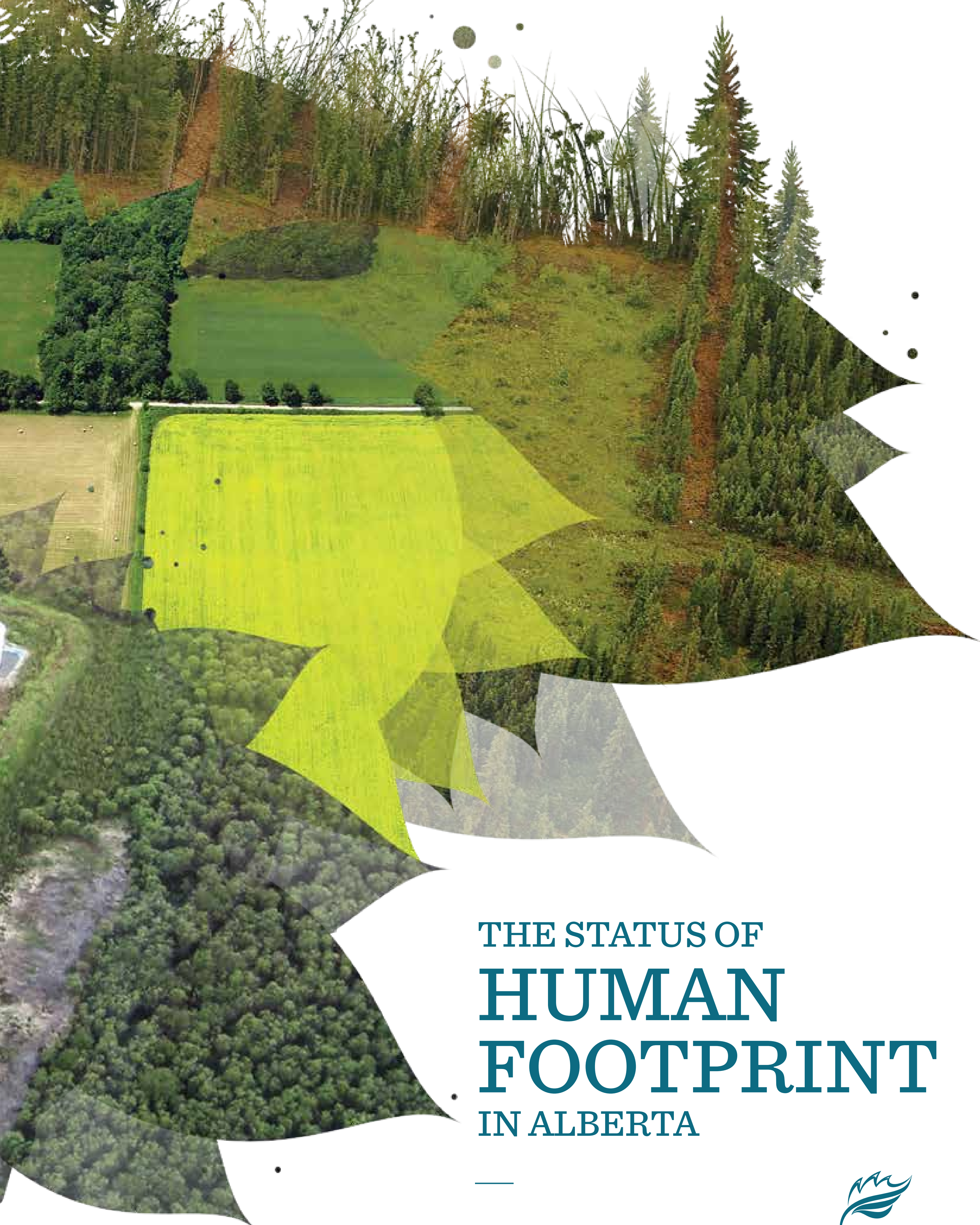

THE STATUS OF HUMAN FOOTPRINT IN ALBERTA

PRELIMINARY REPORT 2017

Alberta Biodiversity Monitoring Institute

This report describes the status of human footprint in Alberta

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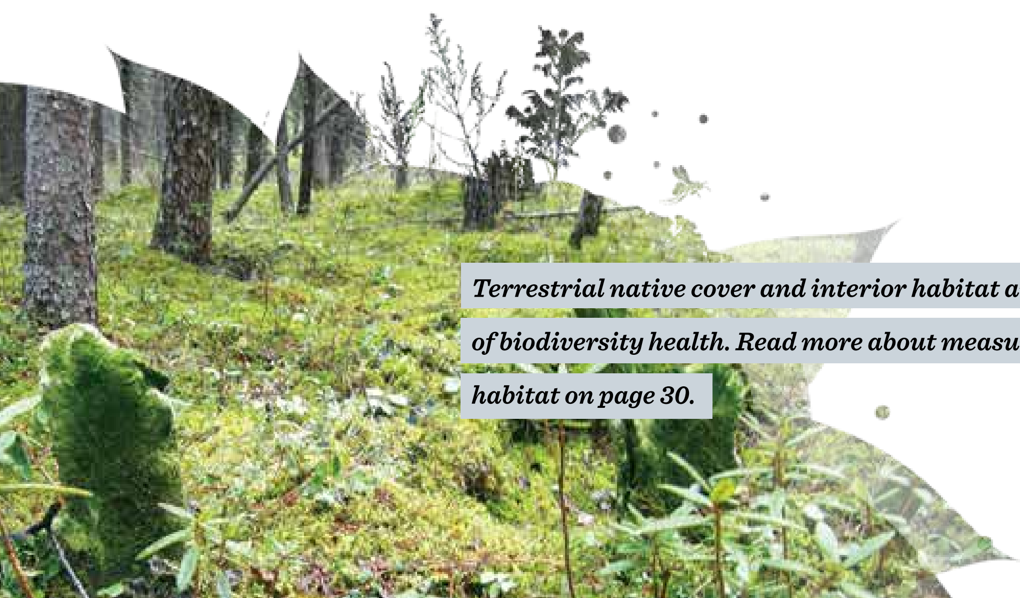


Terrestrial native cover and interior habitat are indicators of biodiversity health. Read more about measuring native habitat on page 30.

ABOUT THE ABMI

The Alberta Biodiversity Monitoring Institute (ABMI) is an arm's-length, not-for-profit scientific organization. The business of the ABMI is to monitor and report on the status (current condition) and trends of Alberta's species, habitat, and human footprint.* The goal of the ABMI is to provide relevant scientific information on the state of Alberta's biodiversity to support natural resource and land-use decision making in the province.

The ABMI is jointly delivered by Innotech Alberta, the Royal Alberta Museum, the University of Alberta, and the University of Calgary. The ABMI Board of Directors includes representatives from the Government of Alberta; environmental non-governmental organizations; the forest, energy, and agriculture sectors; and the research community.

The ABMI reports on a range of biodiversity indicators that act as a guide for establishing biodiversity-related management goals and assessing performance against those goals. Notwithstanding, the ABMI is not a management agency and does not make management recommendations. The ABMI generates value-neutral, independent, publicly accessible data, and presents knowledge derived from the data in a value-neutral format.

The ABMI is guided by a core set of principles—we are independent, objective, credible, accessible, transparent, and relevant.

ABOUT THIS REPORT

Over the past 10 years of operations, the ABMI has produced reports on the status of biodiversity for various regions in the province. These reports (available at: http://abmi.ca/home/publications) were produced as print publications, which limits how frequently their content can be updated to reflect recent ABMI data. As a result, we are moving to an online report format that allows for frequent and regular updates. For this report, The Status of Human Footprint in Alberta, we are producing both a print version and an online version—our first to be released. We encourage readers who are interested to visit the online Human Footprint report (http://abmi.ca/hf-report), provide feedback, and bookmark it for future updates.

*The ABMI defines human footprint as the visible conversion of native ecosystems to temporary or permanent residential, recreational, agricultural, or industrial landscapes.

REPORT SUMMARY

The ABMI measures and reports on the state of biodiversity and human footprint across the province. In this report, we provide an in-depth look at the status and trend of human footprint for Alberta. We provide an overview of human footprint at the provincial scale, and also break down the status and trend of human footprint by natural region (an ecosystem-based approach) and by Land-use Framework (LUF) planning region (an administrative unit approach) to better understand regional differences in human footprint. We also profile human footprint results for two landscapes—the Athabasca Oil Sands Area (Athabasca OSA) and the Southern East Slopes (SES)—to spotlight human footprint status and trends in areas of the province with different environmental pressures. Finally, we present three applications of human footprint data—identifying native habitat, examining effects of industrial sectors on species , and prioritizing linear features for restoration—to demonstrate how ABMI human footprint data can be used to support management.

HUMAN FOOTPRINT AND HOW IT IS MEASURED

The ABMI defines human footprint as the temporary or permanent transformation of native ecosystems to support residential, recreational, or industrial land uses. We define six categories of human footprint: agriculture; forest harvest;[†] mines, wells, and other energy features; transportation; urban, rural, and industrial; and human-created waterbodies.

The ABMI conducts analyses of human footprint at two spatial scales:

1. *Using a systematic sampling design that covers approximately 5%[‡] of the province, the ABMI monitors human footprint annually in 3 × 7 km rectangular areas centred on each ABMI site. These detailed annual samples of human footprint are available from 1999 to 2015 (except for 2000) and are used to evaluate trend in human footprint (see trend analysis on page 16, Figure 02, as an example).*

2. *At the provincial scale, the ABMI creates a wall-to-wall inventory of human footprint leveraging data layers created by the Alberta Human Footprint Monitoring Program (AHFMP; for more information on the AHFMP, see page 47). The ABMI supplements these data layers with additional interpretation of remotely sensed data, as well as the digitization of specific human footprint boundaries.*

HUMAN FOOTPRINT IN ALBERTA

As of 2015, human footprint occupied 29.2% of Alberta. The largest human footprint category was agriculture, which occupied 20.2% of the province, followed by forestry footprint at 4.3% and energy footprint at 1.9%. Human footprint increased by 3.5% between 1999 and 2015. More than half of this increase was driven by the creation of forestry footprint, which increased from 2.1% to 4.3%. Agriculture footprint and energy footprint each increased by 0.5% during this time frame.

HUMAN FOOTPRINT BY NATURAL REGION

As of 2015, human footprint ranged from a low of 0.1% in the Canadian Shield Natural Region to a high of 78.0% in the Parkland Natural Region. Agriculture was the dominant land-use type in three of the six natural regions: the Parkland, Grassland, and Boreal Natural Regions. Forestry was the largest human footprint category in the Foothills and Rocky Mountains Natural Regions. With the exception of the Canadian Shield Natural Region, human footprint increased by at least 1% of the land base in all natural regions between 1999 and 2015. The Foothills Natural Region experienced the greatest expansion of human footprint, with an absolute increase of 10.2% between 1999 and 2015.

[†]At present, the measure of human footprint does not account for the recovery of biodiversity in forests that are regenerating following temporary disturbances such as logging or energy exploration (e.g., seismic lines). The ABMI is currently advancing the science necessary to account for this regeneration so that recovering areas can make a reduced contribution to the estimate of total human footprint.

[‡]Because the 3 × 7 km areas sample only 5% of the province, small, patchy human disturbances may have been overlooked in the samples.

HUMAN FOOTPRINT BY LUF PLANNING REGION

As of 2015, human footprint ranged from a low of 8.1% in the Lower Peace Region to a high of 61.7% in the Red Deer Region. Agriculture was the most common human footprint category in six of the seven LUF planning regions. Forestry footprint was the most common footprint type in the Upper Peace Region. Energy footprint is lower but evenly distributed across planning regions, ranging from 1.5% in the Lower Peace Region to a high of 2.5% in the Red Deer Region. All LUF planning regions experienced an increase of at least 2% of the land base in human footprint between 1999 and 2015. The largest increases occurred in the Upper Athabasca Region and Upper Peace Region, where human footprint grew—in absolute terms—by more than 6%.

OTHER RESULTS OF NOTE

- *Patterns of human footprint amount and trend vary among regions depending on the biophysical characteristics, land-use histories, and development pressures of each, as shown by the SES. Although agriculture footprint represented the largest human footprint category in the region at 22.9%, the increase in human footprint between 1999 and 2015 was shared among forestry, agriculture, and urban footprints.*
- *As of 2015, the total human footprint in the Athabasca OSA was 8.4%, with forestry being the largest human footprint at 4.0%, followed by energy footprint at 2.2%. Between 1999 and 2015, the total human footprint increased by 3.7% (4.8% to 8.4%). This change was mainly due to the creation of new forestry footprint (+2.0%) and energy footprint (+0.9%). As of 2014, total human footprint in the Surface Mineable Region (a subregion within the Athabasca OSA) was 24.5%, and was dominated by energy footprint (11.3%) and urban/industry footprint (7.9%).*

APPLICATIONS

- *ABMI human footprint data can be used to address a variety of management questions; for example, to measure native habitat at a given distance from human footprint, or to map where specific types of human footprint, such as linear disturbance, occur. In the case of linear disturbance, to support caribou habitat enhancement, the ABMI is developing an approach to prioritize seismic lines for reclamation based on the mapping of linear features.*
- *Not all species respond in the same way to different types of human footprint. For example, we found that forestry had the strongest effect per unit area on Alder Flycatchers in the Boreal and Foothills Natural Regions because it created habitat in areas (old upland forest) that otherwise are of low value to the species; this resulted in a predicted increase in the relative regional population. Forestry also had the strongest effect per unit area on the Black-throated Green Warbler because it removed prime upland habitat; as a result, the relative regional population is predicted to decrease.*

This report (as well as the online version available at http://abmi.ca/hf-report) provides a comprehensive overview of human footprint status and trends in Alberta and within specific regions. We provide examples of how human footprint information can be used to support different types of management applications. To support land-use planning efforts in Alberta, the ABMI has collected and will continue to collect data on where human footprint occurs, and how each footprint type is changing (if at all) through time.

INTRODUCTION

Human land use is pervasive across the planet. We transform natural landscapes for a variety of purposes—to grow food, to extract timber and fossil fuels, to make way for new housing developments, or to build roads and rail systems to transport people and goods, to name just a few. The conversion of natural landscapes to ones dominated by human land use is the greatest threat to biodiversity.[1] The extent of human land use in any given area is collectively defined as human footprint.[1,2] The measurement of human footprint is increasingly being used as a land-use planning tool to monitor the status of landscapes.[3]

During the past century, the availability of natural resources in Alberta has defined human land-use patterns, in both time and space. The province was considered a farming frontier in the late 1800s, and the majority of Alberta's human footprint in the central and southern parts of the province is the result of this farming legacy. While agriculture remains important, other human land uses, particularly forestry and oil and gas development, have expanded in recent decades into previously undisturbed areas in the Foothills and Boreal Forest Natural Regions. To meet Alberta's growing population needs, urban areas have expanded to keep up with industrial growth. As these activities continue, understanding and managing the cumulative effects on biodiversity are priorities in Alberta.

The Government of Alberta uses an integrated land management approach to coordinate land-use activities in Alberta.[4] One of the stated outcomes of this approach is to minimize the impact of human land use, or human footprint, so that a balance of economic, social, and environmental objectives can be achieved. Regional plans developed through the Government of Alberta's land-use planning process (e.g., the Lower Athabasca Regional Plan) require that human footprint be monitored and managed to minimize regional impacts.[5,6] For example, terrestrial native cover, defined as terrestrial habitat free of human footprint, has been proposed as a key indicator of the draft Biodiversity Management Framework for the Lower Athabasca Planning Region.[7] We anticipate that all regional plans in Alberta will include goals for the management and reclamation of human footprint. Once indicators and thresholds are established, trend monitoring will measure progress towards meeting these goals.

Effective management of human footprint requires a reliable and credible system for monitoring and reporting. The ABMI has been reporting on human footprint since 2007. And beginning in 2015, the ABMI has been working in collaboration with the Government of Alberta as part of the Alberta Human Footprint Monitoring Program (AHFMP) to improve the accuracy of human footprint; for more information on the AHFMP, see page 47. The base layers produced through this process are used by the ABMI to produce the ABMI 2014 wall-to-wall human footprint inventory. And this product, along with ABMI human footprint trend data is used to report on the amount, type, and distribution of different human footprint categories in the province through time.

In this report, we take an in-depth look at the status and trend of human footprint throughout Alberta. We provide an overview of human footprint at the provincial scale but also break down the information on status and trend of human footprint by natural region (an ecosystem-based approach) and by LUF planning region (an administrative unit approach) to better understand regional differences in human footprint. We also present results of two case studies— the Athabasca OSA and the SES—to spotlight human footprint patterns in areas of the province with different environmental settings and land-use pressures. Finally, we describe three ways the ABMI's human footprint data can be used to support land-use and natural resource decision making in Alberta: 1) to identify the location and extent of native habitat; 2) to examine the effects of different human footprint types on species abundance; and 3) to prioritize linear features for habitat restoration efforts.

ABMI DEFINITION OF HUMAN FOOTPRINT

The ABMI defines human footprint as the visible alteration or conversion of native ecosystems to temporary or permanent residential, recreational, agricultural, or industrial landscapes. The definition includes all areas under human use that have lost their natural cover for extended periods of time, such as cities, roads, agricultural fields, and surface mines. It also includes land that is periodically reset to earlier successional conditions by industrial activities such as forestry cutblocks and seismic lines.[§] Some human land uses, such as grazing, hunting, and trapping, are not yet accounted for in our human footprint analyses.

Six human footprint categories are profiled in this report. They are defined as follows:

- ***Agriculture footprint:*** *areas of annual or perennial cultivation, including crops and tame pasture, as well as confined feeding operations and other high-density livestock areas.*

- ***Forestry footprint:*** *areas in forested landscapes where timber resource extraction has occurred for industrial purposes, including clear-cut and partial-cut logging methods.*

- ***Human-created waterbodies:*** *man-made waterbodies created for a variety of purposes, such as to extract fill (borrow-pits, water treatment), water livestock (dugouts), transport water (canals), meet municipal needs (water supply and sewage), and store water (reservoirs).*

[§]At present, the measure of human footprint does not account for successional recovery following temporary disturbances such as logging or energy exploration (e.g., seismic lines). For example, a regenerating cutblock or seismic line is treated the same as a more recent disturbance of the same type. The ABMI is currently advancing the science necessary to account for this regeneration so that recovering areas make a reduced contribution to the estimate of human footprint.

- ***Mines, wells, and other energy features:*** *areas where vegetation or soil has been disturbed by the creation of mine sites, peat mines, pipelines, seismic lines, transmission lines, well sites, and wind-generation facilities. This footprint type is called "energy footprint" because the majority of this footprint type is associated with the energy industry.*

- ***Transportation footprint:*** *railways, roadways and trails with hard surfaces such as concrete, asphalt, or gravel; roads or trails without gravel or pavement; and the vegetation strips alongside transportation features.*

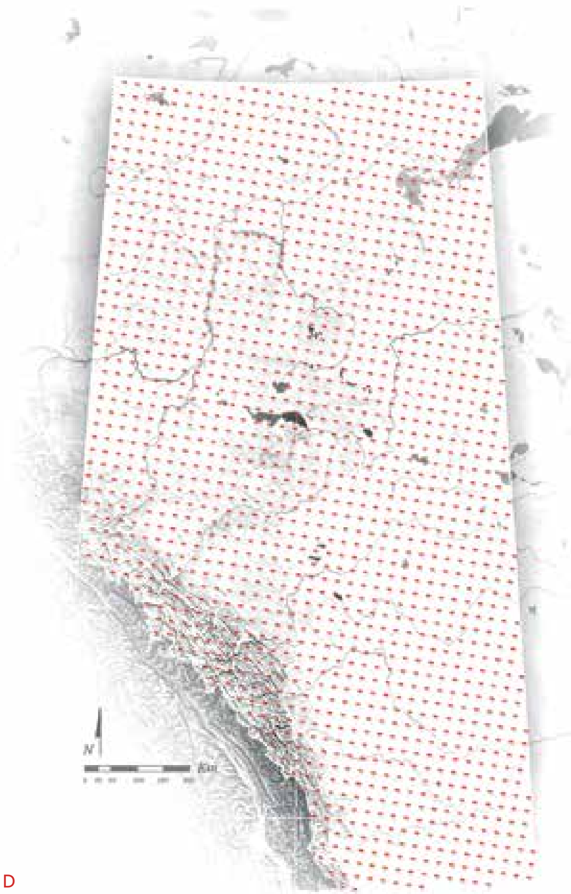
- ***Urban, rural, and industrial footprint*** *(hereafter urban footprint): residences, buildings, and disturbed vegetation and substrate associated with urban and rural settlements, such as housing, shopping centres, industrial areas, golf courses, and recreation areas, as well as bare ground cleared for industrial and commercial development.*

MEASURING AND REPORTING ON HUMAN FOOTPRINT

The ABMI monitors the status of Alberta's human footprint using satellite imagery at two spatial scales:

1. *The ABMI uses human footprint data measured annually at a 1:5,000 scale to track changes in human footprint over time. Detailed annual samples of human footprint are measured in a 3 × 7 km rectangular area centred near each of the ABMI's 1,656 sites, which when summed across all sites amounts to about 5% of the province's land surface (Figure 01). ABMI human footprint trend data† is available from 1999 to 2015, except for 2000.††*

2. *At the provincial scale, the ABMI merges 21 human footprint sub-layers (based on 115 features types) into a single integrated layer by applying a specific order of precedence to create the ABMI Human Footprint Inventory (HFI, circa 2014; Table 01).††† Some of these 21 sub-layers are created by the ABMI and Government of Alberta as part of the Alberta Human Footprint Monitoring Program (Table 01). We use the HFI 2014 for three purposes in this report: to generate maps of human footprint; to standardize the 3 × 7 km trend estimates before reporting; and, to calculate total footprint in regions where there are insufficient sample sites to estimate trend using the 3 × 7 km data (see Landscape Profile: Southern East Slopes, page 24).*



LEGEND

ABMI 3 km × 7 km sites

FIGURE 01.

The ABMI's 1,656 sites are selected based on a systematic grid across the province of Alberta, and are spaced approximately 20 km apart. A detailed inventory of human footprint is created annually for a 3 × 7 km area centred near each ABMI site.

†ABMI trend data are available at: http://www.abmi.ca/home/data-analytics/da-top/da-product-overview/GIS-Human-Footprint-Land-Cover-Data/Human-Footprint-Sample-Based-Inventory.html?scroll=true

††Human footprint cannot be estimated in 2000 because there is no imagery coverage available to the ABMI for that year. Also note, the estimated change in human footprint may be underestimated in the years 2002 and 2003, and overestimated for the year 2004 because of the imagery coverage available for those years.

†††For complete methods see: Alberta Biodiversity Monitoring Institute – Geospatial Centre. 2017. Human Footprint Inventory 2014, Version 1.0. Alberta Biodiversity Monitoring Institute, Alberta, Canada. HFI2014 data and metadata available at: http://www.abmi.ca/home/data-analytics/da-top/da-product-overview/GIS-Human-Footprint-Land-Cover-Data/HF-inventory.html

To report on the status of human footprint, the ABMI presents the percentage of land directly altered by human activities, ranging from 0% (no visible human footprint) to 100% (completely modified by human footprint). In general, cities and cultivated fields have very high human footprint because most of their area has been altered, while protected and undeveloped areas tend to have low human footprint.

To assess the status and trend of human footprint in Alberta, the ABMI uses the detailed 3 × 7 km assessments of human footprint available from 1999 to 2015, except for 2000. Human footprint status and trend are presented for the entire province, Alberta's natural regions, LUF planning regions, and the two landscape profiles (Athabasca OSA and SES). The maps of human footprint in this report are based on the ABMI HFI, circa 2014.

Six human footprint categories are profiled in this report: agriculture footprint, energy footprint, forestry footprint, human-created waterbodies, transportation footprint (including roads used for forestry and energy extraction), and urban footprint.

TABLE 01.

Order of precedence applied to human footprint sub-layers to create the ABMI HFI (circa 2014), and contributing partner(s) responsible for the creation of each sub-layer as part of AHFMP efforts.

Precedence	Sub-layer	Contributing Partner(s)
01	Reservoirs	ABMI
02	Borrow Pits, Sumps, Dugouts and Lagoons	ABMI
03	Non-Vegetated Impermeable Surfaces (Roads)	AHFMP: GoA & ABMI*
04	Rail Lines Hard Surface	AHFMP: GoA & ABMI*
05	Canals	ABMI
06	Vegetated Surfaces of Roads, Trails and Railways	AHFMP: GoA & ABMI*
07	Mine Sites	AHFMP: GoA & ABMI*
08	Industrial Sites	AHFMP: GoA & ABMI*
09	Well Sites (Energy) ACTIVE	AHFMP: GoA & ABMI*
10	Landfill	ABMI
11	Other Vegetated Facilities and Recreation	ABMI
12	Wind Generation Facility	ABMI
13	Transmission Lines	AHFMP: GoA & ABMI*
14	CFO and other High Density Livestock	ABMI
15	Urban and Rural Residential	ABMI
16	Well Sites (Energy) ABANDONED	AHFMP: GoA & ABMI*
17	Cultivation	AHFMP: GoA & ABMI*
18	Cut Blocks	AHFMP: GoA & ABMI*
19	Pipelines	ABMI
20	Seismic Lines	AHFMP: GoA & ABMI*
21	Disturbed Vegetation	ABMI

*Data were enhanced through the AHFMP. For instance, a "Well pad" layer was created by the GoA as part of AHFMP efforts, and was then post-processed by the ABMI. Post-processing included re-attribution, splitting the layer into two HFI sub-layers ("Well Sites (Energy) ACTIVE" and "Well Sites (Energy) ABANDONED"), quality control and further manual data updating (e.g., digitizing missing features).

MEASURING NATIVE HABITAT AND DISTANCE FROM EDGE

To assess the status of **native habitat**, the ABMI uses the HFI, circa 2014. To report on the status of native habitat, we present:

1. *The percentage area of land cover that has no visible human footprint (although land uses like grazing may still occur).*

2. *The percentage area of interior habitat using two edge distances applied outwards from human footprint—50 m and 200 m.[8] These two edge distances are called "base" distances, which are narrowed to account for two factors:*

   - ***Width of human footprint.*** *For narrow human footprint types like linear features, the edge influence that extends into native habitat is reduced because these openings have little surface wind, are shaded in most orientations, and are considered to be under "forest influence" in forestry contexts. Therefore, the base distances of 50 m and 200 m are narrowed to account for the reduced edge effects adjacent to linear features < 20 m wide,** following the formula Distance = Baseline distance * [0.25 + 0.75 * Footprint width / 20], where footprint width is in metres. This formula discounts the distance by a factor that decreases from 1 at 20 m to 0.25 at 0 m footprint widths. For example, the 50 m distance becomes 31 m for a 10 m wide linear feature, 22 m for a 5 m wide feature, and 18 m for a 3 m wide feature. The 0.25 constant is to recognize edge effects from mechanisms like access, snag-falling, or hydrological disruption that may not be reduced in narrow features.*

   - ***Recovery of successional footprint.*** *For any human footprint types that are non-permanent and are allowed to recover toward natural conditions, the edge distance is reduced as the footprint recovers (ages). In the absence of information on tree heights in the footprint, the discounting is based on the age of the footprint. Full recovery is assumed to happen at age 60, which is approximately the average stand age in the boreal. Recovery is linear with age, so the formula is Distance = Baseline distance * Age / 60.*

**The 20 m threshold is based on a rough average tree height for the boreal (including younger stands).

EFFECTS OF DIFFERENT INDUSTRIAL SECTORS ON SPECIES

To model species-habitat associations, we combine a variety of ABMI data, including field-collected species abundance data, human footprint data, and land cover data. The species-habitat models describe species' responses to different natural habitats and human footprint types, and are used to generate information on the spatial variation in species abundance.[9]

We also use our species habitat models along with our GIS (Geographic Information Systems) information to estimate how each type of human footprint has affected the predicted relative abundance of a species.[††] To do this analysis, human footprint data are categorized into 6 industrial sectors: agriculture, forestry, energy (including well pads, pipelines, seismic lines, and power lines), rural and urban areas, and transportation (roads, railways, and their rights-of-way). We apply our species-habitat models to maps where the footprint from all but one industrial sector has been "backfilled" (replaced with an estimate of the natural vegetation that was there prior to the footprint). For each industrial sector, we compare the predicted abundance of a species in the landscape with just that sector's footprint to the abundance in the completely backfilled landscape with no human footprint, to show the effect of that industrial sector.

We provide examples of the effects of different industrial sectors for two species, the Alder Flycatcher, a species that increases in many types of human footprint, and the Black-throated Green Warbler, a species that decreases as human footprint increases.

[††]For a complete summary of analysis methods used to calculate sector effects, see Appendix 4 in: Sólymos, P., C.L. Mahon, P. Fontaine and E.M. Bayne (2015). *Predictive Models for Estimating the Cumulative Effects of Human Development on Migratory Landbirds in the Oil Sands Areas of Alberta, Joint Oil Sands Monitoring: Cause-Effects Assessment of Oil Sands Activity on Migratory Landbirds.* Edmonton, AB. Available at www.borealbirds.ca/files/Technical_Reports/JOSM_report_Solymos_et_al_2015_final_2.pdf.

RESULTS

Human footprint data, including footprint type, amount, and trend, provide the context for interpreting ABMI biodiversity data and for land-use planning across the province. We present results for footprint categories with more than 1% coverage for each region. Full results, including a summary of all six human footprint categories, are available in the Human Footprint online report (http://abmi.ca/hf-report).

HUMAN FOOTPRINT IN ALBERTA

As of 2015, human footprint occupied 29.2% of Alberta (Figure 02, Figure 03).

Agriculture is the dominant human footprint type, covering 20.2% of the province, an area five times larger than forestry footprint, which, at 4.3%, is the second-largest human footprint category (Figure 02). The remaining footprint types, in decreasing order of provincial area covered, include energy (1.9%), transportation (1.5%), urban/industrial (1.0%), and human-created waterbodies (0.3%).

Between 1999 and 2015, the total area of human footprint in Alberta increased by 3.5%, from 25.7% to 29.2% (Figure 02). More than half of the increase in human footprint was driven by the expansion of forestry footprint, which increased by 2.2% (from 2.1% to 4.3%). Both agriculture and energy footprint increased by 0.5% during this time period.

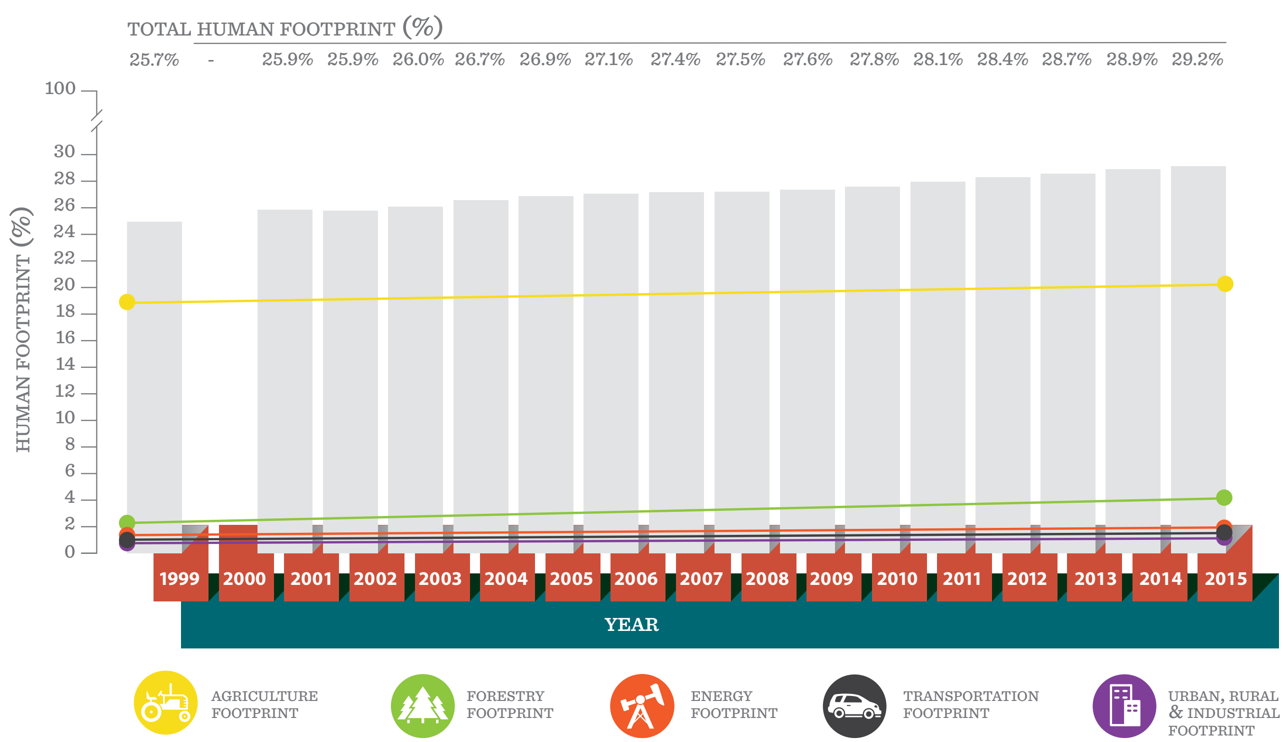
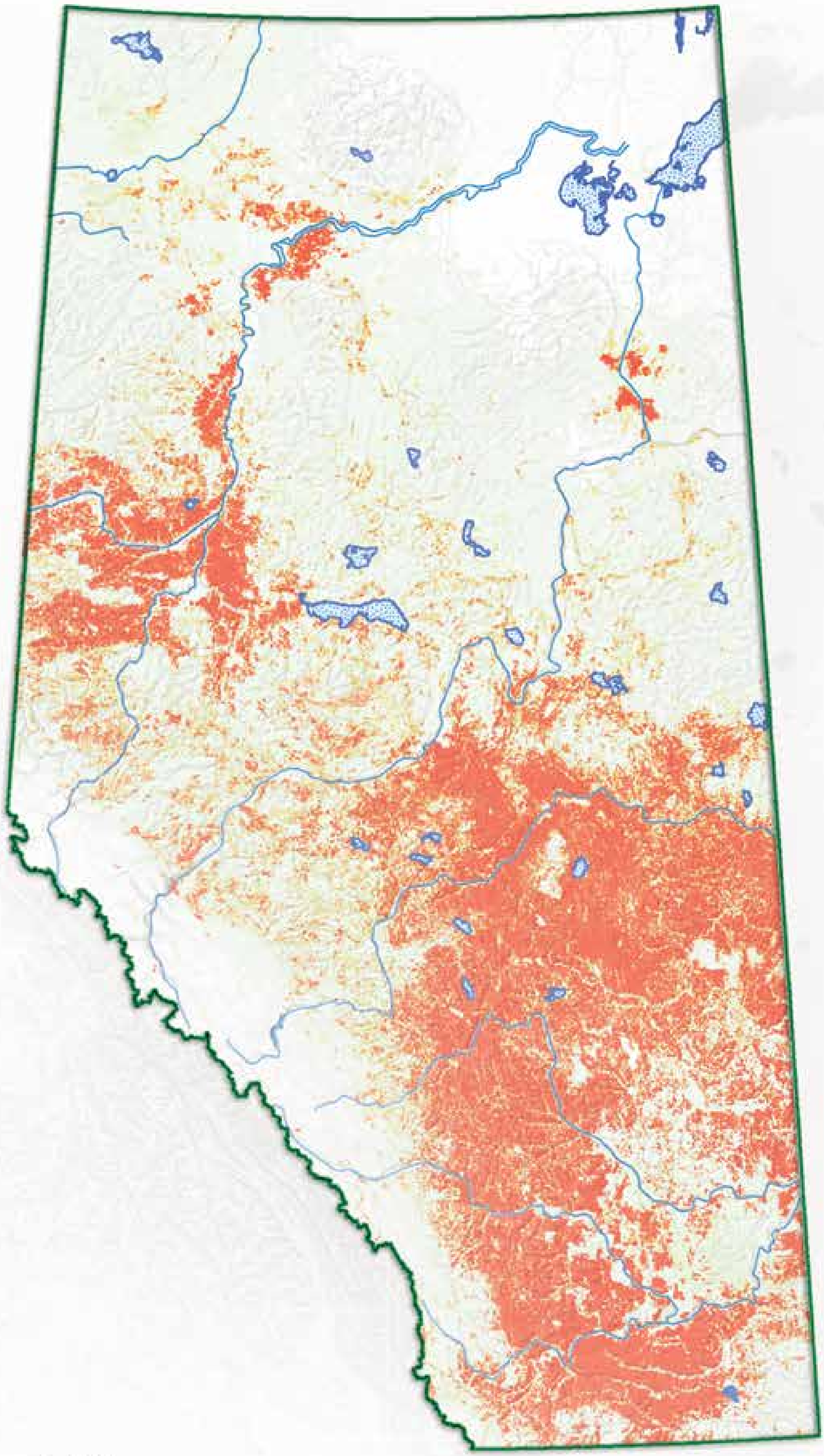


FIGURE 02.

Trend in the percentage area of total human footprint, and for each human footprint category that covers at least 1% of the province, between 1999 and 2015. Grey bars indicate total human footprint.

FIGURE 03.

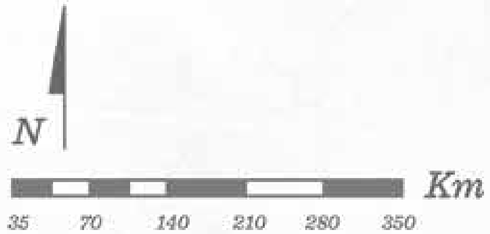
Distribution of human footprint across Alberta, circa 2014. White represents areas in Alberta with no human footprint, light green represents low human footprint, and red represents high human footprint. View distribution of human footprint polygons at http://abmi.ca/hf-report.



LEGEND

HUMAN FOOTPRINT PERCENTAGE

- *90–100*
- *80–90*
- *70–80*
- *60–70*
- *50–60*
- *40–50*
- *30–40*
- *20–30*
- *10–20*
- *> 0–10*
- *0*



HUMAN FOOTPRINT IN ALBERTA'S NATURAL REGIONS

Alberta includes some of the most diverse landscapes in North America, from high mountains to rolling prairies. The Government of Alberta combined information on regional differences in terrain, climate, soils, and vegetation to produce a province-wide ecological mapping system.[12] At its broadest level, the system defines six natural regions, each with its own unique climate, landscape features, and vegetation characteristics.

The **Rocky Mountain Natural Region** is home to high-altitude alpine meadows and coniferous forests.

The **Foothills Natural Region** is a zone of mixed deciduous and coniferous forests, rolling fields, and rocky outcrops.

The **Parkland Natural Region** forms a broad transitional area between the drier grasslands to the south and the boreal forest to the north, and has characteristics of these surrounding ecosystems.

The **Grassland Natural Region** is representative of Alberta's iconic prairie landscape, and includes native mixed and fescue grasslands.

The **Boreal Natural Region** is a mosaic of upland forests interspersed with many low-lying wetlands, bogs, and fens.

The **Canadian Shield Natural Region**, the smallest of the natural regions, is a unique ecosystem of sparse tundra vegetation and exposed bedrock.

Ecosystems are foundational to the persistence of biodiversity, as well as various functions such as nutrient cycling and water storage and release.[13, 14] Understanding the pattern of human footprint in different natural regions helps to identify potential risks to biodiversity and opportunities to manage this risk.

We summarize human footprint status and trend data for each of the six natural regions in Alberta.

As of 2015, human footprint ranged from a low of 0.1% in the Canadian Shield Natural Region to a high of 78.0% in the Parkland Natural Region (Figure 04, Figure 05).

Agriculture is the dominant land use in three of the six natural regions: the Parkland, Grassland and Boreal Forest Natural Regions (Figure 04). Forestry is the largest human footprint in the Foothills and Rocky Mountain Natural Regions.

With the exception of the Canadian Shield Natural Region, human footprint increased by at least 1% in all natural regions between 1999 and 2015 (Figure 05). The Foothills experienced the greatest expansion of human footprint, with an increase of 11.4% between 1999 and 2015 (Figure 05), due to a 10.2% increase in forestry footprint. The creation of forestry footprint also accounted for the largest change in human footprint in the Boreal (+1.8%) and Rocky Mountain (+1.0%) Natural Regions. Agriculture and energy footprint each increased by 1.2% and 1.0%, respectively, in the Grassland Natural Region, and represent the largest increases of footprint in this region. Energy footprint (+1.1%) and urban footprint (+1.0) drove the increase in human footprint in the Parkland Natural Region.

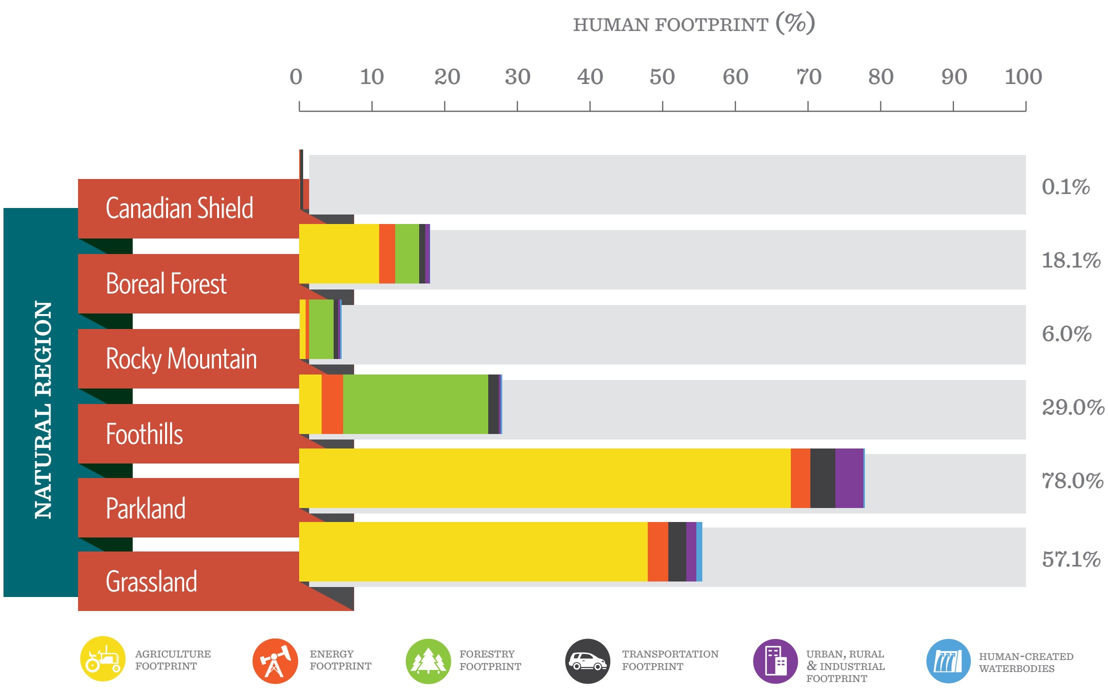
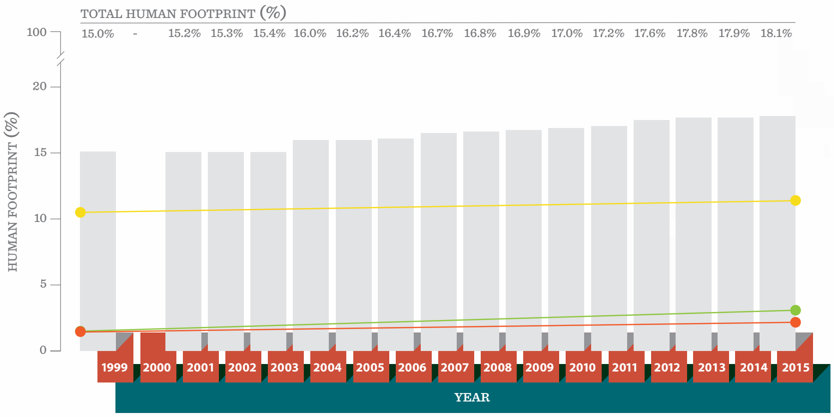


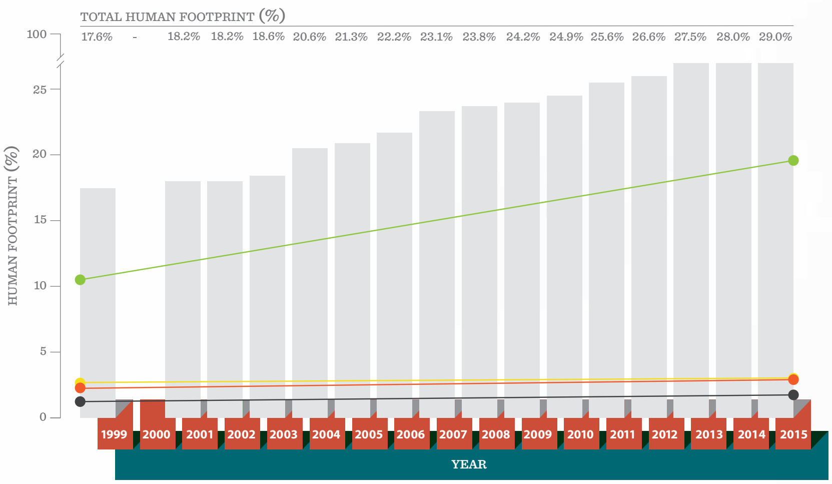
FIGURE 04.

Summary of percentage cover of total human footprint broken down by human footprint category in Alberta's natural regions, circa 2015. Human footprint status and trend results by natural region also available at http://abmi.ca/hf-report.

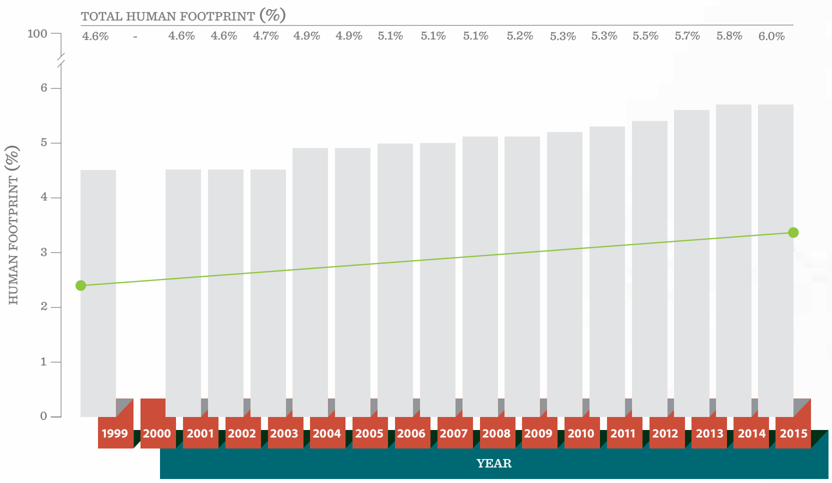
BOREAL FOREST NATURAL REGION

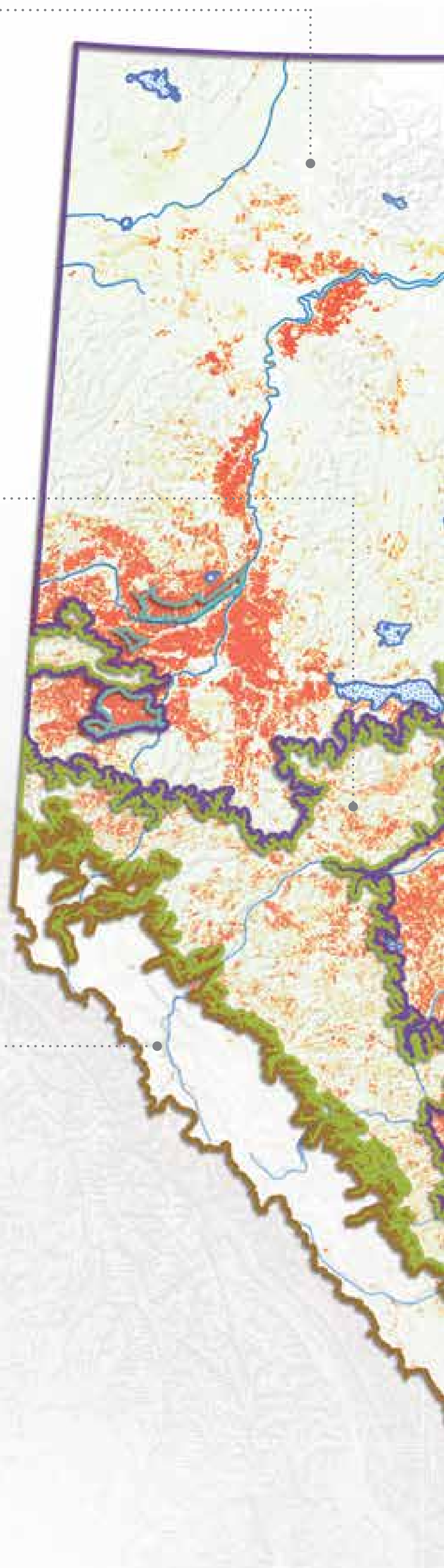


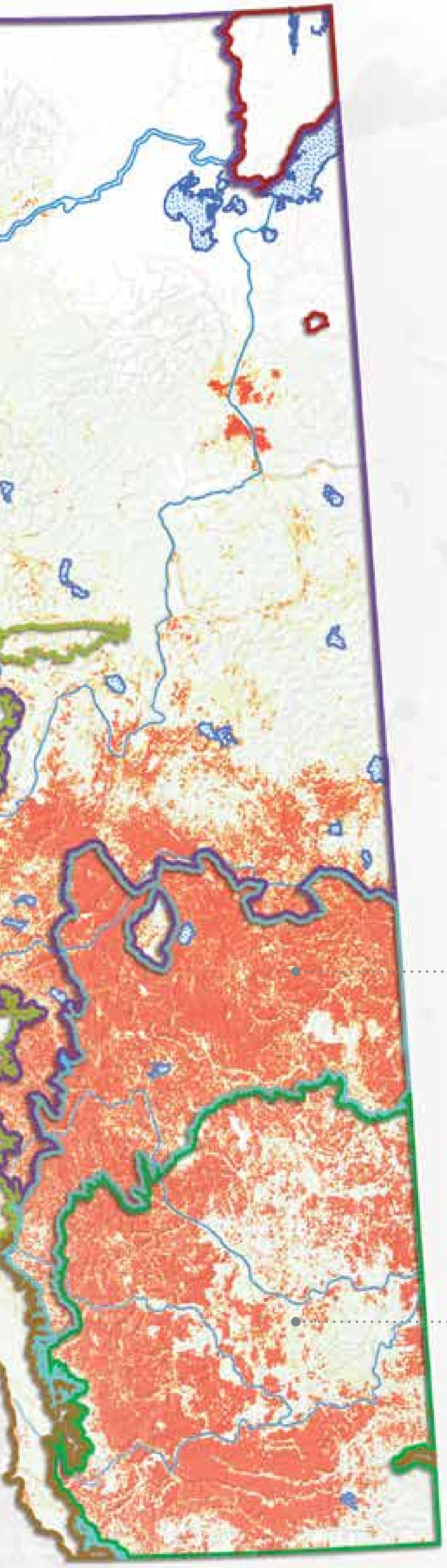
FOOTHILLS NATURAL REGION



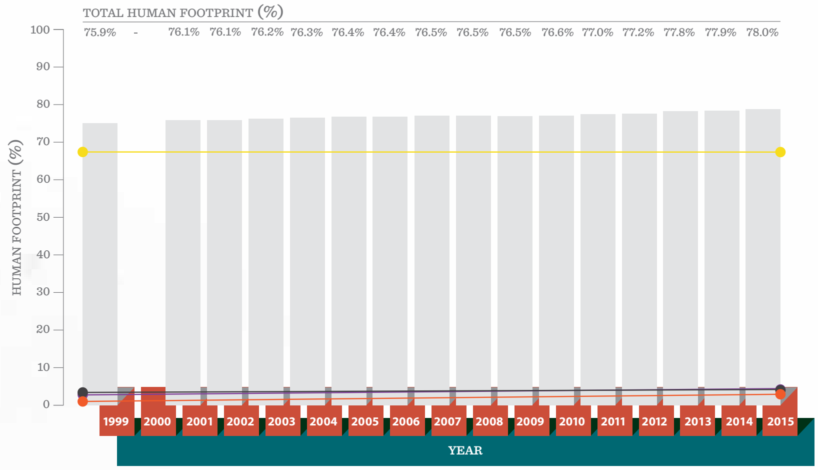
ROCKY MOUNTAIN NATURAL REGION



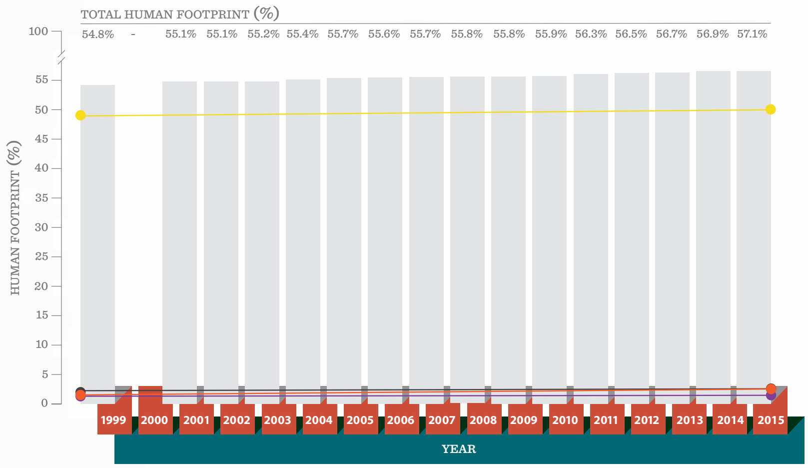




PARKLAND NATURAL REGION



GRASSLAND NATURAL REGION



LEGEND - MAP

HUMAN FOOTPRINT PERCENTAGE

90–100 *80–90* *70–80* *60–70* *50–60*

40–50 *30–40* *20–30* *10–20* *> 0–10* *0*

FOOTHILLS NATURAL REGION
BOREAL FOREST NATURAL REGION
GRASSLAND NATURAL REGION
PARKLAND NATURAL REGION
ROCKY MOUNTAIN NATURAL REGION
CANADIAN SHIELD NATURAL REGION

LEGEND - FIGURES

AGRICULTURE FOOTPRINT
ENERGY FOOTPRINT
FORESTRY FOOTPRINT
TRANSPORTATION FOOTPRINT
URBAN, RURAL & INDUSTRIAL FOOTPRINT

FIGURE 05.

Map shows the distribution of total human footprint in the natural regions of Alberta, circa 2014. Graphs show trend in the percentage area of each human footprint category that covers at least 1% of a particular natural region between 1999 and 2015. Grey bars indicate total human footprint. Total human footprint is < 1% in the Canadian Shield Natural Region, and therefore the human footprint trend graph is not shown. Please note that position of break in y-axis varies among graphs.

LANDSCAPE PROFILE: SOUTHERN EAST SLOPES

Many landscapes in Alberta are under pressure from a variety of land uses. These activities are often not randomly distributed in the landscape but focused in particular vegetation or ecosystem types. Alberta's SES, located in southwestern Alberta, is one such area. This landscape of striking natural beauty includes the rugged peaks of the Rocky Mountains, forest-covered slopes of the foothills, and rolling grasslands of the prairies (Figure 06). The diverse terrain and ecosystems support a range of mountain- and grassland-associated species. The incredible scenery and abundance of wildlife draw people, not only from Alberta but from around the world, for nature-based recreational activities such as camping, hiking, birdwatching, hunting, and fishing.

While large areas of the SES landscape are still undisturbed, much of this region exists as a patchwork of land uses as a result of settlement patterns, farming and ranching, and forestry activities. More recent land uses, specifically expanding human settlements and oil and gas development, are not only converting native habitat to human footprint but also converting existing footprint to new footprint types. Therefore, to support land-use planning efforts, it is important to understand not only where human footprint has increased, decreased, or remained the same through time, but which footprint categories are changing.[15]

As of 2015, the total human footprint in the SES was 32.7% (Figure 06, Figure 07).

Agriculture footprint represented the largest human footprint category in the region, covering 22.9% of the area, followed by urban footprint (3.3%), transportation footprint (2.9%), and forestry footprint (2.5%) (Figure 07). Total human footprint in the region increased by 2.2% of the land base between 1999 and 2015. This increase was shared mainly among forestry (+0.6%), agriculture (+0.6%), and urban footprints (+0.5%).

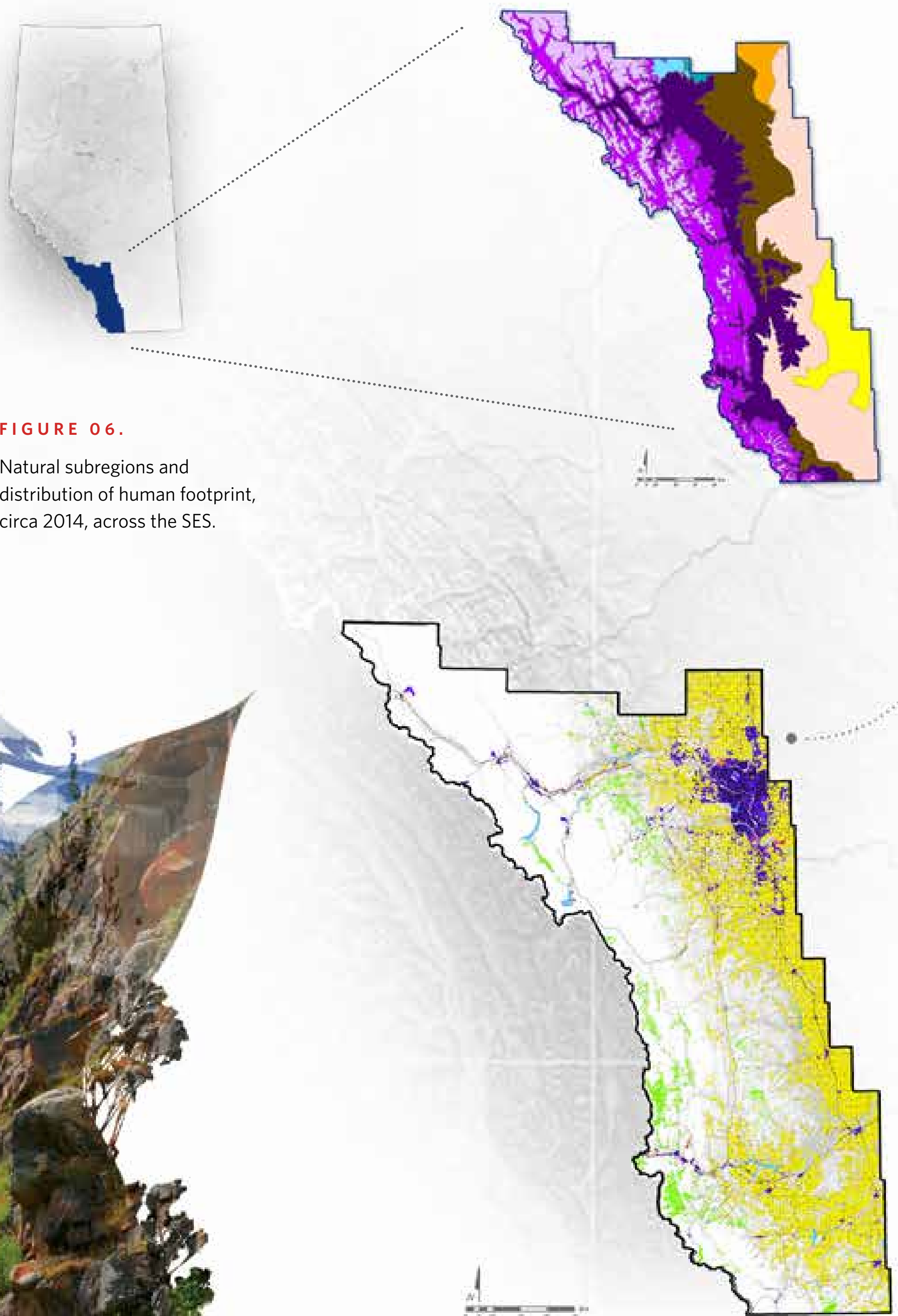


FIGURE 06.

Natural subregions and distribution of human footprint, circa 2014, across the SES.

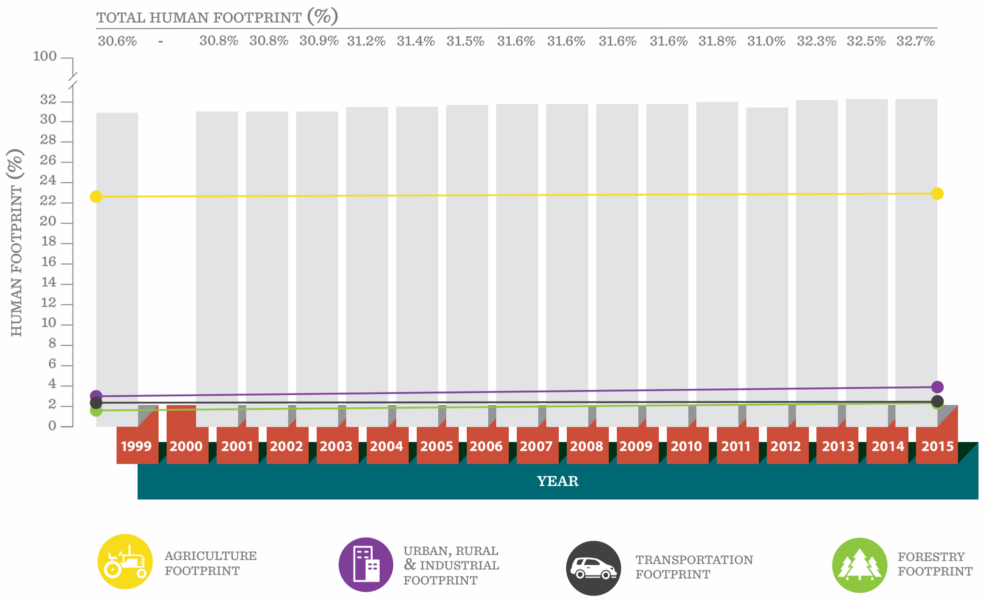


FIGURE 07.

Trend in the percentage area of total human footprint and for each human footprint category that covered at least 1% of the SES region between 1999 and 2015. Grey bars indicate total human footprint.

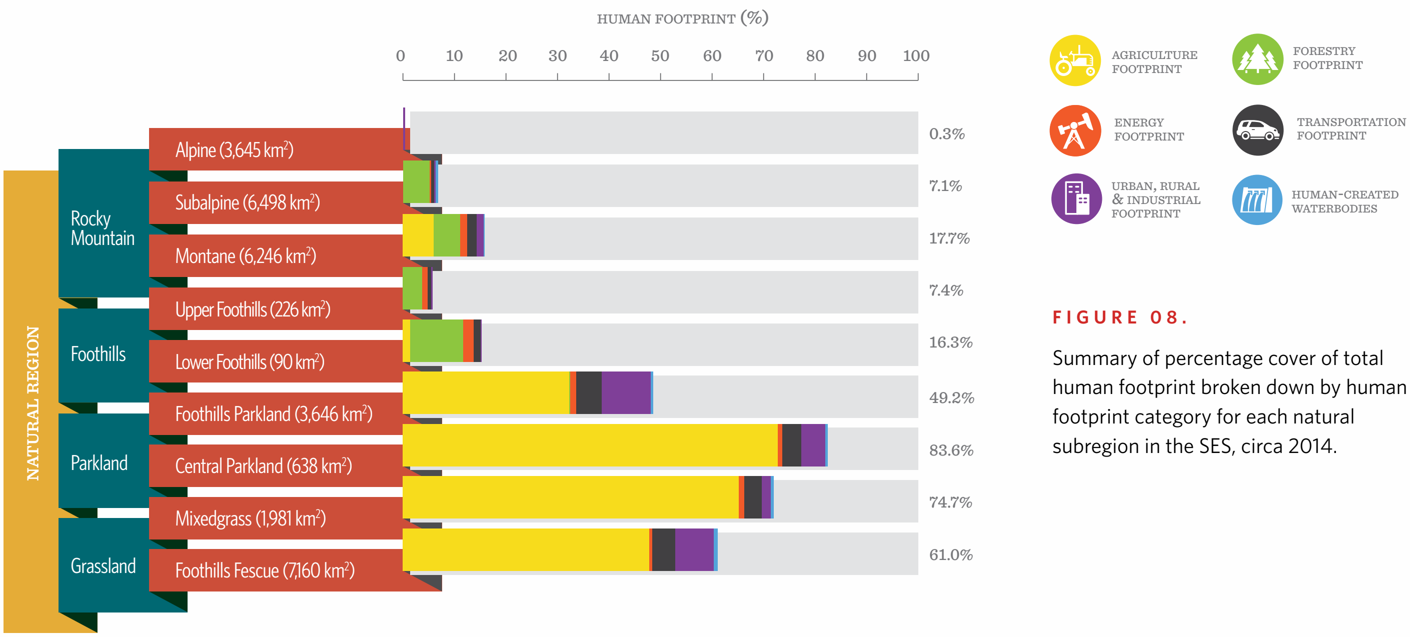


FIGURE 08.

Summary of percentage cover of total human footprint broken down by human footprint category for each natural subregion in the SES, circa 2014.

Total human footprint and individual footprint categories are not evenly distributed across ecosystem types, as represented by natural subregions (Figure 08). Accumulated footprint is highest in the Grassland and Parkland Natural Regions, where it's dominated by agriculture footprint, followed by urban footprint and transportation footprint. In contrast, footprint is lower in the Lower and Upper Foothills, Montane, and Subalpine Natural Subregion, all subregions dominated by forestry footprint. Energy footprint is lower but evenly distributed in all subregions except those in the Rocky Mountain Natural Region.

With the exception of the Alpine Natural Subregion, the increasing human footprint trend is relatively consistent across the SES, although the type of human footprint changes depending on subregion. These patterns and trends can be used to support land-use planning in the region. For example, a high-priority management issue in the SES is watershed protection.[16] Because human land uses in terrestrial areas surrounding water sources can impact water quality,[17, 18] it is important to manage the changing human footprint across the SES to ensure a safe, secure supply of water for downstream users in southern Alberta and beyond.

HUMAN FOOTPRINT IN ALBERTA LAND-USE FRAMEWORK PLANNING REGIONS

The Government of Alberta initiated an Integrated Resource Management System to understand and manage the cumulative effects of economic growth in Alberta.[4] Under this approach, outcomes must be defined and achieved for environmental as well as social and economic values. The regional planning process under the LUF is one government initiative that figures prominently in the management of environmental values under the Integrated Resource Management System.

The Government of Alberta has identified seven LUF planning regions based on the province's major watersheds, and regional priorities related to stakeholders, natural resources, and the environment. A land-use plan is being developed for each planning region that integrates provincial policies and regional land-use objectives, to provide context for future regional land-use decision making.[5] The government has approved the first two of these plans—the Lower Athabasca Regional Plan and the South Saskatchewan Regional Plan—with the other planning regions to follow. A large part of this planning process is managing the impact of human land use on economic, social, and environmental values.

As of 2015, human footprint ranged from a low of 8.1% in the Lower Peace Region to a high of 61.7% in the Red Deer Region (Figure 09, Figure 10).

Agriculture is the dominant human footprint in most LUF planning regions, but particularly the South Saskatchewan Region (42.5%), North Saskatchewan Region (44.1%), and Red Deer Region (54.4%) (Figure 09). Forestry footprint is common in the Upper Athabasca (10.8%) and Upper Peace (9.8%) Regions. Energy footprint is lower but relatively evenly distributed across planning regions, ranging from a low of 1.5% in the Lower Peace Region to a high of 2.5% in the Red Deer Region.

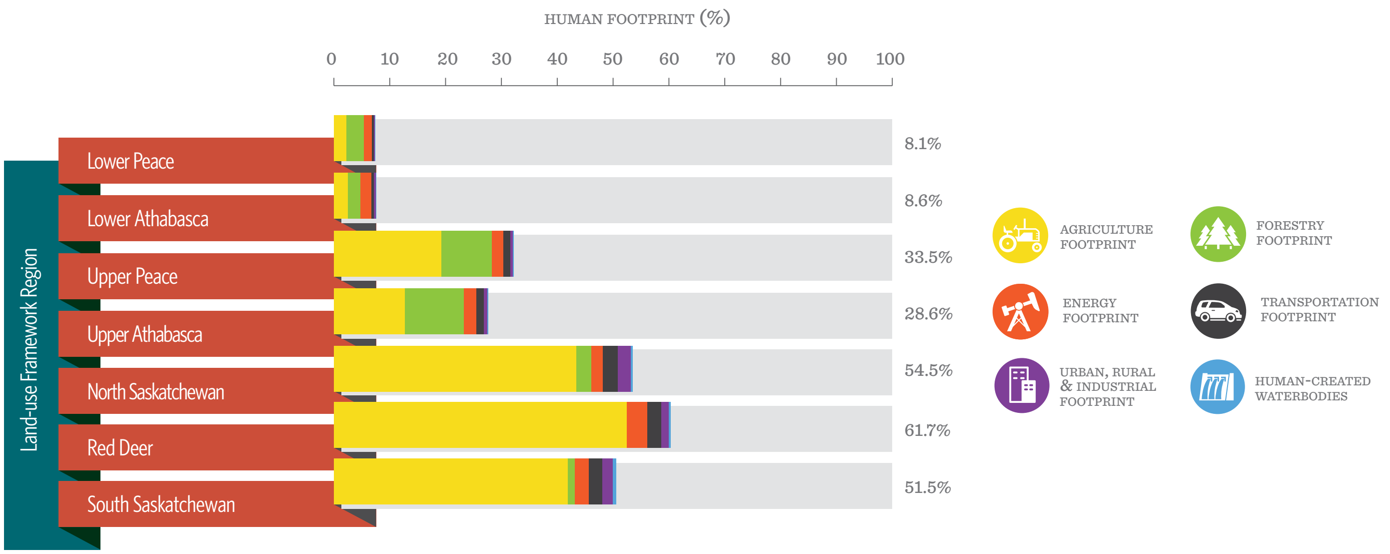
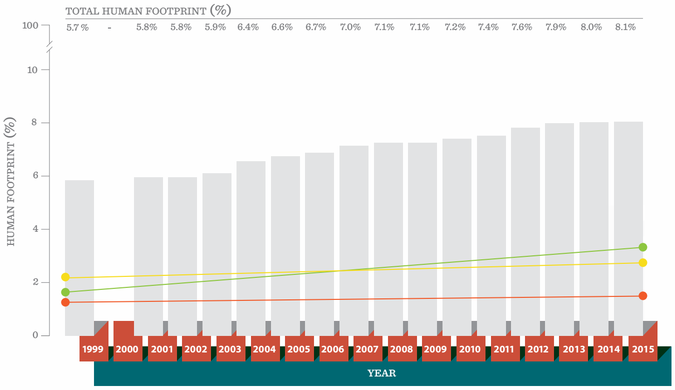


FIGURE 09.

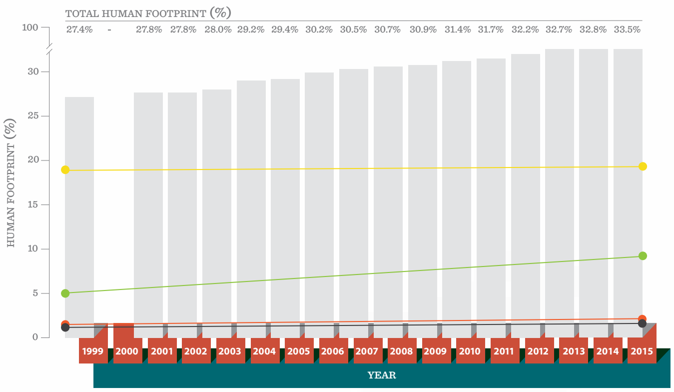
Summary of percentage cover of total human footprint broken down by human footprint category in Alberta's LUF planning regions, circa 2015. Human footprint status and trend results by LUF region also available at http://abmi.ca/hf-report.

All LUF planning regions experienced at least a 2% increase in human footprint between 1999 and 2015 (Figure 10). The largest increases occurred in the Upper Athabasca Region and Upper Peace Region as human footprint increased by more than 6% in each, from 22.2% to 28.6% and 27.4% to 33.5%, respectively. Forestry footprint had the largest increases in five of the seven planning regions, including the Lower Peace (+1.7%), Lower Athabasca (+1.3%), Upper Peace (+4.9%), Upper Athabasca (+5.3%), and North Saskatchewan (+1.6%) Regions. The increase in human footprint in the Red Deer Region was driven by an expansion in energy footprint (+1.4%), and in the South Saskatchewan Region by agricultural activities (+1.0%).

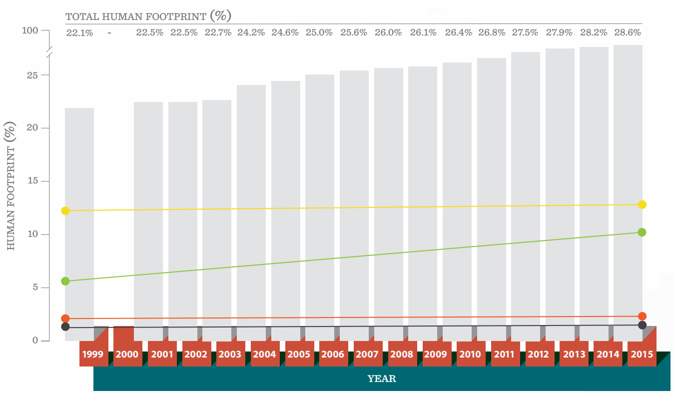
LOWER PEACE REGION



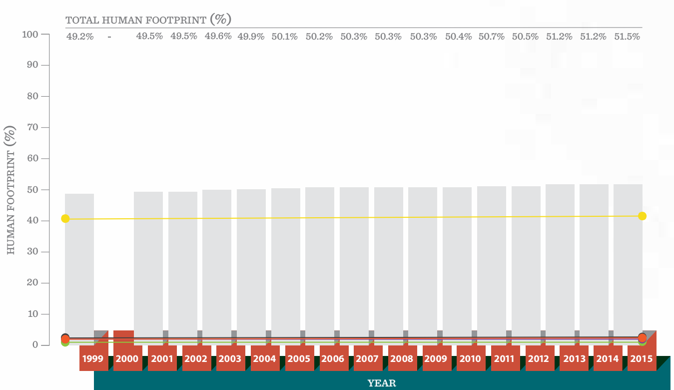
UPPER PEACE REGION

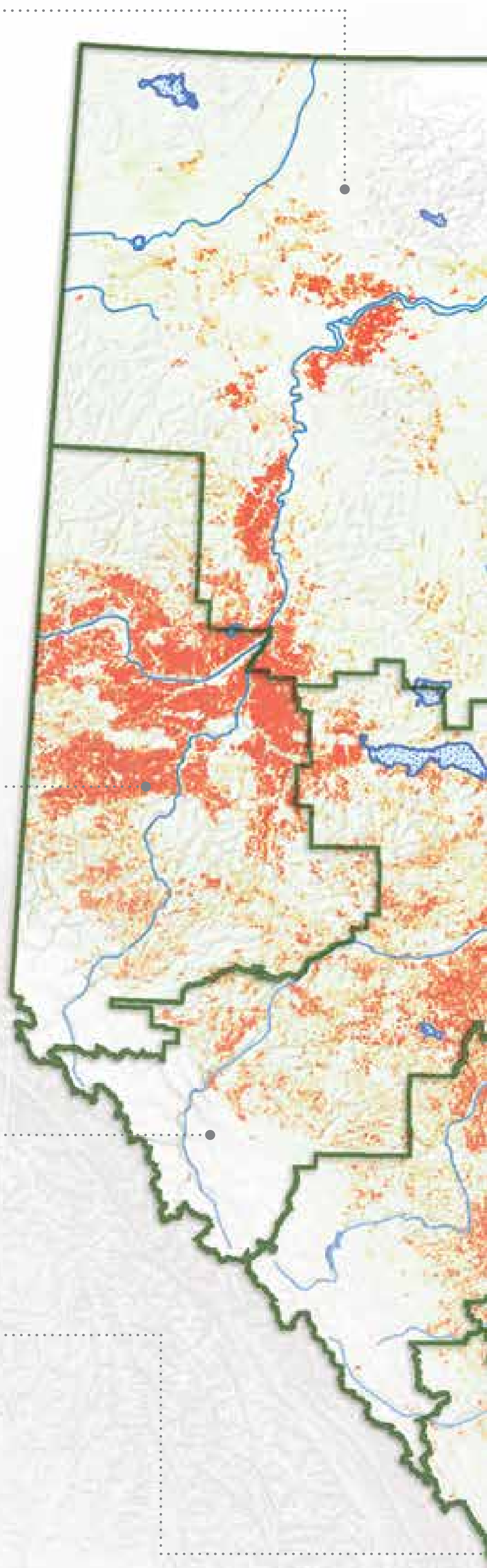


UPPER ATHABASCA REGION



SOUTH SASKATCHEWAN REGION





LEGEND - FIGURES

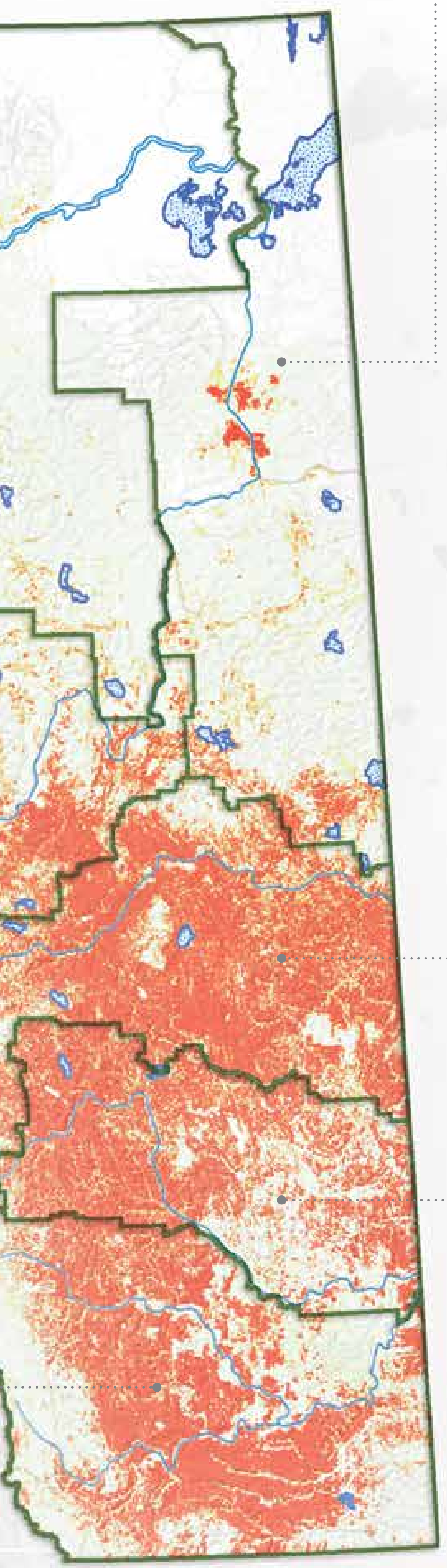
AGRICULTURE FOOTPRINT

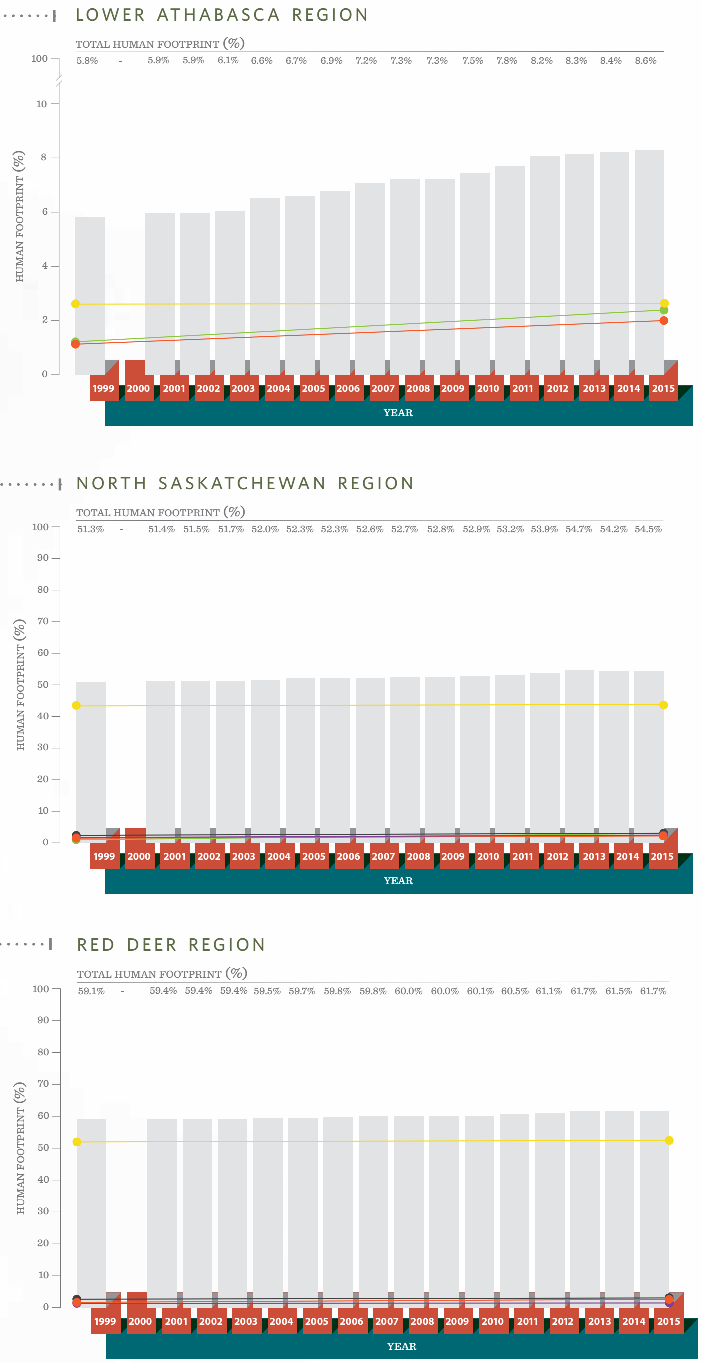
ENERGY FOOTPRINT

FORESTRY FOOTPRINT

TRANSPORTATION FOOTPRINT

URBAN, RURAL & INDUSTRIAL FOOTPRINT





LEGEND - MAP

HUMAN FOOTPRINT PERCENTAGE

90–100 · *80–90* · *70–80* · *60–70* · *50–60*

40–50 · *30–40* · *20–30* · *10–20* · *> 0–10* · *0*

FIGURE 10.

Map shows the distribution of human footprint in the seven LUF planning regions of Alberta, circa 2014. Graphs show the trend in the percentage area of total human footprint and for each human footprint category that covered at least 1% of a planning region between 1999 and 2015. Grey bars indicate total human footprint. Please note that position of break in y-axis varies among graphs.

LANDSCAPE PROFILE: ATHABASCA OIL SANDS AREA

Canada has the third-largest volume of proven oil reserves in the world. Over 95% of these reserves are located in three oil sands deposits in Alberta, including the Athabasca deposit, Cold Lake deposit, and Peace River deposit, all overlaid by administrative boundaries, or oil sands areas, of the same name (Figure 11). This case study describes the status of human footprint in the Athabasca OSA and the Surface Mineable Oil Sands Region (Mineable Region), a subregion within the Athabasca OSA (Figure 11). Human footprint status and trend results for all oil sands areas, including all areas combined, are available at http://abmi.ca/hf-report.

The Athabasca OSA makes up 14% (93,259 km^2) of Alberta's total land area, represents two-thirds of the province's oil sands region, and contains approximately 77% of Canada's proven oil reserves. Most of the bitumen in the Athabasca OSA is recovered using in-situ technology (see inset). The Mineable Region is a landscape under intense public scrutiny because this is where surface mining of oil sands occurs.

The recovery of oil sands using these two different methods produces different patterns of human footprint on the landscape. Surface mining produces high human footprint concentrated in specific areas where bitumen is located less than 75 m from the earth's surface. In-situ extraction results in a footprint that is smaller (in terms of total area) but much more widespread, which can have ecological consequences such as the loss of interior habitat.[19]

Surface mining *only occurs in the Mineable Region; large shovels are used to excavate the oil sands deposits located close to the earth's surface.*

In-situ *extraction is required for bitumen deposits that are located deeper underground (> 75 m below the earth's surface). Several wells are drilled into the deposit, and steam is used to heat and separate the bitumen, which is then pumped to the surface.*

As of 2015, the total human footprint in the Athabasca OSA was 8.4% (Figure 11, Figure 12). As of 2014, total human footprint in the Mineable Region was 24.5% (Figure 11).

At 4.0%, forestry (Figure 12D) was the dominant human footprint in the Athabasca OSA, followed by energy footprint at 2.2% (Figure 12C). The remaining footprint categories all covered < 1% of the region. In the Mineable Region (Figure 12B), energy footprint dominated at 11.3%, followed by urban/industry footprint at 7.9%.

Between 1999 and 2015, the total human footprint in the Athabasca OSA increased by 3.6% (from 4.8% to 8.4%) (Figure 11). This change was mainly due to the creation of new forestry footprint (+2.0%) and energy footprint (+0.9%).

Given that human footprint is still relatively low in the Athabasca OSA, there is significant opportunity for land and resource managers to make informed and deliberate choices about sustainable development, including how to limit the creation of new footprint in the region.

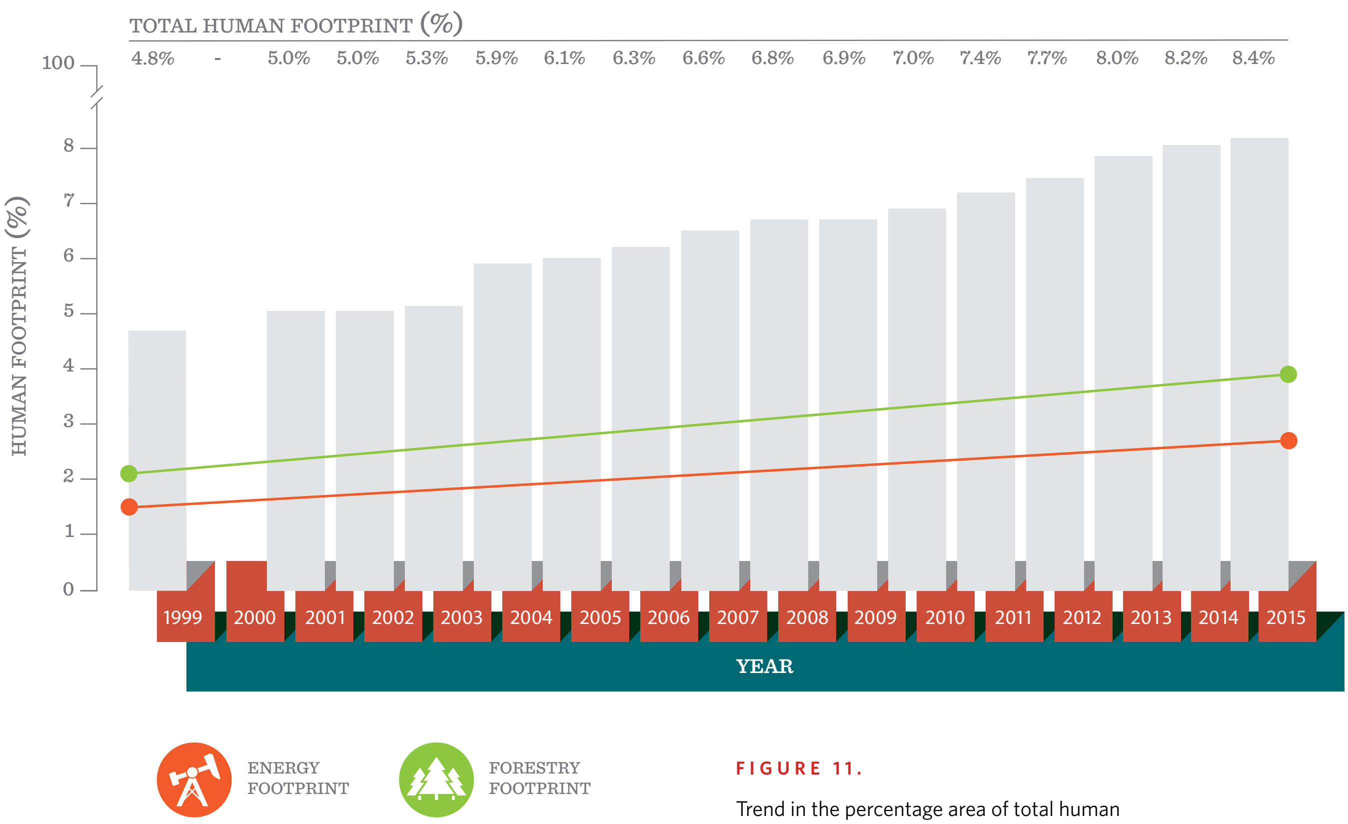
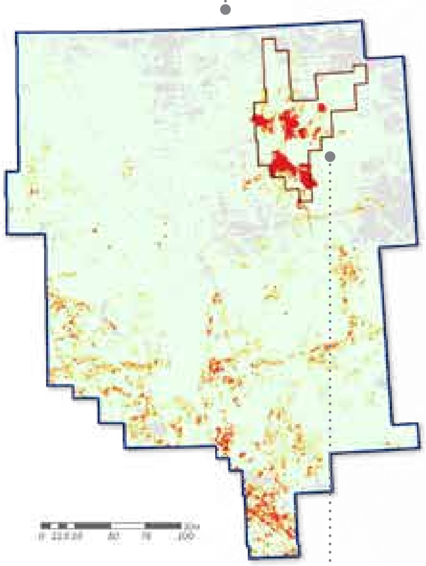


FIGURE 11.

Trend in the percentage area of total human footprint and for each human footprint category that covers at least 1% of the Athabasca OSA between 1999 and 2015. Grey bars indicate total human footprint. Human footprint status and trend results also available at http://abmi.ca/hf-report.



LEGEND

MINEABLE OIL SANDS REGION

ATHABASCA OIL SANDS BOUNDARY

HUMAN FOOTPRINT PERCENTAGE

- 90–100
- 80–90
- 70–80
- 60–70
- 50–60
- 40–50
- 30–40
- 20–30
- 10–20
- > 0–10
- 0

FIGURE 12A.

Distribution of the 8.4% total human footprint in the Athabasca OSA.

LEGEND

HUMAN FOOTPRINT

- AGRICULTURE
- ENERGY
- FORESTRY
- TRANSPORTATION
- URBAN, RURAL & INDUSTRIAL
- HUMAN-CREATED WATERBODIES

FIGURE 12B.

Distribution of the 24.5% of human footprint, by human footprint category, in the Mineable Region.

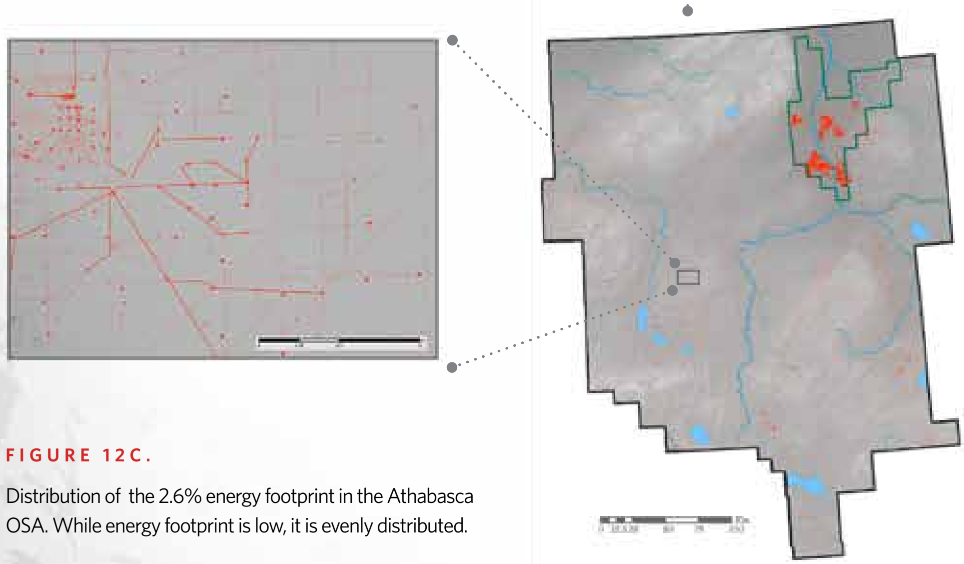


FIGURE 12C.

Distribution of the 2.6% energy footprint in the Athabasca OSA. While energy footprint is low, it is evenly distributed.

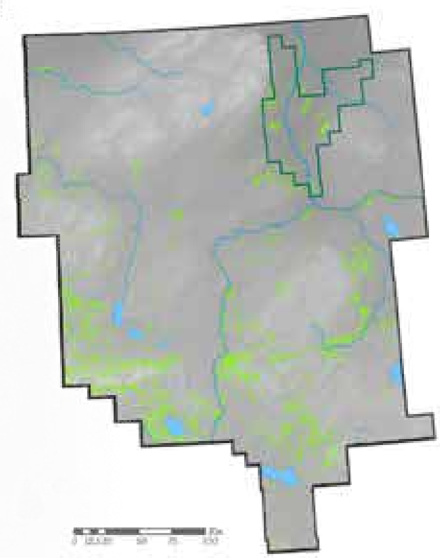


FIGURE 12D.

Distribution of the 3.8% forestry footprint in the Athabasca OSA.

APPLICATIONS

There are a number of ways human footprint data can be used to support land use planning and natural resource decision making. We describe three applications of human footprint data as examples—identifying native habitat, examining the effects of different human footprint types on species, and prioritizing linear features for restoration.

IDENTIFYING NATIVE HABITAT

Habitat loss due to human disturbance is a primary threat to biological diversity. In addition to the loss of native habitat, proximity of human footprint can also impact biodiversity in adjacent native vegetation both positively and negatively. Some species, such as the Dark-eyed Junco and Chipping Sparrow, can use habitat that is adjacent to human footprint.[10] Other species require habitat that is more distant from human footprint, Woodland Caribou being the most well-known example. Caribou avoid areas with linear features like roads and seismic lines due to the increased prevalence of predators and the associated increased mortality risk.[11]

In recognition of habitat loss as a key driver of biodiversity change, the draft Biodiversity Management Framework for the Lower Athabasca Regional Plan includes terrestrial native cover and interior habitat as primary indicators of the health of biodiversity in the region.[7] The ABMI HFI allows areas of terrestrial native cover to be identified—in other words, it lets us identify those areas in the province that have not been visibly disturbed[##] by humans. Further, the ABMI can track the amount of interior habitat that is effectively "away" from the influence of human footprint due to edge effects.

In this report, we present results for two tertiary watersheds in Alberta with different amounts of human footprint (Figure 13)—one with < 1% human footprint and one with > 20% human footprint—to illustrate how edge effects influence the amount of interior habitat.

[##]Natural disturbances, such as wildfire and insect outbreaks, and indirect effects of humans, such as weed invasion and pollution, still occur in areas identified as native habitat, along with direct effects like grazing and hunting.

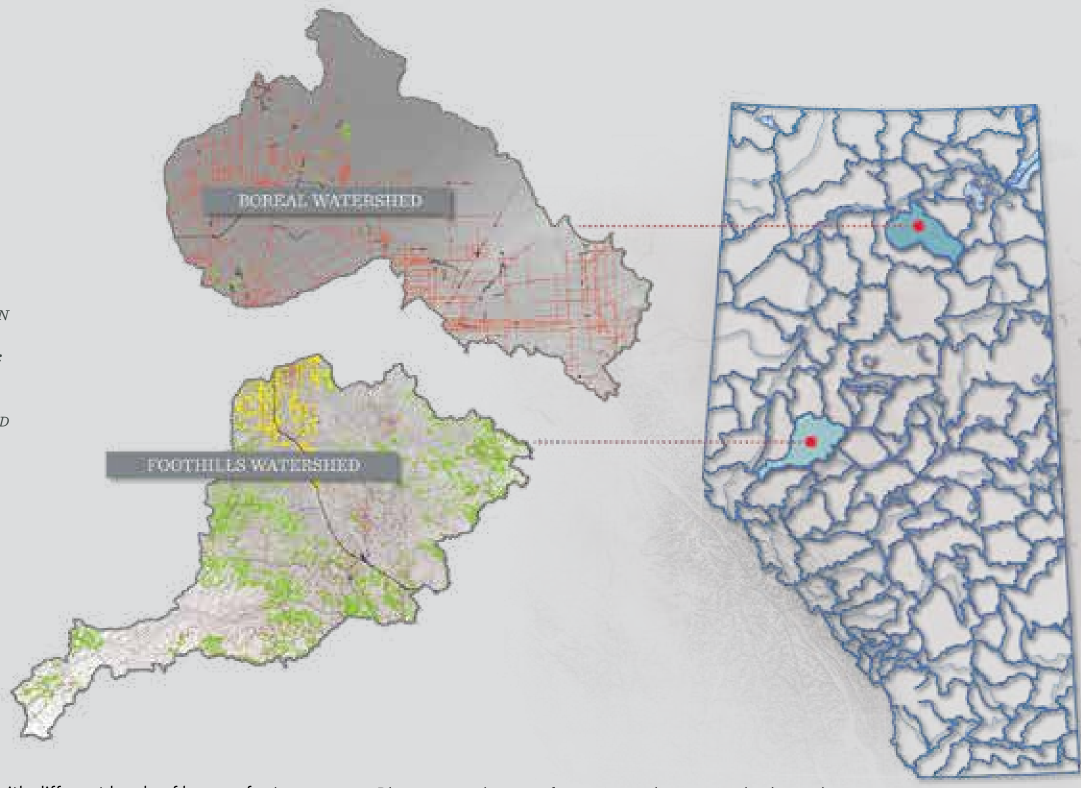


FIGURE 13.

Tertiary watersheds with different levels of human footprint—the foothills watershed has 23.4% human footprint, and the boreal watershed has 0.6% human footprint.

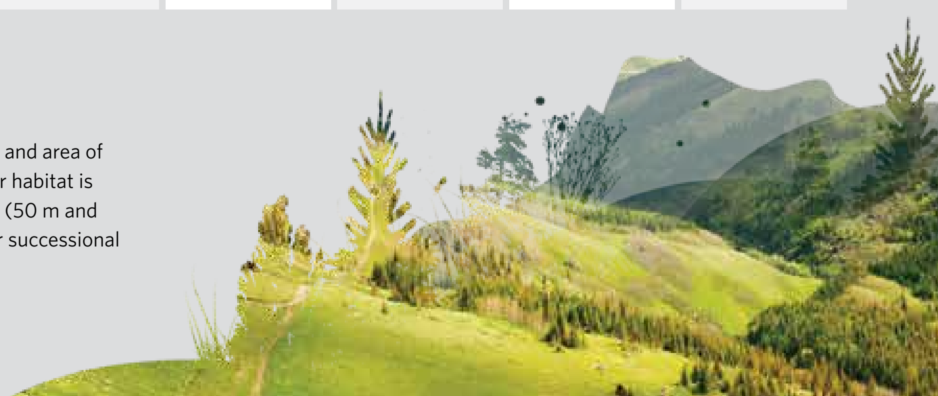
Please note human footprint polygons in the boreal watershed have been outlined to make them more visible.

Human footprint covered 23.4% of the foothills watershed and 0.6% of the boreal watershed (Figure 13, Table 02). Expressed as a percentage of the total watershed area, the percentage areas of interior native habitat at the base distance of 50 m from human footprint were 55.4% and 96.7% for the foothills and boreal watershed, respectively. Interior habitat at the base distance of 200 m from human footprint covered only 22.9% of the foothills watershed compared to 89.1% of the boreal watershed. Even though human footprint in the foothills watershed was 23.4%, because of the distribution of that footprint across the watershed more than 75% of native habitat was within 200 m of some form of human disturbance.

	Human Footprint Edge Influence (km^2)				Interior Habitat (km^2)		
Watershed	Total Area (km2)	Total Human Footprint	Edge Base 50 m	Edge Base 200 m	Edge 0 m	Edge Base 50 m	Edge Base 200 m
Foothills	8,062	1,885 (23.4%)	3,596 (44.6%)	6,216 (77.1%)	6,177 (76.6%)	4,466 (55.4%)	1,846 (22.9%)
Boreal	7,838	45 (0.6%)	259 (3.3%)	857 (10.9%)	7,792 (99.4%)	7,579 (96.7%)	6,981 (89.1%)

TABLE 02.

Area of total human footprint including area of edge influence and area of interior habitat, circa 2014, in two Alberta watersheds. Interior habitat is buffered from human footprint using two base edge distances (50 m and 200 m) with human footprint features adjusted to account for successional recovery and linear feature width.



EFFECTS OF DIFFERENT INDUSTRIAL SECTORS ON SPECIES

Species do not respond in the same way to different types of human footprint.[15.] For example, a species that prefers young forest for nesting and foraging may show a negative response to cultivation because of loss of habitat, but a positive response to forestry because of the creation of suitable habitat in cutblocks. The total area of a given human footprint type is also fundamental in determining how much effect that footprint has on a species. A large area of a footprint type with a moderate negative effect on a species may reduce the overall population of a species more than a small area of a footprint type with a severe negative effect.

Three factors affect the total impact of an industrial sector on the population of a species:

1. ***How strong the effect of the footprint is.*** *Different footprint types can support greater or lesser abundances of a species compared to natural habitat.*
2. ***Where the footprint occurs.*** *Some footprint types occur mainly in particular kinds of habitat, such as forestry in mature upland forests, or agriculture on upland sites with productive soils in areas with suitable climates. Other types, like transmission lines and well pads, occur more equally across vegetation types. If a footprint type occurs more frequently in the preferred habitat of a species, it will have a greater effect than a footprint type that occurs more evenly across all habitat types or in habitat types that the species avoids.*

These first two factors determine how much effect a footprint type has on a species *per unit area.* This combines how strong the footprint's effect is and the degree to which the footprint occurs in good habitat for the species. For a full account of how much effect a footprint type has on a species, the total area of the footprint must also be incorporated.

3. ***Total area of the footprint.*** *The total effect of a footprint type on a species' population is simply the total area of that footprint type multiplied by its effect per unit area. If two footprint types have the same effect per unit area, the type that occupies more area will have more effect on a species than the type that occupies little area.*

We give examples of the effects of industrial sectors for two bird species associated with different habitats in the Boreal and Foothills Natural Regions combined: Alder Flycatcher, a species that often increases with human footprint, and Black-throated Green Warbler, a species that decreases with human footprint.

Black-throated Green Warbler


Alder Flycatcher

ALDER FLYCATCHER

The Alder Flycatcher is a small, plain-coloured bird commonly found in wet shrub habitats in the Boreal, Foothills, and Parkland Natural Regions of Alberta. It prefers to nest in shrub thickets and young deciduous stands, such as willow, alder, and trembling aspen, especially if water is close by.[20] Young stands regenerating after forest harvesting are also common nesting sites. As its name implies, the Alder Flycatcher is almost entirely insectivorous, catching insects on the fly or by gleaning them from surrounding trees and shrubs.

Our species-habitat model for the Alder Flycatcher shows that its relative abundance in natural habitats is highest in young, naturally regenerating upland forest types, as well as larch forest and urban/industrial human footprint (Figure 14). But the highest abundances are found in young upland forests regenerating after forest harvesting.

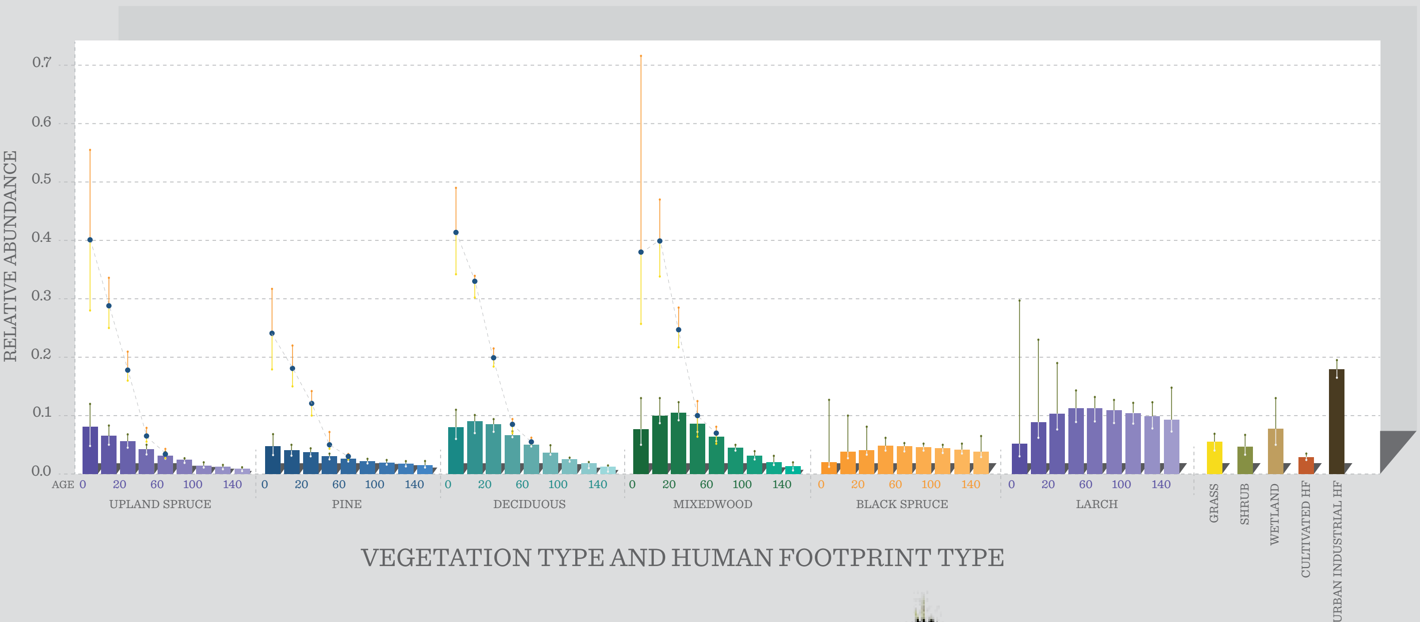


FIGURE 14.

Predicted relative abundance (bars, with lines indicating 90% confidence intervals) of Alder Flycatcher by vegetation type and human footprint type in the Boreal and Foothills Natural Regions of Alberta. Dots show predicted species abundance in cutblocks of various ages within each vegetation type. To see annual updates of this information please visit: http://abmi.ca/home/data-analytics/biobrowser-home.

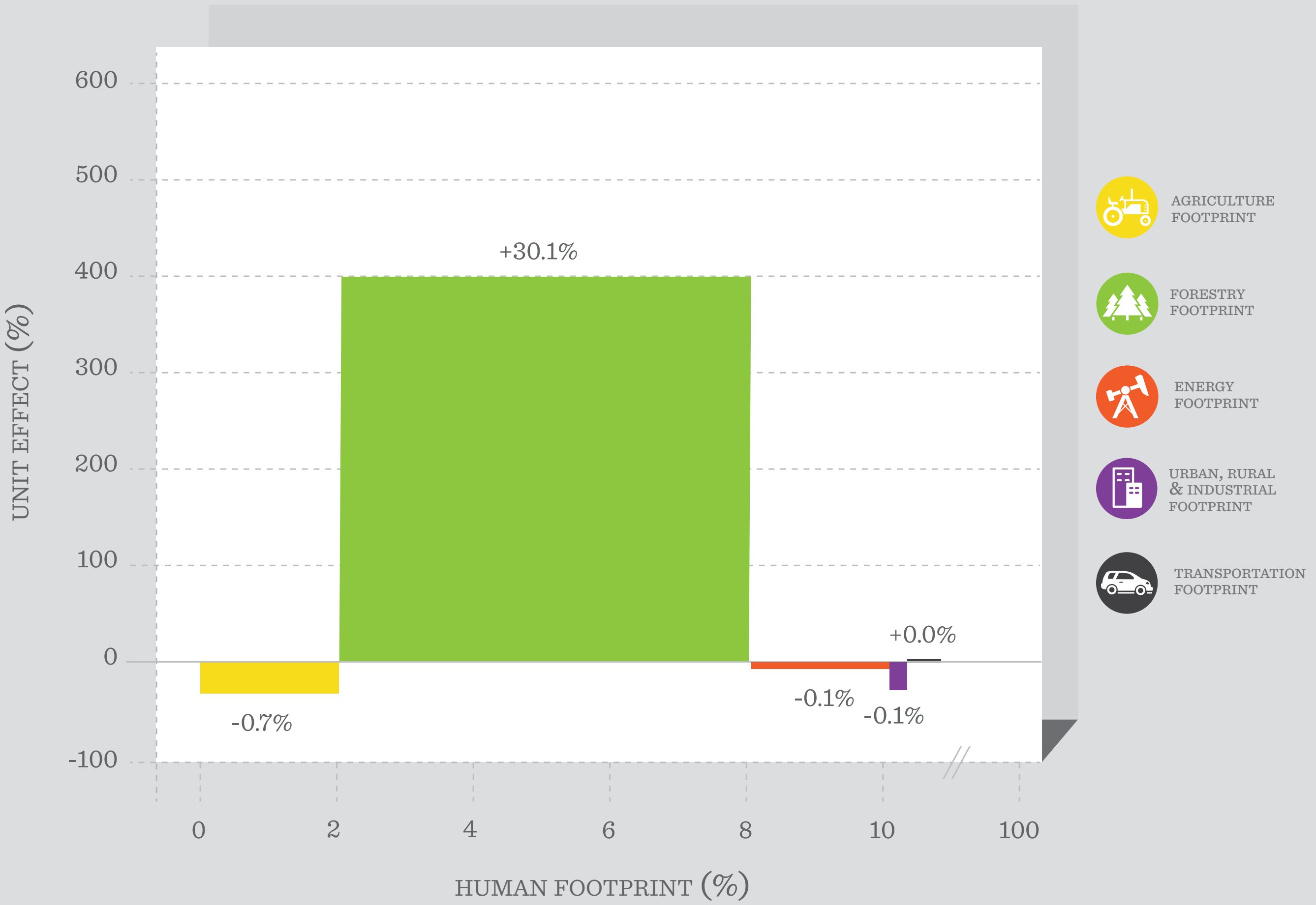


FIGURE 15.

The effects of industrial sectors on Alder Flycatchers in the Boreal and Foothills Natural Regions. Height of the bar shows the effect of the sector per unit area (i.e., how much one hectare of the footprint type would increase or decrease the species compared to the natural vegetation it replaces). Width of the bar shows the area of the footprint type in the region. The area of each sector-specific rectangle (equal to the unit effect multiplied by the area of the footprint) is the total effect of the sector on the species' relative abundance in the region.

Effects of Industrial Sectors

As expected from the species-habitat model (Figure 14), forestry has the strongest per-unit effect on Alder Flycatchers in the Boreal and Foothills Natural Regions combined (height of bars in Figure 15). Young cutblocks have a high abundance of this bird, and cutblocks occur in habitat types (old upland forest) that are otherwise of low value to the flycatcher. The Boreal and Foothills region has approximately 6% of its area converted to cutblocks, resulting in a 30.1% increase in the predicted population abundance of this species. The remaining footprint types have a minimal impact on the predicted population size of the Alder Flycatcher because they occupy relatively small areas in the region.

BLACK-THROATED GREEN WARBLER

A neotropical migrant, the Black-throated Green Warbler breeds in mature and old forest throughout the Boreal and Foothills Natural Regions of Alberta. This species is associated with large White Spruce trees,[21] where it gleans insects from the outer part of the branches. This feeding pattern allows the warbler to coexist with other warblers that forage in other parts of the tree crown.

Our species-habitat model for the Black-throated Green Warbler shows increasing abundance in old deciduous, mixedwood, and upland spruce stands (Figure 16). The species is essentially absent from lowland forest, young stands, and human footprint except for older regenerating cutblocks.

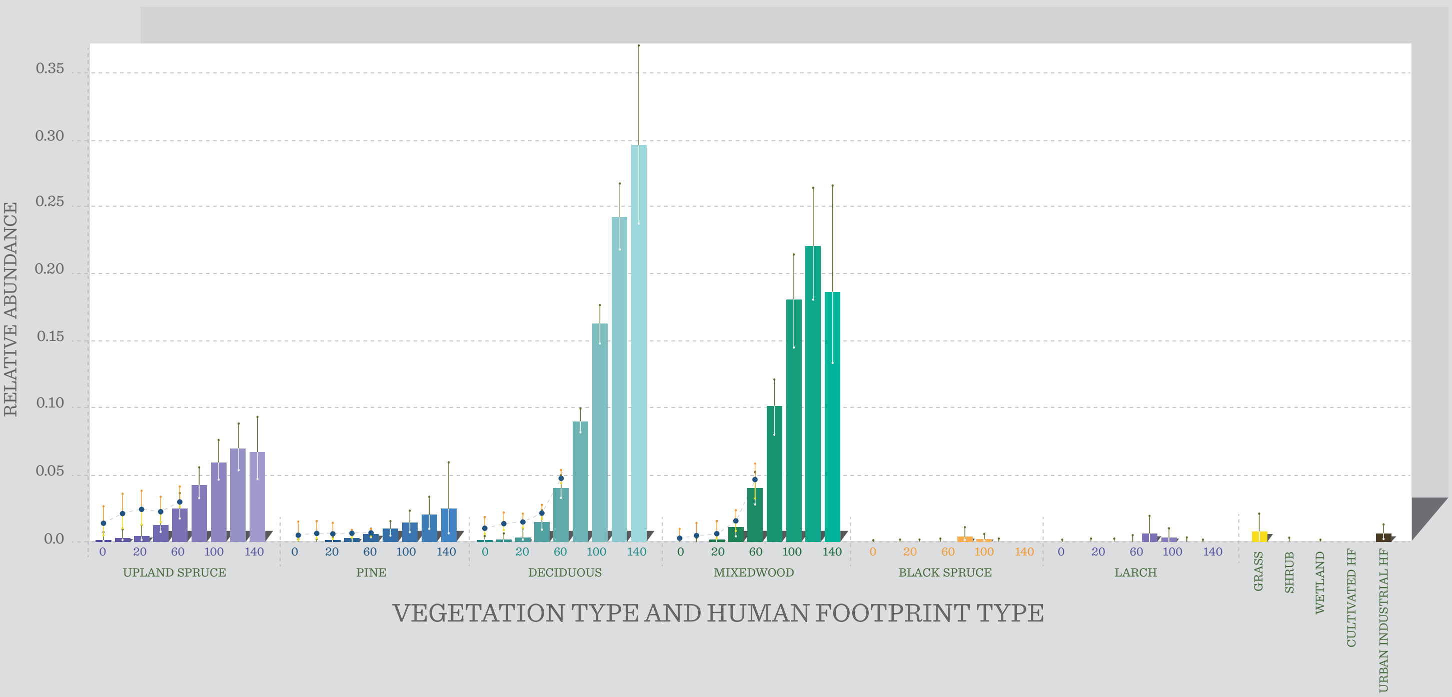


FIGURE 16

Predicted relative abundance (bars, with lines indicating 90% confidence intervals) of Black-throated Green Warbler by vegetation type and human footprint type in the Boreal and Foothills Natural Regions of Alberta. Dots show predicted species abundance in cutblocks of various ages within each vegetation type. To see annual updates of this information please visit: http://abmi.ca/home/data-analytics/biobrowser-home.

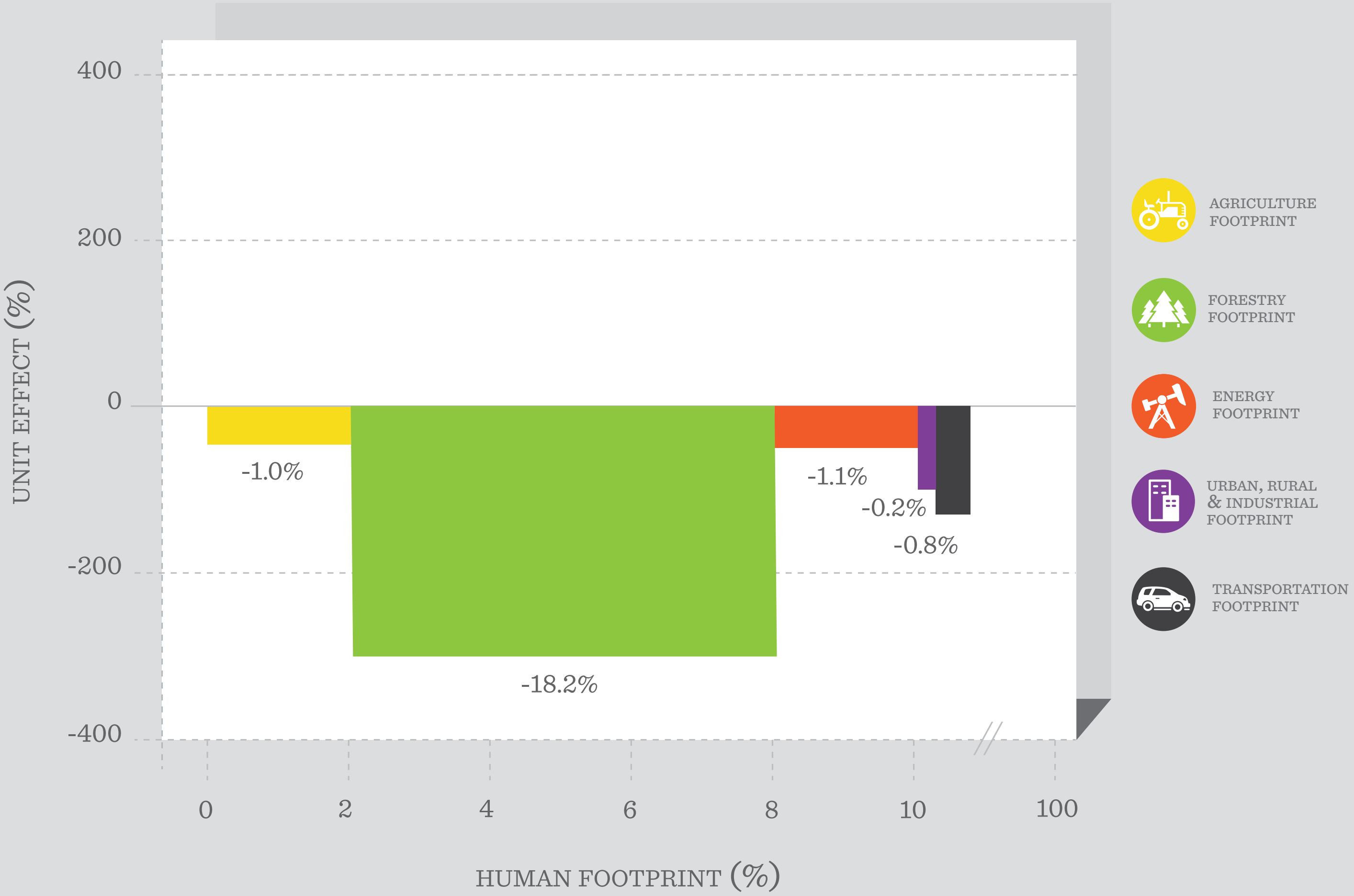


FIGURE 17.

The effects of industrial sectors on the Black-throated Green Warbler in the Boreal and Foothills Natural Regions. Height of the bar shows the effect of the sector per unit area (i.e., how much one hectare of the footprint type would increase or decrease the species compared to the natural vegetation it replaces). Width of the bar shows the area of the footprint type in the region. The area of each sector-specific rectangle (equal to the unit effect multiplied by the area of footprint) is the total effect of the sector on the species' relative abundance in the region.

Effects of Industrial Sectors

Forestry footprint had the strongest effect per unit area on the Black-throated Green Warbler in the Boreal and Foothills Natural Regions combined (Figure 17). Overall, forestry is estimated to have reduced the regional population of this species by 18.2%. This is disproportionately higher than the approximately 6% of the region converted to forestry, because forestry activities occur mainly in the warbler's preferred habitat—old upland forest (although older harvest areas do provide some habitat value for the species). The remaining footprint types also have negative effects on the species, but their total impact is smaller due to their smaller area.

HUMAN FOOTPRINT RECOVERY

Human footprint is not only added to the landscape but can also be mitigated through reclamation and recovery efforts. Monitoring reclaimed human footprint is one way to test whether restoration and management efforts to recover human footprint are effective. The ABMI and its partners are involved in research to quantify the recovery of human footprint across Alberta. For example, the ABMI's Ecological Recovery Monitoring Project is designed to assess the ecological recovery of certified reclaimed oil and gas well sites across the province. The ABMI Geospatial Centre Research Team working out of the University of Alberta and the University of Calgary is developing techniques using geospatial technologies to monitor vegetation recovery of non-permanent human footprint features, such as seismic lines, in the boreal forest. And the ABMI Caribou Monitoring Unit (CMU) is developing criteria to prioritize seismic lines for reclamation in Woodland Caribou range. We describe this latter project in greater detail.

PRIORITIZATION OF LINEAR FEATURES FOR RECLAMATION IN CARIBOU RANGES

Woodland Caribou, classified as a species at risk both federally and provincially, has a high public profile in Alberta. The 16 caribou populations in Alberta have been grouped into two recognized conservation units (termed "Designatable Units"): Central Mountain and Boreal.[22] Boreal Caribou populations are provincially and federally listed as "threatened", while Central Mountain Caribou populations have been federally listed as "endangered". Although the exact number of caribou in each of the populations remains uncertain, the best available science indicates that most have declined over the past 20 years.[23]

Declines in caribou populations across Alberta are linked to habitat alteration, a warming and drying climate, and in particular, altered predator-prey dynamics resulting from increasing human footprint in caribou range.[11] Habitat alteration resulting from both industrial activities (e.g., forestry, energy development) and natural disturbance (e.g., wildfire), in combination with milder winters, favours an increase in the abundance and distribution of moose and deer, and concomitantly wolves, which prey on these species. The increase in the number of wolves results in an unsustainable increase in caribou mortality.[11]

Linear disturbances are a particular management challenge because, along with creating habitat for moose and deer, these disturbances also serve as access routes for their predators into previously inaccessible caribou ranges. Wolves use the linear features to move efficiently through the landscape in search of ungulate prey, increasing their chances of encountering caribou and thereby further increasing caribou mortality risk. Tracking and reclaiming human footprint, and linear disturbances in particular, is an important component of Woodland Caribou recovery in Alberta.

There are hundreds of thousands of kilometres of linear disturbances like seismic lines criss-crossing the boreal forest, and most of these lines have not been reclaimed. Given the scale of the reclamation task, and the limited availability of resources, it is important to prioritize seismic lines for treatment to support Woodland Caribou recovery.

In support of the Government of Canada's Recovery Strategy for the Woodland Caribou (Boreal population), the ABMI provides information on status and trend of human footprint for all caribou ranges in Alberta. In addition, the ABMI CMU provides scientific advice and oversight in management trials aimed at determining when human footprint no longer impacts caribou. These trials include testing methods to reduce the use of linear features by wolves. To this end, the ABMI CMU has developed approaches, using the ABMI's human footprint data, to prioritize seismic lines for reclamation to support caribou habitat enhancement; the following is a summary of one approach.

PRIORITIZING RECLAMATION OF SEISMIC CUTLINES FOR CARIBOU HABITAT RESTORATION

The ABMI CMU used three criteria to prioritize seismic lines for reclamation:

1. *Degree of isolation: Reclaiming seismic lines that are in close proximity to other lines is less effective than reclaiming remote lines because wolves and ungulates can still access caribou habitat using other nearby lines if they are present. The federal criteria also stipulate that habitat within 500 m of human footprint is "disturbed," so reclaiming a line that is close to other lines will not reduce the amount classified as "disturbed" area. Reclaiming seismic lines that are distant from other seismic lines will serve to restrict access and isolate caribou habitat from other ungulates and predators.*

2. *Caribou habitat quality: The success of reclamation efforts will be maximized if restoration is focused on seismic lines that occur in preferred caribou habitat.*

3. *Current status: Not all seismic lines require reclamation because some lines naturally regenerate following disturbance. Focusing reclamation efforts on seismic lines that are not recovering naturally is the most effective use of limited resources.*

These criteria were used to prioritize seismic lines for reclamation in a study area that includes two of Alberta's 16 caribou ranges: Cold Lake and East Side Athabasca River (Figure 18). This area covers 19,845 km^2 and has more than 37,000 km of linear features, including roads, pipelines, and two-dimensional seismic lines.

FIGURE 18.

Location of Cold Lake and East Side Athabasca River caribou ranges. The cross-hatched area where LiDAR data are available defines the study area where the reclamation criteria were applied to prioritize seismic lines for reclamation.

THE PROCESS

Identify Isolated Seismic Lines

We identified seismic lines > 500 m from other seismic lines (as indicated by the white lines in Figure 19). These lines were prioritized for reclamation.

Identify Seismic Lines in Preferred Caribou Habitat

We identified lines that intersect preferred caribou habitat (identified by the white and yellow lines in Figure 20). These lines were ranked as high priority for treatment. Lines that occur in bog and/or fen habitat are considered higher-quality caribou habitat.

FIGURE 19.

Seismic line density.

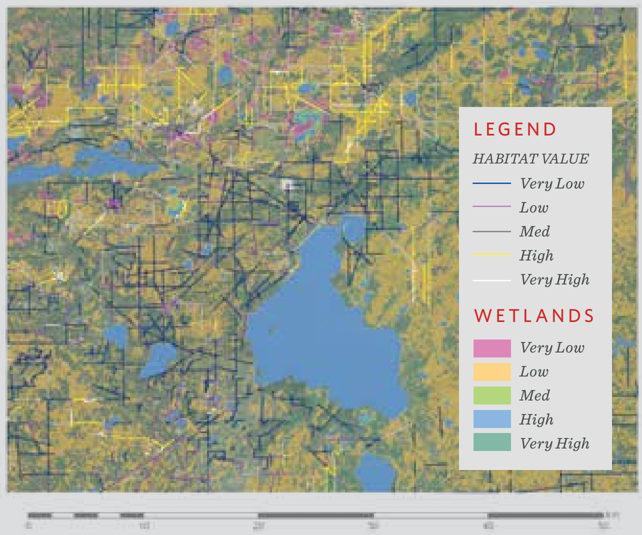


FIGURE 20.

Seismic lines in preferred caribou habitat.

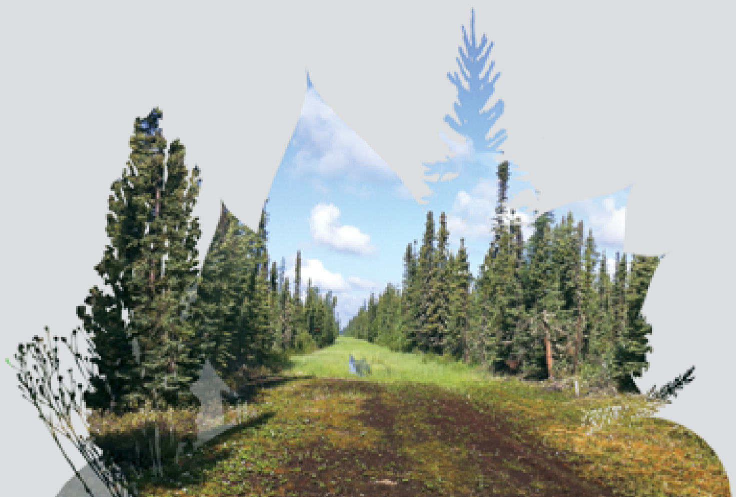
FIGURE 21.

Seismic lines in need of reclamation.

Identify Seismic Lines in Need of Reclamation

Finally, we used LiDAR[§§] data to identify seismic lines where vegetation height was very low or low, and therefore not naturally regenerating (as indicated by white and yellow lines in Figure 21). These lines were prioritized for reclamation.

§§ LiDAR is an acronym for Light Detection and Ranging. LiDAR is a remote sensing technology that maps physical features of a landscape by using a narrow laser beam to illuminate a target, and measure the distance to that target by analyzing the reflected light.



Seismic Lines Prioritized for Reclamation

We identified the seismic lines where reclamation efforts would provide the most benefit to caribou habitat enhancement by combining the results from analyses of these three criteria. Seismic lines ranked as high priority for reclamation were those lines that were isolated from other seismic lines, that passed through preferred caribou habitat, and in which vegetation has not recovered (as indicated by yellow and white lines in Figure 22).

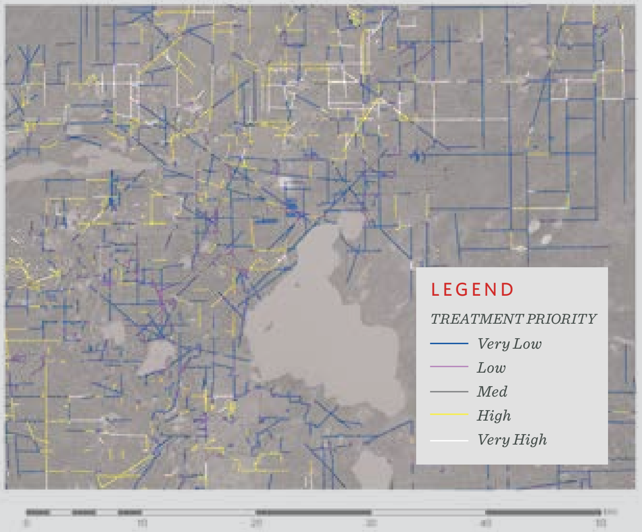


FIGURE 22.

Seismic lines prioritized for reclamation efforts.

NEXT STEPS

With these types of mapping and analysis outputs, companies operating in the area can assess the operational feasibility of restoring specific seismic lines. Additional factors for consideration may also include future access and development plans by industry, rights holders, and other land users. This analysis was completed during the spring of 2015, and is one example of a prioritization exercise conducted by the ABMI CMU. Additional versions have been completed and are helping guide restoration planning within portions of Boreal Caribou range. To view the latest research, visit https://cmu.abmi.ca.

Treatments for restoration include mounding soil, planting seedlings, and bending or felling trees across lines. These treatments help accelerate tree growth and reduce ease of movement by predators.

CONCLUSION

Managing human footprint is one of the main challenges of land-use planning in Alberta. Where human footprint is most abundant, native ecosystems are modified and environmental values are under the most pressure from human activity.[1] The exact consequences of human footprint in any given area are complex, depending on the ecosystems present, history of land use, and current pressures. In this context, the main findings of this report indicate the following:

- *Agriculture is the dominant footprint in many regions of Alberta, covering 20% of the province. Although much of this footprint was present prior to 1999—the start of our analysis period—this footprint type continues to have ecological consequences and is slowly increasing in some areas of the province.*
- *Forestry footprint is a management concern in the Foothills and Boreal Natural Regions. Forestry footprint covered 4.3% of the province in 2015 and was the fastest-growing footprint between 1999 and 2015. In the Foothills Natural Region, forestry footprint increased by more than 10% of the land base in this time frame.*
- *With the exception of the Mineable Region, where surface mining of bitumen occurs, the percentage area occupied by energy footprint is generally low in all units (natural regions and LUF planning regions) of the province. This includes the Athabasca OSA, a region recognized for its energy resources. Even though energy footprint is low across much of the province, it is evenly distributed; the accumulation of these small footprints is a management concern. [19] In addition, energy footprint is increasing steadily.*
- *Transportation footprint occupies a low percentage area but is dispersed throughout the province. Transportation footprint, and other linear features like seismic lines, affect biodiversity by creating edge effects and reducing interior habitat. Linear features are a particular management concern for the Woodland Caribou because they decrease the availability of refuge habitat and increase caribou mortality risk. We demonstrate how the availability of human footprint data is critical to prioritize seismic lines to support caribou habitat restoration; this is one species-specific application of human footprint datasets.*
- *Species do not always respond in the same way to different footprint types, as demonstrated by two species examples in this report—Alder Flycatcher and Black-throated Green Warbler. By understanding how species abundance is affected by each footprint type, it is possible to identify which sectors are having disproportionate impacts on species, and develop ways to mitigate this risk.*

The human footprint status and trend information in this report serves as a baseline for evaluating future land-use changes in Alberta. Currently, there are few specific policy targets for human footprint, but it is expected that thresholds related to human footprint and/or its inverse, undisturbed native habitat, will be established, and that trends in relation to those thresholds will be closely monitored. To evaluate how terrestrial native cover is changing over time and in relation to established thresholds for management action, the availability of human footprint baseline data will be essential. Further, as indicated by the results in this report, the location, extent, and type of human footprint are variable across the landscape. To understand how particular land-use management decisions and actions may translate into trade-offs between environmental performance and economic development, a detailed assessment of human footprint patterns will also be necessary. Moving into the future, as the ABMI continues to update status and trend data on human footprint in Alberta, this information will be found at http://abmi.ca/hf-report.

FUTURE DEVELOPMENTS

The ABMI produces comprehensive human footprint data for the entire province of Alberta. However, several other organizations (e.g., Alberta Environment and Parks, Alberta Energy, Forest Management Agreement holders, the oil and gas industry, and academia) also collect human footprint data; these data are often focused on only a small part of the province or on individual footprint types. As the demand for human footprint data increased, the ABMI and Alberta Environment and Parks initiated the AHFMP in 2015 to consolidate and centralize efforts to measure human footprint in Alberta.

The purpose of the AHFMP is to combine human footprint data sources and create a single comprehensive footprint inventory for the province that will facilitate monitoring of post-disturbance recovery and reclamation. The AHFMP is intended to be the source for standardized, publicly available, and scientifically credible human footprint data and information in Alberta. To ensure the success and responsiveness of the AHFMP, its steering and technical committees comprise a balanced set of stakeholder representatives from government, industry, academia, and non-government environmental organizations.

The AHFMP enhances human footprint monitoring in Alberta to more effectively monitor status and trends in human land use, and support evidence-based decision making related to land use. Its accessibility to the public also supports complementary research, augmenting Alberta's ability to monitor and manage its species and habitats in a changing landscape.

Currently, the ABMI HFI, available through the ABMI's data portal (abmi.ca/data), is being expanded to include additional base layers made available through AHFMP efforts. Going forward, all the human footprint data and information produced by the AHFMP will be made available online in a single authoritative data sharing format.

GENERAL TERMS

LIMITATIONS

The ABMI is designed primarily as a proactive tool used to identify the status, trends, and correlative relationships among common species, habitats, and human footprint.

At present, the ABMI's 3 x 7 km and HFI products do not yet account for recovery of biodiversity in forests that are regenerating following temporary disturbances such as logging or energy exploration (e.g., seismic lines). In other words, cutblocks and seismic lines are treated the same regardless of their age. The ABMI is currently developing the science and tools necessary to account for this recovery, so reclaimed areas can be credibly removed from the estimate of human footprint. In addition, some human land uses that are not visible using our current methodology, such as grazing, hunting, and trapping, are not yet accounted for in our human footprint analyses.

Looking Forward

The ABMI has made considerable strides in supporting biodiversity management in Alberta; however, we are just beginning. The ABMI continues to build momentum and is committed to:

- *Ensuring the effective delivery of relevant, timely, and scientific biodiversity information*
- *Improving biodiversity management by contributing knowledge to decision-making systems*
- *Supporting governments and industries in meeting their domestic and international reporting obligations*
- *Eliminating duplication and redundancy in provincial biodiversity monitoring*
- *Facilitating the transfer of information to government, industry, the research community, and the public.*

The legacy created through the development of the ABMI is enormous. We are committed to continued excellence in biodiversity monitoring.

SCIENTIFIC INTEGRITY

The ABMI is committed to the responsible analysis and interpretation of data. The ABMI holds itself to the highest ethical standards, including operational transparency, honesty, conscientiousness, and integrity. The ABMI strongly encourages the responsible and ethical evaluation and interpretation of the knowledge contained in this report. For a complete discussion of the ethical behaviour endorsed by the ABMI, please see *Honor in Science,* published by Sigma Xi (1997), available at www.sigmaxi.org/programs/ethics/Honor-in-Science.pdf. A broader discussion about the use of ABMI data and information can be found in *Scope and Application of the ABMI's Data and Information* (00048), Version 2008-01-04, Alberta Biodiversity Monitoring Institute, Alberta, Canada. This report is also available at www.abmi.ca under "Publications."

Disclosure

Data used in the preparation of this report are available on the ABMI's website (abmi.ca/data) and include species, habitat, and remotely sensed data collected between 1999 and 2015. The scientific methods used in analyses of data for this report are described in the following document:

Alberta Biodiversity Monitoring Institute - Geospatial Centre. 2017. Human Footprint Inventory 2014, Version 1.0. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at www.abmi.ca under "Publications".

TERMS AND CONDITIONS OF REPORT

PREPARATION

Funding in support of this work was received from the Oil Sands Monitoring Program which is co-led by Alberta Environment and Parks and Environment and Climate Change Canada under the ABMI condition that the following terms be applied in its preparation:

1. *The ABMI reports on a standardized list of human footprint indicators that are relevant to regional planning, policy, and management. Developed by the ABMI, these indicators will be applied consistently.*

2. *The ABMI maintains full control over all language and messaging in this report.*

3. *This human footprint status report uses data collected between 1999 and 2015.*

4. *The report was released publicly in a timely manner.*

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IMAGE CREDITS

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