreational land uses that is visible from air photos.

To develop sector-specific land-use management practices and regulations, it is important to understand the impact of each sector—such as forestry, energy, agriculture, and transportation—on individual species.

In this *ABMI Science Letter*, we estimate the total effect of different sectors on species, using the Boreal Chickadee from northern Alberta as an example. By quantifying the impact of each sector, managers will be able to tease apart the cumulative effects of resource development in a region, identify appropriate approaches for managing species whose abundance is increasing, and mitigate risks for vulnerable species whose abundance is decreasing.

1 Wilcove, D., Rothstein, D., Dubow, J., Phillips, A. & Losos, E., 1998, Quantifying threats to imperiled species in the United States. BioScience, 48:607–615.
2 Shieck, J., Huggard, D. & Sólymos, P., 2014. Human footprint in Alberta. ABMI Science Letters, September 5, 2014.

FIGURE 1
A map of different types of human footprint in Alberta grouped by industrial sector.

MODELING SPECIES ABUNDANCE

As a first step to quantifying sector effects, we created habitat models for a series of individual species. These models produce estimates of a species' expected relative abundance based on land cover and human footprint that are present in an area. In general, a species will be more abundant in suitable habitats than in less suitable habitats; thus, we use relative abundance as a rough proxy for habitat suitability in this document. We used data from the ABMI, Environment Canada, Breeding Bird Surveys, and the Bayne Lab at the University of Alberta to model the relative abundance of each species in different land cover types, including various human footprint types (e.g. cutblocks, cultivation, roads, wellpads, etc.). We then used these models to estimate both current abundance, and what we call "reference abundance"—the expected abundance in the absence of human footprint (that is, when all human footprint is converted back, or "backfilled", to native vegetation types[3]). This was done for each 1 km^2 square in the province. In the case of squares with multiple land cover types, the estimated abundance for each land cover type was summed. Finally, we compared the predicted current and reference abundances for each species in northern Alberta.

ESTIMATING SECTOR EFFECTS

Background

The effect of a sector on a species can be broadly defined as the product of the area of the sector's footprint and the average effect of that sector's footprint per unit area (the "unit effect") on the species. Thus, a larger area or stronger effect per unit area will both result in a greater sector effect.

DEFINITION:

Sector effect
The area of a sector's footprint times the estimated unit effect of that sector's footprint.

Unit effect
The relative difference between a species' estimated current and reference abundances for that sector's footprint type averaged over a target area.

3 Alberta Biodiversity Monitoring Institute, 2015. Alberta Backfilled Wall-to-Wall Vegetation Layer (Version 5) Metadata (version June 22, 2015). URL: http://www.abmi.ca. Alberta Biodiversity Monitoring Institute, Alberta, Canada.

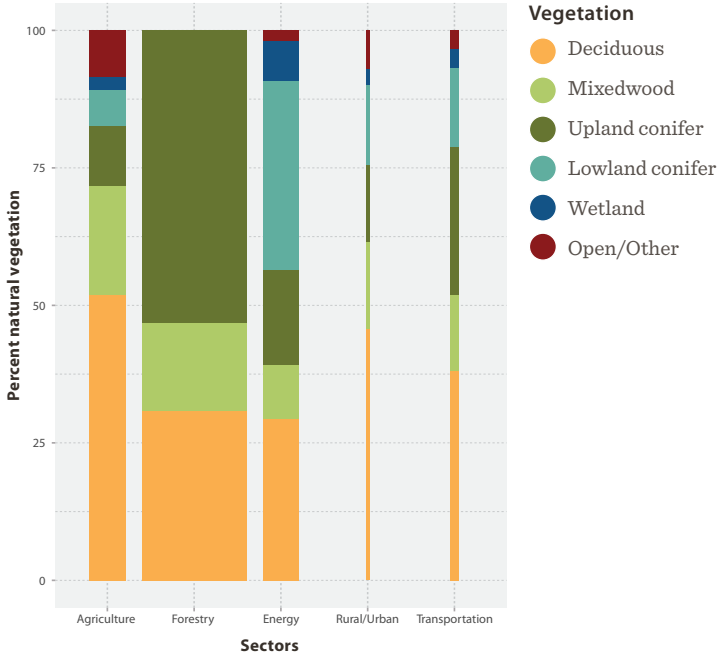
The area of a sector's footprint is the sum of the footprint belonging to a given sector, while the unit effect is the average difference between the species' estimated current and reference abundances for that sector's footprint type summed over all 1-km^2 squares in the area of interest. For example, if the current abundance of a species in a given sector's footprint is only slightly lower than its predicted abundance in the absence of any human footprint, then that sector's unit effect is low. By comparing current and reference abundance, intrinsic differences in habitat quality for a given species are also taken into account. For example, an area affected by a sector's footprint might have a low relative abundance of a target species. However, if the area is predicted to have a low reference abundance—that is, if it represents marginal habitat even without human footprint—then a low current abundance is mostly unrelated to human footprint. Not surprisingly, the effect of footprint is highest when footprint occurs in a species' high quality habitat, and lowest when it is in habitat that is less suitable.

Analysis

By comparing land cover (natural vegetation) and human footprint[4] maps (**Fig. 1**), it is possible to identify which land cover types have been converted to which human footprint types, along with the corresponding changes in habitat suitability for a species. This lets us attribute changes in relative abundance for a species to a specific sector. We have differentiated the following sectors in our analyses: agriculture, urban-rural, energy (including oil and gas extraction, exploration and other energy related features), forestry, and transportation.

In northern Alberta (Boreal Forest, Foothills, and Canadian Shield natural regions), human footprints are concentrated in the Peace River area and in the southern fringe of the Boreal Forest (**Fig. 1**). Different footprint types occur disproportionately in certain land cover types (**Fig. 2**). Agriculture and urban-rural footprints occur most often in deciduous forests; forest harvest and roads occur mainly in upland coniferous and deciduous forests; while energy sector footprint types are most common in lowland coniferous and upland deciduous forests, and to a lesser extent in non-treed wetlands. Differences in the habitat types affected by each sector contribute to the differing effects of the sectors on a species.

FIGURE 2
Breakdown, by percent, of natural vegetation types that have been transformed into a given human footprint type in northern Alberta. For example, areas currently under Agricultural footprint were originally 52% deciduous forest, 20% mixedwood forest, etc. The width of each bar is proportional to the area of the sector in northern Alberta.



EXAMPLE: BOREAL CHICKADEE

In this *ABMI Science Letter,* we present results for the Boreal Chickadee (*Poecile hudsonicus*) from northern Alberta. Results for other species can be found on the ABMI website (species.abmi.ca). The Boreal Chickadee (**Fig. 3**) is a year-round resident species living mainly in coniferous forests throughout the Boreal region of Canada and the United States[5].

FIGURE 3
The Boreal Chickadee is a winter resident bird species that lives mostly in coniferous forests of the Boreal region. ***Photo credit: ABMI.***

4 Alberta Biodiversity Monitoring Institute, 2015. ABMI Human Footprint Inventory for 2012 conditions (Version 3). URL http://www.abmi.ca. Alberta Biodiversity Monitoring Institute, Alberta, Canada.

5 Ficken, Millicent S., Margaret A. Mclaren & Jack P. Hailman, 1996. Boreal Chickadee (*Poecile hudsonicus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: URL http://bna.birds.cornell.edu/bna/species/254

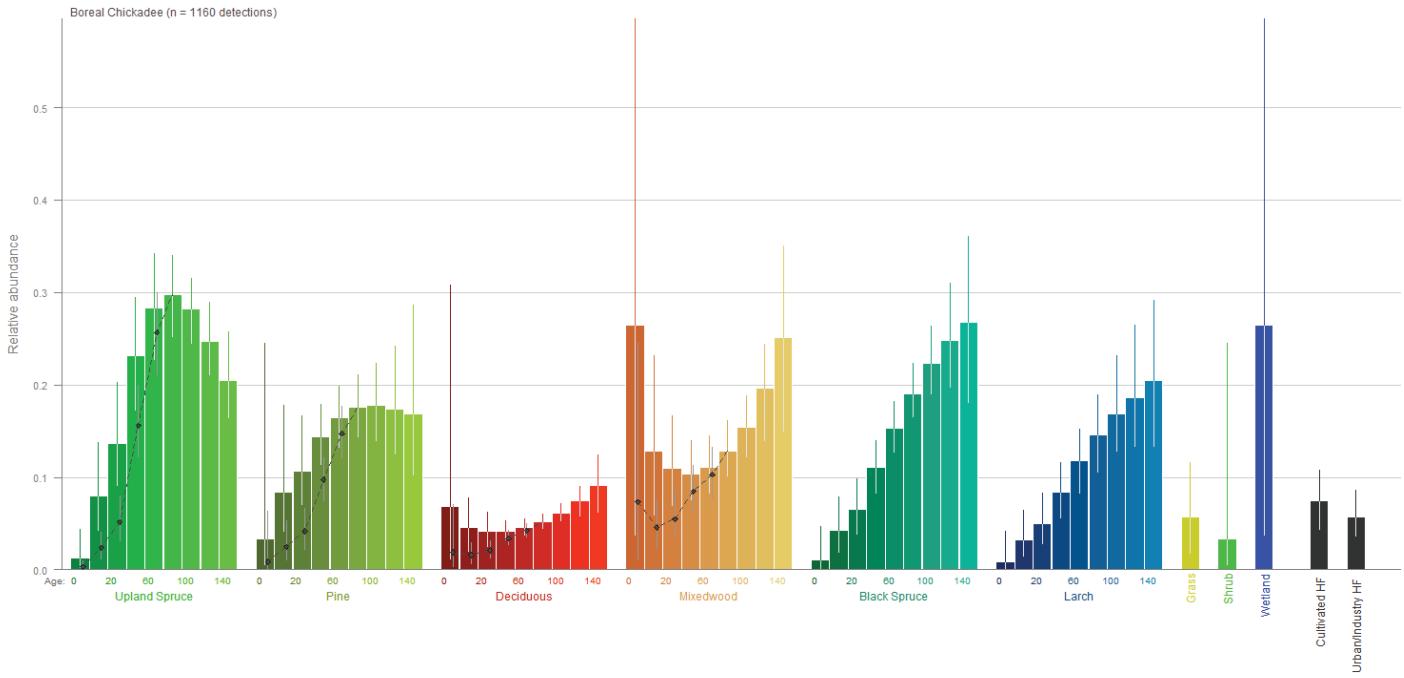
Our models[6] indicate that the most suitable habitats for the Boreal Chickadee comprise mature and old-growth coniferous forest stands (upland spruce and pine forests). Old mixedwood and old lowland coniferous stands were also more suitable than open habitats or deciduous forests. Predicted abundance was generally low in cutblocks, and in areas with cultivation or urban-industrial footprints (**Fig. 4**).

The relative abundance of Boreal Chickadee is estimated to be 8.8% lower now than under reference conditions—that is, in the absence of human footprint—in northern Alberta. Most of this decrease was attributed to forest harvest, which converted 6.0% of the region to cutblocks. Because cutblocks (open areas with patches of residual large trees and snags) occurred in the best habitat for the species (i.e., in mature and old-growth upland forests), it is not surprising that forestry footprint decreased Boreal Chickadee abundance in the region by 7.1% (**Fig. 5**). Energy sector footprints covered 2.1% of the region and resulted in a 0.8% decrease in abundance for Boreal Chickadee. Agriculture covered 2.1% of the region, and its effect on Boreal Chickadee abundance was similar to that of the energy sector (–0.5%). The effect of transportation was somewhat smaller (–0.4%) while the effect of rural-urban footprint on Boreal Chickadee abundance was minimal (–0.1%).

The sector effect per unit area (unit effect) was intermediate and very similar for agriculture, energy, and rural-urban sectors (between –38% and –24%). The unit effect for transportation was –70%, indicating a higher overlap between suitable chickadee habitats and the road network in northern Alberta. Not surprisingly, the unit effect of forest harvest was the highest (–118%), because forestry occurs in the same mature upland forests that provide the best boreal chickadee habitat.

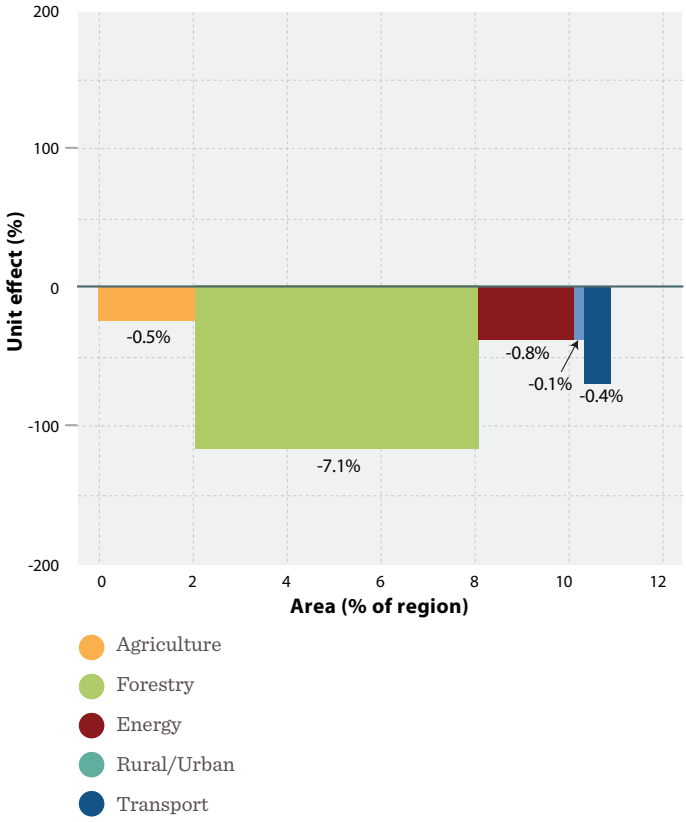
The Boreal Chickadee is only one of the many species in Alberta. The ABMI has estimated sector effects for many bird, mammal, plant, lichen, moss (including liverworts), and mite species. These species show varying responses (positive, neutral, or negative) to development by the different sectors.

FIGURE 4
Habitat associations of Boreal Chickadee in northern Alberta. Predicted relative abundance in each habitat type (a proxy for habitat suitability) is shown with bars. Relative abundance in forest stands is broken into 20-year age classes, and dots show relative abundance in cutblocks of various ages. Other types of footprint are shown at the right end of the diagram. Vertical lines indicate 90% confidence intervals.



6 Alberta Biodiversity Monitoring Institute, 2015. Boreal Chickadee (*Poecile hudsonicus*). ABMI Species Website, version 3.0. URL: http://species.abmi.ca/pages/species/birds/BorealChickadee.html.

FIGURE 5
Sector effects for Boreal Chickadee in northern Alberta. The y-axis shows the effect per unit area of the sector footprint on the species. The x-axis represents the extent of each industrial sector footprint in the region. The areas of the sector-specific rectangles (numbers above/below the bars) are proportional to the total sector-specific effect on abundance for the species in the region.



MANAGEMENT IMPLICATIONS

- These results help managers understand how developments by each industrial sector affect habitat suitability and abundance for each species. Estimating sector effects is complex as they are (1) a function of the size of the area developed, (2) a function of how much effect each human footprint type has on the species, and (3) affected by where footprint occurs in terms of habitat suitability for the species.
- Sector effects on the Boreal Chickadee in northern Alberta were negative for all sectors, with forestry having the largest impact followed by the energy sector.
- The magnitude and direction of sector effects differ among species; results are available at species.abmi.ca.
- Sector effect estimates take into account not only the amount of footprint, but also what habitat types the sector's footprint impacts the most. These estimates thus provide tools for exploring alternative management options in land-use planning.

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