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Disturbance Zones of Influence on Boreal Songbird Communities in Northeastern Alberta

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Prepared by:

Amy F. Darling, Carol I. Stefan, and Corey De La Mare

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EXECUTIVE SUMMARY

Canada's boreal forest is important habitat for many North American birds, which play a vital role in the health of forests, and provide ecosystem services. Expanding human development in northern Alberta raises concerns that fragmentation and loss of habitat could be leading to declines in forest wildlife. Objectives of this boreal songbird analysis were to examine habitat and disturbance associations of boreal songbirds, and determine what habitat and disturbance variables had the greatest influence on mature forest songbird relative abundance and species richness, with the ultimate goal of developing an empirical habitat model to predict the influence of development on mature forest songbirds in northeastern Alberta.

Local habitat associations were assessed separately for all songbirds, species of concern, and mature forest songbirds using fine scale habitat designations made by observers in the field. Detailed vegetation and disturbance data with a broader coverage (i.e., up to 1000 m beyond the point count centre) were available for 1,386 point counts which were used for predictive modeling. Competing hypotheses (models) were compared using Akaike's Information Criteria (AIC) to search for a parsimonious suite of factors useful for predicting variation in mature forest songbird relative abundance and species richness. Multiple spatial scales were considered to better delineate the scale(s) at which disturbance affects songbird population and community parameters.

Seventy-six species and 6,886 individual boreal songbirds, including 27 species and 2,840 individuals in the mature forest songbird guild were recorded during 2,302 point counts (50-m radius surveys) in the Athabasca and Cold Lake portions of the Oil Sands Region (OSR) (ESRD 2012). The six most commonly observed species comprised 50% of all observations, with Tennessee warbler as the most commonly detected species (17% of observations). Mean (\pm standard deviation) relative abundance (i.e., detections per point) or density, species richness and/or diversity of all boreal songbird species combined, songbird species of concern, and the mature forest songbird guild were positively associated with land cover types or habitat groups likely to provide high quantity and quality foraging and nesting microhabitats. Songbird parameters tended to be highest in the coniferous white spruce, mixedwood aspen-white spruce, treed swamp and deciduous aspen-balsam poplar habitat groups. Songbird parameters tended to be lowest in dry or very wet, nutrient poor, and/or open habitat dominated by jack pine and/or black spruce. The habitat most preferred by mature forest songbirds, mixedwood aspen-white spruce, was consistent with previous research. All boreal songbirds combined were also positively associated with non-treed shrubby wetlands, whereas mature forest songbirds were negatively associated with non-treed wetland habitat groups.

Empirical habitat models predicted the influence of development on mature forest songbird relative abundance and species richness in northeastern Alberta. Top models included variables for height of the tallest vegetation layer, landscape preferred habitat groups, landscape avoided habitat groups, and three landscape disturbance types (wide linear disturbance, narrow linear disturbance and non-linear disturbance). The direction (positive/negative) and strength of the influence of disturbance on mature forest songbird relative abundance and species richness depended on the type of disturbance. Examination of cumulative effects of disturbance on songbirds should consider and account for different relationships with different types of disturbance. Measures of fitness consequences associated with habitat selection are required to understand the adaptive significance of habitat use.

The primary drivers of mature forest songbird relative abundance are found both at the local scale and at greater spatial extents. Local habitat characteristics in the 50 m point count are important determinants of mature forest



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songbird relative abundance, as are habitat characteristics in the smallest landscape examined (250 m). However, when controlling for local habitat group in disturbance models, the broadest landscape scale examined, up to 1 km from the point count, had the strongest influence on songbird relative abundance. Disturbance variables had stronger influences at the coarser landscape scales examined, especially at the 500 m spatial scale, whereas preferred habitats had stronger influences at the finer scales (local habitat and at the 250 m landscape scale).

Assessment for songbirds often focuses on fine scale, local habitat use and subsequent mitigation attempts might focus on limiting the proximity of disturbance to sensitive elements. Though this research confirms that local habitat variables are important, considering only local scale variables would fail to account for important landscape level variation in songbird numbers. Examination of zones of influence should move beyond local, fine-scale examinations of distance from disturbance and consider the composition of surrounding natural habitats and cumulative effects of surrounding disturbance, which can influence songbird habitat choice in a hierarchical manner. Models combining local and landscape level variables (habitat composition and structure as well as disturbance types) are recommended to accurately predict development impacts on boreal songbirds.



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1.0 INTRODUCTION

Canada's boreal forest is an immensely important breeding ground for up to 3 billion North American birds (Blancher 2003). Songbirds play a crucial role in the health of forests as pollinators, insect predators, seed dispersers (Venier and Pearce 2007) and more, providing ecosystem services worth billions of dollars (Anielski and Wilson 2009). Approximately 300 species of terrestrial bird species regularly breed in the boreal forest (Blancher 2003), and approximately 93% of individuals migrate south to overwinter in the United States, Mexico, Central America, South America or the Caribbean islands (Blancher and Wells 2005). Canada and the United States have an agreement under the Migratory Birds Convention Act to "protect habitat necessary for the conservation of migratory songbirds" (Government of Canada 1994). Provincial and federal legislation protect songbirds listed as species at risk due to declining numbers (Alberta Sustainable Resource Development [ASRD] 2010, Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2010, Species at Risk Public Registry [SARA] 2012).

In northern Alberta, human disturbance density has increased rapidly in the past decade and likely will continue to increase in the near future (Schneider 2002). For example, Schneider (2002) predicted that industrial footprint would quadruple from 2000 to 2030 (e.g., the amount of edge would increase from 2.0 km/km² to 8.0 km/km²), and 75 km/year of major roads would be built from 2000 to 2050 in Alberta. Human disturbance in northeastern Alberta includes roads, urban (e.g., cities) and industrial (e.g., seismic exploration, wellpads, facilities) areas, agriculture, and forestry (e.g., cutlines and clearcuts). Areas such as roads and industrial areas have lost their natural cover relatively permanently whereas areas affected by forestry, seismic lines and surface mining periodically or temporarily lose their natural cover for resource extraction activities (e.g., forestry, seismic lines, surface mining) (Alberta Biodiversity Monitoring Institute [ABMI] 2012b) and might otherwise have the natural cover replaced by early successional vegetation (Schneider 2002, MacFarlane 2003). With expanding human development, habitat fragmentation and loss could be leading to declines in forest wildlife (Pimm and Askins 1995, Hörnfeldt et al. 2006, Fischer and Lindenmayer 2007, Sullivan et al. 2008). Consequently, it is important to quantify the potential effects of habitat degradation and loss for wildlife, including boreal songbirds.

Understanding boreal songbird habitat requirements and responses to human disturbance is vital for assessing and mitigating the effects of development on songbirds in Alberta. The boreal ecosystem is a dynamic mosaic of uplands and lowlands (wetlands), where wildlife are adapted to cycles of natural disturbance and succession (Schieck and Song 2006, Brawn et al. 2001). Trees often occur in mixtures of deciduous (e.g., aspen [*Populus tremuloides*]) and coniferous (e.g., white spruce [*Picea glauca*]) species (Beckingham and Archibald 1996). Songbirds specializing in mature and old growth forests have been found to prefer stands of mixedwood aspen-white spruce (Hobson and Bayne 2000a), coniferous white spruce (Kirk et al. 1996), and deciduous, especially those with at least a small component of white spruce (Hobson and Bayne 2000a). Boreal forest songbird species richness and abundance have also been found to be low in wet, nutrient poor habitats containing black spruce (*Picea mariana*) (Kirk et al. 1996) and dry jack pine (*Pinus banksiana*) forest (Hobson and Bayne 2000a).

Forest habitat specialists have a higher chance of experiencing detrimental effects of human disturbance due to reliance on particular habitat types and features (Schmiegelow and Mönkönnen 2002). The guild of mature forest songbird species was the focus of predictive modelling. Mature forest songbirds specialize on abiotic and biotic resources (e.g., foraging and nesting microhabitats) found primarily in mature and old growth forest (Schieck et al. 1995, Westworth and Telfer 1993). As habitat specialists, mature forest songbirds might be particularly sensitive to



human disturbance that results in habitat loss or fragmentation (Drapeau et al. 2000, St-Laurent et al. 2009) or removes important habitat elements, such as large trees or snags (ABMI 2012b). Mature forests have a closed canopy of trees compared to other seral stages and vegetation community structure is evident (i.e. multiple age classes of trees) (ASRD 2003). In general, the mature successional stage of a forest in northeastern Alberta is defined as greater than 60 years (Andison 2003, ASRD 2003); therefore, the mature forest songbird guild consisted of species that were more common or had a higher abundance in forests older than 60 years of age, compared to earlier successional forest stages (Schieck et al. 1995, Westworth and Telfer 1993).

Boreal songbirds are naturally adapted to the dynamic boreal forest environment as a result of the natural disturbance regime (i.e., fire and insect outbreaks), consequently they can be expected to respond differently to different types of anthropogenic disturbance, and might be resilient to some kinds of disturbance (Schmiegelow et al. 1997, Volney and Fleming 2000). For example, forestry practices that emulate patchy natural disturbances that boreal songbirds are adapted to, such as fire or insect outbreaks that leave small gaps, residual live or dead trees, might be less detrimental to forest songbirds than large open canopy disturbance such as clearcuts or well pads (Schieck and Song 2006, Forsman et al. 2010, Zhang et al. 2012) or linear disturbance with high edge to area ratios (e.g., roads) (Coffin 2007). For example, narrow seismic lines (2 to 3 m) have a lesser impact on forest songbirds than conventional 8 m wide seismic lines (Bayne et al. 2005a), nest predation is higher in landscapes fragmented by agriculture than landscapes fragmented by forestry (Bayne and Hobson 1997) and building density can negatively influence songbird distributions in urban settings (Pennington and Blair 2011). Wide linear disturbances (e.g., pipelines, powerlines, railway and road) are often maintained and kept free of shrubs or taller plant growth, thus creating and maintaining hard edges (Larrivée et al. 2008), which typically have stronger edge effects and greater negative effects than narrow linear disturbances (e.g., cutlines and seismic lines) (e.g., Pohlman et al. 2007). Furthermore, narrow linear disturbances might be narrow enough to mimic small natural gaps which do not negatively affect most forest songbirds (Forsman et al. 2010). However, limited information is available regarding the way multiple land-uses might act cumulatively to affect the relative abundance of songbirds, or the species richness and diversity of songbird communities. There might be thresholds of cumulative disturbance beyond which songbirds begin to avoid an area (Guénette and Villard 2005), modify their behaviour (Bayne et al. 2005a), or suffer reduced survival (Whitaker et al. 2008) or reproductive success (Hannah et al. 2008), with responses often specific to the type of disturbance (Bayne and Hobson 1997).

Songbird perception of disturbance might also vary with landscape-level composition. Zones of influence of disturbance (ZOI) are often examined in terms of distance from disturbance (e.g., Miller et al. 1998), with the implicit assumption that beyond a certain distance the disturbance will no longer affect the species of interest. However, Drapeau et al. (2000) found that the landscape context was as important as local habitat conditions when determining variation in bird communities in areas influenced by different types of disturbance (i.e., human settlement, agriculture, pre-industrial logging activities, modern timber harvest and natural disturbance). Similarly, Pennington and Blair (2011) also found that habitat selection operated both at local and broader spatial scales. If songbird distributions are affected by the composition of the surrounding landscape (e.g., Drapeau et al. 2000, St-Laurent et al. 2007, Pennington and Blair 2011), the direct ZOI of disturbance (distance from the nearest disturbance) might not adequately describe the cumulative impacts of disturbance. Thus, it is useful to examine varying buffers surrounding potential bird habitats (e.g., circles with radii of 250 m, 500 m, 1000 m) to better delineate the scale(s) at which disturbance affects songbird population and community parameters (Drapeau et al. 2000, St-Laurent et al. 2009, Pennington and Blair 2011).



1.1 Study Objectives

To make inferences about regional songbird habitat associations and predict responses to disturbance in northeastern Alberta, researchers often turn to data from other boreal regions of Canada or in Europe, despite the fact that species from distinct regional communities respond in unique ways to landscape change (Niemi et al. 1998). We used a local, long-term (10 year) dataset linking songbird and GIS data to examine habitat associations of all songbirds, species of concern and mature forest songbirds, and subsequently potential effects of disturbance on mature forest songbirds in northeastern Alberta.

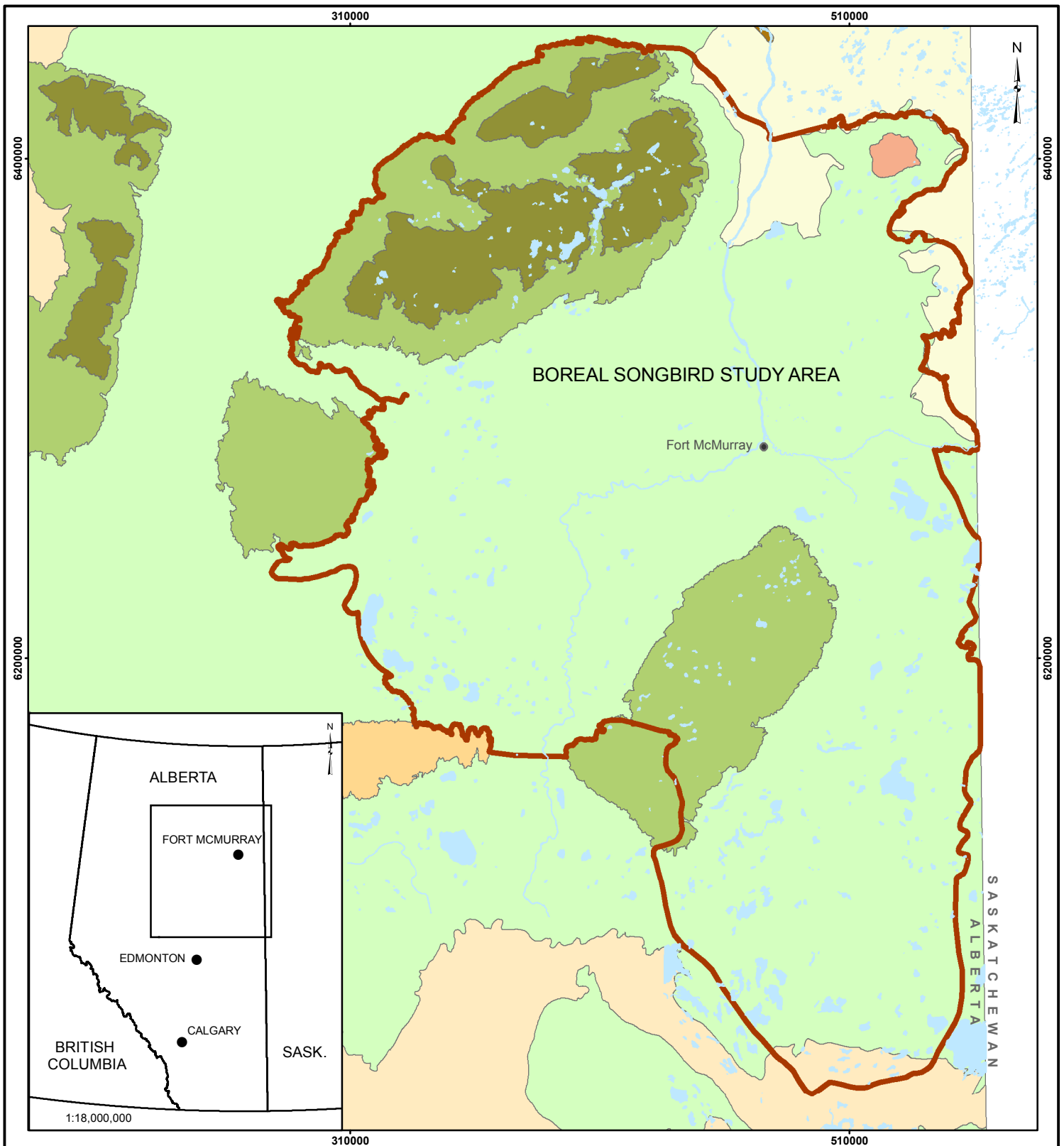
The objectives of the boreal songbird analysis were as follows:

1. Examine habitat associations of all boreal songbirds combined, bird species of concern, and the mature forest songbird guild.
2. Develop empirical habitat models to predict the influence of development on mature forest songbird relative abundance and species richness in northeastern Alberta.
 - i. Determine which disturbance and habitat variables have the greatest influence on mature forest songbird community parameters (e.g., relative abundance and species richness of all songbirds or of mature forest songbirds).
 - ii. Determine the scale(s) at which mature forest songbirds respond to disturbance and how spatial scale influences mature forest songbird response to habitat and disturbance variables.












This research represents a comprehensive assessment of songbird habitat and disturbance associations in northeastern Alberta that can contribute to a better understanding of scale of habitat selection and the cumulative impacts of disturbance on songbirds.

1.2 Study Area

The study area spans 5,809,395 ha and includes the majority of the Oil Sands Region (OSR), including most of the Athabasca and Cold Lake deposits (ESRD 2012), combining six regional study areas used in past Golder Associates Ltd. (Golder) Environmental Impact Assessments (EIAs) (Figure 1). The Oil Sands Region (OSR) considered in this study includes the majority of the Athabasca and Cold Lake deposits (ESRD 2012). The OSR is characterized by four distinctive natural subregions: Central Mixedwood, Lower Boreal Highlands, Upper Boreal Highlands and Athabasca Plain (Natural Regions Committee 2006). Regional vegetation is a mixture of wetlands in areas of poor drainage and terrestrial vegetation in better drained upland locations. Terrestrial vegetation is typically dominated by aspen or mixed stands of aspen, white spruce, balsam poplar (*Populus balsamifera*) or white birch (*Betula papyrifera*). Jack pine (*Pinus banksiana*) is the dominant species on drier sites with coarse textured soils. In poorly drained areas of the regional landscape, there is a diverse range of forested and non-forested wetland types including peatlands represented by bogs and fens, and non-peatland marshes, swamps and shallow open water. Dominant wetland tree species include black spruce (*Picea mariana*) and tamarack (*Larix laricina*), although wetlands might be dominated by shrubs or sedges instead of trees. The landscape in northeastern Alberta has been altered for many land use demands and includes disturbances such as cutlines, clearcuts, wellpads, ATV trails, roads, highways, agriculture, and urban, industrial and other developments.




LEGEND

- | | |
|---|--|
|  BOREAL SONGBIRD STUDY AREA BOUNDARY |  NATURAL SUBREGION |
|  WATER |  CENTRAL MIXEDWOOD |
| |  DRY MIXEDWOOD |
| |  ATHABASCA PLAIN |
| |  LOWER BOREAL HIGHLANDS |
| |  UPPER BOREAL HIGHLANDS |
| |  LOWER FOOTHILLS |
| |  KAZAN UPLANDS |
| |  PEACE-ATHABASCA DELTA |

REFERENCE

NATURAL SUBREGION AND WATER SOURCES OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
 PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12.



PROJECT		BOREAL SONGBIRDS IN NORTHEASTERN ALBERTA	
TITLE		BOREAL SONGBIRD STUDY AREA	
		PROJECT No. IP225361 DESIGN RP 09 Aug. 2011 GIS JC 21 Jan. 2013 CHECK AFD 21 Jan. 2013 REVIEW CIS 21 Jan. 2013	SCALE AS SHOWN REV. 0
			FIGURE: 1



2.0 METHODS

2.1 Boreal Songbird Surveys: Data Collection

Boreal songbird species composition, population and community indices were estimated using surveys conducted in accordance with standard technical procedures for point counts, based on methods described in Ralph (1993). Boreal songbird surveys were designed to document the presence of a wide variety of Neotropical migrants, including federal species of concern such as the olive-sided flycatcher, Canada warbler and rusty blackbird.

Surveys were conducted to describe boreal songbird species use of various land cover types (i.e., ecosite phases, wetland types and other land cover types) in several local study areas (LSAs). Survey points were established a minimum of 250 m apart along transects throughout 30 projects (Local Study Areas for EIAs), and, where possible were further constrained to locations greater than 100 m from roads and 50 m from cutlines. Points were centered within land cover types, and to the extent possible, habitat within 50 m of the point count center was homogenous. Boreal songbird survey points were placed to be representative of the proportional distribution of land cover types in the OSR, while also representing a wide range of habitat types where listed species were more likely to be found.

Surveys were conducted primarily in June and began 30 minutes before sunrise and ended at 10:00 a.m. The first point count location on each transect was accessed using one or a combination of 4x4 truck, ATV and walking. Subsequent point count locations were accessed by walking, or if distances between point counts were greater than 250 m, again using one or a combination of 4x4 truck, ATV and walking.

At each point count location, an initial two minutes of silence allowed the birds to adjust to the observer's presence. A five-minute survey ensued, during which all species heard or observed were recorded. Observations were divided into those species heard within and outside a 50 m radius, and those heard within the first three minutes and in the following two minutes. This method allows for comparison and exchange of data with the North American Breeding Bird Survey, which uses three minute point counts (U.S. Geological Survey Patuxent Wildlife Research Center 2001).

The approximate position of each individual bird in relation to the observer was illustrated on a sketch map of the point count location. In addition, the abbreviated species name, the sex of individuals and movements of individuals around the point count location were recorded. The movements of individuals were carefully monitored to minimize the probability of recounting birds within the same or adjacent points.

Date, time, observer, point count number, GPS waypoint and land cover type were recorded at each point count. All observers were experienced in visual and audial identification of songbirds. To reduce bias in bird detection, surveys were not conducted during periods of high winds, heavy rains or thick fog. Wind speeds greater than 20 km/hr are sufficient to interfere with auditory birding.

2.2 Land Cover Classification

2.2.1 Habitat Associations in the Oil Sands Region

To meet the first objective, habitat associations were examined for all boreal songbirds combined, bird species of concern, and mature forest songbirds. For preliminary analysis, songbird habitat associations were determined using land cover types (ecosite phases, wetland types and other types) collected during field surveys



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(i.e., land cover designations made in the field by the bird observer). Additional habitat metrics were estimated from Alberta Vegetation Inventory (AVI) polygon data for use in mature forest songbird predictive modeling, and are described in Section 2.2.2. Land cover classification followed Beckingham and Archibald (1996) for terrestrial vegetation (ecosite phases) and Halsey et al. (2003) for wetland types. Other classification units (i.e., miscellaneous land cover types, non-vegetated types and disturbance types) were also included, though they were rarely sampled. Land cover classification done during field surveys provides a fine-scale record of the habitat existing at the point count location, though they do not describe the landscape surrounding the point. Land cover types were combined into a coarser scale of habitat and disturbance groups for analysis. Preliminary habitat association analysis did not control for within-habitat characteristics such as stand age.

Over 100 land cover types identified within the study area were reclassified into 14 habitat or disturbance groups. Habitat groups were based largely on dominant tree species composition and understorey composition of ecosite phases (Beckingham and Archibald 1996) and wetland types (Halsey et al. 2003), as well as input from previous ordination results examining habitat groups and songbird guilds for nine projects in the oil sands region (Cenovus FCCL Ltd 2010). Habitat groups with greater than five point count stations were included in the habitat association analysis. Table 1 outlines which land cover types are included in each habitat group.

Table 1: Habitat or Disturbance Groups and Associated Land Cover Types

Applicable Objective(s)	Habitat or Disturbance Group	Land Cover Types
habitat association and predictive modeling	coniferous jack pine- black spruce	lichen-jack pine (a1), blueberry white spruce-jack pine (b4), Labrador tea-mesic jack pine-black spruce (c1), Labrador tea-subhygric black spruce- jack pine (g1)
	coniferous white spruce	low-bush cranberry white spruce (d3), dogwood white spruce (e3), horsetail white spruce (f3)
	deciduous aspen-balsam poplar	blueberry aspen-white birch (b2), low-bush cranberry aspen (d1), dogwood balsam poplar-aspen (e1), horsetail balsam poplar-aspen (f1)
	mixedwood aspen-white spruce	blueberry aspen-white spruce (b3), low-bush cranberry aspen-white spruce (d2), dogwood balsam poplar-white spruce (e2), horsetail balsam poplar-white spruce (f2)
	mixedwood jack pine-aspen	blueberry jack pine-aspen (b1)
	non-treed open wetland	graminoid fen (FONG), graminoid marsh (MONG), open water (WONN)
	non-treed shrubby wetland	shrubby bog (BONS), shrubby fen (FONS), riparian shrubland (Sh), shrubby swamp (SONS)
	treed bog	forested bog (BFNN), wooded bog (BTNN)
	treed fen	forested fen (FFNN), wooded fen (FTNN), wooded fen with patterning (FTPN)
	treed swamp and white spruce-black spruce (referred to as treed swamp)	wooded swamp (STNN), Labrador tea/horsetail white spruce-black spruce (h1)
habitat association	burn ^(a)	burned upland (BUu), burned wetland (BUw)
	clearcut ^(a)	clearcut (CC)



Table 1: Habitat or Disturbance Groups and Associated Land Cover Types (continued)

Applicable Objective(s)	Habitat or Disturbance Group	Land Cover Types
	linear development (vegetated) ^(a)	cutline
	non-linear development (vegetated) ^(a)	clearing, wellpad
predictive modeling	wide linear disturbance ^(b)	pipeline, powerline, railway, road
	narrow linear disturbance ^(b)	cutline, seismic line
	non-linear disturbance ^(b)	acreage, borrow pit, clearcut (CC), clearing, facility, gravel pit, pasture, wellpad, non-linear development (vegetated), non-linear development (unknown vegetation status), salt cavern, sump

^(a) Collected as field data for boreal songbird habitat associations (Section 2.2), not applicable for predictive modeling.

^(b) Calculated for mature forest songbird predictive modelling from GIS data (Section 2.2), not applicable for initial habitat association analysis.

2.2.2 Mature Forest Songbird Predictive Modelling

The second objective was to determine which habitat and disturbance variables have the greatest influence on mature forest songbird community parameters, including within-habitat characteristics such as stand age. For effective prediction for EIAs, ideal covariates cover broad geographical extents, and are collected in a consistent manner. Vegetation and disturbance information was gathered from several sources, most of which were used initially in Environmental Impact Assessments (EIAs), to link to the long-term songbird survey dataset. Alberta Vegetation Inventory (AVI) polygon data were used to derive structural characteristics such as stand age, canopy composition and vegetation height, and to derive mapped land cover types for the 30 projects pooled in this analysis. Alberta Vegetation Inventory data are based on 1987 – 2008 1:20 000 scale aerial photos, with some field verification (Nesby 1997) and have horizontal accuracy of ± 20 m (ASRD 2011). Land cover types for the 30 LSAs were classified based on Golder’s models of relationships between AVI attributes, primarily tree canopy composition and moisture class, and terrestrial and wetlands vegetation classification types. Terrestrial vegetation was classified to ecosite phase (Beckingham and Archibald 1996), whereas wetlands were described and mapped as per Halsey et al. (2003). Other classification units (i.e., miscellaneous land cover types, non-vegetated types and disturbance types) were included to provide complete coverage in neighbourhoods surrounding the point counts. Human disturbance footprints temporally appropriate for each year of songbird data collection were obtained from multiple sources (i.e., 30 datasets for the 30 projects pooled in this analysis), including Alberta-Pacific Forest Industries Inc., AltaLIS, AVI, Cenovus Energy Inc., Cenovus FCCL Ltd., IHS Energy Ltd., six anonymous industrial partners, and through visual interpretation of LSA orthophotos. Polygons derived from the aforementioned sources data were mapped in GIS (Geographic Information System) and further verified by Golder with additional field and aerial photo data. Land cover types were combined into ten habitat and three disturbance groups with high enough sample sizes for inclusion in predictive modeling (Table 1). An ArcGIS statistical analysis tool was applied to shapefile layers to calculate the percent area covered by different vegetation and disturbance types in 250, 500 and 1000 m radius circular buffer zones surrounding each songbird point count. A few types used for the habitat association analysis were excluded or summarized in a different manner. Burn was excluded due to low sample size. Disturbance types were defined as wide or narrow linear disturbance, or non-linear disturbance (Table 1) and were considered only applicable at



the landscape scale for predictive modeling, due to field methods requiring the point count to be disturbance-free.

Songbird point count methods required the habitat to be homogenous within 50 m of the observer, and required the point count to be free of disturbance, unless a disturbance type was the target of the survey. According to land cover type classification made by field observers, point counts included in predictive modeling were vegetated habitats at the point count. A 50 m radius circle is 4% of a 250 m radius circle, thus the maximum allowed disturbance should have been 96% of the 250 m radius circle, assuming the 50 m radius was undisturbed as per the field records and methods. However, disturbance layers available for the accumulated years of wildlife observations (i.e., 2001 to 2010) might have included estimated disturbance (“approved” footprints) in addition to actual disturbed land, which could erroneously lead to percent disturbance over 96%. Therefore, non-linear disturbance proportions were capped at 96% for the 250 m radius circle for 18 affected point counts. The difference was then reclassified to the habitat group corresponding to the AVI designation at the point count (i.e., the habitat within the 50 m radius).

2.3 Data Analysis

Habitat Associations in the Oil Sands Region

Boreal songbird community composition was described by calculating abundance (i.e., the number of individuals of each bird species found), species richness (i.e., number of different species) and species diversity for each point count. Mean relative abundance (mean \pm standard deviation), species richness and species diversity were then calculated for each field-sampled land cover type (i.e., ecosite phases, wetland types, disturbances and other land cover types) or habitat group. Only birds detected within 50 m of plot centres were included in the descriptions of habitat associations as a means of standardizing detection probability over space and time (Nichols et al. 2008).

To increase sample size for statistical analyses, land cover types (ecosite phases, wetland types, disturbances and other land cover types) were grouped into coarser habitat groups based on vegetation community assemblages (i.e., canopy tree species composition and cover, understory species composition, cover and structure), moisture and nutrient regimes, preliminary analysis of songbird habitat associations and literature review (e.g., Hobson and Bayne 2000a; Kirk et al. 1996, references in Section 3.1.2).

Diversity was calculated using the Shannon diversity index (Krebs 2009; Zar 1999) and is represented as:

$$H = - \sum_{i=1}^S p_i \ln p_i$$

Where H is the Shannon diversity index, S is the total number of species in the community (richness) and p_i is the proportion of individuals made up of the i th species.

The probability of detecting birds depends on a number of factors including habitat structure, wind conditions, hearing and identification ability of the observer, song intensity, perch height and orientation of the songbird and distance from observer (Wolf et al. 1995, Diefenbach et al. 2003). By pooling data to produce larger sample sizes in each land cover type and habitat group for the habitat association analysis, bias in detections between habitat groups can be reduced (Marques et al. 2007).



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Specific groups of birds such as hummingbirds, corvids, marshbirds, shorebirds, raptors, owls, and woodpeckers (except yellow-bellied sapsucker) were not included in the descriptions of community composition because they are not adequately sampled using the point count method (Schmiegelow et al. 1997, Kirk et al. 1996). The aim was to determine habitat associations of native, non-invasive boreal songbirds; thus house sparrow, European starling and brown-headed cowbird were also excluded from the analysis.

Boreal songbird communities include a number of species of concern as a result of their provincial (ASRD 2010, internet site) or federal (Species at Risk Public Registry 2012, internet site) listing. Those that might be observed during boreal songbird surveys include:

- barn swallow;
- bay-breasted warbler;
- blackburnian warbler;
- black-throated green warbler;
- brown creeper;
- Canada warbler;
- Cape May warbler;
- common yellowthroat;
- eastern phoebe;
- least flycatcher;
- olive-sided flycatcher;
- rusty blackbird;
- sedge wren;
- western tanager; and
- western wood pewee.

All of the above listed species are provincially listed at “Sensitive”. In addition, the Canada warbler and olive-sided flycatcher are federally listed as “Schedule 1: Threatened” by SARA (Species at Risk Public Registry 2011, internet site). The rusty blackbird is federally listed as “Schedule 1: Special Concern” by SARA (Species at Risk Public Registry 2011, internet site).

We also examined habitat associations of the mature forest songbird guild (Section 3.1.2). Mean relative abundance, species richness and mean relative density of mature forest songbirds within the 50 m radius point count (0.79 ha area) was calculated for each land cover type.



Mature Forest Songbird Predictive Modelling

To address the first and second objectives, predictive modeling focused on the guild of mature forest songbirds. Objectives include determining which habitat and disturbance variables have the greatest influence on songbird community parameters, and at what scales, with the eventual goal of developing an empirical habitat model to predict disturbance impact on songbird communities in northeastern Alberta. The mature forest songbird guild was determined through literature review (e.g., Schieck et al. 1995, Cumming and Diamond 2002, Hobson and Bayne 2000a, Hobson and Bayne 2000b, Kirk et al 1996, Kirk and Hobson 2001, Schieck and Song 2006, Salt 1973, Erskine 1977, ABMI 2009). Birds of North America online reports were also consulted and are listed next to the appropriate species in the list in Section 3.1.2. Although these songbirds are primarily associated with mature or old growth forests, some species do occur in other forest stand ages. Mature forest songbird communities were modelled using relative abundance and species richness, which treat counts of individuals and counts of species as indices of true abundance and true species richness, respectively, and are appropriate given study design standardization described in Section 2.1 (Nichols et al. 2008). Species richness was used to measure community diversity across the study area as a univariate measure of diversity (Costello et al. 2004). Relative abundance and species richness are useful indices of songbird temporal and spatial variation in the absence of demographic information (e.g., survival, fecundity) that is necessary to inform long-term mitigation (Schieck et al. 1995), but is more difficult to obtain (Nichols et al. 2008).

Spatial and temporal trends in songbird communities were examined using generalized linear models (negative binomial or Poisson) in Stata (StataCorp 2009) for a subset of the data (1,386 point counts) for which GIS layer vegetation and disturbance data were available.

Generalized linear models with negative binomial, Poisson, zero-inflated Poisson and zero-inflated negative binomial distributions were considered as potential model options. The commands *countfit* and *estat gof* were used in STATA (StataCorp 2009) to compare fit statistics between models with those distribution types and indicated that the mature forest songbird relative abundance data best fit the negative binomial distribution. Fit statistics indicated that negative binomial was inappropriate for species richness analyses; however *estat gof* indicated Poisson was the most appropriate model for 16 out of the 46 models, and examination of the mean, variance and histogram of mature forest songbird species richness confirmed that Poisson was appropriate (StataCorp 2009).

There were 18 local habitat, landscape habitat, landscape disturbance and temporal variables established for modeling mature forest songbird parameters (Tables 2 and 3). Preferred habitats were defined based on the literature to inform hypotheses (i.e., candidate models). Preferred habitats included mixedwood aspen – white spruce, predicted to be the most-preferred (Hobson and Bayne 2000a), deciduous aspen – balsam poplar (Westworth and Telfer 1993), coniferous white spruce (Kirk et al. 1996), and treed swamp. The treed swamp wetlands type is predicted to be a preferred habitat type because it contains white spruce (Matsuoka and Handel 2007). The importance of white spruce is further noted in the discussion of Birds of North America Online accounts listed in Section 3.1.2. Habitats predicted to be avoided by mature forest songbirds based on lower species richness and abundance included coniferous jack pine–black spruce (dry, nutrient poor and jack pine dominated), treed bog (wet, nutrient poor and black spruce dominated) (Kirk et al. 1996, Hobson and Bayne 2000a) and non-treed shrubby wetland (high contrast edge with an open area) (Brotons et al. 2003, López-Barrera et al. 2006).



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Table 2: Songbird parameter and categorical variable summary. Time categorical variable (year) with 10 levels, and local habitat categorical variable (avi_habitat) with 10 levels. Sample size, mean and standard deviation are displayed for songbird parameters, year and habitat groups. In the latter categorical variables (year and avi_habitat) the mean and standard deviation of mature forest songbird relative abundance are shown.

Variable Category	Variable Description	Code	Sample Size (n)	Mean	Standard Deviation
<u>Songbirds</u>	-	-	Number of Plots with ≥ 1 songbird:		
	mature forest songbird relative abundance	mature_count	1,012	1.47	1.36
	mature forest songbird richness	mature_rich	1,012	1.30	1.16
	songbird richness	richness	1,248	2.35	1.67
				<u>Mature Forest Songbird Relative Abundance</u>	
<u>Time</u>	Year (categories)	Year=	Number of Plots:	Mean	Standard Deviation
		2001	193	1.79	1.48
		2002	104	1.14	0.93
		2003	64	1.44	1.14
		2004	143	1.14	1.21
		2005	141	0.96	1.08
		2006	344	1.61	1.36
		2007	117	1.89	1.63
		2008	41	0.85	1.06
		2009	100	1.64	1.15
		2010	139	1.53	1.61
				<u>Mature Forest Songbird Relative Abundance</u>	
<u>Local Habitat</u>	habitat group (categories)	avi_habitat=	Number of Plots:	Mean	Standard Deviation
	coniferous jack pine–black spruce	1	254	1.24	1.17
	coniferous white spruce	2	38	1.97	1.55
	deciduous aspen–balsam poplar	3	203	2.02	1.41
	mixedwood aspen–white spruce	4	118	2.25	1.73
	mixedwood jack pine–aspen	5	61	1.46	1.19
	non-treed open wetland	6	28	0.39	0.74
	non-treed shrubby wetland	7	130	1.28	1.32
	treed bog	8	150	1.19	1.33
	treed fen	9	329	1.19	1.12
	treed swamp	10	75	1.81	1.38



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Table 3: Continuous variable summary. Four local habitat variables describe the percent canopy closure of old growth at the point count and vegetation height. Thirteen landscape variables are repeated for each of three spatial scales (250 m, 500 m and 1000 m). Range, mean and standard deviation of percentages are shown for continuous variables.

Variable Category	Variable Description	Code	Range	Mean	Standard Deviation
<u>Local Habitat</u>					
	percent canopy closure old deciduous(a)	p_old_decid	0-86	5.71	17.66
	percent canopy closure old coniferous (white spruce or balsam fir)(a)	p_old_up_conifer	0-61	2.36	8.90
	percent canopy closure old jack pine(a)	p_old_pine	0-86	2.30	9.86
	height (tree or shrub)	height	0-31	11.83	7.40
<u>Landscape Habitat</u>					
	Percent cover of coniferous white spruce	p250conif_sw	0-63	2.05	7.02
		p500conif_sw	0-42	1.95	5.18
		p1000conif_sw	0-27	1.75	3.58
	Percent cover of deciduous aspen-balsam poplar	p250decid_aw_pb	0-93	10.91	20.39
		p500decid_aw_pb	0-91	10.33	16.44
		p1000decid_aw_pb	0-78	9.99	13.36
	Percent cover of mixedwood aspen-white spruce	p250mixed_aw_sw	0-100	7.37	16.00
		p500mixed_aw_sw	0-100	7.13	13.13
		p1000mixed_aw_sw	0-73	7.03	10.65
	Percent cover of treed swamp	p250_treed_swamp	0-87	5.58	12.97
		p500_treed_swamp	0-70	5.41	10.64
		p1000_treed_swamp	0-52	5.12	8.20
	Percent cover of coniferous jack pine-black spruce	p250_conif_pj_sb	0-100	15.37	22.40
		p500_conif_pj_sb	0-97	15.17	18.43
		p1000_conif_pj_sb	0-86	14.94	14.98
	Percent cover of non-treed shrubby wetland	p250nt_Sh_wetl	0-98	7.91	16.43
		p500nt_Sh_wetl	0-92	8.00	13.06
		p1000nt_Sh_wetl	0-58	8.10	9.90



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Table 3: Continuous variable summary. Four local habitat variables describe the percent canopy closure of old growth at the point count and vegetation height. Thirteen landscape variables are repeated for each of three spatial scales (250 m, 500 m and 1000 m). Range, mean and standard deviation of percentages are shown for continuous variables (continued)

Variable Category	Variable Description	Code	Range	Mean	Standard Deviation
	Percent cover of treed bog	p250_treed_bog	0-97	10.69	19.72
		p500_treed_bog	0-97	11.24	16.14
		p1000_treed_bog	0-86	11.86	13.31
<u>Landscape Disturbance</u>					
	Percent cover of wide linear disturbance	p250lin_wide	0-41	2.22	5.52
		p500lin_wide	0-27	1.90	3.89
		p1000lin_wide	0-18	1.64	2.77
	Percent cover of narrow linear disturbance	p250lin_narrow	0-27	2.36	3.26
		p500lin_narrow	0-15	2.13	2.56
		p1000lin_narrow	0-14	2.02	2.20
	Percent cover of linear disturbance	p250lin_all	0-41	4.96	6.58
		p500lin_all	0-28	4.35	4.85
		p1000lin_all	0-22	3.97	3.78
	Percent cover of non-linear disturbance	p250_nonlin_all	0-96	3.80	13.02
		p500_nonlin_all	0-96	4.23	12.30
		p1000_nonlin_all	0-86	4.16	10.12
	Percent cover of combined linear and non-linear disturbance	p250_lin_nonlin_all	0-96	8.76	14.91
		p500_lin_nonlin_all	0-96	8.58	13.66
		p1000_lin_nonlin_all	0-88	8.12	11.33

^(a) Calculated from canopy tree species percent composition (%), midpoint of canopy percent closure (%), and stand age (AVI 2005)



Variable types assessed at the point count (local habitat) included: habitat composition (habitat group), habitat structure (height of the tallest vegetation layer), and percent canopy cover of old growth (>80 years old) trees. Old growth estimates in environmental impact assessments are often specific to the leading tree species, for example 100 years for deciduous and mixedwood stands, 120 years for jack pine stands, and 140 years for black spruce and tamarack stands (e.g., Cenovus FCCL Ltd. 2010). The broader stand age of 80 years or older was chosen to align with old growth definitions in the songbird literature (Kirk et al. 1996, Schmiegelow and Mönkönnen 2002, ABMI 2009) and to afford a larger range of variation in percent cover of old trees as a covariate for modeling response of mature forest songbirds.

Habitat composition and disturbance types were assessed at multiple spatial scales. The percent cover of habitat groups and disturbance types surrounding each point were quantified using circular buffers with radii of 250 m, 500 m and 1000 m. For this analysis 'large scale' denotes large area and 'small scale' denotes small area (Pennington and Blair 2011).

Correlations among nested landscape variables of the same kind were positive (e.g., mixedwood aspen – white spruce at the point count and mixedwood aspen – white spruce in the 250 m, 500 m or 1000 m scales) with $r \geq 0.70$ at the 250 m scale, except for treed swamp ($r = 0.62$), $r \geq 0.50$ at the 500 m scale and $r \geq 0.40$ at the 1000 m scale. Because determining the effects of scale was one objective, the categorical variable *avi_habitat* (local point count habitat group) was dropped from consideration in combined local and landscape habitat models in favour of including the percent cover of habitat at one of the three landscape spatial scales.

Eighteen models were constructed, representing competing hypotheses explaining variation in songbird relative abundance and species richness (Section 3.2.1, Table 7). Models were compared using Akaike's Information Criteria (AIC), Akaike weights (w_i for model i , i.e., the probability that the model is best given the data) and evidence ratios (ER; w_i/w_j , where w_i is the Akaike weight for model i , and w_j is the Akaike weight for model j (Burnham and Anderson 2002). Models were selected in a hierarchical fashion using AIC model selection where models with a ΔAIC less than 2 were considered to be competing as best models, models with a ΔAIC of 2 to 7 were considered to have some support (Burnham et al. 2011), and models with ΔAIC of >7 to 10 have very little support (Burnham and Anderson 2002).

Covariate effects for top models were evaluated based on incidence rate ratios (IRR). Incidence rate ratios can be used to describe the factor by which a covariate will decrease counts (IRR <1) or increase counts (IRR >1).

For example, if a continuous covariate x_1 has an IRR of 0.90, a one unit increase in x_1 will decrease the count by a factor of 0.90 (10%) (Hilbe 2008). For a categorical variable, a reference group is chosen and count in each category is said to decrease or increase relative to the reference group by the IRR factor (Hilbe 2008).

The 18 models were divided into one of five categories: local habitat (associated with the 50 m radius point count) (Local), landscape habitat (Lhab), landscape disturbance (Ldis), combined landscape habitat and disturbance (Lcomb), or combinations of local and landscape models (LocalLComb). Before constructing combined models (Lcomb or LocalLComb), the top models were first identified for the Local, Lhab, and Ldis categories, each of which had multiple within-category model types to consider (Section 3.2.1, Table 7). All models contained the variable year to control for temporally varying factors that might influence songbird habitat use, such as fluctuations in availability of insect prey (Kirk et al. 1996).



Delta AIC was calculated for three sets of model comparisons: 1) across spatial scales; 2) within model categories; and 3) across the model set. The comparison across spatial scales assessed the influence of scale (local point count, 250 m, 500 m, or 1000 m) on songbird habitat use. The across spatial scale comparison excluded LocalLComb models, which were combinations of local point count models with other spatial scales, which would have confounded the comparison of local and landscape variables. The within model categories comparison identified the best models within each of the model categories (Local, Lhab, Ldis, Lcomb, LocalLComb). The across the model set comparison was used to identify the top models across the entire model set, regardless of spatial scale or model category.

3.0 RESULTS

3.1 Habitat Associations in the Oil Sands Region

3.1.1 Boreal Songbird Community and Species of Concern

Boreal songbird surveys were conducted in June of 2001 to 2011 (ranging from June 1 to June 23) and July 5, 6 and 7, 2007. In total, 2,302 point counts were completed in 17 ecosite phases, 12 wetland types, shrubland, and six disturbed land cover types (burned wetland, burned upland, clearcut, well, clearing and cutline). Ages of disturbance were unknown. Disturbed areas were underrepresented in boreal songbird surveys by design, except for burns, because sample points are established a minimum of 100 m from roads and a minimum of 50 m from cutlines whenever possible (Section 2.1). Rare land cover types were underrepresented because point counts were typically placed in areas where at least five points of a given land cover type could be sampled to obtain an adequate sample size for local scale analyses.

Songbird Species Present

Considering all boreal songbird species combined, seventy-six species and 6,886 individual birds were recorded in 2,302 point counts in the study area. The six most commonly observed species comprised 50% of all observations. Tennessee warbler (*Vermivora peregrine*), yellow-rumped warbler (*Dendroica coronata*) and chipping sparrow (*Spizella passerina*) were the most common species, occurring at more than 15% of point counts surveyed (scientific names in Appendix A, Table A-3). Tennessee warbler was the most commonly detected species (17% of observations), followed by, in order of decreasing detection frequency, yellow-rumped warbler, chipping sparrow, ovenbird, ruby-crowned kinglet and dark-eyed junco.

Fifty-two species (68% of species recorded) occurred in five or more of the habitat groups surveyed in the study area. Nine species occurred in two or three habitat groups, while 15 species each occurred in only one habitat group (Appendix A, Table A-2). Tennessee warbler, magnolia warbler and red-eyed vireo were the most widespread species at the habitat group level and were found in all habitat groups. Alder flycatcher, chipping sparrow, white-throated sparrow and yellow-rumped warbler were detected in most habitat groups. Common species were most abundant in coniferous white spruce and treed swamp habitat groups. They were least abundant in linear development (vegetated) and mixedwood jack pine–aspen habitat groups.

Chipping sparrow and Tennessee warbler were also found in the most land cover types; they were observed in 33 and 32 of the 36 land cover types sampled, respectively (Appendix A, Table A-2). The most widespread species at the land cover type level were the chipping sparrow, Tennessee warbler, white-throated sparrow, Swainson's thrush, yellow-rumped warbler and alder flycatcher, which were found in the highest number of land cover types. They were most abundant in dogwood white spruce (e3), wooded swamp (STNN), and shrubby



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swamp (SONS). They were least abundant in shrubby bog (BONS), wooded fen with patterning (FTPN) and lichen-jack pine (a1).

Relative Abundance, Species Richness, and Species Diversity

Among habitat groups, mean (\pm standard deviation) relative abundance (i.e., detections per point count), species richness and diversity of all boreal songbirds combined tended to be highest in the moist to wet, medium to rich coniferous white spruce, treed swamp, and non-treed shrubby wetland habitat groups (Table 4), which tend to have high vegetative cover of trees and/or shrubs. Mean relative abundance, species richness and diversity were lowest in the dry, nutrient poor, and open coniferous jack pine–black spruce, mixedwood jack pine–aspen, and linear development (vegetated) habitat groups.

Though sample size was low, vegetated non-linear development (i.e., wellpads) and clearcuts had high relative abundance and species richness of boreal songbirds, with relatively low diversity. The presence of a few common species that use open habitats or young forest, such as Tennessee warbler, alder flycatcher, white-throated sparrow and chipping sparrow is likely influencing the high relative abundance in non-linear developments and clearcuts (Appendix A, Table A-1).

Table 4: Boreal Songbird Mean Relative Abundance, Species Richness and Diversity by Habitat Group in the Oil Sands Region (\pm standard deviation), 2001 to 2011

Habitat Group ^(a)	Number of Point Counts	Number of Birds	Mean Relative Abundance	Mean Species Richness	Mean Species Diversity ^(b)
coniferous jack pine–black spruce	389	797	2.05 (1.57)	1.79 (1.31)	0.51 (0.52)
coniferous white spruce	64	272	4.25 (2.36)	3.44 (1.93)	1.04 (0.60)
deciduous aspen–balsam poplar	245	868	3.54 (2.37)	2.87 (1.75)	0.88 (0.56)
mixedwood jack pine–aspen	88	169	1.92 (1.43)	1.64 (1.11)	0.45 (0.47)
mixedwood aspen–white spruce	422	1,394	3.30 (2.25)	2.76 (1.78)	0.84 (0.59)
non-treed open wetland	60	185	3.08 (2.73)	2.40 (2.06)	0.71 (0.63)
non-treed shrubby wetland	256	955	3.73 (2.73)	3.07 (2.04)	0.92 (0.64)
treed bog	279	719	2.58 (2.07)	2.10 (1.56)	0.61 (0.56)
treed fen	358	977	2.73 (1.85)	2.34 (1.50)	0.70 (0.57)
treed swamp	86	364	4.23 (2.98)	3.51 (2.34)	1.03 (0.65)
burn	25	79	3.16 (2.62)	2.72 (1.90)	0.80 (0.64)
clearcut	19	78	4.11 (2.64)	3.16 (2.12)	0.98 (0.63)
linear development (vegetated)	6	11	1.83 (2.14)	1.67 (1.75)	0.38 (0.64)
non-linear development (vegetated)	5	18	3.60 (1.52)	2.80 (2.05)	0.78 (0.81)
Total	2,302	6,886	2.99 (2.27)	2.49 (1.77)	0.74 (0.60)

^(a) See Table 1 for correlations of land cover types with habitat groups.

^(b) Species diversity was calculated for each point count using the Shannon diversity index (see methods for more details).

Note: Bird values are the mean number of individual birds, species, or diversity values observed per point count (plus or minus standard deviation).



Among land cover types, mean relative abundance was greatest in the dogwood white spruce (e3) ecosite phase, followed by treed swamp (STNN) shrubby swamp (SONS), horsetail white spruce (f3), and dogwood balsam poplar-white spruce (e2) land cover types (Appendix A, Table A-2). Mean species richness was greatest in the treed swamp (STNN) wetland type followed by dogwood white spruce (e3), shrubby swamp (SONS), horsetail white spruce (f3), and dogwood balsam poplar-white spruce (e2) land cover types (Appendix A, Table A-2). Mean species diversity was greatest in the dogwood white spruce (e3) ecosite phase, followed by treed swamp (STNN), horsetail white spruce (f3), dogwood balsam poplar-white spruce (e2), and shrubby swamp (SONS) land cover types (Appendix A, Table A-2).

Among land cover types with more than five point count stations, mean relative abundance tended to be lowest in the lichen jack pine (a1) ecosite phase, followed by disturbed-cutline, blueberry jack pine-aspen (b1), and Labrador tea-mesic jack pine-black spruce (c1) land cover types (Appendix A, Table A-2). Mean species richness was lowest in the lichen jack pine (a1) ecosite phase, followed by the blueberry jack pine-aspen (b1), disturbed-cutline, and Labrador tea-mesic jack pine-black spruce (c1) land cover types (Appendix A, Table A-2). Mean species diversity was lowest in the disturbed-cutline land cover type, followed by lichen jack pine (a1), blueberry jack pine-aspen (b1) and Labrador tea-mesic jack pine-black spruce (c1) land cover types (Appendix A, Table A-2). Though they did not have the lowest values for mean relative abundance, species richness and diversity, the Labrador tea-subhygric black spruce- jack pine (g1), graminoid fen (FONG) and treed bog (BTNN) land cover types tend to have low values for those indices relative to the highest values (Appendix A, Table A-2).

Songbird Species of Concern

Each of the fifteen songbirds listed as species of concern (Section 2.3) were recorded in the study area. In the study area, common yellowthroats and least flycatcher were most commonly detected with a relative abundance of 0.05 per point count station. The barn swallow, Blackburnian warbler, eastern phoebe and sedge wren were each only detected once in the study area. Habitat use in the study area by these listed species is described as follows, with further detail in Appendix A, Table A-1:

- One barn swallow was detected in the shrubby fen (FONS) wetland type.
- Eighty-eight bay-breasted warblers were detected in the study area, and relative abundance was highest in the mixedwood aspen-white spruce and treed swamp habitat groups. Bay-breasted warblers were mainly found in horsetail white spruce (f3) after standardizing by the number of point counts. They were also found in horsetail balsam poplar-white spruce (f2), and horsetail balsam poplar-aspen (f1) ecosite phases, and less commonly in 16 other land cover types.
- One Blackburnian warbler was detected in mixedwood aspen- white spruce habitat group (low-bush cranberry aspen-white spruce (d2) ecosite phase).
- Seventeen black-throated green warblers were detected in the study area, primarily in the deciduous aspen-balsam poplar habitat group (10 individuals). They were predominantly found in dogwood balsam poplar-aspen (e1) ecosite phase (six individuals). Black-throated green warblers were also detected in six other land cover types.



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- Thirty-seven brown creepers were detected in the study area, primarily in the mixedwood aspen–white spruce and deciduous aspen–balsam poplar habitat groups. Brown creepers were mainly found in the dogwood balsam poplar-aspen (e1) and low-bush cranberry aspen-white spruce (d2) ecosite phases after standardizing by the number of point counts. Brown creepers were also detected in nine other land cover types.
- Fifty-four Canada warblers were detected in the study area. Canada warblers had the highest relative abundance in the deciduous aspen–balsam poplar, coniferous white spruce, and mixedwood aspen–white spruce habitat groups. Highest Canada warbler relative abundance was observed in the dogwood white spruce (e3), dogwood balsam poplar-aspen (e1), horsetail balsam poplar-aspen (f1), and dogwood balsam poplar-white spruce (e2) ecosite phases. Canada warblers were also heard in 10 other land cover types.
- Ninety-two Cape May warblers were detected in the study area, primarily in the coniferous white spruce habitat group. Cape May warblers had the highest relative abundance in the dogwood white spruce (e3), low-bush cranberry white spruce (d3) and horsetail white spruce (f3) ecosite phases and were also detected in 13 other land cover types.
- Common yellowthroats were detected predominantly in the non-treed shrubby wetland and non-treed open wetland habitat groups, with 105 individuals detected in the study area. Their relative abundance was highest in graminoid marsh (MONG) and shrubby swamp (SONS) wetland types. Common yellowthroats were also detected in 15 other land cover types.
- One eastern phoebe was detected in the mixedwood aspen–white spruce habitat group (dogwood balsam poplar-white spruce [e2] ecosite phase).
- Least flycatchers were detected predominantly in the clearcut, linear development (vegetated), and deciduous aspen–balsam poplar habitat groups, with 122 individuals detected in the study area. Least flycatchers had the highest relative abundance on cutlines and clearcuts. However, only six points were sampled on cutlines and one least flycatcher was detected, while 19 points were sampled in clearcuts and six least flycatchers were detected. Low-bush cranberry aspen (d1) and dogwood balsam poplar-aspen (e1) ecosite phases had the highest relative abundance of least flycatchers for the non-developed land cover types. Least flycatchers were also observed in 13 other land cover types.
- Thirteen olive-sided flycatchers were detected in the study area; five were in non-treed shrubby wetland habitat group. Relative abundance was highest in the burn habitat group. Olive-sided flycatchers were observed in burned uplands (BUu), shrubby fen (FONS), and shrubby swamp (SONS) land cover types. Olive-sided flycatchers were also observed in five other land cover types.
- Eleven rusty blackbirds were detected in the study area in the non-treed open wetland, non-treed shrubby wetland and treed fen habitat groups. Rusty blackbirds occurred in the graminoid fen (FONG), shrubby fen (FONS) and treed fen (FTNN) wetland types.
- One sedge wren was detected in the non-treed shrubby wetland habitat group (shrubby fen (FONS) wetland type).



- Fifteen western wood pewees were detected in the study area. Seven were detected in the treed fen habitat group. Relative abundance was highest in open water (WONN) and graminoid marsh (MONG) wetland types. Western wood pewees were also observed in six other land cover types.
- Seventy-nine western tanagers were detected in the study area. Relative abundance was highest in the coniferous white spruce and mixedwood aspen–white spruce habitat groups. Western tanager relative abundance was highest in the blueberry aspen-white birch (b2), blueberry aspen-white spruce (b3), and dogwood white spruce (e3) ecosite phases. Western tanagers were also observed in 12 other land cover types.

3.1.2 Mature Forest Songbird Community

Based on the literature, the following 27 species were included in the mature forest songbird guild, which includes 10 species listed as species of concern and 19 Neotropical migrants:

- bay-breasted warbler (Venier et al 2011);
- black-and-white warbler (Kricher 1995);
- blackburnian warbler (Morse 2004);
- black-capped chickadee (Foote et al 2010);
- black-throated green warbler (Morse and Poole 2005);
- blue-headed vireo (James 1998);
- boreal chickadee (Ficken et al 1996);
- brown creeper (Hejl et al 2002);
- Canada warbler (Reitsma et al 2010);
- Cape May warbler (Baltz and Latta 1998);
- golden-crowned kinglet (Ingold and Galati 1997);
- least flycatcher (Tarof and Briskie 2008);
- olive-sided flycatcher (Altman and Sallabanks 2000);
- ovenbird (Porneluzi et al 2011);
- pine siskin (Dawson 1997);
- red-breasted nuthatch (Ghalambor and Martin 1999);
- red-eyed vireo (Cimprich et al 2000);
- ruby-crowned kinglet (Swanson et al 2008);



- Swainson's thrush (Mack and Yong 2000);
- varied thrush (George 2000);
- western tanager (Hudon 1999);
- western wood-pewee (Bemis and Rising 1999);
- white-breasted nuthatch (Grubb and Pravosudov 2008);
- white-winged crossbill (Benkman 1992);
- winter wren (Hejl et al. 2002, Kroodsma 2002);
- yellow-bellied sapsucker (Walters et al 2002); and
- yellow-rumped warbler (Hunt and Flaspohler 1998).

These songbirds are found in a variety of stand types (i.e., coniferous, mixedwood, and deciduous forests). Ten of the 15 species of concern are most prevalent in mature and old forests (ASRD 2011, COSEWIC 2010, SARA 2012).

Mature Forest Songbird Species Present

Twenty-seven mature forest songbird species and 2,840 individual mature forest songbirds were recorded in 2,302 boreal songbird point counts in the study area. The four most commonly observed forest species comprised approximately 58% of observations of mature forest songbird species. The yellow-rumped warbler was the most commonly detected mature forest species (23% of observations), followed by, in order of decreasing detection frequency, ovenbird, ruby-crowned kinglet and Swainson's thrush. The least detected mature forest songbirds (i.e., mean <0.01 per point count station) were Blackburnian warbler, varied thrush, white-breasted nuthatch, black-throated green warbler, olive-sided flycatcher and western wood pewee.

Mature Forest Songbird Relative Abundance and Species Richness

Mean relative abundance and species richness of mature forest songbirds were highest in the coniferous white spruce habitat group (Table 5). Mature forest songbirds were also common in deciduous aspen-balsam poplar, mixedwood aspen-white spruce and treed swamp. The land cover types with the greatest mean relative density (within the 50 m radius point count) of mature forest songbirds were dogwood white spruce (e3), dogwood balsam poplar-white spruce (e2), dogwood balsam poplar-aspen (e1), and blueberry aspen-white birch (b2) (Table 6). Forested subhygric to hygric, nutrient rich, and shrub (dogwood)-dominated land cover types appear to be important habitats for many mature forest songbirds in the boreal forest of northern Alberta. The coniferous white spruce, deciduous aspen-balsam poplar, mixedwood aspen-white spruce and treed swamp habitat groups were carried forward into Section 3.2 as "preferred habitats" for predictive modeling of boreal songbird parameters.



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Table 5: Mature Forest Songbird Mean Relative Abundance and Species Richness (\pm Standard Deviation) by Habitat Group the Oil Sands Region

Habitat Group ^(a)	Number of Point Counts	Number of Mature Forest Songbirds	Mean Relative Abundance of Mature Forest Songbirds	Species Richness of Mature Forest Songbirds
coniferous jack pine–black spruce	389	414	1.06 (1.04)	0.93 (0.89)
coniferous white spruce	64	132	2.06 (1.76)	1.89 (1.55)
deciduous aspen–balsam poplar	245	481	1.96 (1.64)	1.6 (1.22)
mixedwood jack pine–aspen	88	90	1.02 (0.97)	0.89 (0.81)
mixedwood aspen–white spruce	422	791	1.87 (1.65)	1.64 (1.29)
non-treed open wetland	60	18	0.3 (0.7)	0.28 (0.64)
non-treed shrubby wetland	256	156	0.61 (1)	0.54 (0.85)
treed bog	279	267	0.96 (1.19)	0.82 (0.96)
treed fen	358	310	0.87 (1.07)	0.76 (0.85)
treed swamp	86	139	1.62 (1.37)	1.48 (1.21)
burn	25	9	0.36 (0.91)	0.28 (0.61)
clearcut	19	25	1.32 (1.34)	1 (0.94)
linear development (vegetated)	6	4	0.67 (1.21)	0.5 (0.84)
non-linear development (vegetated)	5	4	0.8 (1.3)	0.8 (1.3)
Overall Mean or Total	2,302	2,840	1.23 (1.39)	1.07 (1.13)

^(a) See Table 1 for correlations of land cover types with habitat groups.

Note: Bird values are the mean number of individual birds or species values observed per point count (plus or minus standard deviation).

Mean relative abundance and species richness of mature forest songbirds was lowest in non-treed open wetlands, non-treed shrubby wetlands and burns. In habitat groups with a tree canopy, mean relative density were lowest in those dominated by jack pine and/or black spruce. Lichen jack pine (a1) has the lowest density of mature forest songbirds of any of the land cover types with tree canopy (Table 6). These habitats tend to be nutrient poor and either very wet or very dry. They have low structural complexity and usually lack large trees. The understory is relatively simple, often with high cover of lichen or moss and low cover of short, waxy shrubs. At the stand level, mature forest songbirds are known to respond to tree type (Holmes and Robinson 1981, Young 2005), foliage volume (De Graaf et al. 1985), stand structure (James and Warner 1982), and biomass (Zhang et al. 2012) to meet foraging and nesting needs. A non-treed forest structure limits foraging and nesting opportunities for mature forest songbirds. Non-treed shrubby wetlands, coniferous jack pine- black spruce and treed bog habitat groups were carried forward into Section 3.2 as “avoided habitats” for predictive modeling of boreal songbird parameters.

Though often preferred by mature forest songbirds, coniferous white spruce (Kirk et al. 1996, Hobson and Bayne 2000a) was uncommon in the areas sampled, with a low mean and standard deviation (Table 2). The percent cover of coniferous white spruce was considered in preliminary analysis to confirm that it did not add information to the model (i.e., $\Delta AIC < 2$ with virtually no change in log likelihoods [Burnham and Anderson 2002]) and was subsequently dropped from analyses.



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Table 6: Mature Forest Songbird Mean Density within 50 m (Standard Deviation) and Confidence Intervals by Habitat Group and Land Cover Type; 2001-2011

Habitat Group	Land Cover Type ^(a)	Number of Songbirds	Mean Relative Density (individuals/ha) (\pm SD)	Relative Density Confidence Interval (95%)
coniferous jack pine-black spruce	lichen-jack pine (a1)	48	0.9(1.1)	(1.2,0.7)
	blueberry white spruce-jack pine (b4)	21	1.8(1.4)	(2.5,1.1)
	Labrador tea-mesic jack pine-black spruce (c1)	150	1.5(1.3)	(1.7,1.2)
	Labrador tea-subhygric black spruce- jack pine (g1)	195	1.4(1.4)	(1.6,1.2)
coniferous white spruce	low-bush cranberry white spruce (d3)	63	2.3(2.2)	(3,1.6)
	dogwood white spruce (e3)	42	3.8(2.6)	(5.2,2.5)
	horsetail white spruce (f3)	27	2.3(1.7)	(3.2,1.4)
deciduous aspen-balsam poplar	blueberry aspen-white birch (b2)	46	3.1(2.4)	(4.2,2)
	low-bush cranberry aspen (d1)	360	2.4(2.1)	(2.7,2.1)
	dogwood balsam poplar-aspen (e1)	66	3(2.2)	(3.8,2.2)
	horsetail balsam poplar- aspen (f1)	9	1.6(1)	(2.4,0.9)
mixedwood aspen-white spruce	blueberry aspen-white spruce (b3)	87	2.1(1.4)	(2.4,1.7)
	low-bush cranberry aspen-white spruce (d2)	627	2.4(2.2)	(2.7,2.2)
	dogwood balsam poplar-white spruce (e2)	47	2.8(1.7)	(3.6,2.1)
	horsetail balsam poplar-white spruce (f2)	30	2(2.2)	(3,1)
mixedwood jack pine-aspen	blueberry jack pine-aspen (b1)	90	1.3(1.2)	(1.6,1)
non-treed open wetland	graminoid fen (FONG)	10	0.3(0.9)	(0.6,0.1)
	graminoid marsh (MONG)	6	0.4(0.9)	(0.9,0)
	open water (WONN)	2	0.5(1.1)	(1.5,-0.5)
non-treed shrubby wetland	shrubby bog (BONS)	0	0(na)	na
	shrubby fen (FONS)	67	0.6(1.1)	(0.8,0.4)
	riparian shrubland (Sh)	10	0.5(1)	(0.9,0.1)
	shrubby swamp (SONS)	79	1.1(1.5)	(1.4,0.8)
treed bog	forested bog (BFNN)	1	1.3(na)	na
	wooded bog (BTNN)	266	1.2(1.5)	(1.4,1)
treed fen	forested fen (FFNN)	2	0.8(1.5)	(2.5,-0.8)
	wooded fen (FTNN)	308	1.1(1.4)	(1.3,1)
	wooded fen with patterning (FTPN)	0	0(na)	na
treed swamp	Labrador tea/horsetail white spruce-black spruce (h1)	57	1.9(1.4)	(2.3,1.4)
	wooded swamp (STNN)	82	2.2(2)	(2.8,1.7)
Burn	burned upland (BUu)	9	0.6(1.3)	(1.3,0)
	burned wetland (BUw)	0	0(na)	(0,0)
Clearcut	clearcut (CC)	25	1.7(1.7)	(2.4,0.9)



Table 6: Mature Forest Songbird Mean Density within 50 m (Standard Deviation) and Confidence Intervals by Habitat Group and Land Cover Type; 2001-2011 (continued)

Habitat Group	Land Cover Type ^(a)	Number of Songbirds	Mean Relative Density (individuals/ha) (\pm SD)	Relative Density Confidence Interval (95%)
linear development (vegetated)	Cutline	4	0.8(1.5)	(2.1,-0.4)
non-linear development (vegetated)	Clearing	4	1.3(1.8)	(3,-0.5)
	Well	0	0(na)	na
Overall Mean or Total		2,840	1.6(1.8)	(3.9,3.7)

^(a) Beckingham and Archibald 1996.

Note: Bird values are the mean number of individual birds observed per point count (plus or minus standard deviation). Where standard deviation is (na), there was only one point count and standard deviation could not be calculated.

3.2 Mature Forest Songbird Predictive Modelling

Of the 2,302 boreal songbird point counts, 1,386 point counts had GIS layer vegetation and disturbance data available for predictive modelling (Section 2.3). Of those, 1,248 (90%) had records of one or more boreal songbirds, and 1,012 (73%) had records of one or more mature forest songbirds (Table 2), for a total of 2,040 individual mature forest songbirds. The predictive model dataset included 25 of the 27 mature forest songbird species (Section 3.1.2); no varied thrush or white-breasted nuthatch individuals were observed at point counts that met the criteria for analysis. The number of mature forest songbird species at a point count ranged from zero to six (mean = 1.30), and the number of mature forest songbird individuals at a point count ranged from zero to seven (mean = 1.47) (Table 2).

3.2.1 Mature Forest Relative Abundance

Top Models

Mature forest songbird relative abundance was influenced by local habitat, landscape habitat, and landscape disturbance variables.

Within the local category, the top model (Local-1 in Table 7) included the habitat group at the point count and height of the tallest vegetation layer (tree or shrub) at the point count. The local model with habitat alone had a small amount of support compared to other local category models (Δ AIC of 8.21). Preferred old growth trees (coniferous or deciduous) were not important factors describing mature forest songbird relative abundance (Δ AIC >10), though avoided old growth trees (jack pine) had a small amount of support (Δ AIC of 7.56; Table 7). Due to aforementioned correlations between habitat at nested scales, height was the only local habitat variable carried forward for some combined local and landscape models (LocalLComb or LocalLhab) (Table 7). Because landscape disturbance variables were not collinear with local habitat group, local habitat group could be added to combined local and landscape disturbance models (LocalLdis; Table 7).

Landscape habitat models (Lhab, Table 7) with preferred habitats (mixedwood aspen – white spruce, deciduous aspen – balsam poplar and treed swamp) and avoided habitats (coniferous jack pine–black spruce, non-treed shrubby wetland and treed bog) together (Lhab-4) had more support than models with either preferred habitats alone, avoided habitats alone, or models with mixedwood aspen – white spruce and non-treed shrubby wetland (Δ AIC >8.00, except for preferred habitats-only at the 250 m scale, which represented a competing model [Δ AIC=1.16]). Most landscape habitat-only models had less support than the local habitat-only models.



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Table 7: *A priori* mature forest songbird relative abundance (mature_count) model set. The model types for each category that were carried forward to combined models are bolded (included three spatial scales for Lhab and Ldis). The top model of the entire set is in bold and italics. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model.

Category	Model Number	Model ^(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
Local Habitat									
	Local-1	avi_habitat + height	4,246.20	15.97	0.00	0.00	0.96	29.20	0.00
	Local-2	height + p_old_pine	4,253.76	23.53	0.00	7.56	0.02	36.76	0.00
	Local-3	avi_habitat	4,254.41	24.18	0.00	8.21	0.02	37.41	0.00
	Local-4	height + p_old_up_conifer + p_old_decid	4,275.62	45.39	0.00	29.42	0.00	58.62	0.00
Landscape Habitat									
	Lhab-4a	p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog	4,272.57	42.34	0.00	0.00	0.60	55.57	0.00
	Lhab-4c	p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog	4,274.10	43.87	0.00	1.53	0.28	57.10	0.00
	Lhab-1a	p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp	4,275.72	45.50	0.00	3.16	0.12	58.72	0.00
	Lhab-4b	p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog	4,282.55	52.33	0.00	9.99	0.00	65.55	0.00



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Table 7: A priori mature forest songbird relative abundance (mature_count) model set. The model types for each category that were carried forward to combined models are bolded (included three spatial scales for Lhab and Ldis). The top model of the entire set is in bold and italics. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model ^(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	Lhab-1c	p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp	4,285.27	55.04	0.00	12.70	0.00	68.27	0.00
	Lhab-1b	p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp	4,290.78	60.55	0.00	18.21	0.00	73.78	0.00
	Lhab-2c	p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog	4,304.59	74.37	0.00	32.03	0.00	87.59	0.00
	Lhab-3c	p1000mixed_aw_sw + p1000nt_Sh_wetl	4,306.54	76.31	0.00	33.97	0.00	89.54	0.00
	Lhab-3a	p250mixed_aw_sw + p250nt_Sh_wetl	4,311.26	81.03	0.00	38.69	0.00	94.26	0.00
	Lhab-2b	p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog	4,312.39	82.16	0.00	39.82	0.00	95.39	0.00
	Lhab-3b	p500mixed_aw_sw + p500nt_Sh_wetl	4,313.98	83.75	0.00	41.41	0.00	96.98	0.00
	Lhab-2a	p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog	4,320.61	90.39	0.00	48.05	0.00	103.61	0.00
Landscape Disturbance									
	Ldis-1c	p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	4,311.37	81.14	0.00	0.00	0.81	94.37	0.00
	Ldis-1b	p500lin_wide + p500lin_narrow + p500_nonlin_all	4,314.42	84.20	0.00	3.06	0.18	97.42	0.00
	Ldis-1a	p250lin_wide + p250lin_narrow + p250_nonlin_all	4,319.94	89.71	0.00	8.57	0.01	102.94	0.00
	Ldis-3b	p500_lin_nonlin_all	4,328.95	98.73	0.00	17.59	0.00	111.95	0.00
	Ldis-3c	p1000_lin_nonlin_all	4,329.14	98.92	0.00	17.77	0.00	112.14	0.00
	Ldis-2c	p1000lin_all + p1000_nonlin_all	4,330.00	99.77	0.00	18.63	0.00	113.00	0.00



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Table 7: A priori mature forest songbird relative abundance (mature_count) model set. The model types for each category that were carried forward to combined models are **bolded** (included three spatial scales for Lhab and Ldis). The top model of the entire set is in **bold and italics**. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model ^(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	Ldis-2b	p500lin_all + p500_nonlin_all	4,330.87	100.64	0.00	19.50	0.00	113.87	0.00
	Ldis-3a	p250_lin_nonlin_all	4,333.02	102.79	0.00	21.65	0.00	116.02	0.00
	Ldis-2a	p250lin_all + p250_nonlin_all	4,334.73	104.50	0.00	23.36	0.00	117.73	0.00
Landscape Combined									
	Lcomb-2a	p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250lin_wide + p250lin_narrow + p250_nonlin_all	4,231.67	1.44	0.79	0.00	0.79	14.67	0.00
	Lcomb-1a	p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog + p250lin_wide + p250lin_narrow + p250_nonlin_all	4,234.33	4.10	0.21	2.66	0.21	17.33	0.00
	Lcomb-1c	p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	4,242.81	12.58	0.00	11.14	0.00	25.81	0.00
	Lcomb-2c	p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	4,244.39	14.17	0.00	12.72	0.00	27.39	0.00



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Table 7: A priori mature forest songbird relative abundance (mature_count) model set. The model types for each category that were carried forward to combined models are bolded (included three spatial scales for Lhab and Ldis). The top model of the entire set is in bold and italics. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model ^(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	Lcomb-1b	p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog + p500lin_wide + p500lin_narrow + p500_nonlin_all	4,245.35	15.12	0.00	13.68	0.00	28.35	0.00
	Lcomb-2b	p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500lin_wide + p500lin_narrow + p500_nonlin_all	4,245.80	15.58	0.00	14.13	0.00	28.80	0.00
Local & Landscape Habitat Combined									
	LocalLhab-1c	height + p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog	4,250.89	n/a	n/a	0.82	0.23	33.89	0.00
	LocalLhab-1b	height + p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog	4,254.22	n/a	n/a	4.15	0.04	37.22	0.00
	LocalLhab-1a	height + p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog	4,250.07	n/a	n/a	0.00	0.35	33.07	0.00
	LocalLhab-2c	height + p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp	4,253.35	n/a	n/a	3.28	0.07	36.35	0.00



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Table 7: A priori mature forest songbird relative abundance (mature_count) model set. The model types for each category that were carried forward to combined models are **bolded** (included three spatial scales for Lhab and Ldis). The top model of the entire set is in **bold and italics**. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model ^(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	LocalLhab-2a	height + p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp	4,250.89	n/a	n/a	0.82	0.23	33.89	0.00
	LocalLhab-2b	height + p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp	4,253.35	n/a	n/a	3.28	0.07	36.35	0.00
Local & Landscape Disturbance Combined									
	LocalLdis-1c	avi_habitat + height + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	4,220.97	n/a	n/a	0.00	0.48	3.97	0.08
	LocalLdis-1b	avi_habitat + height + p500lin_wide + p500lin_narrow + p500_nonlin_all	4,221.28	n/a	n/a	0.30	0.42	4.28	0.07
	LocalLdis-1a	avi_habitat + height + p250lin_wide + p250lin_narrow + p250_nonlin_all	4,224.12	n/a	n/a	3.14	0.10	7.12	0.02
Local & Landscape Combined (Habitat And Disturbance)									
	<i>LocalLComb-1a</i>	<i>height + p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250lin_wide + p250lin_narrow + p250_nonlin_all</i>	<i>4,217.00</i>	<i>n/a</i>	<i>n/a</i>	<i>0.00</i>	<i>0.69</i>	<i>0.00</i>	<i>0.58</i>
	LocalLComb-2a	height + p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog + p250lin_wide + p250lin_narrow + p250_nonlin_all	4,219.28	n/a	n/a	2.28	0.22	2.28	0.19



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Table 7: A priori mature forest songbird relative abundance (mature_count) model set. The model types for each category that were carried forward to combined models are **bolded** (included three spatial scales for Lhab and Ldis). The top model of the entire set is in **bold and italics**. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model ^(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	LocalComb-2c	height + p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	4,222.13	n/a	n/a	5.13	0.05	5.13	0.04
	LocalComb-1c	height + p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	4,223.98	n/a	n/a	6.98	0.02	6.98	0.02
	LocalComb-2b	height + p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog + p500lin_wide + p500lin_narrow + p500_nonlin_all	4,226.78	n/a	n/a	9.78	0.01	9.78	0.00
	LocalComb-1b	height + p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500lin_wide + p500lin_narrow + p500_nonlin_all	4,227.22	n/a	n/a	10.22	0.00	10.22	0.00

^(a) All models contained the additional variable "year" to control for temporal variation.



For example, the top landscape habitat-only model (Lhab-4a) had virtually no support compared to the top local habitat model (Local-1) ($\Delta AIC > 10$; Table 7).

Top landscape disturbance models (Table 7) included variables for anthropogenic disturbance categorized into wide linear disturbance, narrow linear disturbance and non-linear disturbance (Ldis-1). These models had more support than models with summed linear and non-linear disturbance (Ldis-3; $\Delta AIC > 10$), which in turn were equivalent to models with two disturbance types, linear and non-linear separated (Ldis-2; $\Delta AIC < 2$ compared to Ldis-3) (Table 7). Landscape disturbance-only models had less support than the top four landscape habitat-only models ($\Delta AIC > 10$) (Table 7).

The top landscape model combining habitat and disturbance (Lcomb) included preferred habitats at the 250 m scale (Lcomb-2a) (Table 7). At the 500 m and 1000 m scales, however, model Lcomb-1, which included preferred and avoided habitats, was equivalent to the model with preferred habitats only ($\Delta AIC < 2$; Table 7). Landscape models combining habitat and disturbance had more support than either the top landscape habitat ($\Delta AIC > 10$) or the top landscape disturbance models ($\Delta AIC > 10$) (Table 7).

There was one top model (LocalLComb-1a) in the combined local and landscape category which also had a 69% probability of being the top model given the data (Table 7). Compared to the top model (LocalLComb-1a), there were five models with some support (ΔAIC of 2 to 7 across the model set), and two models with very little support (ΔAIC of > 7 to 10 across the model set). All eight models with some support ($\Delta AIC < 10$) were variations on three model types at the three spatial scales (250 m, 500 m and 1000 m) examined. Each model combined height of the tallest vegetation layer, landscape habitat, and landscape disturbance (Table 7). The top model (LocalLComb-1a) included the surrounding percent cover of the three preferred habitats (mixedwood aspen – white spruce, deciduous aspen – balsam poplar and treed swamp) and disturbance split into three types (wide and narrow linear disturbance, non-linear disturbance) at the 250 m scale (Table 7). The second model type (LocalLComb-2) differed from the top model in that it included avoided habitat groups, and the third model type (LocalLdis-1) combined local variables (point count habitat group and height) with landscape disturbance (Table 7). Models combining local habitat (height) and landscape characteristics (models beginning with LocalL) had more support than any of the other categories ($\Delta AIC \geq 3$) (Table 7). Models combining height and landscape habitat (LocalLhab) had less support than models combining height, local habitat group and landscape disturbance (LocalLdis; $\Delta AIC > 10$). However, LocalLcomb models combining height, landscape habitat and landscape disturbance had the most support ($\Delta AIC > 3$ across the model set, except LocalLdis-1 which included the third-, fourth-, and seventh-best models) (Table 7). Across the model set, models with disturbance and/or preferred habitat variables were nearly equivalent (Evidence Ratio (ER) [disturbance/preferred habitat] = 1.20), and both had close to four times more support than models with avoided habitat variables (ER [disturbance/avoided habitat] = 4.23 and ER [preferred habitat/avoided habitat] = 3.57).

Effects of Spatial Scale

Across landscape models, the smallest scale (250 m) or the largest scale (1000 m) was each the top model for over half the relative abundance model types (Table 7). The exception was Ldis-3 (summed linear and non-linear disturbance), for which the 500 m scale model performed as well as the 1000 m model ($\Delta AIC = 0.19$) and better than the 250 m model ($\Delta AIC = 4.07$) (Table 7). Akaike weights summed for each scale across the model set strongly support the 250 m models (sum of AIC weights = 0.79) or the 1000 m models (sum of AIC weights = 0.14) with little support for the intermediate 500 m scale (sum of AIC weights = 0.08) and virtually no support for



the local point count scale (sum of AIC weights = 0.00) (Table 7). In models of disturbance variables controlling for local habitat (LocalLdis), the 1000 m scale was best, followed by the 500 m scale and lastly the 250 m scale, though differences between models were small ($\Delta AIC < 4$). However, in landscape habitat models that excluded local habitat group due to collinearity with buffer percent covers, the 250 m scale models had the most support, followed by the 1000 m scale and lastly the 500 m scale. Together, this suggests both a strong influence of local habitat conditions and an influence of the larger landscape scale. When the model did not include the finest measure of habitat (local point count habitat group), the smallest landscape scale (250 m) performed best. However, when fine scale habitat was represented by the local point count habitat group in disturbance models, the largest landscape scale of habitat examined (1000 m) performed best.

The top model types within a category were similar across scales for landscape models (Lcomb, Lhab and Ldis), whereas top combined local and landscape models (Lcomb, LocalLComb, LocalLdis or LocalLhab) differed between the 250 m scale and the 500 m and 1000 m scales (Table 7). However, the same three combined model types (LocalLComb-1, LocalLComb-2 and LocalLdis-1) had some support at each scale ($\Delta AIC < 9$). One 500 m model performed best compared to the other scales (Ldis-3b) (Table 7). For four out of 14 landscape models, the 500 m model was second-best. Most of the 500 m models that performed well focused on landscape disturbance variables (i.e., Ldis-1, Ldis-2, Ldis-3 and LocalLdis-1) (Table 7). Most of the 1000 m models that were top or second-best models also included disturbance variables (Table 7). By contrast, all of the 250 m models that performed better than one of the other scales included landscape habitat variables and less than half contained disturbance variables (Table 7).

Within the 500 m scale, models with disturbance variables had over nine times more evidence compared to models with landscape preferred habitat variables (ER [disturbance/preferred habitat] = 9.67) and 17 times more evidence compared to models with avoided habitat variables (ER [disturbance/avoided habitat] = 17.43). Within the 500 m scale, models with preferred habitats had almost two times more evidence compared to models with avoided habitats (ER [preferred habitat/avoided habitat] = 1.8). Models with disturbance variables were nearly equivalent to models with preferred habitat variables within the 250 m scale (ER [disturbance/preferred habitat] = 1.02) and had two times the evidence of models with preferred habitat variables within the 1000 m scale (ER [disturbance/preferred habitat] = 2.28). Within the 250 m scale, models with disturbance variables and models with preferred habitat variables each had four times more evidence than models with avoided habitat variables (ERs = 4.22). Within the 1000 m scale, models with disturbance variables had over three times more evidence than models with avoided habitats (ER [disturbance/avoided habitat] = 3.18), though models with preferred habitat variables had similar evidence compared to models with avoided habitat variables (ER [preferred habitat/avoided habitat] = 1.40). Thus, avoided habitats had little supportive evidence within each landscape scale, with the least evidence within the 250 m scale and the most evidence within the 1000 m scale, relative to other landscape variables. Evidence ratios also favoured models with disturbance variables over preferred variables within each landscape scale, with strongest evidence within the 500 m scale and weakest evidence within the 250 m scale. Preferred habitat variables had the most evidence within the 250 m scale, relative to other spatial scales.

Model Description

At the landscape level, mature forest songbirds were positively associated with their preferred habitat groups as predicted (mixedwood aspen–white spruce, deciduous aspen–balsam poplar, and treed swamp), though coefficients were low (Tables 7 and 8). For the top model, each 1% increase in mixedwood aspen–white spruce



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in the 250 m radius zone surrounding the point count was associated with an estimated 1% increase in relative abundance of mature forest songbirds (IRR=1.01) (Table 8). Each 1% increase in the surrounding cover of treed swamp was also associated with an estimated 1% increase in relative abundance of mature forest songbirds, while a 1% increase in the surrounding cover of deciduous aspen–balsam poplar resulted in a less than 1% increase in the relative abundance of songbirds (IRR=1.01 and IRR=1.00, respectively) (Table 8). Each 1 m increase in height of the tallest vegetation layer (tree or shrub) was estimated to result in a 2% increase in relative abundance (IRR=1.02) (Table 8),

Relative abundance was higher in 2001 relative to all other years, except for 2009 (Table 8). Compared to 2001, point counts surveyed in 2002-2008 and 2010 were predicted to have 14% to 42% fewer individual mature forest songbirds though the confidence interval for 2007 overlapped zero in the top model (Table 8). In the top model, point counts surveyed in the year 2009 were predicted to have 5% more individual mature forest songbirds, although the confidence interval overlapped zero. The magnitude of the decrease from 2001 to each of the other years except 2009 is highly variable, as demonstrated by effect sizes varying by an order of magnitude (lowest coefficient is 10 times smaller than the highest coefficient in Table 8).

Table 8: The mature forest songbird relative abundance top model LocalComb-1a consisted of the local variable height and 250 m landscape variables (three preferred habitats and three disturbance types) combined. Negative binomial regression.

Variable ^(a)	Coefficient	95% Confidence Interval for the Coefficient	Incident Rate Ratio
mature_count			
year==2002	-0.26*	[-0.51,-0.02]	0.77
year==2003	-0.32*	[-0.57,-0.06]	0.73
year==2004	-0.53***	[-0.75,-0.31]	0.59
year==2005	-0.56***	[-0.79,-0.33]	0.57
year==2006	-0.20*	[-0.37,-0.03]	0.82
year==2007	-0.15	[-0.34,0.05]	0.86
year==2008	-0.54**	[-0.90,-0.18]	0.58
year==2009	0.05	[-0.17,0.27]	1.05
year==2010	-0.38***	[-0.60,-0.16]	0.69
height	0.02***	[0.01,0.02]	1.02
p250mixed_aw_sw	0.01***	[0.01,0.01]	1.01
p250decid_aw_pb	0.00***	[0.00,0.01]	1.00
p250_treed_swamp	0.01**	[0.00,0.01]	1.01
p250lin_wide	0.02***	[0.01,0.03]	1.02
p250lin_narrow	-0.02*	[-0.04,-0.00]	0.98
p250_nonlin_all	0.01***	[0.00,0.01]	1.01
Constant	0.23*	[0.05,0.42]	-
lnalpha constant	-3.21***	[-4.50,-1.91]	-
alpha	0.04	[0.01, 0.15]	-

* p<0.05, ** p<0.01, *** p<0.001

^(a) Reference group for the dummy variable was year==2001, see Table 2 for variable descriptions.



For the top model (250 m scale), each 1% increase in the percent cover of wide linear disturbance surrounding the point count is associated with an estimated 2% increase in relative abundance of mature forest songbirds and each 1% increase in the percent cover of non-linear disturbance is associated with an estimated 1% increase in relative abundance of songbirds (Table 8). By contrast, a 1% increase in the surrounding cover of narrow linear disturbance is estimated to decrease the relative abundance of mature forest songbirds by a factor of 0.98 (2%) (Table 8).

Results for the aforementioned variables in the top model were similar in the second- and third-best models (Tables 8 and 9, respectively). In the second-best model, confidence intervals contained zero for the surrounding percent cover of avoided habitats (coniferous jack pine–black spruce, non-treed shrubby wetland and treed bog) indicating a lack of response by mature forest songbirds to the surrounding percent cover of avoided habitats (Table 9). All other local habitat groups were likely to have fewer individual mature forest songbirds than point counts with mixedwood aspen–white spruce by factors ranging from 0.22 (78% decrease in relative abundance in non-treed open wetland) to 0.85 (15% decrease in relative abundance in treed swamp), though confidence intervals included zero for non-treed shrubby wetland and treed swamp (Table 10).

Model parameter estimates were similar for a given variable at each scale, though avoided habitats and disturbance types tended to be stronger predictors at coarser scales (500 m or 1000 m) (unpublished data).



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Table 9: The mature forest songbird relative abundance second-best model LocalComb-2a ($\Delta AIC = 2.28$) consisted of year, height and 250 m landscape variables (three preferred habitats and three disturbance types) combined. Negative binomial regression.

Variable ^(a)	Coefficient	95% Confidence Interval for the Coefficient	Incident Rate Ratio
mature_count			
year==2002	-0.26*	[-0.51,-0.02]	0.77
year==2003	-0.33*	[-0.58,-0.07]	0.72
year==2004	-0.52***	[-0.74,-0.30]	0.59
year==2005	-0.55***	[-0.79,-0.32]	0.58
year==2006	-0.20*	[-0.37,-0.03]	0.82
year==2007	-0.15	[-0.35,0.04]	0.86
year==2008	-0.52**	[-0.89,-0.16]	0.59
year==2009	0.05	[-0.17,0.28]	1.06
year==2010	-0.36**	[-0.58,-0.14]	0.70
height	0.02***	[0.01,0.03]	1.02
p250mixed_aw_sw	0.01***	[0.00,0.01]	1.01
p250decid_aw_pb	0.00**	[0.00,0.01]	1.00
p250_treed_swamp	0.01**	[0.00,0.01]	1.01
p250_conif_pj_sb	0.00	[-0.00,0.00]	1.00
p250nt_Sh_wetl	0.00	[-0.00,0.01]	1.00
p250_treed_bog	0.00	[-0.00,0.00]	1.00
p250lin_wide	0.02***	[0.01,0.03]	1.02
p250lin_narrow	-0.02*	[-0.04,-0.00]	0.98
p250_nonlin_all	0.01***	[0.00,0.01]	1.01
Constant	0.23*	[0.02,0.44]	-
lnalpha constant	-3.28***	[-4.67,-1.89]	-
alpha	0.04	[0.01,0.15]	-

* p<0.05, ** p<0.01, *** p<0.001

^(a) Reference group for the dummy variable was year==2001, see Table 2 for variable descriptions.



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Table 10: The mature forest songbird relative abundance third-best model LocalLdis-1c ($\Delta AIC=3.97$) consisted of year, local habitat, height and 1000 m landscape variables (three disturbance types). Negative binomial regression.

Variable ^(a)	Coefficient	95% Confidence Interval for the Coefficient	Incident Rate Ratio
mature_count			
avi_habitat==1	-0.46***	[-0.66,-0.27]	0.63
avi_habitat==2	-0.29*	[-0.56,-0.02]	0.75
avi_habitat==3	-0.20*	[-0.37,-0.04]	0.82
avi_habitat==5	-0.41**	[-0.66,-0.16]	0.66
avi_habitat==6	-1.49***	[-2.15,-0.84]	0.22
avi_habitat==7	-0.28	[-0.59,0.02]	0.75
avi_habitat==8	-0.41**	[-0.68,-0.14]	0.66
avi_habitat==9	-0.39**	[-0.62,-0.15]	0.68
avi_habitat==10	-0.16	[-0.40,0.09]	0.85
year==2002	-0.49***	[-0.74,-0.24]	0.61
year==2003	-0.42**	[-0.68,-0.16]	0.66
year==2004	-0.68***	[-0.91,-0.46]	0.50
year==2005	-0.72***	[-0.96,-0.49]	0.49
year==2006	-0.30***	[-0.47,-0.13]	0.74
year==2007	-0.22*	[-0.42,-0.01]	0.81
year==2008	-0.57**	[-0.93,-0.21]	0.57
year==2009	-0.08	[-0.30,0.13]	0.92
year==2010	-0.41***	[-0.62,-0.19]	0.67
height	0.01*	[0.00,0.03]	1.01
p1000lin_wide	0.02*	[0.00,0.04]	1.02
p1000lin_narrow	-0.05**	[-0.07,-0.02]	0.96
p1000_nonlin_all	0.01***	[0.00,0.01]	1.01
Constant	0.86***	[0.54,1.19]	-
lnalpha constant	-3.28***	[-4.67,-1.90]	-
alpha	0.04	[0.01,0.15]	-

* p<0.05, ** p<0.01, *** p<0.001

^(a) Reference groups for dummy variables were Avi_habitat==4 and year==2001, see Table 2 for variable descriptions.



3.2.2 Mature Forest Species Richness

Top Models

Mature forest songbird species richness was influenced by local habitat, landscape habitat and landscape disturbance variables (Table 11), with patterns similar to those observed for relative abundance.

Within the local habitat category, the top model (Local-1r in Table 11) included the habitat group and height of the tallest vegetation layer (tree or shrub) at the point count. The other three models had virtually no support within the local category ($\Delta AIC > 10$; Table 11). Height was the only local habitat variable carried forward for most combined local and landscape models (LocalLComb or LocalLhab) and habitat group was also used in combined local and landscape disturbance models (LocalLdis).

Landscape habitat models (Lhab; Table 11) with preferred habitats and avoided habitats together (L-hab-4r) had more support than other landscape habitat models. Preferred habitats alone had some support at the 250 m scale ($\Delta AIC = 2.91$). Most landscape habitat-only models had less support than the local habitat-only models. The top landscape habitat-only model had virtually no support compared to the top local habitat model ($\Delta AIC > 10$; Table 11).

Similar to relative abundance results, top landscape disturbance models for species richness included variables for anthropogenic disturbance categorized into wide linear disturbance, narrow linear disturbance and non-linear disturbance (Ldis-1) (Table 11). Unlike results for relative abundance, the 500 m summed linear and nonlinear disturbance model was competitive (within category $\Delta AIC = 1.75$), and there was some support for models with summed linear disturbance (within category ΔAIC of 2.39 to 5.46). For consistency with the relative abundance model set, the three detailed disturbance types were carried forward for local and landscape combined models.

The top landscape model combining habitat and disturbance (Lcomb) included preferred habitats and three disturbance types at the 250 m scale (Lcomb-2a) (Table 11). The addition of avoided habitats had some support at the 250 m scale ($\Delta AIC = 2.42$) (Table 11). However, the models with preferred and avoided habitats together (Lcomb-1) had more support at the 500 m and 1000 m scales than the models with only preferred habitats. Landscape models combining habitat and disturbance had more support than either the top landscape habitat model, or the top landscape disturbance model ($\Delta AIC > 10$) (Table 11).

There were two competing top models (LocalLComb-2r_a and LocalLComb-1r_a) in the combined local and landscape category. Given the data, the top model LocalLComb-2r_a had a 61% probability of being the top model across the model set, and the competing model LocalLComb-1r_a had a 37% probability of being the top model (Table 11). Both competing models included 250 m spatial scale landscape habitat and disturbance variables, and differed in that the top model included the three avoided habitat groups (Table 11). Compared to the top models there was one model with very little support (LocalLComb-2r_c; $\Delta AIC = 8.60$) and the rest of the models had $\Delta AIC > 10$ across the model set (Table 11). The top seven models (most with $\Delta AIC > 10$) were all variations on the two top model types (LocalLComb-2 and LocalLComb-1) at the three spatial scales (250 m, 500 m and 1000 m) examined (Table 11). Each of the top seven models combined height of the tallest vegetation layer, preferred habitat groups and three disturbance types, with (LocalLComb-2r) or without (LocalLComb-1r) avoided habitat groups (Table 11). Across the model set, models with disturbance and/or preferred habitat variables were equivalent (ER [disturbance/preferred habitat] = 1.00), and both had close to two times more support than models with avoided habitat variables (ER [disturbance/avoided habitat] = 1.59 and ER [preferred habitat/avoided habitat] = 1.59).



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Table 11: *A priori* mature forest songbird species richness model set (response variable *mature_rich*). The model types for each category that were carried forward to combined models are bolded (multiple spatial scales for Lhab and Ldis). The top model of the entire set is in bold and italics. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model

Category	Model Number	Model(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
Local Habitat									
	Local-1r	avi_habitat + height	3,910.47	9.04	0.01	0.00	1.00	28.95	0.00
	Local-3r	avi_habitat	3,922.94	21.51	0.00	12.47	0.00	41.42	0.00
	Local-2r	height + p_old_pine	3,925.71	24.28	0.00	15.24	0.00	44.19	0.00
	Local-4r	height + p_old_up_conifer + p_old_decid	3,941.68	40.25	0.00	31.21	0.00	60.16	0.00
Landscape Habitat									
	Lhab-4r_a	p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog	3,934.98	33.55	0.00	0.00	0.76	53.46	0.00
	Lhab-1r_a	p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp	3,937.89	36.46	0.00	2.91	0.18	56.37	0.00
	Lhab-4r_c	p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog	3,940.19	38.76	0.00	5.21	0.06	58.67	0.00
	Lhab-4r_b	p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog	3,945.86	44.43	0.00	10.89	0.00	64.34	0.00
	Lhab-1r_c	p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp	3,953.88	52.45	0.00	18.90	0.00	72.36	0.00



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Table 11: *A priori* mature forest songbird species richness model set (response variable mature_rich). The model types for each category that were carried forward to combined models are bolded (multiple spatial scales for Lhab and Ldis). The top model of the entire set is in bold and italics. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	Lhab-1r_b	p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp	3,955.87	54.44	0.00	20.90	0.00	74.35	0.00
	Lhab-2r_c	p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog	3,980.44	79.01	0.00	45.47	0.00	98.92	0.00
	Lhab-3r_c	p1000mixed_aw_sw + p1000nt_Sh_wetl	3,988.02	86.59	0.00	53.04	0.00	106.50	0.00
	Lhab-2r_b	p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog	3,991.41	89.99	0.00	56.44	0.00	109.89	0.00
	Lhab-3r_a	p250mixed_aw_sw + p250nt_Sh_wetl	3,992.43	91.00	0.00	57.46	0.00	110.91	0.00
	Lhab-3r_b	p500mixed_aw_sw + p500nt_Sh_wetl	3,996.76	95.33	0.00	61.79	0.00	115.24	0.00
	Lhab-2r_a	p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog	4,002.59	101.17	0.00	67.62	0.00	121.07	0.00
Landscape Disturbance									
	Ldis-1r_b	p500lin_wide + p500lin_narrow + p500_nonlin_all	4,029.57	128.15	0.00	0.00	0.31	148.05	0.00
	Ldis-1r_a	p250lin_wide + p250lin_narrow + p250_nonlin_all	4,030.97	129.54	0.00	1.40	0.15	149.45	0.00
	Ldis-1r_c	p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	4,031.13	129.71	0.00	1.56	0.14	149.61	0.00
	Ldis-3r_b	p500_lin_nonlin_all	4,031.33	129.90	0.00	1.75	0.13	149.81	0.00
	Ldis-2r_b	p500lin_all + p500_nonlin_all	4,031.96	130.53	0.00	2.39	0.09	150.44	0.00
	Ldis-3r_c	p1000_lin_nonlin_all	4,032.16	130.73	0.00	2.59	0.09	150.64	0.00
	Ldis-2r_c	p1000lin_all + p1000_nonlin_all	4,033.96	132.53	0.00	4.39	0.03	152.44	0.00
	Ldis-3r_a	p250_lin_nonlin_all	4,034.41	132.98	0.00	4.83	0.03	152.89	0.00



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Table 11: *A priori* mature forest songbird species richness model set (response variable mature_rich). The model types for each category that were carried forward to combined models are bolded (multiple spatial scales for Lhab and Ldis). The top model of the entire set is in bold and italics. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	Ldis-2r_a	p250lin_all + p250_nonlin_all	4,035.03	133.60	0.00	5.46	0.02	153.51	0.00
Landscape Combined									
	Lcomb-2r_a	p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250lin_wide + p250lin_narrow + p250_nonlin_all	3,901.43	0.00	0.76	0.00	0.77	19.91	0.00
	Lcomb-1r_a	p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog + p250lin_wide + p250lin_narrow + p250_nonlin_all	3,903.85	2.42	0.23	2.42	0.23	22.33	0.00
	Lcomb-1r_c	p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	3,918.96	17.53	0.00	17.53	0.00	37.44	0.00
	Lcomb-2r_c	p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	3,923.33	21.90	0.00	21.90	0.00	41.81	0.00
	Lcomb-1r_b	p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog + p500lin_wide + p500lin_narrow + p500_nonlin_all	3,919.11	17.68	0.00	17.68	0.00	37.59	0.00



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Table 11: *A priori* mature forest songbird species richness model set (response variable mature_rich). The model types for each category that were carried forward to combined models are bolded (multiple spatial scales for Lhab and Ldis). The top model of the entire set is in bold and italics. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	Lcomb-2r_b	p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500lin_wide + p500lin_narrow + p500_nonlin_all	3,920.76	19.33	0.00	19.33	0.00	39.24	0.00
Local & Landscape Habitat Combined									
	LocalLhab-1r_c	height + p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog	3,907.01	n/a	n/a	6.06	0.04	25.49	0.00
	LocalLhab-1r_b	height + p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog	3,906.34	n/a	n/a	5.40	0.06	24.82	0.00
	LocalLhab-1r_a	height + p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog	3,900.95	n/a	n/a	0.00	0.86	19.43	0.00
	LocalLhab-2r_c	height + p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp	3,913.89	n/a	n/a	12.94	0.00	32.37	0.00
	LocalLhab-2r_a	height + p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp	3,907.01	n/a	n/a	6.06	0.04	25.49	0.00



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Table 11: *A priori* mature forest songbird species richness model set (response variable mature_rich). The model types for each category that were carried forward to combined models are bolded (multiple spatial scales for Lhab and Ldis). The top model of the entire set is in bold and italics. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	LocalLhab-2r_b	height + p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp	3,917.53	n/a	n/a	16.58	0.00	36.01	0.00
Local & Landscape Disturbance Combined									
	LocalLdis-1r_c	avi_habitat + height + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	3,903.56	n/a	n/a	3.03	0.13	22.04	0.00
	LocalLdis-1r_b	avi_habitat + height + p500lin_wide + p500lin_narrow + p500_nonlin_all	3,902.12	n/a	n/a	1.59	0.27	20.60	0.00
	LocalLdis-1r_a	avi_habitat + height + p250lin_wide + p250lin_narrow + p250_nonlin_all	3,900.53	n/a	n/a	0.00	0.60	19.01	0.00
Local & Landscape Combined (Habitat And Disturbance)									
	<i>LocalLComb-2r_a</i>	<i>height + p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250_conif_pj_sb + p250nt_Sh_wetl + p250_treed_bog + p250lin_wide + p250lin_narrow + p250_nonlin_all</i>	<i>3,881.52</i>	<i>n/a</i>	<i>n/a</i>	<i>0.00</i>	<i>0.62</i>	<i>0.00</i>	<i>0.62</i>
	<i>LocalLComb-1r_a</i>	<i>height + p250mixed_aw_sw + p250decid_aw_pb + p250_treed_swamp + p250lin_wide + p250lin_narrow + p250_nonlin_all</i>	<i>3,882.55</i>	<i>n/a</i>	<i>n/a</i>	<i>1.03</i>	<i>0.37</i>	<i>1.03</i>	<i>0.37</i>



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Table 11: *A priori* mature forest songbird species richness model set (response variable mature_rich). The model types for each category that were carried forward to combined models are bolded (multiple spatial scales for Lhab and Ldis). The top model of the entire set is in bold and italics. Δ AIC is the change in Akaike Information Criteria and w_i is the weight of evidence for that model (continued)

Category	Model Number	Model(a)	AIC	Across Spatial Scale Δ AIC	Across Spatial Scale w_i	Within Category Δ AIC	Within Category w_i	Across Model Set Δ AIC	Across Model Set w_i
	LocalLComb-2r_c	height + p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000_conif_pj_sb + p1000nt_Sh_wetl + p1000_treed_bog + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	3,890.12	n/a	n/a	8.60	0.01	8.60	0.01
	LocalLComb-2r_b	height + p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500_conif_pj_sb + p500nt_Sh_wetl + p500_treed_bog + p500lin_wide + p500lin_narrow + p500_nonlin_all	3,892.26	n/a	n/a	10.74	0.00	10.74	0.00
	LocalLComb-1r_c	height + p1000mixed_aw_sw + p1000decid_aw_pb + p1000_treed_swamp + p1000lin_wide + p1000lin_narrow + p1000_nonlin_all	3,896.29	n/a	n/a	14.77	0.00	14.77	0.00
	LocalLComb-1r_b	height + p500mixed_aw_sw + p500decid_aw_pb + p500_treed_swamp + p500lin_wide + p500lin_narrow + p500_nonlin_all	3,896.92	n/a	n/a	15.40	0.00	15.40	0.00

^(a) All models contained the additional variable "year" to control for temporal variation.



Effects of Spatial Scale

Across landscape models, the smallest scale (250 m) or the largest scale (1000 m) was each the top model for over half the species richness model types (Table 7). The exceptions were the three landscape disturbance models, for which the 500 m scale model performed as well or better than the 250 m and 1000 m scale models (Table 11). Overall, Akaike weights summed for each scale across the model set strongly support the 250 m models (summed AIC $w_i=0.99$), with little evidence for 1000 m models (summed AIC $w_i = 0.01$) and virtually no evidence for 500 m models (summed AIC $w_i = 0.00$). For species richness models of disturbance variables controlling for local habitat (LocalLdis) the 250 m scale model was best, followed by the 500 m scale and lastly the 1000 m scale, which was opposite the trend for relative abundance models, though differences between models were small ($\Delta AIC < 5$) (Table 11). In landscape habitat-only models, the 250 m or 1000 m models performed best. Overall, mature forest songbird species richness was modeled best by the fine-scale 250 m variables (Table 11). Comparatively, relative abundance models had more support for 1000 m variables compared to species richness models (Tables 3 and 10).

The top model types within a category were usually the same across spatial scales for landscape and combined models. One exception occurred within the local and landscape combined category, where models of preferred and avoided habitats combined performed better at the 500 m and 1000 m scales than models with only preferred habitat; the latter performed better at the 250 m scale (Table 11). Similar to results for relative abundance, avoided habitats had little supportive evidence within each landscape scale, with the least evidence within the 250 m scale (ERs [disturbance/avoided habitats] = 1.60 and [preferred habitats/avoided habitats] = 1.60) and the most evidence within the 1000 m scale (ERs [disturbance/avoided habitats] = 1.05 and [preferred habitats/avoided habitats] = 1.05), relative to other landscape variables. Evidence ratios slightly favoured models with disturbance variables over preferred variables within each landscape scale. Though evidence was very weak overall, it was again strongest within the 500 m scale (ER [disturbance/preferred habitats] = 1.01) and weakest within the 250 m scale (ER [disturbance/preferred habitats] = 1.00). Preferred habitat variables had the most evidence within the 250 m scale, relative to other spatial scales.

Model Description

At the landscape level, for both top models, each 1% increase in mixedwood aspen–white spruce in the 250 m radius zone surrounding the point count was associated with an estimated 1% increase in species richness of mature forest songbirds (IRR=1.01), as was each 1% increase in the surrounding amount of treed swamp (IRR=1.01; Tables 12 and 13). A 1% increase in the surrounding cover of deciduous aspen–balsam poplar resulted in a less than 1% increase in the relative abundance of songbirds (IRR=1.00, respectively) (Tables 12 and 13). Each 1 m increase in height of the tallest vegetation layer (tree or shrub) was estimated to result in a 2% increase in the number of mature forest songbird species (IRR=1.02) (Tables 12 and 13). Though included in the second-best model, avoided habitats were not strong predictors of the number of mature forest songbird species, with confidence intervals overlapping zero (Tables 12 and 13).

Year was modeled as a continuous variable to evaluate trends in number of species observed over time. The model estimated that with each increasing year, the number of mature forest songbird species would decrease by a factor of 0.98, i.e., there was a trend for a 2% decrease in the number of species observed each year (Tables 12 and 13).

For both top models, each 1% increase in the percent cover of wide linear disturbance surrounding the point count is associated with an estimated 2% increase in the number of mature forest songbird species and each 1% increase in the percent cover of non-linear disturbance is associated with an estimated 1% increase in the



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number of mature forest songbird species (Tables 12 and 13). By contrast, a 1% increase in the surrounding cover of narrow linear disturbance is estimated to decrease the number of mature forest songbird species by a factor of 0.99 (1%) (Tables 12 and 13). For a given model type, model parameter estimates were similar for a given variable at each scale, though avoided habitat, wide linear disturbance, and non-linear disturbance variables tended to be stronger predictors at coarser scales (500 m or 1000 m) (unpublished data).

Table 12: The mature forest songbird species richness top model LocalComb-2r_a consisted of the local variable height and 250 m landscape variables combined. Landscape variables included preferred habitat, avoided habitat and three disturbance types. Poisson regression.

Variable	Coefficient	95% Confidence Interval for the Coefficient	Incident Rate Ratio
mature_rich			
year	-0.02*	[-0.04,-0.00]	0.98
height	0.02***	[0.01,0.03]	1.02
p250mixed_aw_sw	0.01***	[0.00,0.01]	1.01
p250decid_aw_pb	0.00**	[0.00,0.01]	1.00
p250_treed_swamp	0.01***	[0.00,0.01]	1.01
p250_conif_pj_sb	0.00	[-0.00,0.00]	1.00
p250nt_Sh_wetl	0.00	[-0.00,0.01]	1.00
p250_treed_bog	0.00	[-0.00,0.00]	1.00
p250lin_wide	0.02***	[0.01,0.02]	1.02
p250lin_narrow	-0.01	[-0.02,0.01]	0.99
p250_nonlin_all	0.00**	[0.00,0.01]	1.00
Constant	40.16*	[1.13,79.19]	

* p<0.05, ** p<0.01, *** p<0.001

Table 13: The mature forest songbird species richness second-best model LocalComb-1r_a ($\Delta AIC=1.03$) consisted of the local variable height and 250 m landscape variables combined. Landscape variables included preferred habitat and three disturbance types. Poisson regression.

Variable	Coefficient	95% Confidence Interval for the Coefficient	Incident Rate Ratio
mature_rich			
year	-0.02*	[-0.04,-0.00]	0.98
height	0.02***	[0.01,0.03]	1.02
p250mixed_aw_sw	0.01***	[0.01,0.01]	1.01
p250decid_aw_pb	0.00***	[0.00,0.01]	1.00
p250_treed_swamp	0.01***	[0.00,0.01]	1.01
p250lin_wide	0.02***	[0.01,0.03]	1.02
p250lin_narrow	-0.01	[-0.02,0.01]	0.99
p250_nonlin_all	0.01***	[0.00,0.01]	1.01
Constant	43.13*	[4.57,81.69]	

* p<0.05, ** p<0.01, *** p<0.001



4.0 DISCUSSION

Local habitat features and landscape composition were both found to influence mature forest songbird habitat selection in the study area. This demonstrates the need to consider the hierarchical nature of breeding songbird habitat selection (Pennington and Blair 2011) when assessing and mitigating the effects of disturbance on songbirds (i.e., songbirds selecting home ranges within a landscape, territories within a home range, and nest or foraging microhabitats within a territory) (Rolstad et al. 2000, Latif et al. 2011).

In predictive models, habitat variables and disturbance variables both influenced mature forest songbird community parameters, at small and large scales. Preferred habitat groups (mixedwood aspen–white spruce, deciduous aspen–balsam poplar, and treed swamp) have a strong influence on mature forest songbird relative abundance, especially at finer scales (i.e., the local point count and the 250 m scale). Avoided habitat groups (coniferous jack pine–black spruce, non-treed shrubby wetland and treed bog) have a lesser influence on mature forest songbirds (i.e., in our system the avoidance is weak); however, failure to detect selection at the scales examined does not preclude selection at broader spatial scales than those we examined (Mayor et al. 2009) or selection based on aspects of habitat not considered in this study (Pennington and Blair 2011). Disturbance influence varied by type and was possibly more influential at larger landscape scales, especially the mid-range spatial scale examined (500 m).

4.1 Habitat Associations in the Oil Sands Region

Coniferous white spruce, treed swamp and non-treed shrubby wetland habitat groups had highest overall songbird relative abundance, species richness and species diversity and were also often selected by species of concern. Component land cover types of these highly preferred habitat groups tended to be moist (mainly subhydric to mesic) with a medium to rich nutrient regime and high vegetation cover (Beckingham and Archibald 1996, Halsey et al. 2003). Songbird-preferred ecosite phases have high cover in the form of a white spruce canopy and a shrubby understory, whereas preferred wetland types have high cover of willows and other shrubs (Beckingham and Archibald 1996, Halsey et al. 2003). The high vegetative cover likely provides more structural complexity, greater plant species diversity and thus more alternatives for nest site selection and foraging for songbirds (Hobson and Bayne 2000a). For birds in temperate regions, there appears to be a close relationship between habitat diversity and species diversity (Rosenzweig 1995). Non-treed shrubby wetlands are likely to support high numbers of insect prey (Cheskey et al. 2011), as well as higher foraging cover compared to non-treed open wetlands.

For mature forest songbirds, coniferous white spruce, deciduous aspen-balsam poplar and mixedwood aspen-white spruce habitat groups had highest relative abundance and species richness. Coniferous white spruce, deciduous aspen-balsam poplar and mixedwood aspen-white spruce are characterized by moist soils, a medium-rich nutrient regime and a diverse and complex understory with tall leafy shrubs such as cranberry (Beckingham and Archibald 1996). The land cover types associated with these habitat groups tend to have a stratified broadleaf shrub layer (i.e., prickly rose, Saskatoon, cranberry, willow, twinflower, dogwood, raspberry, honeysuckle) (Beckingham and Archibald 1996). Horizontal and vertical cover is high, and these habitats provide a wide variety of foraging and nesting microhabitats. These nutrient rich habitats usually have larger trees than the other habitats, leading to increased foliage volume, and thus increased foraging and nesting opportunities (Hobson and Bayne 2000a). Mature deciduous stands tend to be well-stratified forests with relatively open sub-canopy beneath a dense upper canopy (Breckenridge 1956, Sherry 1979, Briskie 1995). These habitats also tend to have at least a small percentage (i.e., 1-5%) of conifers such as white spruce



(Beckingham and Archibald 1996). Based on the Birds of North America accounts listed in Section 3.1.2 for the 27 species classified as mature forest songbirds, 63% (n=17) nest in live trees and 70% (n=12) of those most often nest in conifer tree species. In addition, 67% of the mature forest songbirds are more prevalent in conifer dominated habitats, regardless of nest site selection (Birds of North America accounts listed in Section 3.1.2).

Overall boreal songbird relative abundance, species richness and diversity tended to be lowest in dry or very wet, nutrient poor, and/or open habitat dominated by jack pine and/or black spruce. Hobson and Bayne (2000a) found that overall, white spruce and trembling aspen stands had higher species richness and relative abundance than jack pine or black spruce stands. Jack pine and black spruce habitat groups have less structural and plant species diversity in the overstorey and understory than aspen or white spruce dominated habitat groups (Kirk and Hobson 2001), as well as lower shrub and ground cover diversity. Component land cover types of avoided habitat groups tend to be open, dry, and nutrient poor with a sparse understory and low shrub and ground cover diversity. Land cover types with low boreal songbird relative abundance, species richness and diversity are dominated by shrubs less than 0.5 m in height, by stunted trees, or by graminoids (Beckingham and Archibald 1996, Halsey et al. 2003). Similarly, cutlines tend to be open, hot and dry with low songbird relative abundance, richness and diversity. However, low sample size might be leading to spurious results for anthropogenic disturbances (clearcut, cutlines, clearing and wellpad) and burned areas. Mature forest songbird abundance, density and richness were similarly low in dry uplands dominated by jack pine and/or black spruce. Mature forest songbird parameters were also low in non-treed open or shrubby wetlands, however overall songbird abundance, richness and diversity were high in non-treed shrubby wetlands. Future research examining songbird use of disturbed, regenerating or reclaimed land cover types would require additional sampling of the underrepresented land cover types.

4.2 Mature Forest Songbird Predictive Modelling

Local and Landscape Habitat Influence

Influential local habitat variables included compositional (habitat group) and structural (height of the tallest vegetation layer [tree or shrub]) variables, similar to other research showing that both habitat composition and structure are important for forest songbirds (Drapeau et al. 2000, Pennington and Blair 2011, Zhang et al. 2012). At the local point count scale, mixedwood aspen–white spruce was identified as the best habitat for mature forest songbirds, similar to findings of Kirk et al. (1996), Drapeau et al. (2000) and Hobson and Bayne (2000a), and coniferous jack pine–black spruce and non-treed open wetland had the lowest relative abundance and species richness of mature forest songbirds, though sample size was low for non-treed open wetland. The percent cover of different types of old growth trees were not influential variables, in contrast with other studies (Schieck et al. 1995, Kirk et al. 1996, Brotons et al. 2003). Mature forest songbirds were positively associated with height of the tallest vegetation layer (shrub or tree), and it is possible that vegetation height, although not correlated directly with the percent cover of old growth trees, might have acted as a structural surrogate for old, large diameter trees, preferred as nest trees by some species (Matsuoka and Handel 2007), such that the percent cover of old growth variables did not improve the model.

Influential landscape habitat variables included the percent cover of preferred habitat groups (mixedwood aspen–white spruce, deciduous aspen–balsam poplar, and treed swamp), which is consistent with observed patterns of habitat associations (Section 3.1), and with the literature (Kirk et al. 1996, Hobson and Bayne 2000a). Though three out of eight models with some support included the percent cover of avoided habitats, confidence intervals were overlapping. Thus, mature forest songbirds did not show strong avoidance of habitats dominated



by black spruce (Kirk et al. 1996), jack pine (Hobson and Bayne 2000a) or non-treed shrubby wetlands at the landscape scale. In the case of point counts in forests surrounded by some percentage of treed bog or non-treed shrubby wetlands, the lack of response could indicate that those shrubby wet areas were perceived as “soft” edges, and might provide important resources (i.e., insects to feed their chicks; Rodriguez et al. 2001) when occurring in low amounts adjacent to preferred old or mature forest, unlike “hard” edges (López-Barrera et al. 2006) with open areas, which are often negatively associated with old growth birds (Brotons et al. 2003).

The top models of mature forest songbird relative abundance and mature forest songbird richness included both local habitat and landscape habitat variables. However, local habitat models had more support than landscape habitat-only models. Support for both local and landscape observations together is consistent with previous research. For example, St-Laurent et al. (2007) found that local stand structure explained more variation than landscape characteristics, though both were important. Drapeau et al. (2000) found that local and landscape scale variables contributed equally to explaining variation in bird community data, and Zhang et al. (2012) demonstrated that local-scale vegetation observations collected across large geographical extents were required to understand bird diversity across scales.

The trend for decreasing abundance and richness with year warrants further investigation into potential causes, such as fluctuations in weather patterns or insect abundance (Volney and Fleming 2000), increasing amount of disturbance in the boreal, or other changes in songbird resources over time.

Landscape Disturbance Influence

Models with disturbance differentiated into detailed disturbance types (non-linear disturbance, wide linear disturbance and narrow linear disturbance) had a greater influence on songbird community parameters than did models with all disturbance, or models with two types of disturbance. The models with three disturbance types were favoured more strongly for relative abundance than for species richness. The importance of disturbance type is supported by findings of Bayne et al. (2005a), who found that ovenbird distribution was influenced more strongly by wide (8-m) conventional seismic lines than narrow (2- to 3-m) seismic lines. Kociolek et al. (2011) summarized negative effects of paved road networks on birds, which might be contributing to the worldwide decline of bird populations, and noted that some bird species are reluctant to cross even 10–30 m wide dirt roads, while others are limited only once the gap is 50 m in size. Summed linear and non-linear disturbance had more support than disturbance including a variable for “all” linear disturbance, likely due in part to the opposite direction of response to wide (positive) and narrow (negative) linear disturbances. This result underscores the idea that disturbance categories need to be created at a resolution that matches the resolution of a species’ response in order for an effect to be detected (Bayne et al. 2005a).

Mature forest songbird relative abundance and species richness were positively associated with increasing amounts of wide linear disturbance and non-linear disturbance. This is not intuitive, because there are many examples of negative effects of wide linear features (e.g., roads) or non-linear gaps on forest birds (e.g., Bélisle and Desrochers 2002, Fahrig and Rytwinski 2009, Kociolek et al. 2011). Wide linear disturbances (e.g., pipelines, powerlines, railways and roads) are often purposefully maintained as open features and have hard edges (Larrivée et al. 2008), compared to narrow linear disturbances (e.g., cutlines and seismic lines) which might not exhibit edge effects (Pohlman et al. 2007) and are often left to regenerate, though regeneration could be suppressed (Bayne et al. 2005a). Cutlines and seismic lines furthermore might be narrow enough to mimic small natural gaps, which have been noted to have little effect on boreal songbirds (Forsman et al. 2010). The influence of disturbance at a local scale could not be demonstrated with this dataset, because methods required



the local point count to be free of disturbance. Future field studies could be designed to account for the effects of local scale disturbance, for example by sampling in severely disturbed forest. One hypothesis would be that increased density of local disturbance might have a more prominent negative effect than disturbance at a landscape scale. However, this unexpected result could occur within forest remnants at any scale if relative abundance or species richness in a particular habitat is not indicative of the quality of that habitat, especially in human-disturbed areas where changes to quality might be unrecognizable to birds (Hannah et al. 2008). In some cases, avian density can even be negatively related to reproductive success (Bock and Jones 2004). Woodland birds might choose nesting sites with heterogeneous structure (Schlaepfer et al. 2002, Pennington and Blair 2011), which is adaptive in a natural setting, such as the diverse understorey of a mixedwood aspen–white spruce forest stands. However, in human-disturbed areas, edge habitats with heterogeneous structure remain attractive to woodland birds, but also can have high rates of nest failure due to nest predators and parasites (Schlaepfer et al. 2002) and therefore negative fitness consequences (Latif et al. 2011). Forest remnants surrounded by increasing amounts of wide linear disturbance might be causing an ecological trap, wherein mature forest songbird relative abundance is high in response to normally adaptive cues, but nesting success and/or survival might be low (Schlaepfer et al. 2002, Hannah et al. 2008). Positive response to wide linear disturbance or non-linear disturbance could also relate to overcrowding of mature forest songbirds if disturbance is relatively new such that edge effects have not yet developed (Schmiegelow et al. 1997, Villard et al. 2007), or if songbirds are unable or unwilling to cross non-linear or wide linear gaps (Forsman et al. 2010) to disperse to less crowded forest remnants. Given the unexpected positive relationship of relative abundance with two types of human disturbance, demographic measures of population processes (e.g., competition, survival, reproduction, recruitment and dispersal) (Lampila et al. 2005) and fitness consequences are required to understand the significance of disturbance use (Jones 2001).

The negative association with narrow linear disturbances (cutlines and seismic lines) provides a clue that competition for space and dispersal limitation might be at work. Bayne et al. (2005a) and Machtans (2006) found that species nesting on the ground (e.g., ovenbird) and in shrubs would include seismic lines in their territories, but would defend larger territories, perhaps to compensate for lower food availability due to habitat loss from seismic line construction. Dominant individuals excluded subordinate birds from their enlarged territories, and the subordinate birds were likely able to cross the narrow gaps created by seismic lines (Forsman et al. 2010) and disperse to a new area, thus lowering the relative abundance of songbirds at the point count (Bayne et al. 2005a). Gap crossing studies show that songbird dispersal and other movements can be limited by large gaps and small gaps have a lesser effect for some species (Forsman et al. 2010, Kociolek et al. 2011). By contrast, wide linear disturbances and non-linear disturbance (which also tends to be wider than seismic lines and cutlines) might act as a dispersal barrier that birds are unwilling to cross (Rodriguez et al. 2001, Bélisle et al. 2001), trapping individual birds at least temporarily in close quarters, despite low amounts of food, negative competitive interactions, or other detrimental fitness consequences.

Despite evidence for negative effects, Whitaker et al. (2008) suggested that boreal songbird populations are resilient and able to compensate for major disturbance through adaptable movement behaviours whereby individuals use the landscape at a scale that exceeds that of major disturbance events. Disturbance would have to be spatially and temporally similar to natural disturbance, and remaining habitat would need to be below carrying capacity (Bayne et al. 2005b) in order for the birds to be naturally resilient (Whitaker et al. 2008). It is possible that the boreal forest is not at carrying capacity for songbirds, such that individuals are not as constrained by territorial neighbours and by definition suitable but unused “excess” habitat exists in the



landscape (Bayne et al. 2005b). If the boreal forest is below carrying capacity, the increase in mature forest songbird relative abundance in remnant forest patches surrounded by increasing amounts of disturbance could occur without negative demographic effects, i.e., there would be no ecological trap. However, there are likely thresholds of disturbance and habitat loss at the landscape scale beyond which birds have reached or exceeded carrying capacity, have used up the “excess” habitat, and are no longer able to compensate (Bayne et al. 2005b). Beyond such thresholds of disturbance, resilience would break down and adverse demographic effects and extinctions would occur (Whitaker et al. 2008). For example, Edenius and Sjöberg (1997) noted that patches larger than 10 ha are likely required to maintain specialist species and thus high species richness in the boreal forest of northern Sweden.

Two species within the mature forest songbird guild, ruby-crowned kinglet and yellow-rumped warbler, were common (17% and 31% of mature forest songbird observations used in predictive modeling, respectively) and are associated with edges between forest and open areas (St-Laurent et al. 2009), though yellow-rumped warbler movement is also known to be impeded by forest gaps (Bélisle and St. Clair 2001) and both species had lower apparent survival in landscapes with clearcuts (Whitaker et al. 2008). These two common edge-associated species, and other less common species such as the olive-sided flycatcher, could be influencing the positive response of the mature forest songbird guild to disturbance, and perhaps the aforementioned lack of avoidance of soft edges between preferred upland forest and treed bog or non-treed shrubby wetland. Future research should consider multiple aspects of songbird habitat preference (i.e., relation to edge, as well as to forest age), and other aspects of life history (e.g., Zhang et al. 2012 examined guilds based on dietary preference, habitat specialization and migratory status) when assessing responses of guilds to disturbance or other landscape features.

Disturbance layers available for the accumulated years of wildlife observations (i.e., 2001 to 2010) might have overestimated the amount of existing disturbed land in two ways, both of which could exaggerate the positive influence of non-linear and wide linear disturbance. First, disturbance might include “approved” disturbance that was planned in green field areas but not existing yet at the time of bird surveys. This is especially relevant for non-linear disturbance. For example a single approved non-linear block, such as an industrial facility, could cover a large portion of the circular buffer zones examined in this study. Second, the age of most disturbances was unknown, such that disturbance might have regenerated to shrubby or treed habitat. Brotons et al. (2003) found that songbirds benefited in forest adjacent to shrubby areas due to increased insect prey in the adjacent shrubby area, and Villard et al. (2007) found that disturbance edge effects developed over time as vegetation regenerated. Future desktop research is recommended to refine disturbance layers to include age or regeneration state of the disturbance where possible and ensure existing and approved disturbance are digitally separated. However, such refinement requires additional digital imagery and labor, which can be expensive for large scale studies, thus collaboration between industry partners is also recommended. Field studies targeting disturbance types and/or forest adjacent to disturbance could provide empirical validation of disturbance associations.

Landscape Features and Effects of Spatial Scale

Habitat selection often depends on the scale of measurement, and often in non-linear ways that do not directly predict habitat selection at other scales (Mayor et al. 2009). Nonetheless, the three landscape scales assessed in this study (250 m, 500 m and 1000 m) had similar patterns of model support (i.e., the same model types were top models or had some support at each spatial scale).



There is no single “correct” scale of analysis and assessing multiple scales provides a more complete characterization of habitat use patterns than studies conducted at single scales, because animals may select different habitat components at different scales (Mayor et al. 2009, Pennington and Blair 2011). Within the 500 m and 1000 m scales, models with three avoided habitats as additional covariates had more support compared to models with only preferred habitat, which was the top model within the 250 m scale, perhaps due to unequal variation within the covariates at different spatial scales, which can affect model performance (Vernier et al. 2008) (i.e., six variables might be needed to explain the same amount of information explained by three variables at the 250 m scale). However, across the relative abundance model set, model types for which the 500 m scale had more support (top or second-best model) included either landscape disturbance variables, or landscape avoided habitats, and did not include landscape preferred habitats, whereas model types for which the smallest scale (250 m) had more support always included landscape preferred habitat variables. Disturbance variables had strongest support compared to preferred habitat variables at the 500 m scale, and relatively weaker support at the 250 m scale. Thus, variables predicted to have negative relationships with songbird populations (i.e., avoided habitats and disturbance) might have the strongest influence at intermediate landscape scales (500 m), some influence at the coarsest scale examined (1000 m), and the least influence at the finest landscape scale examined (250 m). Patterns were similar for mature forest songbird species richness, though with weaker distinctions between sets of landscape variables.

The apparent stronger influence of preferred habitat in the 250 m models could also be due to the local habitat group variable (Zuur 2010), which is nested within each landscape scale and had the strongest correlations with habitat groups at the 250 m scale. In fact, once the local point count habitat group was controlled for in landscape disturbance models, which had no collinearity issues, 1000 m relative abundance models had more support than finer scale models. This illustrates that coarser spatial scales are also important for explaining songbird relative abundance, but only once local scale factors are accounted for. This pattern did not appear for species richness, suggesting that the number of species might be less sensitive to disturbance at coarser scales than the number of individuals. The 50 m point count (0.79 ha) is smaller than many mature forest songbird species’ home range and territory sizes, whereas the finest landscape scale (circles with radii of 250 m [19.63 ha]) is larger than some territory sizes and smaller than others (Section 3.1.2 references). The coarser landscape scales (500 m [78.54 ha] and 1000 m [314.6 ha]) are larger than most territory and home range sizes (e.g., Section 3.1.2 references, Bayne et al. 2005a, Anich et al. 2009, Vitz and Rodewald 2010). The additional support for disturbance variables and/or avoided habitats at the coarser scales and habitat variables at the finest landscape scale (similar to Fletcher and Hutto 2008) could suggest that songbirds are limited by landscape-level disturbance or poor habitat when selecting home ranges, and once they have found a suitable landscape (i.e., a “nice neighbourhood”) songbirds might change what component they are selecting for (Mayor et al. 2009). Within the home range, the amount of preferred habitat might influence where songbirds establish breeding territories to defend food resources, attract a mate, and protect and raise their young (Anich et al. 2009, Pennington and Blair 2011). At a still-finer scale, within their territories, mature forest songbirds might seek tall, old trees for nesting sites (Matsuoka and Handel 2007).

Management and Research Implications

The importance of mixedwood forests (e.g., forests with coniferous white spruce and trembling aspen) to boreal songbird communities is emphasised by this research and in the literature (e.g., Kirk et al. 1996, Drapeau et al. 2000, Hobson and Bayne 2000a). Forest management and reclamation practices that result in more



homogenous (i.e., pure coniferous or pure deciduous) forest stand types and even-aged forests could lead to reductions in bird diversity (Kirk et al. 1996).

The direction of the disturbance effect depended on the type of disturbance, with more information provided by detailed linear disturbance descriptions than by summed linear disturbance. Studies on cumulative effects of disturbance on songbirds should consider and account for relationships that might differ based on disturbance characteristics, such as vegetation characteristics, width, contrast with natural edge, microclimate, or human activity on the disturbance (Saunders et al. 1991, Pennington and Blair 2011, Bayne et al. 2005a, López-Barrera et al. 2006, Pohlman et al. 2007, Kociolek et al. 2011).

Fine-scale local habitat and broad-scale landscape characteristics both have an influence on mature forest songbird parameters and both should be considered when assessing development impacts and implementing mitigation strategies. The influence of multiple scales on songbird community parameters has implications for determining and interpreting ZOI and establishing setback distances (Environment Canada 2009). Miller et al. (1998) found that most songbirds occurred in higher numbers 75 m to 100 m from recreational trails. Based on this, a land manager might choose 150 m as a conservative ZOI estimate and assume that disturbances setback further than 150 m from a habitat patch are no longer influencing songbirds in that habitat patch. However, the assumption that effects of disturbance dissipate beyond a setback distance would fail to account for cumulative effects of disturbance in the surrounding landscape. The results of this research suggest that the amount and composition of disturbance up to 1000 m from the habitat patch where a mature forest songbird is observed can also influence the individual songbird's choice to inhabit that patch. The songbird might have arrived at that habitat patch because wide linear disturbance or non-linear disturbance was high in the surrounding 500 m or 1000 m, and the habitat patch might have been the best remnant patch in a fragmented landscape. Or, the individual songbird might be inhabiting that patch because it is surrounded by less narrow linear disturbance, and local competition for space and food resources might be lower (Bayne et al. 2005a). At the scale that songbirds search for a good home range, distance to disturbance (ZOI) and other landscape configuration measures might not matter as much as the landscape composition (Drapeau et al. 2000, Bélisle et al. 2001).

One goal of this analysis was to explore whether or not datasets created during EIA processes from 2001 to 2010 could be combined to create predictive models of songbird relative abundance and richness. It was possible to create one structural variable (height), several compositional variables (e.g., habitat group) and three variables that were structural and compositional (percent cover of old growth coniferous trees, deciduous trees, and jack pine). Other fine scale characteristics important for birds, such as stand structure (e.g., number of vegetation layers) (Zhang et al. 2012) or understory composition (Pennington and Blair 2001) had low range of variation in AVI data, and were not suitable for use in predictive modeling. Given the importance of fine scale habitat structure observed in other research (e.g., Westworth and Telfer 1993, Pennington and Blair 2011, Zhang et al. 2012), standard AVI data used in EIA processes might be missing some information important for building strong predictive models. Additional field data on stand level structural characteristics, and increased effort to coordinate locations of vegetation plots and songbird point counts are recommended to improve model predictions for mature forest songbirds. Coordinated plot designs are employed by ABMI (2012c) and allow researchers to relate songbird abundance and richness to local habitat characteristics such as large trees or snags at a regional scale (ABMI 2012a).

Also, it is difficult to verify the accuracy of spatial estimates of disturbance variables without expending potentially prohibitive effort and funds to examine successive years of orthophotos or digital imagery to account



for regeneration, identify and remove “approved” disturbance, or add new disturbances not yet captured in the GIS datasets. Thus, uncertainty in spatial estimates might limit the ability to reliably predict habitat use by boreal forest songbirds using standard EIA datasets. When costs are not prohibitive, disturbance layers created for the EIA process should be constructed with maximum distinction of disturbance types, sources, and ages, in order to maximize efficiency for potential future modeling work, and to allow screening out of potentially misleading disturbance types. Additional field data and refinement of landscape disturbance metrics are recommended to improve predictions about boreal songbirds (Saveraid et al. 2001). Continuation of this research will include model validation using additional datasets created for EIAs, but should include only existing disturbance, and ideally should include indication of the age of disturbance.



5.0 CONCLUSIONS

Several conclusions can be drawn in relation to study objectives as follows:

1. All boreal songbird species combined, songbird species of concern, and the mature forest songbird guild were positively associated with habitat groups likely to provide high quantity and quality foraging and nesting microhabitats (Latif et al. 2011).
 - i. Preferred habitat groups included mixedwood aspen – white spruce, deciduous aspen – balsam poplar, coniferous white spruce and treed swamp. All boreal songbirds combined were also positively associated with non-treed shrubby wetlands, whereas mature forest songbirds were negatively associated with non-treed wetland habitat groups.
 - ii. All groups of songbirds were negatively associated with nutrient poor dry uplands dominated by jack pine and/or black spruce.
2. Empirical habitat models were developed to predict the influence of development on mature forest songbird relative abundance and species richness in northeastern Alberta.
 - i. Top models included variables for height of the tallest vegetation layer, landscape preferred habitat groups, landscape avoided habitat groups, and three landscape disturbance types (wide linear disturbance, narrow linear disturbance and non-linear disturbance).
 - ii. Top models included the finest landscape scale examined (250 m spatial scale).
 - iii. Within a given model type, the coarsest landscape scale examined (1000 m spatial scale) was always second-best, if not the top model within that category.
 - iv. Disturbance variables had stronger influences at the coarser landscape scales examined, especially at the 500 m spatial scale, whereas preferred habitats had stronger influences at the finer scales (local habitat and at the 250 m landscape scale).

5.1 Habitat Associations in the Oil Sands Region

Boreal songbirds as a whole, many songbird species of concern, and the guild of mature forest songbirds each selected habitat groups likely to provide high quantity and quality foraging and nesting microhabitats (Latif et al. 2011), with moist soils, a medium to rich nutrient regime, large trees, high foliage cover and a diverse and complex understorey. The habitat with highest mature forest songbird relative abundance, density and species richness, mixedwood aspen-white spruce, included mixtures of coniferous and deciduous trees, consistent with previous research (e.g., Drapeau et al. 2000, Hobson and Bayne 2000a). At the local scale, mature forest songbirds avoided some habitats (treed bog and non-treed shrubby wetlands) that were weak negative predictors at the landscape scale, potentially due to songbirds capitalizing on insect food resources in “soft” edges of forest adjacent to shrubby wet areas (Brotons et al. 2003). All groups of songbirds were negatively associated with nutrient poor, dry uplands dominated by jack pine and/or black spruce (e.g., coniferous jack pine–black spruce and mixedwood jack pine–aspen).

5.2 Mature Forest Songbird Predictive Modelling

Combined models of height, landscape preferred habitat, landscape avoided habitat and landscape disturbance variables had most support for predicting mature forest songbird relative abundance and species richness. Mature forest songbirds were positively associated with height and preferred habitats, whereas the direction and



strength of the disturbance effect depended on the type of disturbance. Positive associations with wide linear disturbance and non-linear disturbance were unexpected and require measures of fitness consequences to understand the adaptive significance of habitat use (Jones 2001) in increasingly disturbed landscapes. Mature forest songbirds might be experiencing detrimental fitness consequences and overcrowding in forest remnants (Schlaepfer et al. 2002, Hannah et al. 2008), or no detrimental effects if 1) songbirds are resilient and not negatively impacted by the disturbance types examined (Whitaker et al. 2008) and/or 2) carrying capacity has not yet been reached in this region of the boreal forest (Bayne et al. 2005b), such that songbirds can crowd together in forest remnants without negative population consequences. Negative associations with narrow linear disturbances suggest that detrimental effects are possible. Local effects are biased towards natural, undisturbed habitat by design, such that none of the sites examined were severely disturbed at the local scale, and local effects of disturbance might be underestimated. Examination of cumulative effects of disturbance on songbirds should continue to consider the different relationships with different types of disturbance, at a resolution appropriate to the species of interest, which might require sampling disturbed habitats in addition to intact forest remnants.

The primary drivers of mature forest songbird relative abundance are found both at the local scale and at greater spatial extents. Local habitat characteristics in the 50 m point count are important determinants of mature forest songbird relative abundance, as are habitat characteristics in the smallest landscape examined (250 m). However, we found that when controlling for local habitat group in disturbance models, the broadest landscape scale examined, up to 1 km from the point count, had the strongest influence on songbird relative abundance, and that models with disturbance variables performed particularly well at the 500 m scale. The importance of both local variables and larger landscape scales might relate to selection pressures on different fitness components at different scales (Mayor et al. 2009). Mature forest songbird selection of tall trees and preferred local habitats could reflect selection of nesting or foraging microhabitats at the fine scale (within-territory), whereas selection of preferred mixedwood aspen–white spruce and influence of disturbances at coarser landscape scales might reflect selection of home ranges on the landscape, and territories within home ranges.

5.3 Management and Research Implications

This research represents a comprehensive assessment of songbird habitat and disturbance associations in northeastern Alberta that contributes to a better understanding of scale of habitat selection and the cumulative impacts of disturbance on songbirds.

The importance of mixedwood forests (e.g., forests with coniferous white spruce and trembling aspen) to boreal songbird communities is emphasised; forest management and reclamation practices that result in more homogenous (i.e., pure coniferous or pure deciduous) forest stand types and even-aged forests could lead to reductions in bird diversity (Kirk et al. 1996). Studies on cumulative effects of disturbance on songbirds should consider and account for relationships that might differ based on disturbance characteristics, such as width, vegetation, edge contrast, microclimate, or human activity (Saunders et al. 1991, Pennington and Blair 2011, Bayne et al. 2005a, López-Barrera et al. 2006, Pohlman et al. 2007, Kociolek et al. 2011).

Assessment and mitigation for songbirds often focuses on fine scale, local habitat use. For example, to predict impacts of a proposed development on songbirds, a commonly used method is to assess area losses of habitat groups the songbirds are found in locally, perhaps with a buffer corresponding to a setback distance. However, fine-scale local habitat and broad-scale landscape characteristics both have an influence on mature forest songbird relative abundance and species richness and both should be considered when assessing development



impacts and implementing mitigation strategies. Although this research confirms that local habitat variables are important, considering only local scale variables would fail to account for important landscape level variation in songbird numbers. Predictions of the regional impact of development on songbirds from models based solely on local scale factors could be misleading, especially if sampling points continue to exclude disturbance. For example, the local habitat group models would predict high abundance and richness of mature forest songbirds in mixedwood aspen–white spruce, regardless of surrounding amount of disturbance. By contrast, a model including only disturbance types would predict higher densities in any habitat group surrounded by more wide linear disturbance or non-linear disturbance, or less narrow linear disturbance. In this scenario, predictive maps created from the local model would overestimate the importance of mixedwood aspen-white spruce, and predictive maps created from the landscape disturbance model might underestimate the importance of that same preferred habitat group. Furthermore, if landscape influences are not considered, studies of ZOI could mistakenly conclude that disturbance located further than a certain setback distance from a sampled forest remnant have no bearing on songbird relative abundance or richness in that remnant. Consideration of the cumulative effects of local and surrounding disturbance and natural habitats is required to accurately predict development impacts on boreal songbirds so that effective regional mitigation can be implemented. By considering landscape composition and percent cover of disturbance types while controlling for local habitat characteristics, regions likely to strongly impact mature forest songbirds can be identified and prioritized for mitigation.

This research has demonstrated habitat choice by mature forest songbirds at multiple spatial scales, resulting in use of some habitats more than others, and responses that vary by disturbance type. However, measures of fitness consequences are required to understand the adaptive significance of observed habitat choices (Jones 2001).



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8.0 ABBREVIATIONS

%	Percent
<	Less than
>	More than
±	Plus or minus
ESRD	Alberta Environment and Sustainable Resource Development
CI	Confidence Interval
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
EIA	Environmental Impact Assessment
GIS	Geographic Information System
GLM	General Linear Model
Golder	Golder Associates Ltd.
SARA	<i>Species at Risk Act</i>



9.0 GLOSSARY

Anthropogenic	Caused by human activity.
Bog	Ombrotrophic, acidic, peat-forming wetlands that receives its surface moisture from precipitation. Characterized by a level, raised or sloping peat surface with hollows and hummocks.
Boreal Forest	The northern hemisphere, circumpolar, tundra forest type consisting primarily of black spruce and white spruce with balsam fir, birch and aspen.
Canopy	An overhanging cover, shelter or shade. The tallest layer of vegetation in an area.
Coniferous	Bearing cones or strobili (a cone-like cluster).
Cutblock	Previously forested area that has been harvested for timber and is presently regenerating at various stages of regrowth.
Deciduous	Tree species that lose their leaves at the end of the growing season.
Ecological trap	In an environment that has been altered suddenly by human activities, an organism makes a maladaptive habitat choice based on formerly reliable environmental cues, despite the availability of higher quality habitat (Schlaepfer et al. 2002).
Ecosite	Ecological units that develop under similar environmental influences (climate, moisture and nutrient regime). Ecosites are groups of one or more ecosite phases that occur within the same portion of the moisture/nutrient grid. Ecosite is a functional unit defined by the moisture and nutrient regime. It is not tied to specific landforms or plant communities, but is based on the combined interaction of biophysical factors that together dictate the availability of moisture and nutrients for plant growth.
Ecosite Phase	A subdivision of the ecosite based on the dominant tree species in the canopy. On some sites where the tree canopy is lacking, the tallest structural vegetation layer determines the ecosite phase.
Environmental Impact Assessment (EIA)	A review of the effects that a proposed development will have on the local and regional environment.
Fen	Sedge peat materials derived primarily from sedges with inclusions of partially decayed stems of shrubs formed in a eutrophic environment due to the close association of the material with mineral rich waters. Minerotropic peat-forming wetlands that receive surface moisture from precipitation and groundwater. Fens are less acidic than bogs, deriving most of their water from groundwater rich in calcium and magnesium.



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Geographic Information System (GIS)	Computer software designed to develop, manage, analyze and display spatially referenced data.
Global Positioning System (GPS)	A system of satellites, computers and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.
Graminoid	Grasses and grass-like plants such as sedges and rushes.
Guild	A set of co-existing species that share a common resource.
Habitat	The place or environment where a plant or animal naturally or normally lives or occurs.
Habitat Fragmentation	Occurs when extensive, continuous tracts of habitat are reduced by habitat loss to dispersed and usually smaller patches of habitat. Generally reduces the total amount of available habitat and reduces remaining habitat into smaller, more isolated patches.
Home Range	The area within which an animal normally lives, and traverses as part of its annual travel patterns.
Invasive Species	A species that has moved into an ecosystem and reproduced so successfully that it has displaced the original structure of the community.
Linear Disturbance	Disturbance with high edge to area ratio, such as cutlines, seismic lines, pipelines, transmission lines, rights-of-ways, roads
Local Study Area (LSA)	Defines the spatial extent directly or indirectly affected by the project.
Lowland Areas	Areas with ground slopes of less than 0.5% and typically poorly drained.
Mean	Centroid value of a data population when viewing its probability distribution function (or histogram) as a mass distribution.
Mesic	A moderate soil moisture regime value whereby water is removed somewhat slowly in relation to supply; neither wet nor dry. Available soil water reflects climatic inputs.
Mixedwood	A terrestrial forest type that is an assemblage of both deciduous and coniferous tree species.
Non-linear disturbance	A disturbance with relatively low edge to area ratio, such as an acreage, borrow pit, clearcut (CC), clearing, facility, gravel pit, pasture, well pad, non-linear development (vegetated), non-linear development (unknown vegetation status), salt cavern, or sump.



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Oil Sands Region	The Oil Sands Region includes the Fort McMurray – Athabasca Oil Sands Subregional Integrated Resource Plan (IRP), the Lakeland Subregional IRP and the Cold Lake – Beaver River Subregional IRP.
Old Growth Forest	An ecosystem distinguished by old trees and related structural attributes. Old growth encompasses the later stages of stand development that typically differ from earlier stages in a variety of characteristics which may include tree size, accumulations of large dead woody material, number of canopy layers, species, composition, and ecosystem function. Old growth forests are those forested areas where the annual growth equals annual losses, or where the mean annual increment of timber volume equals zero. They can be defined as those stands that are self-regenerating (i.e., having a specific structure that is maintained).
Orthophoto	A digital image of an aerial photograph.
Peatland	Areas where there is an accumulation of peat material at least 40 cm thick. These are represented by bog and fen wetland types.
Point Count	A circular plot survey where observers spend a prescribed time looking and listening for birds.
Relative Abundance	The proportional representation of the number of individuals of a species in a sample or a biological community (e.g., habitat).
Riparian	Refers to terrain, vegetation or simply a position next to or associated with a stream, floodplain or standing waterbody.
Sedge	Any plant of the genus <i>Carex</i> , perennial herbs, often growing in dense tufts in marshy places. They have triangular jointless stems, a spiked inflorescence and long grass-like leaves which are usually rough on the margins and midrib. There are several hundred species.
Seral Stage	In an ecological succession, the series of biotic communities that follow one another on the way to the stable stage, or climax community.
Shannon diversity index	<p>A diversity measure based on information theory, a measure of species richness and evenness in the number of individuals per species within a particular system. Greater values represent greater diversity. The Shannon diversity index is represented by:</p> $H = - \sum_{i=1}^S p_i \ln p_i$ <p>Where H is the Shannon diversity index, S is the total number of species in the community (richness) and p_i is the proportion of individuals made up of the ith species.</p>



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Snag	A naturally occurring, standing dead or dying tree often missing a top or most of the smaller branches. It plays an important role in providing habitat for a variety of forest-dwelling wildlife species as well as epiphytic lichens.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Species Diversity	A description of a biological community that includes both the number of different species and their relative abundance. Provides a measure of the variation in number of species in a region. This variation depends partly on the variety of habitats and the variety of resources within habitats and, in part, on the degree of specialization to particular habitats and resources.
Species Richness	The number of different species occupying a given area.
Stand Age	The number of years since a forest has been affected by a stand-replacing disturbance event (e.g., fire or logging) and has since been regenerating.
Standard Deviation (Sd)	A measure of the variability or spread of the measurements about the mean. It is calculated as the positive square root of the variance.
Subhygric	Soil moisture conditions where water is removed slowly enough to keep the soil wet for a significant part of the growing season. There is some temporary seepage and possible mottling below 20 cm.
Succession	A series of dynamic changes by which one group of organisms succeeds another through stages leading to a climax community.
Successional Stage	A particular phase of the forest succession continuum with its own characteristic of age, structure and composition of species. Stages may include the following: pioneer, young seral, maturing seral, old seral, young edaphic, mature edaphic, young climatic, mature climatic and disclimax.
Swamp	Land having soils that are saturated with water for at least part of the year and which usually occur next to waterbodies or in areas in association with fluctuating water levels such as along peatland margins.
Terrestrial Vegetation	Forested or non-forested areas of the landscape with non-saturated and non-peat-forming soils. Excludes bogs, fens, swamps and marshes.
Understorey	Trees or other vegetation in a forest that exist below the main canopy level.
Upland Areas	Areas that have typical ground slopes of 1 to 3% and are better-drainage.



BOREAL SONGBIRD COMMUNITIES IN NORTHEASTERN ALBERTA

Wetlands	Wetlands are land where the water table is at, near or above the surface or which is saturated for a long enough period to promote such features as wet-altered soils and water tolerant vegetation. Wetlands include organic wetlands or “peatlands,” and mineral wetlands or mineral soil areas that are influenced by excess water but produce little or no peat.
Wildlife	Under the <i>Species at Risk Act</i> , wildlife is defined as a species, subspecies, variety or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus that is wild by nature and is native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.



Report Signature Page

GOLDER ASSOCIATES LTD.

Amy Darling, M.Sc.
Terrestrial Ecologist

Carol Stefan, M.Sc.
Wildlife Ecologist, Associate

Corey de la Mare, B.Sc.
Senior Wildlife Biologist, Principal

AD/CS/DW

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APPENDIX A

Boreal Songbird Habitat Associations in the Oil Sands Region



APPENDIX A BOREAL SONGBIRD HABITAT

Table A-1: Breeding Bird Mean Relative Abundance (± Standard Deviation) by Land Cover Type in the Oil Sands Region, 2001 to 2011

Habitat Group	Coniferous Jack Pine-Black Spruce				Coniferous White Spruce			Deciduous Aspen-Balsam Poplar				Mixed-Wood Jack Pine-Aspen	Mixed Wood Aspen-White Spruce				Non-Treed Open Wetland			Non-Treed Shrubby Wetland				Treed Bog		Treed Fen			Treed Swamp		Burn		Clear Cut	Linear Development (Vegetated)	Non-Linear Development (Vegetated)	Overall Mean	Number of Birds	
	Land Cover Type(a)	a1	b4	c1	g1	d3	e3	f3	b2	d1	e1		f1	b1	b3	d2	e2	f2	FONG	WONG	WONN	BONS	FONS	Sh	SONS	BFNN	BTNN	FFNN	FTNN	FTPN	h1	STNN						BUu
Number of Point Counts	66	15	131	177	35	14	15	19	191	28	7	88	54	328	21	19	38	17	5	1	137	24	94	1	278	3	354	1	39	47	18	7	19	6	4	1	2,302	
alder flycatcher	0.02 (0.12)	-	0.02 (0.19)	0.02 (0.18)	0.03 (0.17)	-	0.13 (0.52)	0.05 (0.23)	0.04 (0.21)	-	-	-	0.02 (0.14)	<0.01 (0.12)	-	0.05 (0.23)	0.16 (0.49)	0.12 (0.33)	0.20 (0.45)	-	0.17 (0.41)	0.75 (0.74)	0.62 (0.72)	-	0.03 (0.16)	0.33 (0.58)	0.05 (0.21)	-	0.03 (0.16)	0.30 (0.66)	0.67 (0.69)	0.29 (0.49)	0.32 (0.58)	0.17 (0.41)	0.50 (0.58)	-	0.08 (0.33)	19
American redstart	-	-	<0.01 (0.09)	-	-	-	-	0.05 (0.23)	0.07 (0.31)	0.21 (0.50)	-	-	0.02 (0.14)	0.02 (0.14)	0.10 (0.30)	0.11 (0.32)	0.05 (0.32)	-	-	-	<0.01 (0.09)	0.04 (0.20)	0.12 (0.35)	-	-	-	<0.01 (0.08)	-	-	0.21 (0.55)	-	0.14 (0.38)	-	-	0.25 (0.50)	-	0.03 (0.18)	62
American robin	0.02 (0.12)	-	0.02 (0.15)	<0.01 (0.08)	-	0.07 (0.27)	0.07 (0.26)	0.05 (0.23)	0.06 (0.28)	-	-	-	-	0.02 (0.14)	-	0.05 (0.23)	0.11 (0.45)	0.18 (0.53)	-	-	<0.01 (0.09)	0.04 (0.20)	0.02 (0.15)	-	<0.01 (0.08)	-	<0.01 (0.08)	-	0.03 (0.16)	0.04 (0.20)	0.17 (0.51)	-	-	-	-	0.02 (0.16)	49	
barn swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.09)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1
bay-breasted warbler	0.06 (0.24)	0.13 (0.35)	<0.01 (0.09)	<0.01 (0.08)	0.11 (0.32)	0.14 (0.36)	0.40 (0.63)	-	0.02 (0.18)	0.04 (0.19)	0.14 (0.38)	0.06 (0.28)	0.06 (0.23)	0.12 (0.35)	0.10 (0.30)	0.16 (0.37)	-	-	-	-	-	-	-	-	0.01 (0.10)	-	<0.01 (0.05)	-	0.13 (0.41)	0.02 (0.15)	-	-	-	-	-	0.04 (0.21)	88	
black-and-white warbler	0.03 (0.17)	0.07 (0.26)	<0.01 (0.09)	0.02 (0.13)	0.03 (0.17)	-	0.07 (0.26)	0.37 (0.60)	0.04 (0.19)	0.14 (0.36)	-	0.01 (0.11)	0.04 (0.19)	0.03 (0.18)	0.19 (0.40)	0.11 (0.32)	-	-	-	-	0.02 (0.15)	0.13 (0.45)	0.11 (0.31)	-	<0.01 (0.06)	-	<0.01 (0.05)	-	0.03 (0.16)	0.23 (0.43)	-	-	0.11 (0.32)	0.25 (0.50)	-	0.03 (0.19)	80	
blackburnian warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.06)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1	
black-capped chickadee	0.02 (0.12)	-	0.02 (0.15)	-	0.03 (0.17)	-	-	0.11 (0.32)	0.04 (0.21)	-	0.14 (0.38)	0.01 (0.11)	0.02 (0.14)	0.03 (0.20)	0.05 (0.22)	-	-	-	-	-	0.03 (0.24)	-	0.04 (0.25)	-	0.01 (0.17)	-	<0.01 (0.05)	-	-	0.09 (0.35)	0.11 (0.47)	-	0.16 (0.50)	-	-	0.02 (0.18)	50	
blackpoll warbler	-	-	0.05 (0.21)	0.03 (0.20)	-	-	-	-	0.01 (0.10)	-	-	-	-	<0.01 (0.06)	-	0.05 (0.23)	-	-	-	-	<0.01 (0.09)	-	0.05 (0.23)	-	0.02 (0.13)	-	0.02 (0.14)	-	-	-	-	-	-	-	-	0.01 (0.12)	33	
black-throated green warbler	-	-	-	-	-	0.14 (0.36)	-	0.05 (0.23)	0.02 (0.12)	0.21 (0.42)	-	-	-	<0.01 (0.10)	0.05 (0.22)	0.05 (0.23)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.09)	17	
blue-headed vireo	0.03 (0.17)	0.07 (0.26)	-	0.01 (0.11)	0.03 (0.17)	-	0.13 (0.35)	-	0.02 (0.12)	0.07 (0.26)	-	0.02 (0.15)	0.04 (0.19)	0.02 (0.15)	0.05 (0.22)	0.05 (0.23)	-	-	-	-	-	0.04 (0.20)	0.01 (0.10)	-	-	-	<0.01 (0.08)	-	-	-	-	-	-	-	-	0.01 (0.12)	31	
boreal chickadee	0.03 (0.17)	-	0.04 (0.19)	0.02 (0.15)	0.14 (0.43)	0.14 (0.53)	0.07 (0.26)	-	-	-	0.14 (0.38)	0.05 (0.30)	0.09 (0.40)	0.05 (0.27)	-	-	-	-	-	-	-	0.08 (0.41)	0.04 (0.25)	-	0.06 (0.42)	-	0.06 (0.29)	-	0.08 (0.48)	-	-	-	-	-	-	0.04 (0.27)	93	
Brewer's blackbird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.11)	-	-	-	-	-	-	-	-	<0.01 (0.04)	2	
brown creeper	-	-	<0.01 (0.09)	<0.01 (0.08)	0.03 (0.17)	-	-	0.05 (0.23)	0.04 (0.21)	0.07 (0.26)	-	0.02 (0.15)	-	0.06 (0.26)	-	0.05 (0.23)	-	-	-	-	-	-	-	-	-	<0.01 (0.06)	-	-	-	0.03 (0.16)	-	-	-	-	-	0.02 (0.14)	37	
Canada warbler	-	-	-	-	0.03 (0.17)	0.21 (0.43)	-	-	0.08 (0.32)	0.18 (0.39)	0.14 (0.38)	0.01 (0.11)	0.04 (0.19)	0.05 (0.26)	0.14 (0.48)	0.05 (0.23)	-	-	-	-	-	-	0.01 (0.10)	-	-	-	-	-	0.03 (0.16)	0.04 (0.20)	-	-	-	-	0.25 (0.50)	-	0.02 (0.17)	54
Cape May warbler	-	0.13 (0.35)	0.03 (0.17)	0.06 (0.26)	0.26 (0.44)	0.36 (0.50)	0.20 (0.41)	-	0.01 (0.10)	0.07 (0.26)	-	0.07 (0.25)	0.07 (0.26)	0.07 (0.25)	-	-	0.03 (0.16)	-	-	-	-	-	-	-	0.04 (0.23)	-	<0.01 (0.09)	-	0.15 (0.37)	0.02 (0.15)	-	-	-	-	-	0.04 (0.20)	92	
cedar waxwing	-	-	-	-	-	0.14 (0.53)	-	-	0.03 (0.20)	-	-	0.01 (0.11)	-	0.02 (0.22)	-	-	-	0.12 (0.49)	-	-	0.01 (0.17)	-	0.10 (0.59)	-	<0.01 (0.06)	-	-	-	-	0.15 (0.47)	0.17 (0.51)	-	0.16 (0.50)	-	-	-	0.02 (0.20)	44
chipping sparrow	0.17 (0.41)	0.07 (0.26)	0.15 (0.38)	0.20 (0.46)	0.17 (0.51)	0.21 (0.43)	0.67 (0.82)	0.16 (0.37)	0.15 (0.41)	0.07 (0.26)	-	0.19 (0.43)	0.35 (0.62)	0.17 (0.42)	0.24 (0.44)	0.32 (0.58)	0.18 (0.46)	0.12 (0.33)	-	1.00 (na)	0.42 (0.60)	0.25 (0.44)	0.22 (0.47)	1.00 (na)	0.31 (0.53)	0.33 (0.58)	0.33 (0.54)	1.00 (na)	0.41 (0.64)	0.38 (0.53)	0.22 (0.43)	0.57 (0.79)	0.16 (0.37)	-	1.00 (2.00)	2.00 (na)	0.25 (0.50)	57
clay-coloured sparrow	-	0.07 (0.26)	-	-	-	-	-	-	<0.01 (0.07)	-	-	-	-	-	-	-	0.08 (0.27)	-	-	-	0.07 (0.34)	0.08 (0.28)	0.19 (0.53)	-	<0.01 (0.08)	-	<0.01 (0.08)	-	-	0.06 (0.24)	-	0.05 (0.23)	0.17 (0.41)	0.25 (0.50)	-	0.02 (0.16)	43	
common yellowthroat	-	-	-	-	-	0.07 (0.27)	-	-	<0.01 (0.07)	0.04 (0.19)	0.14 (0.38)	-	-	<0.01 (0.06)	0.05 (0.22)	-	0.11 (0.31)	0.47 (0.80)	-	-	0.16 (0.39)	0.13 (0.34)	0.41 (0.69)	-	<0.01 (0.08)	-	0.02 (0.17)	-	-	0.17 (0.38)	0.06 (0.24)	0.29 (0.76)	0.11 (0.32)	-	-	-	0.05 (0.24)	10
Connecticut warbler	-	-	-	-	0.03 (0.17)	0.07 (0.27)	-	-	0.05 (0.22)	-	-	-	0.02 (0.14)	0.03 (0.16)	0.05 (0.22)	0.05 (0.23)	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06 (0.32)	-	-	-	-	-	0.01 (0.11)	28	
dark-eyed junco	0.20 (0.50)	-	0.21 (0.49)	0.18 (0.44)	-	0.07 (0.27)	0.07 (0.26)	0.11 (0.32)	0.02 (0.12)	-	-	0.08 (0.31)	-	0.03 (0.18)	-	0.05 (0.23)	0.05 (0.23)	0.18 (0.53)	-	-	0.12 (0.39)	0.13 (0.34)	0.11 (0.34)	-	0.32 (0.60)	-	0.29 (0.55)	-	0.15 (0.43)	0.09 (0.28)	0.11 (0.32)	0.29 (0.49)	-	-	-	-	0.15 (0.42)	33
eastern kingbird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02 (0.19)	-	0.01 (0.10)	-	-	-	<0.01 (0.05)	-	-	-	-	-	-	-	-	<0.01 (0.06)	5	
eastern phoebe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05 (0.22)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1	
evening grosbeak	-	-	-	-	0.03 (0.17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1	
fox sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.05)	-	-	-	-	-	-	-	-	<0.01 (0.02)	1	



APPENDIX A BOREAL SONGBIRD HABITAT

Table A-1: Breeding Bird Mean Relative Abundance (± Standard Deviation) by Land Cover Type in the Oil Sands Region, 2001 to 2011 (continued)

Habitat Group	Coniferous Jack Pine-Black Spruce				Coniferous White Spruce			Deciduous Aspen-Balsam Poplar				Mixed-Wood Jack Pine-Aspen	Mixed Wood Aspen-White Spruce				Non-Treed Open Wetland			Non-Treed Shrubby Wetland			Treed Bog		Treed Fen			Treed Swamp		Burn		Clear Cut	Linear Development (Vegetated)	Non-Linear Development (Vegetated)	Overall Mean	Number of Birds		
	Land Cover Type(a)	a1	b4	c1	g1	d3	e3	f3	b2	d1	e1		f1	b1	b3	d2	e2	f2	FONG	MONG	WONN	BONS	FONS	Sh	SONS	BFNN	BTNN	FFNN	FTNN	FTPN	h1						STNN	BUu
Number of Point Counts	66	15	131	177	35	14	15	19	191	28	7	88	54	328	21	19	38	17	5	1	137	24	94	1	278	3	354	1	39	47	18	7	19	6	4	1	2,302	
golden-crowned kinglet	0.02 (0.12)	0.13 (0.35)	<0.01 (0.09)	0.02 (0.13)	0.09 (0.28)	0.14 (0.53)	-	-	0.01 (0.10)	-	-	-	0.06 (0.23)	0.02 (0.16)	-	-	0.05 (0.32)	-	-	-	-	-	0.01 (0.10)	-	0.01 (0.10)	-	<0.01 (0.05)	-	0.13 (0.34)	-	-	-	-	-	-	-	0.02 (0.13)	35
hermit thrush	0.11 (0.31)	0.07 (0.26)	0.10 (0.32)	0.11 (0.37)	0.03 (0.27)	0.07 (0.27)	0.13 (0.35)	0.05 (0.23)	0.05 (0.24)	0.04 (0.19)	-	0.09 (0.29)	0.02 (0.14)	0.04 (0.21)	0.05 (0.22)	0.11 (0.46)	-	-	-	-	<0.01 (0.09)	0.04 (0.20)	0.03 (0.18)	-	0.09 (0.33)	-	0.06 (0.23)	-	-	0.04 (0.20)	0.17 (0.38)	-	0.05 (0.23)	-	-	-	0.06 (0.26)	13 7
house wren	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.06)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1
Le Conte's sparrow	-	-	-	<0.01 (0.08)	-	-	-	-	-	-	-	-	-	-	-	-	0.26 (0.60)	0.24 (0.44)	0.20 (0.45)	-	0.08 (0.32)	0.13 (0.34)	0.05 (0.23)	-	0.01 (0.15)	-	<0.01 (0.08)	-	-	0.04 (0.29)	-	0.14 (0.38)	-	-	0.17 (0.41)	-	0.02 (0.16)	45
least flycatcher	-	-	-	<0.01 (0.08)	-	-	0.07 (0.26)	0.05 (0.23)	0.23 (0.69)	0.21 (0.57)	-	-	-	0.06 (0.32)	0.19 (0.51)	0.16 (0.50)	-	-	-	-	0.04 (0.24)	0.04 (0.20)	0.07 (0.34)	-	<0.01 (0.06)	-	0.02 (0.13)	-	-	0.21 (0.59)	0.17 (0.51)	-	0.32 (0.67)	0.33 (0.82)	-	-	0.05 (0.31)	12 2
Lincoln's sparrow	-	-	-	<0.01 (0.08)	-	-	0.07 (0.26)	-	0.01 (0.10)	-	-	-	-	<0.01 (0.06)	-	-	0.08 (0.27)	0.06 (0.24)	0.20 (0.45)	-	0.22 (0.52)	0.17 (0.48)	0.14 (0.40)	-	0.04 (0.20)	-	0.16 (0.43)	-	-	0.06 (0.25)	0.06 (0.24)	0.29 (0.76)	0.05 (0.23)	0.17 (0.41)	-	-	0.06 (0.27)	13 1
magnolia warbler	-	0.07 (0.26)	0.03 (0.17)	0.03 (0.18)	-	-	0.13 (0.35)	0.05 (0.23)	0.04 (0.19)	-	0.14 (0.38)	0.02 (0.15)	0.02 (0.14)	0.05 (0.22)	0.05 (0.22)	0.11 (0.32)	0.11 (0.31)	0.24 (0.56)	-	-	0.11 (0.31)	-	0.05 (0.23)	-	0.02 (0.13)	-	0.04 (0.20)	-	0.03 (0.16)	0.09 (0.28)	0.06 (0.24)	-	0.05 (0.23)	0.17 (0.41)	0.25 (0.50)	-	0.04 (0.21)	98
marsh wren	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.29 (0.69)	0.20 (0.45)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.07)	6
mountain bluebird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1	
mourning warbler	-	-	-	<0.01 (0.08)	0.06 (0.24)	0.14 (0.53)	0.07 (0.26)	-	0.12 (0.37)	0.21 (0.42)	-	-	-	0.03 (0.18)	0.10 (0.30)	-	-	-	-	-	<0.01 (0.09)	0.04 (0.20)	0.03 (0.18)	-	-	-	-	-	-	0.11 (0.31)	0.06 (0.24)	-	0.05 (0.23)	-	-	-	0.02 (0.17)	57
Nashville warbler	-	-	<0.01 (0.09)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01 (0.10)	-	-	-	-	-	-	-	0.06 (0.24)	0.14 (0.38)	-	-	-	-	<0.01 (0.04)	4
Nelson's sharp-tailed sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03 (0.16)	-	-	-	-	-	0.02 (0.15)	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.04)	3
northern waterthrush	-	-	-	-	-	-	0.07 (0.26)	-	-	0.04 (0.19)	-	-	-	<0.01 (0.06)	0.05 (0.22)	-	0.03 (0.16)	0.18 (0.39)	-	-	-	-	0.10 (0.33)	-	-	-	<0.01 (0.08)	-	-	0.13 (0.40)	-	-	0.11 (0.32)	-	-	-	0.01 (0.12)	27
olive-sided flycatcher	-	-	<0.01 (0.09)	-	0.03 (0.17)	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20 (0.45)	-	0.02 (0.15)	-	0.02 (0.15)	-	<0.01 (0.08)	-	<0.01 (0.05)	-	-	-	0.11 (0.32)	-	-	-	-	-	<0.01 (0.07)	13
orange-crowned warbler	-	-	-	0.01 (0.11)	0.03 (0.17)	-	-	-	<0.01 (0.07)	-	-	0.02 (0.15)	-	<0.01 (0.08)	-	-	-	-	-	-	0.04 (0.28)	0.04 (0.20)	0.11 (0.37)	-	0.02 (0.13)	-	0.01 (0.11)	-	-	0.04 (0.20)	0.11 (0.32)	-	0.05 (0.23)	-	-	-	0.02 (0.14)	38
ovenbird	0.02 (0.12)	0.07 (0.26)	0.02 (0.17)	0.01 (0.11)	0.17 (0.45)	0.21 (0.58)	0.07 (0.26)	0.63 (0.83)	0.70 (0.80)	0.43 (0.63)	0.43 (0.53)	0.14 (0.35)	0.43 (0.63)	0.51 (0.69)	0.29 (0.46)	0.21 (0.42)	-	-	-	-	-	-	0.02 (0.21)	-	<0.01 (0.08)	-	<0.01 (0.08)	-	0.13 (0.41)	0.04 (0.20)	-	-	0.11 (0.32)	-	-	0.18 (0.47)	40 4	
palm warbler	0.06 (0.30)	0.07 (0.26)	0.07 (0.28)	0.12 (0.35)	-	-	-	-	-	-	-	0.01 (0.11)	0.04 (0.19)	<0.01 (0.08)	-	-	0.13 (0.34)	-	-	-	0.32 (0.61)	0.04 (0.20)	-	-	0.19 (0.50)	-	0.38 (0.64)	-	0.03 (0.16)	0.11 (0.37)	-	0.29 (0.49)	-	-	-	0.13 (0.40)	28 8	
Philadelphia vireo	-	-	-	-	-	-	-	-	0.03 (0.17)	-	-	-	-	<0.01 (0.10)	0.05 (0.22)	-	-	-	-	-	-	-	0.04 (0.20)	-	-	-	-	-	-	0.04 (0.20)	0.06 (0.24)	-	-	-	-	<0.01 (0.09)	18	
pine siskin	0.02 (0.12)	-	<0.01 (0.09)	<0.01 (0.08)	-	0.07 (0.27)	-	-	-	-	-	-	-	0.01 (0.22)	-	-	0.03 (0.16)	-	-	-	<0.01 (0.09)	-	-	-	<0.01 (0.08)	-	<0.01 (0.11)	-	-	-	-	-	-	-	-	<0.01 (0.11)	14	
purple finch	0.02 (0.12)	-	-	-	-	-	-	-	-	-	-	-	-	0.01 (0.13)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.06)	5	
red crossbill	-	-	-	-	-	-	-	0.05 (0.23)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01 (0.10)	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.04)	4
red-breasted nuthatch	0.02 (0.12)	-	<0.01 (0.09)	0.02 (0.13)	0.11 (0.32)	0.21 (0.43)	-	0.05 (0.23)	0.01 (0.10)	0.11 (0.31)	-	0.03 (0.18)	0.06 (0.30)	0.05 (0.29)	-	0.05 (0.23)	-	-	-	-	-	-	-	-	0.02 (0.13)	-	<0.01 (0.08)	-	-	0.02 (0.15)	-	-	-	-	-	0.02 (0.16)	51	
red-eyed vireo	-	-	-	0.02 (0.13)	0.11 (0.32)	-	0.07 (0.26)	0.21 (0.42)	0.34 (0.57)	0.21 (0.42)	0.29 (0.49)	0.01 (0.11)	0.07 (0.26)	0.11 (0.33)	0.33 (0.48)	0.05 (0.23)	0.03 (0.16)	0.12 (0.33)	-	-	-	0.04 (0.20)	0.03 (0.18)	-	<0.01 (0.08)	-	<0.01 (0.05)	-	0.03 (0.16)	0.21 (0.46)	0.11 (0.32)	-	0.42 (0.69)	0.17 (0.41)	0.25 (0.50)	-	0.07 (0.28)	16 5
red-winged blackbird	-	-	-	-	-	-	-	<0.01 (0.07)	-	-	-	-	-	-	-	-	0.16 (0.44)	0.53 (0.94)	0.40 (0.89)	-	-	-	0.02 (0.21)	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.12)	20	
rose-breasted grosbeak	-	-	-	-	0.03 (0.17)	-	-	-	0.06 (0.24)	0.04 (0.19)	0.14 (0.38)	0.01 (0.11)	0.04 (0.19)	0.03 (0.17)	0.05 (0.22)	-	-	-	0.20 (0.45)	-	-	-	-	-	<0.01 (0.06)	-	-	-	0.03 (0.16)	0.04 (0.20)	-	-	0.11 (0.32)	-	-	-	0.02 (0.12)	36
ruby-crowned kinglet	0.06 (0.24)	0.20 (0.56)	0.29 (0.55)	0.31 (0.52)	0.06 (0.34)	-	0.13 (0.35)	-	0.02 (0.18)	-	-	0.10 (0.34)	0.09 (0.29)	0.04 (0.22)	0.05 (0.22)	-	0.03 (0.16)	0.06 (0.24)	-	-	0.09 (0.29)	-	0.07 (0.30)	-	0.30 (0.52)	0.67 (1.15)	0.24 (0.46)	-	0.08 (0.27)	0.19 (0.40)	-	-	-	-	-	0.15 (0.39)	34 0	



APPENDIX A BOREAL SONGBIRD HABITAT

Table A-1: Breeding Bird Mean Relative Abundance (± Standard Deviation) by Land Cover Type in the Oil Sands Region, 2001 to 2011 (continued)

Habitat Group	Coniferous Jack Pine-Black Spruce				Coniferous White Spruce			Deciduous Aspen-Balsam Poplar				Mixed-Wood Jack Pine-Aspen	Mixed Wood Aspen-White Spruce				Non-Treed Open Wetland			Non-Treed Shrubby Wetland			Treed Bog		Treed Fen			Treed Swamp		Burn		Clear Cut	Linear Development (Vegetated)	Non-Linear Development (Vegetated)	Overall Mean	Number of Birds			
	Land Cover Type(a)	a1	b4	c1	g1	d3	e3	f3	b2	d1	e1		f1	b1	b3	d2	e2	f2	FONG	MONG	WONN	BONS	FONS	Sh	SONS	BFNN	BTNN	FFNN	FTNN	FTPN	h1						STNN	BUu	BUw
Number of Point Counts	66	15	131	177	35	14	15	19	191	28	7	88	54	328	21	19	38	17	5	1	137	24	94	1	278	3	354	1	39	47	18	7	19	6	4	1	2,302		
rusty blackbird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05 (0.23)	-	-	-	0.03 (0.21)	-	-	-	-	-	0.01 (0.14)	-	-	-	-	-	-	-	-	-	-	<0.01 (0.08)	11
savannah sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11 (0.45)	0.06 (0.24)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.06)	5
sedge wren	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.09)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1
song sparrow	-	-	-	-	-	-	-	-	-	0.04 (0.19)	-	-	-	-	-	0.05 (0.23)	-	-	-	-	0.01 (0.17)	-	-	-	<0.01 (0.08)	-	<0.01 (0.05)	-	-	-	-	-	-	-	-	0.25 (0.50)	-	<0.01 (0.07)	8
Swainson's thrush	0.03 (0.17)	0.07 (0.26)	0.08 (0.29)	0.11 (0.37)	0.14 (0.43)	0.29 (0.47)	0.20 (0.41)	0.37 (0.83)	0.07 (0.28)	0.18 (0.48)	-	0.07 (0.25)	0.26 (0.44)	0.16 (0.39)	0.24 (0.44)	0.26 (0.45)	0.03 (0.16)	0.06 (0.24)	-	-	0.06 (0.24)	0.04 (0.20)	0.21 (0.58)	-	0.06 (0.23)	-	0.07 (0.28)	-	0.21 (0.41)	0.36 (0.53)	-	-	0.05 (0.23)	-	0.25 (0.50)	-	0.11 (0.35)	25 2	
swamp sparrow	-	0.07 (0.26)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.29 (0.61)	0.47 (0.80)	-	-	0.11 (0.43)	0.08 (0.28)	0.33 (0.54)	-	<0.01 (0.06)	-	0.03 (0.18)	-	-	0.11 (0.37)	-	-	-	-	-	-	0.04 (0.22)	84	
Tennessee warbler	0.32 (0.66)	0.67 (0.72)	0.15 (0.44)	0.26 (0.57)	1.23 (0.94)	1.57 (0.76)	1.27 (1.10)	0.74 (0.81)	0.61 (0.82)	0.96 (1.14)	1.00 (0.82)	0.42 (0.75)	0.65 (0.80)	0.81 (0.88)	1.19 (1.17)	0.58 (0.69)	0.16 (0.44)	0.53 (0.87)	0.60 (0.89)	-	0.32 (0.64)	0.38 (0.65)	0.80 (0.97)	-	0.42 (0.80)	0.67 (0.58)	0.27 (0.62)	-	0.56 (0.82)	0.85 (1.10)	0.39 (0.61)	0.29 (0.49)	1.11 (0.99)	0.17 (0.41)	0.25 (0.50)	-	0.51 (0.81)	1, 17 5	
tree swallow	-	-	<0.01 (0.09)	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05 (0.32)	0.06 (0.24)	0.40 (0.89)	-	0.03 (0.24)	-	-	-	-	-	<0.01 (0.08)	-	-	-	-	0.11 (0.47)	-	-	-	-	<0.01 (0.10)	14	
varied thrush	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.06)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1	
vesper sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.09)	-	-	-	<0.01 (0.06)	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.03)	2	
warbling vireo	-	-	-	-	-	-	-	0.05 (0.23)	<0.01 (0.07)	-	-	-	-	-	0.05 (0.22)	0.05 (0.23)	-	-	-	-	-	-	0.01 (0.10)	-	-	-	-	-	-	0.02 (0.15)	-	-	-	-	0.17 (0.41)	-	<0.01 (0.06)	7	
western tanager	0.02 (0.12)	-	-	-	0.14 (0.43)	0.43 (0.65)	0.07 (0.26)	0.16 (0.50)	0.04 (0.19)	0.04 (0.19)	-	0.01 (0.11)	0.11 (0.37)	0.12 (0.37)	0.05 (0.22)	0.05 (0.23)	-	-	-	-	-	-	-	-	<0.01 (0.08)	-	-	-	0.05 (0.22)	0.04 (0.20)	-	-	-	-	-	-	0.03 (0.20)	79	
western wood-pewee	-	-	-	-	0.03 (0.17)	-	-	-	-	-	-	-	-	<0.01 (0.08)	-	-	0.03 (0.16)	0.06 (0.24)	0.20 (0.45)	-	<0.01 (0.09)	-	0.01 (0.10)	-	-	-	0.02 (0.16)	-	-	-	-	-	-	-	-	-	<0.01 (0.09)	15	
white-breasted nuthatch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03 (0.16)	-	-	-	-	-	-	-	-	<0.01 (0.02)	1	
white-crowned sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.06)	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1		
white-throated sparrow	0.02 (0.12)	0.13 (0.35)	0.02 (0.12)	0.02 (0.13)	0.09 (0.28)	0.07 (0.27)	0.20 (0.41)	0.21 (0.42)	0.15 (0.42)	0.29 (0.60)	-	0.01 (0.11)	-	0.07 (0.31)	0.14 (0.36)	0.16 (0.37)	0.03 (0.16)	0.18 (0.39)	-	-	0.15 (0.43)	0.17 (0.48)	0.28 (0.56)	-	0.05 (0.30)	-	0.09 (0.33)	-	0.08 (0.27)	0.49 (0.78)	0.11 (0.32)	0.29 (0.49)	0.42 (0.69)	-	0.25 (0.50)	-	0.10 (0.35)	22 6	
white-winged crossbill	0.02 (0.12)	-	-	0.01 (0.11)	-	0.14 (0.36)	0.07 (0.26)	-	0.01 (0.10)	0.11 (0.42)	-	0.05 (0.30)	-	0.05 (0.53)	0.05 (0.22)	-	-	-	-	-	-	-	-	-	0.03 (0.25)	-	0.04 (0.42)	-	0.03 (0.16)	-	-	-	-	-	-	-	0.02 (0.29)	55	
Wilson's warbler	-	-	<0.01 (0.09)	<0.01 (0.08)	0.03 (0.17)	-	-	-	-	-	0.14 (0.38)	0.01 (0.11)	-	-	-	0.05 (0.23)	0.05 (0.32)	-	-	-	0.05 (0.22)	0.04 (0.20)	0.18 (0.44)	-	0.01 (0.15)	-	0.02 (0.13)	-	-	0.02 (0.15)	0.06 (0.24)	-	-	-	-	-	0.02 (0.15)	45	
winter wren	0.02 (0.12)	-	<0.01 (0.09)	<0.01 (0.08)	0.06 (0.24)	0.29 (0.47)	0.13 (0.35)	-	0.02 (0.12)	0.04 (0.19)	-	0.01 (0.11)	0.02 (0.14)	0.04 (0.19)	0.10 (0.30)	0.11 (0.32)	-	-	-	-	<0.01 (0.09)	0.04 (0.20)	0.05 (0.23)	-	<0.01 (0.08)	-	<0.01 (0.08)	-	0.08 (0.27)	0.06 (0.25)	-	-	-	-	-	-	0.02 (0.15)	50	
yellow warbler	0.03 (0.17)	0.07 (0.26)	0.02 (0.17)	0.01 (0.11)	-	-	0.07 (0.26)	-	<0.01 (0.07)	-	-	-	0.04 (0.19)	<0.01 (0.08)	0.05 (0.22)	0.11 (0.32)	-	-	-	-	0.03 (0.17)	-	0.04 (0.25)	-	<0.01 (0.08)	-	<0.01 (0.05)	-	-	0.09 (0.28)	-	-	-	-	-	-	0.01 (0.12)	31	
yellow-bellied flycatcher	0.02 (0.12)	-	-	0.03 (0.17)	-	-	-	0.05 (0.23)	-	-	-	0.01 (0.11)	0.02 (0.14)	<0.01 (0.06)	-	-	0.03 (0.16)	-	-	-	0.01 (0.12)	-	0.01 (0.10)	-	0.03 (0.20)	-	0.03 (0.20)	-	-	-	-	-	-	-	-	-	0.01 (0.13)	33	
yellow-bellied sapsucker	0.02 (0.12)	0.07 (0.26)	-	0.01 (0.11)	0.03 (0.17)	0.14 (0.36)	-	0.32 (0.58)	0.09 (0.30)	0.04 (0.19)	-	-	-	0.05 (0.24)	0.14 (0.36)	0.05 (0.23)	-	-	-	-	<0.01 (0.09)	-	0.03 (0.18)	-	-	-	<0.01 (0.05)	-	-	-	-	-	-	-	-	-	0.03 (0.16)	58	
yellow-headed blackbird	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.06)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (0.02)	1		
yellow-rumped warbler	0.35 (0.54)	0.47 (0.83)	0.61 (0.76)	0.46 (0.59)	0.17 (0.45)	0.07 (0.27)	0.13 (0.35)	0.05 (0.23)	0.10 (0.31)	0.21 (0.50)	-	0.35 (0.61)	0.17 (0.38)	0.23 (0.47)	0.24 (0.44)	0.16 (0.37)	0.05 (0.23)	0.06 (0.24)	-	-	0.19 (0.39)	-	0.09 (0.32)	1.00 (na)	0.36 (0.58)	-	0.36 (0.55)	-	0.28 (0.51)	0.19 (0.40)	-	-	0.16 (0.50)	0.17 (0.41)	-	-	0.28 (0.52)	64 2	
Overall Mean	1.68 (1.53)	2.67 (1.72)	2.01 (1.57)	2.16 (1.56)	3.54 (2.08)	5.50 (2.31)	4.73 (2.58)	4.05 (2.66)	3.41 (2.43)	4.29 (1.80)	2.86 (1.07)	1.92 (1.43)	2.83 (1.44)	3.30 (2.34)	4.48 (2.09)	3.47 (2.44)	2.55 (2.44)	4.35 (3.24)	2.80 (1.92)	1.00 (na)	3.04 (2.17)	2.96 (2.20)	4.96 (3.15)	2.00 (na)	2.58 (2.07)	2.00 (2.00)	2.74 (1.85)	1.00 (na)	2.79 (1.69)	5.43 (3.29)	3.22 (2.29)	3.00 (3.56)	4.11 (2.64)	1.83 (2.14)	4.00 (1.41)	2.00 (na)	2.99 (2.27)	6, 88 6	

(a) See Table H-2 for land cover type associated with each map code.

Note: Breeding bird species values are the Mean number of individual birds observed per point count (plus or minus standard deviation). Standard deviation is (na) where there was only one point count.



APPENDIX A BOREAL SONGBIRD HABITAT

Table A-2: Breeding Songbird Mean Relative Abundance, Species Richness and Diversity (\pm Standard Deviation) by Habitat Group and land Cover Type in the Oil Sands Region 2001 to 2011

Habitat Group	Land Cover Type ^(a)	Land Cover Type Description ^(a)	Number of Point Counts	Number of Birds	Mean Relative Abundance	Mean Species Richness	Mean Species Diversity ^(b)
coniferous jack pine–black spruce	a1	lichen jack pine	66	111	1.68 (1.53)	1.48 (1.29)	0.43 (0.50)
	b4	blueberry white spruce-jack pine	15	40	2.67 (1.72)	2.33 (1.68)	0.70 (0.57)
	c1	Labrador tea–mesic jack pine-black spruce	131	263	2.01 (1.57)	1.69 (1.27)	0.46 (0.52)
	g1	Labrador tea–subhygric black spruce-jack pine	177	383	2.16 (1.56)	1.92 (1.30)	0.55 (0.53)
coniferous white spruce	d3	low-bush cranberry white spruce	35	124	3.54 (2.08)	2.83 (1.82)	0.84 (0.61)
	e3	dogwood white spruce	14	77	5.50 (2.31)	4.43 (1.74)	1.35 (0.49)
	f3	horsetail white spruce	15	71	4.73 (2.58)	3.93 (1.91)	1.20 (0.52)
deciduous aspen–balsam poplar	b2	blueberry aspen-white birch	19	77	4.05 (2.66)	3.32 (1.92)	1.02 (0.63)
	d1	low-bush cranberry aspen	191	651	3.41 (2.43)	2.75 (1.72)	0.85 (0.55)
	e1	dogwood balsam poplar-aspen	28	120	4.29 (1.8)	3.46 (1.84)	1.06 (0.58)
	f1	horsetail balsam poplar-aspen	7	20	2.86 (1.07)	2.57 (1.13)	0.82 (0.57)
mixedwood aspen–white spruce	b3	blueberry aspen-white spruce	54	153	2.83 (1.44)	2.46 (1.36)	0.79 (0.51)
	d2	low-bush cranberry aspen-white spruce	328	1,081	3.30 (2.34)	2.71 (1.79)	0.82 (0.60)
	e2	dogwood balsam poplar-white spruce	21	94	4.48 (2.09)	3.81 (1.78)	1.19 (0.49)
	f2	horsetail balsam poplar-white spruce	19	66	3.47 (2.44)	3.21 (2.27)	0.92 (0.75)
mixedwood jack pine–aspen	b1	blueberry jackpine-aspen	88	169	1.92 (1.43)	1.64 (1.11)	0.45 (0.47)
non-treed open wetland	FONG	graminoid fen	38	97	2.55 (2.44)	2.05 (1.93)	0.60 (0.63)
	MONG	graminoid marsh	17	74	4.35 (3.24)	3.24 (2.33)	0.96 (0.62)
	WONN	open water	5	14	2.80 (1.92)	2.20 (1.48)	0.75 (0.52)
non-treed shrubby wetland	BONS	shrubby bog	1	1	1.00 (na)	1.00 (na)	-
	FONS	shrubby fen	137	417	3.04 (2.17)	2.58 (1.72)	0.77 (0.60)
	Sh	shrubland	24	71	2.96 (2.20)	2.54 (1.86)	0.76 (0.61)
	SONS	shrubby swamp	94	466	4.96 (3.15)	3.95 (2.23)	1.18 (0.61)



APPENDIX A BOREAL SONGBIRD HABITAT

Table A-2: Breeding Songbird Mean Relative Abundance, Species Richness and Diversity (\pm Standard Deviation) by Habitat Group and land Cover Type in the Oil Sands Region 2001 to 2011 (continued)

Habitat Group	Land Cover Type ^(a)	Land Cover Type Description ^(a)	Number of Point Counts	Number of Birds	Mean Relative Abundance	Mean Species Richness	Mean Species Diversity ^(b)
treed bog	BFNN	forested bog	1	2	2.00 (na)	2.00 (na)	0.69 (na)
	BTNN	wooded bog	278	717	2.58 (2.07)	2.10 (1.56)	0.61 (0.56)
treed fen	FFNN	forested fen	3	6	2.00 (2.00)	1.67 (1.53)	0.58 (0.53)
	FTNN	wooded fen	354	970	2.74 (1.85)	2.35 (1.50)	0.70 (0.57)
	FTPN	wooded fen with patterning	1	1	1.00 (na)	1.00 (na)	-
treed swamp	h1	Labrador tea/horesetail white spruce-black spruce	39	109	2.79 (1.69)	2.38 (1.35)	0.75 (0.52)
	STNN	wooded swamp	47	255	5.43 (3.29)	4.45 (2.58)	1.27 (0.65)
burn	BUu	burned upland	18	58	3.22 (2.29)	2.78 (1.73)	0.84 (0.64)
	BUw	burned wetland	7	21	3.00 (3.56)	2.57 (2.44)	0.68 (0.67)
clearcut	CC	disturbed - clearcut	19	78	4.11 (2.64)	3.16 (2.12)	0.98 (0.63)
linear development (vegetated)	cutline	disturbed - cutline	6	11	1.83 (2.14)	1.67 (1.75)	0.38 (0.64)
non-linear development (vegetated)	clearing	disturbed - clearing	4	16	4.00 (1.41)	3.25 (2.06)	0.98 (0.78)
	wellpad	disturbed - wellpad	1	2	2.00 (na)	1.00 (na)	-
Overall Mean or Total			2,302	6,887	2.99 (2.27)	2.49 (1.77)	0.74 (0.60)

^(a) Based on ecosite phase classification of Beckingham and Archibald (1996) and wetlands type classification of Halsey et al. (2003).

^(b) Species diversity was calculated for each point count using the Shannon diversity index (see methods for more details).

Note: Bird values are the Mean number of individual birds, species, or diversity values observed per point count (plus or minus standard deviation). Where standard deviation is (na), there was only one point count and standard deviation could not be calculated.



APPENDIX A BOREAL SONGBIRD HABITAT

Table A-3: Common and Scientific Names of Boreal Songbirds in the Oil Sands Region, 2001 to 2011

Common Name	Scientific Name	Guild	ESRD Status (ASRD 2011)	COSEWIC Status (2012)	SARA Status (Schedule) (2013)
alder flycatcher	<i>Empidonax alnorum</i>	other	Secure		
American redstart	<i>Setophaga ruticilla</i>	other	Secure		
American robin	<i>Turdus migratorius</i>	other	Secure		
barn swallow	<i>Hirundo rustica</i>	other	Sensitive	Threatened	
bay-breasted warbler	<i>Dendroica castanea</i>	mature forest	Sensitive		
black-and-white warbler	<i>Mniotilta varia</i>	mature forest	Secure		
blackburnian warbler	<i>Dendroica fusca</i>	mature forest	Sensitive		
black-capped chickadee	<i>Parus atricapillus</i>	mature forest	Secure		
blackpoll warbler	<i>Dendroica striata</i>	other	Secure		
black-throated green warbler	<i>Dendroica virens</i>	mature forest	Sensitive		
blue-headed vireo	<i>Vireo solitarius</i>	mature forest	Secure		
boreal chickadee	<i>Parus hudsonicus</i>	mature forest	Secure		
Brewer's blackbird	<i>Euphagus cyanocephalus</i>	other	Secure		
brown creeper	<i>Certhia americana</i>	mature forest	Sensitive		
Canada warbler	<i>Wilsonia canadensis</i>	mature forest	Sensitive	Threatened	Threatened (Schedule 1)
Cape May warbler	<i>Dendroica tigrina</i>	mature forest	Sensitive		
cedar waxwing	<i>Bombycilla cedrorum</i>	other	Secure		
chipping sparrow	<i>Spizella passerina</i>	other	Secure		
clay-coloured sparrow	<i>Spizella pallida</i>	other	Secure		
common yellowthroat	<i>Geothlypis trichas</i>	other	Sensitive		
Connecticut warbler	<i>Oporonis agilis</i>	other	Secure		
dark-eyed junco	<i>Junco hyemalis</i>	other	Secure		



APPENDIX A BOREAL SONGBIRD HABITAT

Table A-3: Common and Scientific Names of Boreal Songbirds in the Oil Sands Region, 2001 to 2011 (continued)

Common Name	Scientific Name	Guild	ESRD Status (ASRD 2011)	COSEWIC Status (2012)	SARA Status (Schedule) (2013)
eastern kingbird	<i>Tyrannus tyrannus</i>	other	Secure		
eastern phoebe	<i>Sayornis phoebe</i>	other	Sensitive		
evening grosbeak	<i>Coccothraustes vespertinus</i>	other	Secure		
fox sparrow	<i>Passerella iliaca</i>	other	Secure		
golden-crowned kinglet	<i>Regulus satrapa</i>	mature forest	Secure		
hermit thrush	<i>Catharus guttatus</i>	other	Secure		
house wren	<i>Troglodytes aedon</i>	other	Secure		
Le Conte's sparrow	<i>Ammodramus leconteii</i>	other	Secure		
least flycatcher	<i>Empidonax minimus</i>	mature forest	Sensitive		
Lincoln's sparrow	<i>Melospiza lincolnii</i>	other	Secure		
magnolia warbler	<i>Dendroica magnolia</i>	other	Secure		
marsh wren	<i>Cistothorus palustris</i>	other	Secure		
mountain bluebird	<i>Sialia currucoides</i>	other	Secure		
mourning warbler	<i>Oporornis philadelphia</i>	other	Secure		
Nashville warbler	<i>Vermivora ruficapilla</i>	other	Secure		
Nelson's sparrow	<i>Ammodramus nelsoni</i>	other	Secure	Not at Risk	
northern waterthrush	<i>Seiurus noveboracensis</i>	other	Secure		
olive-sided flycatcher	<i>Contopus borealis</i>	mature forest	May Be At Risk	Threatened	Threatened (Schedule 1)
orange-crowned warbler	<i>Vermivora celeta</i>	other	Secure		
ovenbird	<i>Seiurus aurocapillus</i>	mature forest	Secure		
palm warbler	<i>Dendroica palmarum</i>	other	Secure		
Philadelphia vireo	<i>Vireo philadelphicus</i>	other	Secure		
pine siskin	<i>Carduelis pinus</i>	mature forest	Secure		



APPENDIX A BOREAL SONGBIRD HABITAT

Table A-3: Common and Scientific Names of Boreal Songbirds in the Oil Sands Region, 2001 to 2011 (continued)

Common Name	Scientific Name	Guild	ESRD Status (ASRD 2011)	COSEWIC Status (2012)	SARA Status (Schedule) (2013)
purple finch	<i>Carpodacus purpureus</i>	other	Secure		
red crossbill	<i>Loxia curvirostra</i>	other	Secure		
red-breasted nuthatch	<i>Sitta canadensis</i>	mature forest	Secure		
red-eyed vireo	<i>Vireo olivaceus</i>	mature forest	Secure		
red-winged blackbird	<i>Agelaius phoeniceus</i>	other	Secure		
rose-breasted grosbeak	<i>Pheucticus ludovicianus</i>	other	Secure		
ruby-crowned kinglet	<i>Regulus calendula</i>	mature forest	Secure		
rusty blackbird	<i>Euphagus carolinus</i>	other	Sensitive	Special Concern	Special Concern (Schedule 1)
savannah sparrow	<i>Passerculus sandwichensis</i>	other	Secure		
sedge wren	<i>Cistothorus platensis</i>	other	Sensitive	Not at Risk	
song sparrow	<i>Melospiza melodia</i>	other	Secure		
Swainson's thrush	<i>Catharus ustulatus</i>	mature forest	Secure		
swamp sparrow	<i>Melospiza georgiana</i>	other	Secure		
Tennessee warbler	<i>Vermivora peregrina</i>	other	Secure		
tree swallow	<i>Tachycineta bicolor</i>	other	Secure		
varied thrush	<i>Ixoreus naevius</i>	mature forest	Secure		
vesper sparrow	<i>Pooecetes gramineus</i>	other	Secure		
warbling vireo	<i>Vireo gilvus</i>	other	Secure		
western tanager	<i>Piranga ludoviciana</i>	mature forest	Sensitive		
western wood-pewee	<i>Contopus sordidulus</i>	mature forest	Sensitive		
white-breasted nuthatch	<i>Sitta carolinensis</i>	mature forest	Secure		
white-crowned sparrow	<i>Zonotrichia leucophrys</i>	other	Secure		
white-throated sparrow	<i>Zonotrichia albicollis</i>	other	Secure		



APPENDIX A BOREAL SONGBIRD HABITAT

Table A-3: Common and Scientific Names of Boreal Songbirds in the Oil Sands Region, 2001 to 2011 (continued)

Common Name	Scientific Name	Guild	ESRD Status (ASRD 2011)	COSEWIC Status (2012)	SARA Status (Schedule) (2013)
white-winged crossbill	<i>Loxia leucoptera</i>	mature forest	Secure		
Wilson's warbler	<i>Wilsonia pusilla</i>	other	Secure		
winter wren	<i>Troglodytes troglodytes</i>	mature forest	Secure		
yellow warbler	<i>Dendroica petechia</i>	other	Secure		
yellow-bellied flycatcher	<i>Empidonax flaviventris</i>	other	Undetermined		
yellow-bellied sapsucker	<i>Sphyrapicus varius</i>	mature forest	Secure		
yellow-headed blackbird	<i>Xanthocephalus xanthocephalus</i>	other	Secure		
yellow-rumped warbler	<i>Dendroica coronata</i>	mature forest	Secure		

^(a) ASRD (Alberta Sustainable Resource Development). 2011. The General Status of Alberta Wild Species 2010. Edmonton, AB. Submitted August 2011. Available online at: <http://www.srd.alberta.ca/FishWildlife/SpeciesAtRisk/GeneralStatusOfAlbertaWildSpecies/GeneralStatusOfAlbertaWildSpecies2010/Default.aspx>. Accessed January 28, 2013.

^(b) COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2012. Canadian Species at Risk, October 2012. Canadian Wildlife Species at Risk. Committee on the Status of Endangered Wildlife in Canada. Gatineau, QC. 119pp. Available online at: http://www.cosewic.gc.ca/eng/sct0/rpt/rpt_csar_e.cfm. Accessed January 28, 2013.

^(c) Species at Risk Public Registry. 2012. Government of Canada, Ottawa. Available at: http://www.sararegistry.gc.ca/sar/index/default_e.cfm. Accessed January 28, 2013.

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Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
102, 2535 - 3rd Avenue S.E.
Calgary, Alberta, T2A 7W5
Canada
T: +1 (403) 299 5600

