Status of the Canada Warbler (*Cardellina canadensis*) in Alberta

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Alberta Conservation Association

Alberta

Status of the Canada Warbler (*Cardellina canadensis*) in Alberta: Update 2022

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Table of Contents

List of Figures

List of Tables

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Executive Summary

The Canada warbler (*Cardellina canadensis*) was listed as *Threatened* in Canada by COSEWIC in 2008 because of large and long-term declines in population size, and because a significant portion of the global population occurs in Canada. It was subsequently appended to Schedule 1 of the Species at Risk Act in 2010 as a Threatened species. The cause of the decline in this species' population size is not known, but loss and degradation of habitat on the breeding and wintering grounds is suspected. In Alberta, the general status of the Canada warbler has been Sensitive since 1996. This designation reflects the species' low numbers in the province, a long-term decline in population size, and vulnerability to loss of old-growth deciduous forest habitat.

The Canada warbler is a medium-sized, insectivorous Neotropical migrant songbird that breeds in the northern forests of North America and winters in northern South America. It is generally uncommon across its range, but can be locally abundant in suitable habitat. In Alberta, it is commonly associated with stands of mature to old-growth deciduous and mixedwood forest near incised streams in the Boreal Forest and Foothills natural regions. Approximately 11% of the global breeding population of the Canada warbler and 18% of its global area of occupancy are in Alberta. Based on the Breeding Bird Survey, the Alberta population has declined at 2.95% per year since 1970. During the most recent ten-year period, the Alberta population has declined by 1.62% per year. There is evidence to suggest that the long-term decline is levelling off; however, more time is needed to establish a definitive trend.

Habitat conversion that results in loss of old-growth deciduous forest and forested riparian areas at the local scale, and loss of deciduous forest at the landscape scale, are likely the ultimate limiting factors for the Canada warbler in Alberta. Current forestry practices that preferentially target mature forest stands threaten to eliminate older age classes of forest from the Alberta landscape, except for remnant fragments in logged stands and protected areas. Management practices aimed at conserving old-growth deciduous forest are likely needed to ensure the persistence of suitable breeding habitat for the Canada warbler. Future research that identifies how the indirect effects of habitat alteration on the breeding grounds and carry-over effects from habitat loss on the wintering grounds influence the survival and reproductive success of Canada warblers is necessary to ensure the long-term stability of this species. The continued monitoring of changing population trends will be critical to determining the future trajectory of this species.

1.0 Introduction

The Canada warbler (*Cardellina canadensis*) is a medium-sized, Neotropical migrant songbird (Reitsma *et al*. 2010). Its breeding range spans the boreal forest of North America from Yukon to Nova Scotia, extending southward in the east into the hardwood forests of New England and at higher elevations along the Appalachian Mountains to northern Georgia and Tennessee. Its winter range is primarily in northern South America across the Andes Mountains from Venezuela to Peru (Reitsma *et al*. 2010).

Canada warblers are generally uncommon across their range, but they can be locally abundant in suitable habitat. Habitat associations vary by region. In the western portion of their range they are associated with stands of mature to old-growth deciduous and mixedwood forest that have a dense shrub understorey and are often near incised streams in valleys with steep banks. Canada warblers have also been recorded in low numbers in stands of regenerating forest that have a dense shrub layer and patches of live residual trees. In the eastern portion of their range they are associated with mixedwood swampland forests and early successional forests created by logging or natural disturbance.

Panjabi *et al*. (2012) found that the number of Canada warblers detected on their breeding grounds had been declining steadily since broad-scale breeding bird surveys began in the mid-1960s. The decline is believed to have occurred on a range-wide scale; however, until recently, Canada warblers have been the focus of few directed studies, particularly in the western portion of their range, hampering accurate assessment. Reasons for the decline are unknown, but loss of suitable habitat on both the breeding and wintering grounds is suspected. Declining numbers coupled with the majority of the breeding population occurring in Canada prompted the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to assess the species as *Threatened*[*] in 2008. It was subsequently listed on Schedule 1 of the *Species at Risk Act* as a *Threatened* species in 2010. Several provinces followed suit and increased their provincial risk assessments. The Canada warbler is currently considered *Sensitive* in Alberta (Alberta Environment and Parks [AEP] 2017); this assessment has remained unchanged since 1996. Recent studies within the province indicate that population declines have begun to level out; however, there remains uncertainty around the persistence of this trend and the source of historical declines. This status report compiles and summarizes all current information with the goal of updating the status of the Canada warbler in Alberta.

[*] See Appendix 2 for definitions of selected status designations

2.0 Taxonomy

Until 2011, Canada warbler was in the genus *Wilsonia* along with Wilson's warbler (formerly *W. pusilla*) and hooded warbler (formerly *W. citrina*). Phylogenetic analyses of wood warblers (family Parulidae) resulted in the reclassification of several species, including Canada warbler. These new data resulted in species within *Wilsonia* being subsumed into two other genera, *Cardellina* and *Setophaga* (Lovette *et al*. 2010). Canada warbler and Wilson's warbler were determined to be more closely related to the red-faced warbler (*C. rubrifrons*), red warbler (*C. ruber*) and pink-headed warbler (*C. versicolor*). This reclassification was adopted by the American Ornithologists' Union in 2011 (Chesser *et al*. 2011).

3.0 Distribution

3.1. Alberta

Alberta is near the northern and western limits of the Canada warbler's breeding range. The species is broadly distributed across the northern part of the province in the Boreal Forest and Foothills natural regions, as well as the Peace River Parkland Natural Subregion near Grande Prairie (Figure 1). Possible breeding records have been reported as far south as the Cypress Hills (Figure 1). The known extent of occurrence of the species' breeding range in Alberta is 492 396 km^2 (Figure 1), which corresponds to 17.9% of the global range (2 756 662 km^2; Berlanga *et al*. 2010; Panjabi *et al*. 2012). This is larger than the extent of occurrence reported in the previous version of this report, for which the Cypress Hills were not noted to be occupied but the Cypress Hills observations are likely a result of the area not being extensively surveyed, as opposed to a range expansion. The extent of occurrence of breeding birds is based on observations of singing males, which are assumed to provide evidence of breeding.

Based on all known breeding locations (Figure 1), Canada warblers occupy 2872 km^2 of Alberta (where occupancy is defined as ≥ 1 individual detected in a 2-km × 2-km area). Canada warblers are most likely to be found in the Boreal Forest Natural Region, followed by the Foothills, Parkland and Grassland natural regions, where they are detected much less frequently (Table 1). Few Canada warblers have been recorded in the Rocky Mountain and Canadian Shield natural regions of Alberta (Table 1). There has been too little survey effort to draw any conclusions about Canada warbler use of the Canadian Shield Natural Region, although habitats in this region are predicted to be of low value for this species (Ball *et al*. 2013). The majority of detections in the Parkland (429/470) and Grassland natural regions (310/317) are records from outside the breeding season (approximately 30 May to 15 July; Flockhart 2010; J. Gregoire unpublished data). The limited number of records despite a large survey effort indicate a lower quality habitat in those regions. By comparison, over 70% of detections in the Foothills and Boreal Forest natural regions are of singing males, females

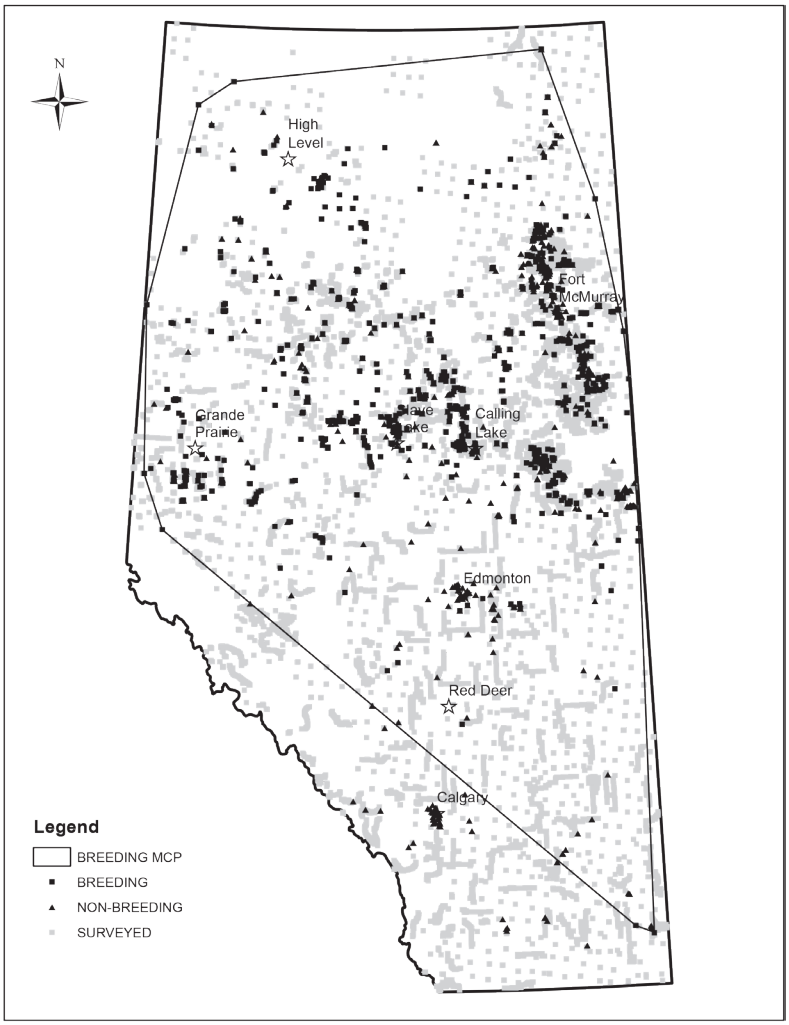

Figure 1. Canada warbler observations within 4-km^2 areas in the province of Alberta. Observations with evidence of breeding are shown as black squares, whereas observations that could not be associated with evidence of breeding are shown as triangles. The 100% minimum convex polygon for all Canada warbler breeding records is shown as a solid black line ("Breeding MCP"); this is referred to as the Extent of Occurrence in the report and does not represent equal existing or potential occupancy across the given area. Data sources are identified in Appendix 1. Locations surveyed where Canada warblers were not detected (light gray squares) are from Wildtrax and BAM (Appendix 1). Locations of cities and of studies referred to in the text (i.e., Calling Lake, Slave Lake) are indicated with stars.

Table 1. Numbers of 2-km × 2-km grid cells where Canada warblers have been detected, numbers of cells surveyed, and percentage of surveyed cells occupied in each natural region in Alberta.

Natural Region	# Cells Occupied	# Breeding Cells	# Cells Surveyed	% Surveyed Cells Occupied	% Surveyed Cells Breeding
Parkland	53	12	724	7.3	1.7
Boreal Forest	844	623	5253	16.1	11.9
Foothills	92	79	828	11.1	9.5
Grassland	35	2	1418	2.5	0.1
Rocky Mountains	8	0	481	1.7	0.0
Canadian Shield	4	2	30	13.3	6.7

or hatch-year birds within the breeding season, which are indicative of breeding activity. The Boreal Forest Natural Region also contains many banding records from during the breeding season and during migration at Lesser Slave Lake Bird Observatory, where several Canada warbler nests have been located. These data indicate that the majority of Canada warblers breeding in Alberta are in the Foothills and Boreal Forest natural regions and relatively few are likely breeding in the Parkland Natural Region.

The area of occupancy estimate of 2872 km^2 is based on known locations. It does not account for areas that have not been surveyed and, therefore, should be considered a minimum estimate. For example, given that the province is divided into 4-km^2 grid cells, only 5.3% of the 165 803 4-km^2 cells in Alberta have had any known survey effort (Figure 1). It follows that several areas of this unsurveyed portion of Alberta are within suitable habitat for Canada warblers. Future surveys that target areas not previously visited (e.g., remote habitats in the north; Figure 1) will likely result in increased range and occupancy estimates. Sampling effort within each surveyed 4-km^2 area also is highly variable, ranging from a single point to hundreds of points sampled for over 20 years. Using the habitat suitability model of Ball *et al*. (2016), Canada warblers occupy 105 798 km^2 in Alberta during the breeding period. This estimate is based on the number of 1-km^2 cells (i.e., one section area; raster cell size of model) predicted to support ≥ 0.01 males/ha on average. Predicted Canada warbler density was based on land cover, human footprint*, forest age, forest type, wetness, topography and spatial location. This estimate assumes that there are no Canada warblers breeding in the Grassland Natural Region of Alberta. D. Stralberg (pers. comm.) obtained an occupancy estimate of 347 315 km^2 (95% CI: 278 548-420 222) using data from a national climate suitability model and the same minimum density threshold of 0.01 males/ha in a 4-km × 4-km cell. These model-based estimates suggest that the area occupied in Alberta is 17%–19% of that occupied in North America during the breeding season (Stralberg *et al*. 2013; D. Stralberg pers. comm.). It is important to note that these model estimates have not been validated with data independent of the data used to construct the model. Such validation is needed to ensure that these estimates are accurate. Regardless, these model-based estimates suggest that the area occupied is potentially much larger than the current estimate of area of occupancy based on known locations.

* Human footprint is defined as the visible conversion of native ecosystems to temporary or permanent residential, recreational, agricultural, or industrial landscapes (ABMI 2018). ABMI defines six categories of human footprint: agriculture; forest harvest; mines, wells and other energy features; transportation; urban, rural, and industrial; and human-created waterbodies.

There are insufficient data to indicate whether the extent of occurrence and area of occupancy in Alberta vary annually or have decreased in the past; however, it is possible that the extent of habitat may decrease in the future, if agricultural expansion in the southern boreal forest continues and climate change results in loss of forest (see 6.0 Population Size and Trends and 7.0 Threats for further discussion). There is no indication that the population is either severely fragmented or separated into distinct subpopulations within Alberta. Canada warblers are continuously distributed across northern Alberta, with local abundance varying in relation to habitat quality, which is primarily a function of forest stand composition, stand age, wetness and topography (Ball *et al*. 2013, 2016). Because habitat suitability is positively associated with forest age, occupancy can be expected to increase in stands that remain undisturbed by natural or human processes (e.g., Vernier *et al*. 2009; but see 7.0 Threats for further discussion).

3.2. Other Areas

The Canada warbler's breeding range extends across the northern forested region of North America from southeastern Yukon and northeastern British Columbia to Nova Scotia, extending southward into the United States in forested regions around the Great Lakes and in the northeast, and extending southward at higher elevations (1000–1400 m) of the Appalachian Mountains to northern Georgia (Figure 2; Ridgely *et al*. 2003, Reitsma *et al*. 2010; Chandler and Hepinstal-Cymerman 2016; Céspedes and Bayly 2018; Chandler *et al*. 2018). Canada warblers migrate south from the breeding grounds across the central-eastern and eastern United States; individuals from Alberta first cross over to Manitoba before flying south (Roberto-Charron 2018). Studies indicate that migration routes converge at the Gulf of Mexico and follow the western edge of the gulf through Central America, after which they disperse. Cárdenas-Ortiz *et al*. (2017) found the Darién region in northwest Colombia (where Central and South America meet) to be a stopover for individuals from across the breeding range. They suggested that hatch-year birds are more likely to follow the coastline and that the over-representation of females in their study could be explained by a difference in routes between sexes. Canada warblers have been known to winter across the Andean cordilleras in northern South America. Their winter range extends from Venezuela in the northeast to Ecuador and central Peru in the southwest with rare records ranging as far north as Costa Rica and as far southeast as the Amazon region of Brazil (Figure 2; Reitsma *et al*. 2010; González-Prieto *et al*. 2017). Wintering locations of the Alberta population of Canada warblers have been identified in both Colombia and Venezuela (González-Prieto *et al*. 2017; Roberto-Charron 2018).

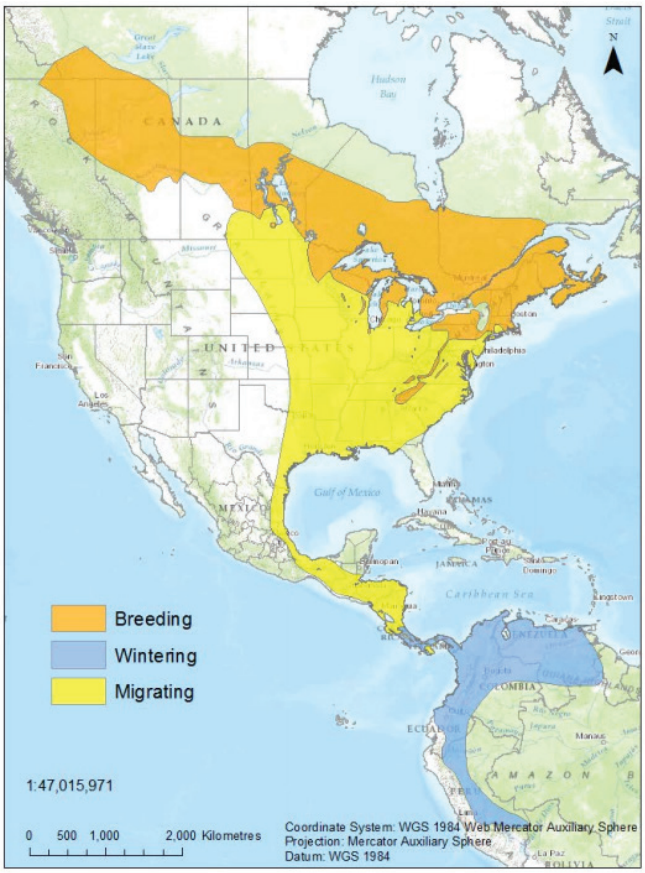

Figure 2. Breeding, migrating and wintering ranges of Canada warbler (from Environment Canada 2016, based on multiple sources).

Habitat loss on the breeding and wintering grounds is considered the primary threat to this species (Reitsma *et al*. 2010; NatureServe 2014; see 7.0 Threats). The extent of occurrence and area of occupancy would be expected to decline in response to habitat loss and alteration, although we are not aware of any estimates of historical or predicted changes in extent or area occupied. Canada warblers use early successional forests, particularly in the eastern portion of their breeding range, and moderately disturbed habitats on their wintering grounds (see 4.0 Habitat), which may buffer their sensitivity to some land uses in some areas. Recent detections in British Columbia suggest that the species is expanding the western edge of its range (Cooper *et al*. 1997). Surveys targeted at delimiting the extent of their northwestern range appear warranted. Range expansion also may have occurred in the northeastern United States during the early to mid-1900s in response to an increase in forested cover on previously agricultural land (Reitsma *et al*. 2010). Continued forest maturation from an early to a moderate successional state is a potential risk to the northeastern part of the range as habitat suitability decreases with canopy closure and inhibited understorey development (Grinde and Niemi 2016). Over-browsing of understorey vegetation by deer (*Odocoileus* sp.) and the loss of forested wetlands have also contributed to a loss of suitable habitats in this region.

4.0 Habitat

The majority (> 90%) of the Canada warbler breeding population inhabits northern forests (Berlanga *et al*. 2010; Panjabi *et al*. 2012). Habitat associations of Canada warbler have been well described in eastern regions and in relation to logging and forest fire in Alberta. Habitat associations vary by region, but throughout their range Canada warblers are most commonly found in moist to wet habitats with a dense understorey, which may be important for foraging and nesting success (Schieck *et al*. 1995; Lambert and Faccio 2005; Hallworth *et al*. 2008a, 2008b; Chace *et al*. 2009; Flockhart and Krikun 2012).

4.1. Local and Landscape Scales

In western regions, including Alberta, Canada warblers are most commonly associated with stands of mature (> 80 years old) and old-growth deciduous and mixedwood forest, preferably adjacent to incised streams and small rivers as opposed to broad wet areas (Schieck *et al*. 1995, 2000; Kirk *et al*. 1996; Norton *et al*. 2000; Vernier *et al*. 2009; Flockhart and Krikun 2012; Ball *et al*. 2013, 2016; Mahon *et al*. 2016; Alberta Biodiversity Monitoring Institute and Boreal Avian Modelling Project [ABMI and BAM] 2019). Old growth is defined as forest that is more than 125 years post-disturbance (Lee 2002). Canopy trees achieve their maximum size and density during this stage. Trees from the original cohort also begin to grow old and fall, which results in the accumulation of downed woody material on the forest floor and, in mixedwood stands, a gradual replacement of deciduous canopy trees with slower-growing conifer trees. Abundance of Canada warblers declines as the proportion of conifer trees in the canopy increases in Alberta (Norton *et al*. 2000; Ball *et al*. 2013, 2016), but small proportions of white spruce (*Picea glauca*) (as well as paper birch [*Betula papyrifera*]) in the canopy are preferred in northeastern British Columbia (Cooper *et al*. 1997). The fallen trees leave large gaps in the forest canopy, which allows more sunlight to reach the forest understorey, promoting vertical stratification through accelerated growth of the sub-canopy and shrub layers, and increased density and diversity of vascular plants on the forest floor (Lee 2002). Canada warblers also inhabit alder (*Alnus* spp.) and willow (*Salix* spp.) thickets (Flockhart and Krikun 2012). Agriculture and urban-industrial habitats are avoided (Ball *et al*. 2013; ABMI and BAM 2019).

In the larger landscape, Canada warbler abundance is positively associated with the amount of deciduous forest of any age and negatively associated with the amount of black spruce (*P. mariana*) (Norton *et al*. 2000; Vernier *et al*. 2009; Ball *et al*. 2013). The habitat model developed by Ball *et al*. (2016; also see ABMI and BAM 2019) indicated that old mixedwood forests were the second most valuable habitat type (after old deciduous forests) according to density; however, the total number of individuals was less than that of young deciduous forest, shrubby lowlands and swamps because of limited available area. The Ball *et al*. (2016) model did not show strong support for differences in Canada warbler abundance in areas with differing densities of energy sector linear features (i.e., seismic lines, pipelines and service access roads) and well pads, and the ABMI and BAM (2019) model suggests that linear footprints are predicted to have only small negative effects on relative abundance in the forested region. The availability of suitable habitat generally increases from south to north and from east to west within the boreal forest of Alberta, but suitable habitat exists in the south and east where favourable conditions exist, irrespective of the general spatial trend (Ball *et al*. 2013, 2016; ABMI and BAM 2019).

Canada warblers have also been recorded in early seral stages of trembling aspen (*Populus tremuloides*) in Alberta, albeit at much lower densities compared to old-growth forest (Schieck *et al*. 1995, 2000; Kirk *et al*. 1996; Schieck and Hobson 2000; Schieck and Song 2006; Ball *et al*. 2016; ABMI and BAM 2019). Canada warblers are generally absent from recently disturbed stands, particularly those without live residual trees (0–10 years post-disturbance; Schieck *et al*. 1995; Kirk *et al*. 1996; Norton *et al*. 2000; Schieck and Song 2006). Densities in adjacent habitats may increase in the first year after disturbance as displaced individuals crowd into remaining suitable habitats (Song 1998). However, densities return to pre-disturbance levels in the following year, suggesting that displaced individuals disperse from the area. Canada warbler abundance in regenerating stands generally peaks at 11 to 30 years post-disturbance, and the species' numbers decline to rare or uncommon as canopy closure begins to inhibit understorey development (31–75 years post-disturbance; Kirk *et al*. 1996; Hobson and Schieck 1999; Schieck and Song 2006; Grinde and Niemi 2016). The numbers of Canada warbler increase thereafter as stands continue to mature into the preferred older age classes.

Logged stands with large patches of live residual trees and a dense shrub layer are generally preferred relative to burned stands that commonly lack these features (Schieck and Hobson 2000; Schieck and Song 2006; Hunt *et al.* 2017). Abundance of Canada warblers in early seral habitats is positively correlated with the amount of tree retention and residual patch size. Canada warblers were absent from logged stands when residual retention was 6%, but were present when residual retention was between 30% and 40% and was aggregated into larger patches (Norton and Hannon 1997; Schieck and Hobson 2000; Schieck *et al*. 2000; Ball *et al*. 2016). In a study in boreal Alberta (Hunt *et al*. 2017), 44% of male Canada warblers that were captured less than 200 m from a logged stand (< 30 years since disturbance) included it within their home range. Although logged stands made up < 20% of the total area, mean home range size was larger for birds with logged stands in their home range compared to those without. This indicates that logged stands have limited resource availability, requiring a larger area to provide needed resources. Male Canada warblers also spent more time within the unlogged sections of their home range, which suggests that they have to defend these more desirable portions of their range from conspecifics. Alternatively, there has been evidence that adult Canada warblers tend to use edges, either natural or man-made (Cooper *et al*. 1997; Reitsma *et al*. 2010; D.T.T. Flockhart pers. comm.), and they may select for residual forest patches that provide suitable habitat contrasts or understorey composition or structure near their margins. Researchers have suggested that emergent trees are important perches for territorial displays (Hallworth *et al*. 2008a; Chace *et al*. 2009). However, aggregated residual patches are preferred to single trees that could function as suitable song perches, which suggests that the presence of a canopy may be an important habitat component that determines where birds settle (Norton and Hannon 1997; Schieck and Hobson 2000; Schieck *et al*. 2000; Westwood 2016; Westwood *et al*. 2017).

At a coarse level, there is a large amount of deciduous-dominated forest in the Boreal Forest Natural Region of Alberta where Canada warblers likely can breed. However, specific habitat attributes such as dense shrub cover near to small, incised wet areas are rarer. Importantly, there is no easy way to map the density of shrubs in Alberta at this time, which precludes a direct estimation of "suitable but not occupied" habitat. Suitable habitat for the Canada warbler in Alberta can be predicted from a model that includes the following predictor variables: forest age, forest type, wetness, topography, and spatial location (Ball *et al*. 2013, 2016).

In the eastern portion of their range, Canada warblers are commonly associated with forested swamps and riparian areas under a closed to semi-open mixedwood or coniferous canopy with a naturally dense understorey (Lambert and Faccio 2005; Hallworth *et al*. 2008a; Grinde and Niemi 2016). They have also been associated with early seral upland habitats in this region, where natural or human disturbance has opened the forest canopy allowing a dense understorey to develop (Drapeau *et al*. 2000; Hagan and Meehan 2002; Faccio 2003; Lambert and Faccio 2005; Chace *et al*. 2009; Becker *et al*. 2012). However, using multi-season occupancy models, Grinde and Niemi (2016) found younger stands to have a greater probability of site abandonment during the breeding season. This suggests that early seral upland forests offer temporary ideal habitat (5–20 years post-disturbance). The duration for which they remain habitable is influenced by the extent and type of logging, the number of residual trees and the development of vertical structure in the understorey (3–5 m; Chace *et al*. 2009; Becker *et al*. 2012; Grinde and Niemi 2016). These disturbed upland forests may be lower quality habitat compared to wet forests, and they are abandoned when the understorey becomes taller than 6 m (Hagan and Meehan 2002; Hallworth *et al*. 2008a).

4.2. Nest Site

The nest is a bulky cup of dry leaves, bark, twigs, grass, plant fibres and animal hair (Cooper *et al.* 1997; Reitsma *et al.* 2010). Nests are located on or near the ground, typically in a well-concealed location such as beneath or within root masses, rotting stumps, logs, rocks, mossy hummocks, brush piles, clumps of grass, or small hillocks with deep litter and dense saplings. There is no information regarding nest site limitation.

4.3. Winter

Canada warblers select habitats with a dense understorey in the foothills, mountains and lowlands of the Andean cordilleras. They are found in primary (unlogged) forest, but they are tolerant of moderate levels of disturbance and are also found in young and old secondary (regenerating) forests, forest edges, scrub habitats, semi-open areas and coffee plantations between 500 m and 2000 m above sea level (Komar 2006; Reitsma *et al.* 2010; Davidson *et al.* 2011; Colorado Z. and Rodewald 2017). In Colombia, Canada warblers have been known to occupy shade-grown coffee plantations with at least 40% shade during the dry season (Colorado Z. and Rodewald 2017; González-Prieto 2018). The suitability of this habitat varies seasonally with precipitation; female Canada warblers in coffee plantations lost approximately 6% of their body weight during the dry season (see 7.0 Threats; González-Prieto 2018). In an older study from Colombia, Canada warblers were not found in landscapes with less than 20% regional forest cover (within 1 km^2), and they were virtually absent from stands with a degraded understorey and less than 45% canopy cover (Colorado 2011).

5.0 Biology

The Canada warbler is a medium-sized, Neotropical migrant wood warbler. Males are readily identified by their slate-grey back, yellow underparts, black necklace and prominent supraloral stripe and eye ring that give the appearance of spectacles (Reitsma *et al*. 2010). Females appear similar to males, although they are duller in colour overall. Despite their broad distribution and characteristic appearance, Canada warblers have been the focus of few research studies, particularly in the western portion of their range, and many aspects of their breeding biology are not well known.

5.1. Migration and Breeding Phenology

Canada warblers have a short breeding period compared to other wood warblers (Flockhart 2007). They are one of the last warblers to arrive on their northern breeding grounds. This is suggested to be a contributing factor in their exclusion from upland deciduous and coniferous forests in Minnesota by more aggressive songbird species that establish territories earlier (Grinde and Niemi 2016). In Alberta, older males arrive at Lesser Slave Lake Bird Observatory by 1 June on average, two to three days ahead of females and younger males (Flockhart 2007). Earlier arrival may allow older males to settle in higher quality habitats (Hallworth *et al*. 2008a, 2008b). Territory establishment and pairing happen quickly, and initiation of breeding (mean date of first egg laid = 11 June) and moulting (mean = 12 July) are synchronized with other warbler species in the region (Flockhart 2010). This synchrony may reflect an evolutionary constraint to match the energy demands of reproduction with peak food abundance and to avoid provisioning nestlings during moult, which is a critical stage in the annual cycle requiring time and energy for adults to complete. Moult initiation begins immediately after nestlings fledge (mean = 11 July). The duration of moult for Canada warblers in Alberta is approximately 28 days, which is 2–41 days shorter than other wood warbler species monitored at Lesser Slave Lake (Flockhart 2010). Female Canada warblers depart the breeding grounds on their southward migration two days after completing their moult (mean = 4 August). Hatch-year birds depart two to four days after females, and males depart last, approximately eight days after females (mean = 12 August). Individuals defend winter territories, and birds may depart early to secure space in high-quality habitat (Rohwer *et al*. 2005). In total, males and females spend an average of 72 days and 62 days, respectively, on the breeding grounds (Flockhart 2007). This contracted breeding period may pose significant time and energetic constraints on breeding, re-nesting opportunities, moult and survival, particularly for females (Flockhart 2007). Canada warblers arrive in South America from late September to early November, with roughly 77% passing through the Darién region in Colombia from October 9–20 (Cárdenas-Ortiz *et al*. 2017). Cárdenas-Ortiz *et al*. (2017) reported that the arrival date of after-hatch-year birds (10 October ± 2.9 days) was an average of six days earlier than that of hatch-year birds (16 October ± 2.6 days), and that males arrived before females (12 October ± 3.5 days vs. 15 October ± 4.0 days).

5.2. Reproductive Behaviour

Canada warblers build an open cup nest on the ground, typically in dense vegetation. In eastern portions of their range, nest success is positively associated with concealment by complex ground vegetation and shrub density (Goodnow and Reitsma 2011). Canada warbler nests are frequently parasitized by brown-headed cowbirds (*Molothrus ater*) in some areas, and dense understorey vegetation may be important to reproductive success by providing protection from nest predators and cowbirds (Reitsma *et al*. 2010). Brood parasitism by cowbirds is uncommon in the boreal forest of Alberta, except in landscapes with an extensive agricultural matrix (Hannon *et al*. 2009; Ball *et al*. no date). Parents sit tight on the nest when approached by observers, which suggests that adults may actively defend their eggs and nestlings from predators and cowbirds or attempt to camouflage their nest with their slate grey back (Goodnow and Reitsma 2011). Red squirrels (*Tamiasciurus hudsonicus*) are the dominant nest predator in Alberta, and visual nest concealment does not affect the rate of nest predation by squirrels, as they are guided by their sense of smell (Flockhart *et al*. 2016; Ball *et al*. no date). In a study conducted by Flockhart *et al*. (2016), conspecific density, shrub cover, squirrels present within a territory, and position of the territory adjacent to a shoreline had a direct negative effect on territory size and, consequently, an indirect negative effect on breeding success. Under conditions of limited or patchy distribution of available habitat and high conspecific attraction, selection for dense shrubby vegetation may have adverse effects on Canada warbler population in Alberta.

Nestlings fledge (leave the nest) approximately eight days after hatch (before they can fly), and they remain in the vicinity of the nest for a few days (Reitsma *et al*. 2010). A dense understorey may be important for concealing fledglings and moulting adults from predators during this vulnerable period (Chace *et al*. 2009). No records exist for the post-fledging period of Canada warblers in Alberta. Fledglings achieve flight within two to three days after leaving the nest and gain independence within two weeks after fledging (Reitsma *et al*. 2010).

5.3. Diet and Foraging Behaviour

Canada warblers forage primarily on flying insects, but their diet also includes beetles and non-flying arthropods such as caterpillars and spiders (Reitsma *et al*. 2010). They forage in a wide range of microhabitats within low branches of deciduous and coniferous trees and shrubs of varying heights, and they employ a variety of foraging methods (Sohdi and Paszkowski 1995; Reitsma *et al*. 2010). During the breeding season, adults provide nestlings with larval and adult lepidoptera, diptera and spiders (Reitsma *et al*. 2010; Flockhart and Krikun 2012). Local abundance of Canada warblers may be positively associated with larval biomass in years of low prey abundance, which suggests that this is an important food resource during the breeding period (Song 1998). On the wintering grounds, in regions with a high proportion of agroecosystems (natural ecosystems that have been modified for the production of food and fibre), Canada warblers will occupy shade-grown coffee plantations, which may support an abundant insect population (Colorado Z. and Rodewald 2017; González-Prieto 2018). In forested habitat with dense mid-level vegetation, they have been frequently observed along creeks (González-Prieto 2018), where insect prey is presumably more abundant.

5.4. Demography and Dispersal

Canada warblers begin breeding at one year of age (Reitsma *et al*. 2010). Females typically lay a single clutch of four to five eggs (range = 2–6) and fledge an average of 3.8 young/nest (Reitsma *et al*. 2010). In New Hampshire, Demko *et al*. (2016) found that 58% of nests in 2010 and 81% of nests in 2011 successfully fledged young. Reitsma *et al*. (2010) report a daily nest survival rate of 0.9555 for 37 nests. The probability of a nest surviving from hatch to fledge is 0.32 ($[0.9555]^{25\ days}$), assuming a constant probability of daily survival, a five-egg clutch with one egg laid per day, a twelve-day incubation period, and an eight-day nestling period. Canada warblers are not known to attempt a second brood if the first nest is successful, but they will attempt to re-nest if the first nest fails early in the breeding season (Reitsma *et al*. 2010).

The average ages of breeding adults and adult survivorship are not known. Reitsma *et al*. (2010) reported that four-year-old males were common in a New Hampshire breeding population and that several individuals were known to be older. The average return rate for males is 52% in this region, which suggests that apparent survival is high in good-quality habitat (Hallworth *et al*. 2008a; Demko *et al*. 2016). Estimates of apparent survival are typically lower than true survival because they do not account for the fate of emigrants. However, true survival in this region may be less than 52% if site fidelity is high in high-quality habitats (i.e., most birds that fail to return are dead) and apparent survival is low in poorer quality habitats. In North Carolina, along the southern extent of the breeding range, Chandler *et al*. (2018) reported low recapture rates with only 30.28% (n=33) of Canada warblers captured two or more times within a four-year period. Apparent survival increased with elevation (0.04 at 900 m to 0.29 at roughly 1550 m), suggesting that habitat quality is poor at lower elevations in this region. The oldest known individuals from banding records are 8.0 years (Quebec) and 7.92 years old (New York; North American Bird Banding Program 2017). Juvenile survival is also unknown but is commonly considered to be half that of adult survival for passerine birds (Ricklefs 1973).

Little is also known about dispersal of adults and juveniles. Demko *et al.* (2016) reported high site fidelity in adult male Canada warblers in New Hampshire. Song sharing, resulting in locally common songs between neighbouring territories, may play a role in the retention of territories between years. Prospecting males with audibly distinct songs were unable to establish a territory or were displaced by late returning tenants from the previous year. Chandler *et al*. (2018) found that within- and among-year recaptures were all less than 200 m from the original location, confirming high site fidelity and low dispersal among adults. However, in New Hampshire there is evidence of males traveling > 1 km (n=5) and > 2 km (n=1) to sire extra-pair young (Reitsma *et al*. 2018). Banding records provide little insight because of extremely low recapture rates; 0.004% of the 104 857 Canada warblers banded in North America from 1960 to 2020 have been recaptured (North American Bird Banding Program 2017). One individual of the 3059 banded in Alberta during that period has been recaptured, which occurred during spring migration in Minnesota (R. Krikun pers. comm.). No birds that have been banded elsewhere have been recaptured in Alberta (R. Krikun pers. comm.). Brewer *et al*. (2006) report that, of the 10 767 Canada warblers captured by banding programs in Canada between 1955 and 1995, only nine (0.08%) have been re-sighted, with a maximum movement of 946 km between encounters. Most of these (six of nine) were originally banded in the United States during migration. Only two Canadian-banded birds have been recaptured elsewhere, with a mean distance of 18 km between encounters. A telemetry study conducted on fledglings in New Hampshire suggests that dispersal distance is highly variable, with some fledglings leaving the study area within a week of departing the nest and others remaining for the life of the transmitters (Reitsma *et al*. 2010).

6.0 Population Size and Trends

6.1. Alberta

Canada warblers are relatively uncommon and, particularly in the west, they are broadly distributed across remote areas with limited access. Estimates of population size and trend are hampered by limited data in western regions, including Alberta. The population of Canada warblers in Alberta was estimated in *The Alberta Wild Species General Status Listing 2015* to be between 2000 and 10 000 individuals (AEP 2017). More recent estimates based on the latest statistical advances and a dataset compiled over numerous years and studies suggests that the population size is between 395 300 and 773 758 breeding males (see below). Population size is estimated for breeding males because the standard survey protocol targets singing individuals and, for most species of songbirds, including Canada warbler, only territorial breeding males sing. Management decisions based on total population size that is derived by doubling the number of breeding males should be conservative to reflect uncertainty in the ratio of females to males in the breeding population. The ratio of females to males could be less than one if energetic constraints on the breeding grounds (see 5.0 Conservation Biology) and sexual habitat segregation on the wintering grounds (e.g., Marra and Holmes 2001) have disproportionately high survival costs for females. The proportion of non-breeding adults (i.e., "floaters") in the population is also unknown.

Based on a national climate suitability model built to exclude non-habitat (agriculture, urban development, water and unforested wetlands), there are an estimated 773 758 (95% CI: 636 532–910 984) adult male Canada warblers in Alberta (D. Stralberg unpublished results based on methods in Stralberg and Bayne 2013). This climate suitability model includes seven variables that are direct or derived measures based on temperature and precipitation. Using this same method, Stralberg estimated the breeding population in Alberta to represent 11% (95% CI: 8%–13%) of the global breeding population. Using similar bird data, but a more detailed model that included a greater number of environmental predictor variables, Ball *et al*. (2016) estimated the number of adult male Canada warblers in Alberta, based on habitat supply, to be 395 300 (90% CI: 331 800–498 500).

Both the Stralberg and Bayne (2013) and Ball *et al*. (2016) models use new statistical advances to correct for detection error and detection radius as per Boreal Avian Modelling Program (BAM) protocols (www.borealbirds.ca). BAM density results in much higher estimates of density and, therefore, population size than the current Partners in Flight (PIF) standard. In short, BAM computes density using distance estimation and corrects for singing rates. The distance estimation function computes the effective detection radius, which is the distance at which the probability of missing a bird within that distance is the same as the probability of detecting a bird outside that distance. In essence, this effective detection radius provides the area over which a point count is divided to convert a count to density. PIF uses an alternative and much more conservative approach based on the maximum detection distance that Canada warblers can be heard during a point count (Rosenberg and Blancher 2005; Will *et al*. 2019). For Canada warbler, this distance is 125 m; however, this is a conservative density correction based on a forest environment and bird vocalizations can be heard over greater distances when surveying from a road. Using the approach of Matsuoka *et al*. (2012) to convert the BAM density estimates of Stralberg and Bayne (2013) and Ball *et al*. (2016) to PIF density estimates, the number of breeding male Canada warblers in Alberta is roughly 264 329 and 135 041, respectively. PIF are expecting to switch their approach to include species-specific effective detection radii in future updates (Will *et al.* 2019).

The number of Canada warblers detected on Breeding Bird Surveys (BBS) in Alberta declined by 2.95%/year (95% credible interval: -6.00 to -0.070) between 1970 and 2019 (A. Smith unpubl. update of Smith *et al*. 2019; Figure 3). This represents a 76.9% decline in the population over a 49-year period. However, the detection rate per BBS survey route is low and the average annual difference amounts to a decline of 0.012 individuals/route/year. The latest 10-year period shows a levelling off of this decline (2009–2019: -1.62%/year [-7.47 to 5.57]) or 15.1% total decline (-54% to 56%) (Figure 4). The latest five-year trend is not provided. However, the annual indices in Alberta reflect this reduced rate of decline, which indicates that the most recent five-year period will have continued that pattern. Based on the above 10-year annual rate of change, the estimated total decline over the most recent five-year period is < -7.8% (-32% to 25%). The numbers detected annually per route do not exhibit extreme fluctuations (Figure 3).

The trend based on BBS data should be interpreted with caution because most survey routes in Alberta are located along major roadways in the southern boreal and do not cover the majority of the species' range in the province (see 3.0 Distribution), which has not been adequately surveyed. The BBS data are meant to represent population trends at larger scales than those

of local populations, assuming that the sampled population represents the larger population (i.e., the population in Alberta, for the purposes of this report); therefore the BBS trend will not necessarily be reflected at the local scale. For example, a long-term study that has monitored songbirds annually since 1993 at Calling Lake, Alberta, has detected a substantive increase in the number of Canada warblers beginning around 2007, which has resulted in an approximately 250% increase in the size of the local Canada warbler population (E.M. Bayne and F.K.A. Schmiegelow, unpubl. data reviewed in 2014). The cause of the increase at Calling Lake is not known, but there is evidence of increases elsewhere in the province as well. A recent study by Leston *et al*. (2020) combined species distribution models and land use simulation models within the Alberta Pacific Forest Industry Inc.'s Forest Management Area (hereafter, ALPAC FMA) to predict 50-year population trends of songbird species under different forest management strategies and cumulative effects scenarios. Both management strategies (deferring logging versus not deferring logging in habitat of caribou, Rangifer tarandus) showed an increase in abundance that was associated with an overall increase in forest age; logging deferral increased the projected population by 6%. In comparison to a baseline land use scenario (including fire and the development of forestry, bitumen, gravel pits, roads and settlements), excluding the effects of future fire and energy sector development resulted in substantial increases in projected population size (61% and 35% respectively). Further surveys targeted at Canada warbler are needed to monitor local increases in population and determine whether forest succession has allowed the development of old growth, providing suitable localized habitat for Canada warblers.

There is no evidence to suggest that the current provincial trend will not continue over the next 5- to 10-year period. The potential does exist in some regions for short-term improvements in habitat quality and increased occupancy if the species is currently limited by the availability of suitable habitat in the province. For example, mature and old-growth forests that provide suitable habitat for Canada warblers in the ALPAC FMA in northwestern Alberta are predicted to increase over the next couple of decades as forest succession results in the maturation of stands originally disturbed by fires that occurred in the 1920s and 1930s (Schneider 2002; Vernier *et al*. 2009; ALCES Group 2011). Current forest management plans also incorporate a 20-year deferral of logging in woodland caribou (*R. t. caribou*) ranges, which may further increase potential habitat for Canada warblers (Leston *et al*. 2020). However, a study by Mahon *et al.* (2014) projected

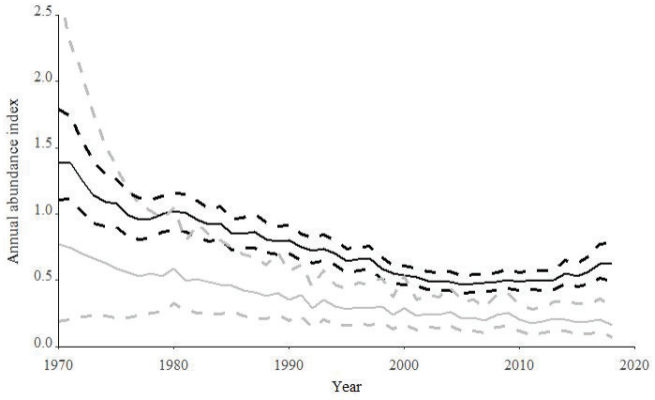

Figure 3. Average number of Canada warblers detected per Breeding Bird Survey route in Alberta (grey lines) and in Canada (black lines; A. Smith unpubl. update of Smith *et al*. 2019) from 1970 to 2019. Solid lines represent average values and dashed lines represent 95% credible intervals (A. Smith unpubl. update of Smith *et al*. 2019).

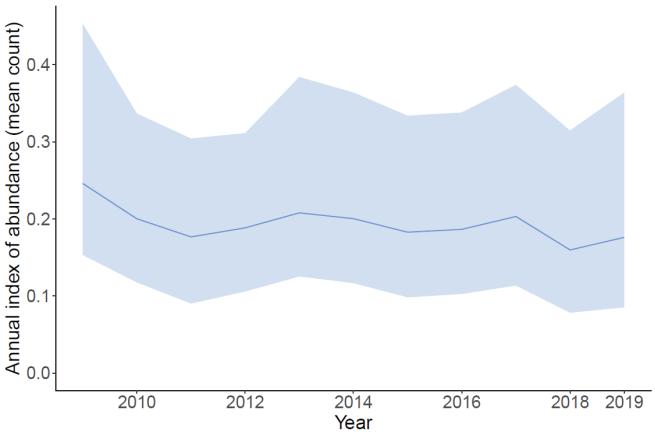

Figure 4. Average number of Canada warblers detected per Breeding Bird Survey route in Alberta from 2009 to 2019. The shaded area represents the 95% credible intervals (A. Smith unpubl. update of Smith *et al*. 2019).

that the area of mature and old forest habitats (hardwood, mixedwood, white spruce, pine, hygric softwood/black spruce) would decline sharply over the next 100 years under the existing logging and energy sector development scenario and a 20% protected area scenario within the ALPAC FMA. Specifically, old hardwood and mixedwood (older than 80 years old) declined to below current levels by year 30 in their simulation. Additionally, the availability of sub-optimal habitat offered by logged stands will fluctuate by year as they mature into the "middle age class" of succession in which canopy closure limits understorey growth (Grinde and Niemi 2016). Management strategies that include the exclusion of some old-growth forest from logging may be necessary to protect suitable habitats (ALCES Group 2011). Fire suppression also may be necessary if the frequency of forest fires increases with climate change in the future (ALCES Group 2011). Opportunities currently exist to conserve habitats that are, or will soon be, suitable for Canada warblers in the ALPAC FMA and in other FMAs in the province that have maturing forest stands that are becoming increasingly suitable for Canada warblers.

6.2. Other Areas

Based on a national climate model, D. Stralberg (pers. comm.; Stralberg *et al*. 2013) estimated a current global Canada warbler population of 7.3 million individuals (95% CI:6.5 million–8.1 million). This is nearly triple the most recent PIF estimate of 2.6 million individuals (Partners in Flight Science Committee 2020). Much of this difference is explained by the underlying statistical assumptions made by PIF versus BAM approaches. Regardless, both approaches provide similar estimates of the relative percentage of the breeding population estimated to occur in Canada (Panjabi *et al*. 2012: 82%; Stralberg pers. comm.: 78% [68–90]).

The number of Canada warblers detected has declined between 1970 and 2019 by 1.43%/year (95% credible interval: -2.14 to -0.72) or 51% overall across their North American breeding range during that 49-year period (A. Smith unpubl. update of Smith *et al*. 2019; Figure 3). The trend during the most recent 10-year period (Figure 5) was 3.47%/year (1.18 to 6.24), which amounts to a 40.59% increase overall. Annual indices in North America appear to be consistent with an increasing trend in recent years (A. Smith unpubl. update of Smith *et al*. 2019; Figure 3). Declines are prominent in the east and during years prior to the mid-1990s, whereas populations are increasing in the Appalachian Mountains and around the Great Lakes. Historically, the decline in the east may have been driven by loss or degradation of forested swampland (Hallworth *et al*. 2008b) and by the maturation of upland forests on former agricultural lands so that they were no longer suitable habitat (Reitsma *et al*. 2010). It is not clear why previously declining trends have become positive over the last decade, but continued land use may be creating suitable early successional habitats in some eastern regions. There are no global population projections for the next 5 to 10 years.

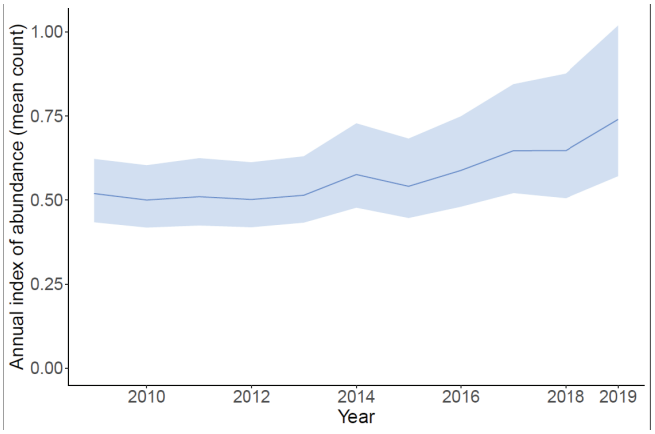

Figure 5. Average number of Canada warblers detected per Breeding Bird Survey route in Canada from 2009 to 2019. The shaded area represents the 95% credible intervals (A. Smith unpubl. update of Smith *et al*. 2019).

6.3. Rescue Potential

Canada warblers numbers in Saskatchewan are increasing (A. Smith unpubl. update of Smith *et al*. 2019), and range expansion is occurring in British Columbia (Cooper *et al*. 1997). Furthermore, the recent appearance of Canada warblers in British Columbia (Cooper *et al*. 1997) and the increase in numbers at Calling Lake (E.M. Bayne and F.K.A. Schmiegelow, unpubl. data) suggest that immigration is possible and that these immigrants are adapted to survive in newly settled habitats. Together, these data suggest that rescue of Alberta populations from adjacent regions is possible if suitable habitat in Alberta is available to be settled. Declines in the numbers of Canada warblers in Alberta are hypothesized to be caused, at least in part, by declines in the quantity or quality of breeding habitat within the province (see 7.0 Threats). This suggests that potential immigrants to Alberta might not find vacant suitable habitat. The increase in numbers of Canada warblers at Calling Lake suggests that suitable vacant habitat is available there, possibly as a result of succession and the development of old growth stages, and that it is being settled by local recruits or by immigration from outside the local area. These improvements in habitat quality at Calling Lake and in the ALPAC FMA will be short-lived without changes to current land-use practices.

7.0 Threats

Reasons for the long-term decline in Canada warbler populations are not known, but loss and deterioration of habitat on the breeding and wintering grounds are considered to be the primary causes. Permanent loss of forest to development, particularly along the southern fringe of the boreal forest, is the biggest threat to birds in the western boreal forest (North American Bird Conservation Initiative 2012). Wells (2011) estimated that 24% of the breeding distribution of Canada warblers in the Canadian boreal forest was within areas affected by anthropogenic disturbance, while only 7% of their distribution was within protected areas. This lack of protection may represent a threat to the persistence of Canada warblers in Alberta, depending on how land outside of protected areas is managed. Other known or potential threats (listed in likely order of immediate severity and discussed below) include increased rates of nest predation and brood parasitism (potentially associated with habitat fragmentation), climate change, over-browsing of understorey vegetation by deer, and declining spruce budworm (*Choristoneura fumiferana*) biomass.

7.1. Loss and Fragmentation of Breeding Habitat

Habitat conversion that results in loss of mature to old-growth deciduous and mixedwood forest and forested riparian areas at the local scale and loss of deciduous forest at the landscape scale is reasonably expected to negatively affect Canada warbler in Alberta (Ball *et al*. 2013, 2016). Areas of Alberta's forests that are under the greatest development pressure that also have been identified as having suitable Canada warbler habitat are the eastern part of the province from highway 16 south of Cold Lake to north of Fort McMurray, north of Whitecourt, north and west of Grande Prairie, and east of Peace River (Lee *et al*. 2009 [p.87]; Ball *et al*. 2013). As of 2010, 21% of Alberta's Boreal Plains Ecozone, which contains the majority of Alberta's northern forests and encompasses 90% of Alberta's oil sands region, has been directly altered by human activity, more than half of which constitutes habitat loss to agriculture (ABMI 2012). Oil sands extraction activities that result in loss of forest cover also may negatively affect Canada warblers. Restoration of mined oil sands habitats from peatland to incised, upland forests in the northeastern portion of the province may benefit Canada warblers when these forests mature, if appropriate shrub and soil moisture/topography conditions are taken into account (Rooney *et al*. 2012).

Canada warblers are most strongly associated with deciduous landscapes and old-growth deciduous stands near incised streams. Current logging strategies are meant to replicate a natural disturbance regime, which, in Alberta's boreal forest, is primarily fire. However, logging selectively targets old-growth stands, whereas fire generally affects all age classes (Cyr *et al*. 2009; Lee *et al*. 2009). The result is that older age classes are under-represented and young age classes are over-represented on the landscape compared to a landscape without human impact. Logging and regeneration strategies that increase the vigour and representation of coniferous trees at early stages of succession, at the expense of deciduous trees (Lieffers *et al*. 2008), will contribute to a loss or reduced duration of older deciduous-dominated forest stages and, therefore, may reduce the amount of suitable habitat available to Canada warblers. The Alberta Biodiversity Monitoring Institute (ABMI 2012) estimated that deciduous trees had declined by 32% and old-growth deciduous trees had declined by 50% compared to landscapes with no evidence of human impact. Current forestry and oil and gas practices are predicted to increase the anthropogenic footprint and reduce older forests, and this loss of old forest is predicted to cause declines in Canada warbler numbers (Carlson *et al*. 2009). A similar scenario has already played out in Europe, where forestry has nearly eliminated old forests from the landscape and many of the species that depend on these forests are now threatened (Cyr *et al*. 2009). Conservation planning aimed at the retention of mature deciduous trees (> 80 years since disturbance) would be expected to contribute to the persistence of Canada warblers in Alberta (Ball *et al*. 2016).

Old-growth deciduous trees are retained as residuals in logged stands and as buffers along streams. Hunt *et al*. (2017) found no evidence that residual stands within a logged area influenced Canada warbler density. Logged stands (< 30 years since disturbance) were included within home ranges; however, only when adjacent to unlogged stands. Vernier *et al*. (2009) suggest that a minimum residual patch size of 100 ha is necessary for Canada warblers. Current buffer widths along riparian corridors (10 m–60 m; Alberta Sustainable Resource Development 2008; Westwood 2016; Westwood *et al*. 2017) may also be too small to function as habitat (and small, intermittent streams have no treed buffer requirement in Alberta). For example, Lambert and Hannon (2000) found that ovenbirds (*Seiurus aurocapillus*) were absent from 20-m riparian buffer strips following logging. Further study is needed to determine what types of streams and buffer characteristics (e.g., Braithwaite and Mallik 2012)

constitute preferred habitats for Canada warblers, and such work is being undertaken by E.M. Bayne of the University of Alberta in collaboration with Lesser Slave Lake Bird Observatory. Implementing buffers for small riparian zones, increasing the size of residual patches not associated with riparian areas and using site preparation techniques that encourage deciduous tree growth would be expected to benefit Canada warblers.

Canada warbler density is negatively affected by the amount of industrial development at both the local and landscape scales (Ball *et al*. 2013; Haché *et al*. 2014; Sólymos *et al*. 2014; ABMI and BAM 2019). This decline in density as the industrial footprint increases likely reflects a loss of suitable habitat rather than an avoidance of anthropogenic features. For example, Machtans (2006) found that territory placement was unaffected by seismic lines. Instead, lines were included within the defended space and treated as unusable habitat, and territory size was increased accordingly. Furthermore, the habitat model created by Ball *et al*. (2016) did not identify linear features as an important predictor of Canada warbler abundance, either at the stand-level or landscape scale. Boreal forest birds, and birds in forested systems in general, are buffered against negative fragmentation effects when an extensive amount of forest is retained on the landscape (Schmiegelow *et al*. 1997; Norton *et al*. 2000; Betts *et al*. 2006). Because Canada warblers will establish territories in early seral habitats, albeit at much lower densities compared to old-growth forests, and use scrubby habitats on the wintering grounds, logging is not expected to restrict dispersal through fragmented landscapes so long as some shrub or sapling cover is present.

7.2. Loss and Fragmentation of Wintering Habitat

Loss and degradation of habitat on the wintering grounds are considered to be important factors contributing to the decline of Canada warblers across their range (COSEWIC 2008; Reitsma *et al*. 2010). Low juvenile survival during the non-breeding season has led to poor recruitment within both the eastern and western breeding populations (Cárdenas-Ortiz *et al*. 2017; Wilson *et al*. 2018). The forests of the northern Andes Mountains continue to be developed to serve the growing human population in the region (Davis *et al*. 1997; Robinson 1997; Davidson *et al*. 2011). Forest cover in this region continues to be lost at 50 000 to 500 000 ha/yr (Food and Agriculture Organization 2010). Only 15 of the 68 terrestrial regions in the Andean–Southern Cone region, which includes the area occupied by Canada warblers, are considered relatively stable (Roca *et al*. 1996). In Colombia, Canada warblers predominantly winter in montane forest, which is one of the most fragmented ecosystems within the region—a result of human activities (González-Prieto 2018). Further, the Piedmont region of the Colombian Andes was found to have the highest rate of increase in anthropogenic footprint across the breeding and wintering range of Canada warbler from 1993 to 2009 (Wilson *et al*. 2018).

Studies have shown that Canada warblers will occupy shade-grown coffee plantations; however, the suitability of this habitat may vary with intra-seasonal precipitation patterns (Colorado Z. and Rodewald 2017; González-Prieto 2018). González-Prieto (2018) found that females in shade-grown coffee plantations can lose up to 6% of their total body mass during the dry period (December to mid-February), but will return to a weight matching those of female forest birds by the end of the season. In the driest two years of the three-year study, males were significantly more likely than females to be found in forested habitat, suggesting that there is a selective preference for forests by dominant individuals (96% of birds in the forested habitat were male in 2014 and 87% in 2015; González-Prieto 2018). While shade-grown coffee plantations are not optimal habitat, they are currently the best alternative among agroecosystems dominating the region. However, this habitat is also at risk, as the modernization of coffee cultivation to more sun-grown and high-yield varieties has reduced shade-grown plantations by more than 60% (Perfecto *et al*. 1992; González-Prieto *et al*. 2017).

7.3. Nest Predation and Brood Parasitism Rates

Nest predation is a primary cause of reproductive failure for many songbirds (Ricklefs 1969). Increased rates of nest predation and brood parasitism in fragmented landscapes, particularly near habitat edges, have been implicated in contributing to the declining numbers of some species (Robinson *et al*. 1995). These negative fragmentation effects are commonly reported in eastern North America and in landscapes with an extensive agricultural matrix (George and Dobkin 2002). Alberta's boreal forest has a largely forested matrix and a nest predator community composed of endemic species that do not respond positively to edge habitats resulting from forest fragmentation (Ibarzabal and Desrochers 2001; Ball *et al*. no date). Therefore, Canada warbler nests that are in fragmented boreal landscapes and nests nearer to forest edges are unlikely to experience elevated rates of nest predation. The presence of red squirrels has been shown to negatively influence territory size of Canada warblers and consequently have an indirect, negative effect on breeding success (Flockhart *et al*. 2016). However, no evidence has been found that nest predation by red squirrels varies with proximity to an edge (Ibarzabal and Desrochers 2001). Brown-headed cowbirds are rare across most of the boreal region and nest parasitism is not a concern except along the southern fringe of the boreal forest where there is a significant amount of agriculture on the landscape (Hannon *et al*. 2009). Canada warblers are frequently parasitized by cowbirds in some regions (Reitsma *et al*. 2010), so Canada warblers could be adversely affected by parasitism in forests near agriculture and by agriculture expansion in Alberta.

7.4. Climate Change

Climate change is predicted to change the distribution of Alberta's forests, particularly in the latter half of this century (Schneider 2013). A substantial portion of habitats ranked as being most suitable for Canada warblers is roughly located in the Central Mixedwood and Dry Mixedwood natural subregions of the Boreal Forest Natural Region (Ball *et al*. 2013). These regions are predicted to transition to parkland then grassland habitat, which will shrink and fragment the remaining forest habitats (Schneider 2013). The rate and extent of habitat conversion will depend on the amount of drying and changes in the fire frequency (Schneider 2013). The Northern Mixedwood Subregion is expected to transition from wetland dominated by bogs and fens to suitable Canada warbler habitat, but not before the end of the century because the permafrost underlying the region will likely significantly delay the transition (Schneider 2013). The Upper and Lower Boreal Highlands natural subregions are predicted to transition into habitats similar to either the Central Mixedwood or Dry Mixedwood natural regions (Schneider 2013. Overall, based on the average estimate from 19 global climate models, the current Canada warbler range in Alberta is predicted to contract and shift upslope into the Boreal Highlands natural subregion over the coming century (Stralberg and Bayne 2013). The numbers of Canada warbler in the province are predicted to decline by 2% (± 16% [2 SE]) by 2040 and by 45% (± 20%) by the end of the century. In contrast, corvids associated with agriculture are predicted to increase, which, combined with fragmentation, could further increase the predicted Canada warbler declines through increased rates of nest predation. Nationally, Canada warblers are predicted to increase in response to climate change, with the largest increases (46% ± 29% [2 SE]) occurring in the Northwestern Interior Forest and Taiga Shield and Hudson Plains bird conservation regions by the end of the century (Stralberg *et al*. 2013). However, at the southern extent of their breeding range, Canada warblers are at risk from habitat alteration and isolation. Habitat alteration resulting from climate change is expected to cause an upslope shift in the species' area of occurrence along the Appalachian Mountains (DeLuca and King 2017; Ferrari *et al*. 2018). This type of shift can lead to local extirpation as available habitat decreases and becomes more isolated from similar patches (Chandler and Hepinstall-Cymerman 2016; Deluca and King 2017; Ferrari *et al*. 2018). The predicted change in numbers of Canada warbler is in response to the predicted change in local climate. Local climate is considered a major driver of local habitat conditions and the predicted change in numbers of Canada warblers is in response to an increase in the amount of suitable habitat available on the landscape. However, it is important to note that there is a large amount of uncertainty in how climate is going to change and in how and when habitats will respond to that change. Additionally, these climate models do not account for increased rates of development in the boreal forest, which will further affect the availability of suitable habitats.

The Biodiversity Management & Climate Change Adaptation project, which is led by the Alberta Biodiversity Monitoring Institute with collaborators from the University of Alberta and the Miistakis Institute, has assessed climate change vulnerability for Alberta species (Shank and Nixon 2014). Canada warbler is considered one of the more vulnerable among the 173 species assessed; however, at this time it is unclear what implications this information has for the species' provincial status evaluation.

7.5. Other Limiting Factors

Over-browsing by deer can negatively affect ground-nesting songbirds that depend on dense understorey growth. Although white-tailed deer have increased substantially in Alberta in recent decades, current densities (0.7–1.7 white-tailed deer per km^2 in north-central Alberta; Latham *et al*. 2011) are still well below those reported in systems where over-browsing has been reported. For example, DeGraaf *et al*. (1991) reported that Canada warblers may avoid stands in Massachusetts where white-tailed deer are abundant ($13/km^2$–$23/km^2$), but they do not avoid stands where deer are present in low numbers ($1/km^2$–$3/km^2$). On Haida Gwaii, Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) densities range as high as $21/km^2$–$36/km^2$ and bird species that were dependent on understorey vegetation were significantly less abundant on islands with high numbers of deer (Allombert *et al*. 2005). DeCalesta (1994) estimated a threshold deer density of $7.9/km^2$–$14.9/km^2$ was necessary for numbers of forest songbirds to be negatively affected by over-browsing. Although concerns regarding the impact of deer on Canada warblers are currently unwarranted in Alberta, management may be necessary in the future if deer numbers continue to increase.

Local avian abundance may respond positively to insect outbreaks through dispersal to the affected area and a corresponding change in productivity. Some warbler species have a known association with spruce budworm, an irruptive moth species. Crawford and Jennings (1989) described a positive association between numbers of Canada warblers and spruce budworm across northern New Hampshire and western Maine. In Canada, the area defoliated by the larvae of spruce budworm has declined in recent decades, and Sleep *et al*. (2009) proposed that reduced spruce budworm numbers were responsible, in part, for declining numbers of Canada warbler. This hypothesis has since been refuted by Venier *et al*. (2012), based on a critical review of Sleep *et al*. (2009) and analysis of a larger dataset. In a more recent study, Drever *et al.* (2018) suggested that Canada warbler response to spruce budworm may be based on a more complex relationship associated with changes in forest structure. In much of their study area in eastern Canada, predicted population trajectories of Canada warbler showed a neutral response to spruce budworm abundance; however, they identified potential positive associations at a regional scale in New Brunswick and Nova Scotia. This may also be linked to variations in habitat association across the Canada warbler's breeding range; along the eastern coast in Canada and the United States, they are more frequently associated with lowland coniferous forests than is the case in the western extent of the range (Grinde and Niemi 2016; Westwood 2016; Westwood *et al*. 2017). Further study needs to be done on Canada warbler response to insect outbreaks, focusing on indirect effects from changing forest structure and spillover of species in adjacent habitats.

7.6. Locations

There is no indication that the population is separated into distinct subpopulations or locations within Alberta (the latter defined as distinct areas within which all individuals would be affected by a single threatening event).

In the context of this status report, threats are important to consideration of "locations," which are geographically or ecologically distinct areas vulnerable to a single plausible threatening event, either natural (e.g., disease outbreak) or anthropogenic (e.g., habitat destruction) (as defined by IUCN 2012). The most imminent threat to Canada warbler is habitat loss and fragmentation, which is occurring throughout the species' breeding and wintering range (see 7.1 Loss and Fragmentation of Breeding Habitat and 7.2. Loss and Fragmentation of Wintering Habitat). These threats tend to be widespread, but each threat acts at a relatively small scale when it occurs. Therefore, although the exact number of locations for Canada warbler is unknown, it is likely to be a relatively large number.

8.0 Status Designations

8.1. Alberta

Canada warbler has not been listed as *Endangered* or *Threatened* under Alberta's *Wildlife Act*. Its general status has been Sensitive in Alberta since 1996 (AEP 2017; previously termed Yellow B [Alberta Environmental Protection 1996]). This designation reflects its relative rarity in the province, a decline in numbers throughout its provincial range since 1966, and its potential vulnerability to habitat loss or deterioration because of various land uses (AEP 2017). Prior to 1996, its general status rank was *Status Undetermined* because of the lack of information available to determine an accurate assessment (Alberta Forestry, Lands and Wildlife 1991). The Canadian Endangered Species Conservation Council (CESCC; 2016) ranks Canada warbler as S3S4B, S3S4M (*Vulnerable*) in Alberta.

8.2. Other Areas

Nationally, the Canada warbler was assessed as *Threatened* by COSEWIC in 2008 and was listed on Schedule 1 of the *Species at Risk Act* as a *Threatened* species in 2010 (Government of Canada 2020). This designation resulted from significant long-term population declines across the species' Canadian range that showed no signs of being reversed, and because 80% of the breeding range occurs in Canada. Reasons for decline were unclear, but loss of primary forest on the wintering grounds in South America was listed as a potential cause (COSEWIC 2008). COSEWIC re-assessed and downlisted this species to *Special Concern* in 2020, as declines had started to slow in 2003 and numbers have increased steadily since 2012 (Government of Canada 2020).

In response to the 2008 COSEWIC assessment, the Canadian Endangered Species Conservation Council (CESCC; 2011) increased its national risk assessment of Canada warbler from *Secure* in 2000 and 2005 to At Risk in 2010. In 2015, CESCC adopted NatureServe's status assessment system (see NatureServe 2020 for details) and ranked Canada warbler as N3 (Vulnerable) in Canada (CESCC 2016); CESCC's rankings are expected to be updated for 2020. NatureServe (2014) currently ranks Canada warbler as N4 (*Apparently Secure*) nationally in Canada, N5 (*Secure*) in the United States, and G5 (*Secure*) globally because of its large population size and large breeding range. The Canada warbler is designated a species of *Least Concern* globally on *The IUCN Red List of Threatened Species*, although a declining population trend is recognized (BirdLife International 2016). Partners in Flight lists Canada warbler as a species of conservation concern on its *US–Canada Watch List*, and as a species of tri-national concern in North America because of significant large declines in population size, moderate threats on the breeding grounds, and high threats on the non-breeding grounds (Panjabi *et al*. 2012). PIF also considers Canada warbler to be a US–Canada stewardship species because of its high reliance (> 90% of breeding population) on a single avifaunal biome (i.e., Northern Forest: Bird Conservation Regions 4, 6–8, 12, 14). The Canada warbler was included on Audubon's *Yellow List* as a species of conservation concern (Butcher *et al*. 2008).

Following the 2008 COSEWIC assessment and the addition of Canada warbler to Schedule 1 of the *Species at Risk Act*, CESCC increased provincial general status ranks from Secure to Sensitive in Ontario and Quebec, and from *Undetermined* (Northwest Territories), *Secure* (New Brunswick, Nova Scotia), *Sensitive* (Prince Edward Island), and *May Be At Risk* (Yukon) to *At Risk* for 2010 in those provinces (CESCC 2011). Canada warbler was ranked as *Sensitive* in Saskatchewan in 2000, but was changed to *Secure* in 2005 and remained *Secure* in 2010. Status ranks remained at *Sensitive* in British Columbia and *Secure* in Manitoba from 2000 to 2010 (CESCC 2011). The species is currently listed as *Threatened* under Manitoba's *Endangered Species and Ecosystems Act* (Government of Manitoba 2020).

Provincial NatureServe (2014) designations are generally the same as those of the CESCC (2016): *Vulnerable* (S3S4) in British Columbia (referred to as *Blue* [BC Conservation Data Centre 2020]); *Critically Imperiled* (S1) in Yukon (see also Yukon Conservation Data Centre 2019); *Imperiled/Vulnerable* (S2S3) in the Northwest Territories; *Secure* (S5) in Saskatchewan; and eastward ranging from *Imperiled* (S2) in Prince Edward Island to *Vulnerable* (S3) in Manitoba, New Brunswick and Nova Scotia; *Vulnerable/Apparently Secure* (S3S4) in Quebec; and *Apparently Secure* (S4) in Ontario. One exception is that CESCC (2011) ranks Canada warbler as *Apparently Secure* (S4) in Saskatchewan (see also Saskatchewan Conservation Data Centre 2020). Breeding populations in the northeastern United States are designated from *Critically Imperiled* (S1) to *Secure* (S5). Breeding populations in North and South Dakota and Minnesota have not been assessed or are under review (SNR/SU/SNA; NatureServe 2014).

9.0 Recent Management and Research in Alberta

Canada warblers have been the focus of several directed studies in Alberta over the past decade because they are considered to be of high conservation concern by provincial forest managers (Hannon *et al*. 2004) and because of knowledge gaps that have been identified regarding the species' annual distribution and population trends and factors contributing to its decline. Recently, Ball *et al*. (2016) updated and published their previous habitat assessment of Canada warblers in Alberta. The previous model was made available to forest companies across Alberta, as well as provincial and federal governments, to help predict future impacts of current activities and identify suitable habitat for conservation planning. The current model uses an updated dataset to predict the population and distribution of Canada warblers in the province and the influence of current land-use practices.

Habitat use does not always equate with habitat quality, which requires some estimate of fitness (Van Horne 1983). Lesser Slave Lake Bird Observatory and E.M. Bayne (University of Alberta) have conducted multi-year research projects on Canada warbler. They have recently collaborated on several projects focusing on local habitat association, factors affecting space use and breeding success (i.e., food availability, predator abundance, conspecific density, etc.), and drivers of demographic decline across the breeding range (Flockhart *et al*. 2016; Krikun *et al*. 2018; Wilson *et al*. 2018). Measures of fine-scale habitat association are important components of habitat suitability that may not be easily detected by coarse-scale assessments. Shrub density and a deciduous canopy cover are known habitat associations of this species; however, local plant species may influence territory size, which is directly related to breeding success (Flockhart *et al*. 2016, Krikun *et al*. 2018). Territory size is also influenced by the abundance of predators and conspecific density. Together, this indicates that habitat quality and breeding success are influenced, in part, by a range of local habitat attributes that are interrelated and can vary by region. Wilson *et al.* (2018), identified anthropogenic contributors to demographic declines across the breeding range. This was important to identify conservation priorities across the breeding range and clarify the extent of the anthropogenic contribution to overall demographic declines.

In Alberta, forestry and hydrocarbon extraction are the main sources of anthropogenic disturbance in the Canada warbler's breeding range. Several graduate students within E.M. Bayne's lab have developed projects focusing on the impacts of these industries at both local and landscape scales. Research topics include Canada warbler habitat selection and use of space in response to logging method (i.e., logged area and residual patch size) and seismic line regeneration (Hunt 2017; J. Gregoire unpublished data). Cumulative impacts associated with the energy sector are being addressed in an ongoing project by E.M. Bayne, which uses a systematic grid of 100 recorders, with 600-m spacing, across steam-assisted gravity drainage (SAGD) oil extraction leases at various stages of development. Most recently, Leston *et al*. (2020) have applied computer simulation tools to predict the effects of habitat management for woodland caribou and the cumulative effects of anthropogenic and natural disturbances on Canada warblers. This research will help to inform management practices for future activities and will contribute to our understanding of demographic changes in response to legacy features.

Migratory connectivity is an important component in understanding demographic trends across the annual cycle of migratory songbirds. Threats that occur on the wintering grounds may have consequences during the breeding season, and vice versa. As Canada warbler is a species subject to locally specific habitat requirements, identifying population-specific breeding and wintering grounds, and the migratory pathways between, can help to develop targeted conservation plans. Roberto-Charron (2018) used geolocators to track Canada warblers during migration. Individuals from Alberta crossed over to Manitoba before migrating south to Venezuela and Colombia. They exhibited a crossed migratory pattern, occupying more eastern wintering grounds than did those individuals from the eastern portion of the breeding range. Using isotopic analysis in a more focused study on Canada warblers wintering in the Colombian Andes, González-Prieto *et al*. (2017) identified a parallel migration pattern with a broad-scale longitudinal gradient. The exception was individuals originating from the western edge of the breeding grounds (i.e., Alberta and British Columbia), which overwintered in Santander (the northern-most location of the eastern Andes).

Finally, during the development of conservation efforts aimed at Canada warblers, wildlife managers have begun to consider the effects of climate change. Two ongoing projects address the predicted effects of climate change on Canada warblers in Alberta. The Alberta Biodiversity Monitoring Institute used NatureServe's Climate Change Vulnerability Index to forecast the potential impacts of climate change on Canada warbler and other Alberta species (Young *et al*. 2011; Shank and Nixon 2014). Stralberg and the Boreal Avian Modelling Project (Stralberg and Bayne 2013; Stralberg *et al*. 2013; Stralberg *et al*. 2019; see also Westwood *et al*. 2020) have developed climate change models that predict the distribution of Canada warblers in Alberta and across their range under future climate scenarios. An important component of this project is the identification of refugia where current and future high quality habitats are predicted to overlap. This relaxes the critical assumption that habitats will track changes in climate and only assumes that local habitats will persist in climates similar to current conditions. These refugia would be valuable to future conservation planning.

10.0 Synthesis

Modern statistical methods suggest that there are more Canada warblers in Alberta than previously estimated. Breeding Bird Survey data show that numbers of Canada warblers in Alberta have declined overall since the late 1960s; however, within the past decade or two, declines have slowed and the species is now increasing in many parts of its range. Breeding Bird survey trends should be interpreted with caution because most BBS survey routes in Alberta are located along major roadways in the southern boreal forest, and these routes do not cover the majority of the species' range in the province. Systematic surveys conducted by ABMI cover the entire province and will become valuable in monitoring changing trends for Canada warbler in the future, once sufficient data have been accumulated (Huggard 2013). Additional trend monitoring beyond ABMI's efforts is not required; however, targeted surveys aimed at quantifying the amount of habitat that is potentially suitable but vacant and the use of habitats that are becoming suitable as a result of succession (e.g., in the ALPAC FMA) could prove useful for understanding observed increases at Calling Lake and the potential for Alberta's population to be rescued by local recruits or immigrants.

There is no information on whether the extent of occurrence or area of occupancy have declined in the past or will decline in the near future so long as suitable habitat is retained on the landscape. Canada warblers are strongly associated with stands of mature and old-growth deciduous forest adjacent to incised streams in landscapes dominated by deciduous forest. However, the value of these habitats for survival and reproduction are unknown. Future research is needed to identify habitat components that increase chances of survival and successful reproduction, to ensure that these features are considered in forest management strategies.

The prevalence of old-growth forest in Alberta is expected to decline. Mature forest stands are preferentially targeted for logging, which contributes to a reduction in over-mature and old stands through time. This decline in the amount of suitable habitat for Canada warblers is expected to lead to a decline in population numbers. The quantity, size and spatial configuration of old-growth stands and retention patches under current forest management may be inadequate for ensuring a continued supply of suitable breeding habitat. Research is needed to determine the amount and configuration of old-growth forest required at the landscape scale for Canada warbler populations to be successful. Research is also needed at the local scale to quantify associations with different-sized streams to identify suitable riparian buffer widths, and to identify the amount of tree retention, retention patch size, and appropriate cutblock treatments that are necessary for Canada warblers to be successful in/persist in logged areas. Further, detailed habitat studies that include the movement of adults and fledglings are needed to ensure that the species is not adversely affected by fragmentation of old-growth habitat. Loss and fragmentation of forests in Alberta is also a predicted effect of climate change, especially in the latter half of this century. Current modelling efforts investigating the importance of climate refugia may be useful for conservation planning for this species.

Population declines observed on the breeding grounds are assumed to be due, in part, to loss and degradation of wintering habitat. Poor recruitment within both the eastern and western breeding populations has been attributed to low juvenile survival during the non-breeding season (Cárdenas-Ortiz *et al*. 2017; Wilson *et al*. 2018). Identifying the connection between breeding and wintering grounds is an important first step to address this. Regionally, studies have shown a parallel migration pattern along a longitudinal gradient (Cárdenas-Ortiz *et al*. 2017; González-Prieto *et al*. 2017). However, there is some indication that this pattern may be reversed at a broader scale across the wintering range (Roberto-Charon 2018). Further study is needed on the breeding origins of Canada warblers that migrate to the eastern and western extent of the wintering range. This would allow the creation of partnerships that promote research and the conservation of important winter habitats (for example, the Association of Fish & Wildlife Agencies' Southern Wings program [www.fishwildlife.org/afwa-inspires/southern-wings]). There has been limited research on the relationships between winter habitat use and survival of Canada warblers. González-Prieto (2018) identified patterns of preferential selection for forest habitat over shade-grown coffee plantations by male Canada warblers and variation in body mass of females with seasonal precipitation. The negative implications for overall body condition have potential carry-over effects during migration and on the breeding grounds. Wilson *et al*. (2018) assessed change in anthropogenic footprint across the breeding and wintering grounds from 1993 to 2009; they found that the rate of change was highest along the Piedmont region of the Colombian Andes. Canada warblers from this region were determined to have eastern breeding origins, which is where the highest declines in abundance have been found (González-Prieto *et al.* 2017). Further studies focused on juvenile survival during the non-breeding season, selection of stop-over sites, and habitat use on the wintering ground would provide conclusive insight into the main drivers of demographic declines across annual cycle of Canada warblers.

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12.0 Appendices

Appendix 1: Data-sources Summary Table

Data Source	Type(s) of Location Data	Type(s) of Additional Information	Number of Observations	Time span
Bird Banding Office (Environment and Climate Change Canada)	geographic	age, sex	24 795	1960–2018
eBird (Cornell Lab of Ornithology)	geographic		1404 (including >2508 individuals)	1969–2018
FWMIS[1] (Fish and Wildlife Management Information System)	ATS, geographic, UTM	age, sex	4644 (including 4736 individuals)	1992–2015
BAM[2] (Boreal Avian Modelling Project)—AB CAWA Project	geographic		2216 (including 2513 individuals)	1993–2020
ABMI[3] (Alberta Biodiversity Monitoring Institute)	geographic		330	2003–2017
Environment and Climate Change Canada	geographic		273 (including 361 individuals)	2011–2017
LSLBO (Lesser Slave Lake Bird Observatory)	geographic	age, sex	828	2014–2018
Habitat Association of Canada Warbler in Alberta	geographic	sex, reproductive status	50 (including 56 individuals)	2012
Helen Schuler Nature Center (HSNC)	geographic		8 (including 9 individuals)	1993–2017
Weyerhaeuser Company and STRIX Ecological Consulting	geographic		84	2007–2019
Nature Alberta (Federation of Alberta Naturalists)	geographic (10 km x 10 km centroid)	breeding status	290	1987–1991 2000–2005
Other (Matrix Solutions, Inc.)	UTM		14	2007–2010

[1] Provincial database managed by Alberta Environment and Parks (https://www.alberta.ca/fisheries-and-wildlife-management-information-system.aspx); where a range for # of observations was provided, the minimum estimate was used.

[2] BAM data partners: https://borealbirds.ualberta.ca/about-us/partners-sponsors/ (including Breeding Bird Survey and Breeding Bird Atlas)

[3] ABMI data partners: https://abmi.ca/home/about-us/our-partners-sponsors/partners.html

Appendix 2: Definitions of Legal Designations and Status Ranks

A. Alberta Species at Risk Formal Status Designations (Alberta Environment and Parks 2020)

These status designations are recommended by Alberta's Endangered Species Conservation Committee and approved by the Minister of Environment and Parks. Those in bold have legal meaning when designated under Alberta's *Wildlife Act*.

Designation	Definition
Endangered	A species facing imminent extirpation or extinction.
Threatened	A species likely to become endangered if limiting factors are not reversed.
Special Concern	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Data Deficient	A species for which there is insufficient scientific information to support status designation.

B. Canada Species at Risk Formal Status Designations (after Government of Canada 2014; COSEWIC 2020)

These status designations are assigned by the Committee on the Status of Endangered Wildlife in Canada. Those in bold have legal meaning when designated under Canada's *Species at Risk Act*.

Designation	Definition
Extinct	A wildlife species that no longer exists.
Extirpated	A wildlife species that no longer exists in the wild in Canada, but exists elsewhere.
Endangered	A wildlife species facing imminent extirpation or extinction.
Threatened	A wildlife species likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern	A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Not at Risk	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient	A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment, or (b) to permit an assessment of the wildlife species' risk of extinction.

C. United States Endangered S pecies Act Designations (US Fish and Wildlife Service 2005)

Designation	Definition
Endangered	Any species that is in danger of extinction throughout all or a significant portion of its range.
Threatened	Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

D. General Status of Alberta Wild Species Ranks (Government of Alberta 2011)

Used in 2000, 2005, 2010, 2015 and 2020 general status exercises.

Designation	Definition
At Risk	Any species known to be At Risk after formal detailed status assessment and legal designation as Endangered or Threatened in Alberta.
May Be At Risk	Any species that may be at risk of extinction or extirpation, and is therefore a candidate for detailed risk assessment.
Sensitive	Any species that is not at risk of extinction or extirpation but may require special attention or protection to prevent it from becoming at risk.
Secure	Any species that is not At Risk, May Be At Risk or Sensitive.
Undetermined	Any species for which insufficient information, knowledge or data is available to reliably evaluate its general status.
Not Assessed	Any species that has not been examined.
Exotic/Alien	Any species that has been introduced as a result of human activities.
Extirpated/Extinct	Any species no longer thought to be present in Alberta (Extirpated) or no longer believed to be present anywhere in the world (Extinct).
Accidental/Vagrant	Any species occurring infrequently and unpredictably in Alberta, i.e., outside its usual range.

E. Conservation Status Ranks (after NatureServe 2017)

Global (G), national (N) and subnational (S) ranks.

Designation	Definition
G1/N1/S1	Critically Imperilled. At very high risk of extinction or extirpation because of very restricted range, very few populations or occurrences, very steep declines, very severe threats or other factors.
G2/N2/S2	Imperilled. At high risk of extinction or extirpation because of restricted range, few populations or occurrences, steep declines, severe threats or other factors.
G3/N3/S3	Vulnerable. At moderate risk of extinction or extirpation because of a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats or other factors.
G4/N4/S4	Apparently Secure. At fairly low risk of extinction or extirpation because of an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats or other factors.
G5/N5/S5	Secure. At very low or no risk of extinction or extirpation because of a very extensive range, abundant populations or occurrences, and little to no concern from declines or threats.
GX/NX/SX	Presumed Extinct/Extirpated. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood of rediscovery.
GH/NH/SH	Possibly Extinct/Extirpated. Known from only historical occurrences but some hope of rediscovery.
G?/N?/S?	Inexact Numeric Ra nk. Denotes inexact numeric rank.
G#G#/N#N#/S#S#	Range Rank. A numeric range rank (e.g., G2G3, G1G3) is used to indicate the range of uncertainty about the exact status of a taxon or ecosystem type. Ranges cannot skip more than two ranks.
GU/NU/SU	Unrankable. Currently unrankable because of lack of information or substantially conflicting information about status or trends.
GNR/NNR/SNR	Unranked. Conservation status not yet assessed.
GNA/NNA/ SNA	Not Applicable. A conservation status rank is not applicable because the species is not a suitable target for conservation activities.

Appendix 3: Technical Summary

A summary of information contained within this report, and used by the Scientific Subcommittee of Alberta's Endangered Species Conservation ommittee for the purpose of status assessment based on International Union for the Conservation of Nature Red List criteria. For definitions of terms used in this technical summary, go to: https://www.iucnredlist.org/resources/categories-and-criteria and https://www.cosewic.ca/index.php/en-ca/reports/preparing-status-reports.html.

Note that the following terms have specific meanings as defined in the sources referenced above: generation, observed, estimated, inferred, projected, suspected, mature individual, continuing decline, subpopulation, location, Extent of Occurrence, Area of Occupancy, Index of Area of Occupancy, Biological Area of Occupancy, severely fragmented, extreme fluctuation.

Genus species: *Cardellina canadensis*
Common name: Canada warbler
Range of occurrence in Alberta: Primarily associated with mature and old-growth deciduous forest near incised streams in the Boreal Forest and Foothills natural regions.

Demographic Information:

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time, as indicated in the most recent IUCN guidelines, is being used) *See 5.0 Conservation Biology (5.4 Demography and Dispersal).* Average age of breeding adults and adult survivorship are not known, but based on demographic information (i.e., 4-year-old males being reported as common in eastern NA; longevity records of approximately eight years; average return rate for males in New Hampshire of 52%; average clutch size of 4–5 eggs and average young fledged per nest of 3.8) generation length is likely in the range of approximately three years.	Likely 3 yrs
Is there an [observed, inferred or projected] continuing decline in number of mature individuals? *See 6.0 Population Size and Trends (6.1 Alberta) and Figure 3.* Alberta Breeding Bird Survey data show that the historical decline has continued within the past two decades; however, the rate of decline is less and shows potential to level off. The trend based on BBS data should be interpreted with caution because most survey routes in Alberta are located along major roadways in the southern boreal and do not cover the majority of the species' range in the province, which has not been adequately surveyed. Also, long-term data from a study that has monitored songbirds annually since 1993 at Calling Lake, Alberta, show a substantive, local increase in the number of Canada warblers beginning around 2007. The cause of the increase at Calling Lake is not known, but there is evidence of other local populations increasing in the province.	Yes—estimated (but see qualification at left)
[Estimated percent of continuing decline in total number of mature individuals within five years] *See 6.0 Population Size and Trends (6.1 Alberta).* Based on Alberta Breeding Bird Survey data, using the annual index from the trend over the most recent 10-year period. Decline over the most recent five-year period is expected to have occurred at a decreased rate compared to the trend that has been estimated for the most recent ten years.	Less than 7.8% (95% CI: -32% to 25%) decline estimated over the most recent five years

[Observed, estimated, inferred, or suspected] percent reduction in total number of mature individuals over the next [10 years or 3 generations]. *See 6.0 Population Size and Trends (6.1 Alberta).* Based on Alberta Breeding Bird Survey data.	15.1% decline estimated over the most recent 10 years (95% CI: -54% to 56%)
[Projected or suspected] percent reduction in total number of mature individuals over the next [10 years, or 3 generations]. *See 6.0 Population Size and Trends (6.1 Alberta).* Based on Alberta Breeding Bird Survey data. Continued decline at a similar rate is expected over the next ten years, although the rate of population decline might increase somewhat in some areas in the short term.	Less than 15.1% decline projected over the next 10 years
Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10-year, or 3-generation] period, over a time period including both the past and the future. *See 6.0 Population Size and Trends (6.1 Alberta).*	Approximately 15.1% estimated and projected over any 10 years (including both past and future)
Are the causes of the decline clearly reversible and understood and ceased? *See 7.0 Threats.*	No
Are there extreme fluctuations in number of mature individuals? *See 6.0 Population Size and Trends (6.1 Alberta) and Figure 3.* Breeding Bird Survey data do not indicate extreme fluctuation.	No

Extent and Occupancy Information:

Estimated extent of occurrence *See 3.0 Distribution (3.1. Alberta) and Figure 1.* Based on a 100% minimum convex polygon around observations with evidence of breeding.	492 396 km^2
Area of occupancy (AO) (Always report 2-km x 2-km grid value. An additional estimate of AO using a measure that is more biologically relevant to the species may be included). *See 3.0 Distribution (3.1 Alberta).* Based on occupancy of a 2-km x 2-km grid, using known observations with evidence of breeding. This is a minimum estimate as the majority of the area within the area of occupancy has not been surveyed. Using a habitat suitability model, the area of occupied habitat in Alberta during the breeding period is estimated as 105 798 km^2. However, as a predictive technique, this model does not guarantee that these habitats are occupied.	2872 km^2 (based on a 2-km x 2-km grid)

Is the total population severely fragmented? *See 3.0 Distribution (3.1 Alberta).* The population is continuously distributed across its range; there is no indication of severe fragmentation.	No
Number of locations *See 7.0 Threats (7.6 Locations).* There is no indication of separate locations.	Unknown
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence? *See 3.0 Distribution (3.1 Alberta) and 7.0 Threats (7.1 Loss and Fragmentation of Breeding Habitat; 7.4 Climate Change).* Insufficient data to determine. However, agricultural expansion in the southern boreal forest is shrinking the amount of forest habitat; climate change is also expected to shrink the amount of forest in the province.	Unknown, but possible
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? *See 3.0 Distribution (3.1 Alberta) and 7.0 Threats (7.1 Loss and Fragmentation of Breeding Habitat; 7.4 Climate Change).* Insufficient data to determine. Given the broad distribution of the species, it is expected that the area of occupancy will respond similarly to fluctuations in the population. Current BBS trends suggest that population declines are levelling out. However, there will likely be some local variation resulting from changes in land use. This is largely dependent on the balance between ongoing logging of old-growth/ mature forest and any gains in habitat area from forest succession.	Unknown, but possible
Is there an [observed, inferred, or projected] continuing decline in number of subpopulations? *See 3.0 Distribution (3.1 Alberta).* Insufficient data to determine, but there is no indication that the population is divided into distinct subpopulations within Alberta.	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of locations? *See 3.0 Distribution (3.1 Alberta).* Insufficient data to determine, but there is no indication that the population is divided into distinct locations in Alberta.	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? *See 7.0 Threats.* Current forest management practices and rates of human development, if continued, will lead to declines in the quality and quantity of habitat.	Yes

Are there extreme fluctuations in number of subpopulations? *See 3.0 Distribution (3.1 Alberta).* There is no indication that this species' population is separated into distinct subpopulations.	No
Are there extreme fluctuations in number of locations? *See 3.0 Distribution (3.1 Alberta).* There is no indication that this species' population is separated into distinct locations.	No
Are there extreme fluctuations in extent of occurrence? *See 3.0 Distribution (3.1 Alberta).* New data have identified possible breeding records in areas of southern Alberta (e.g., in the Cypress Hills) that were likely previously occupied but not extensively surveyed.	No
Are there extreme fluctuations in index of area of occupancy? *See 3.0 Distribution (3.1 Alberta).* Updated statistical methods used in recent habitat models may have resulted in a more accurate reporting of the area of occupancy from previous estimates.	Unknown

Number of Mature Individuals (in each population):

Population	N Mature Individuals
Total *See 6.0 Population Size and Trends (6.1 Alberta).* From various density- and habitat-based models; only adult males estimated in models.	Range of estimates from 395 300 to 773 758 adult males (would be ~790 600 to 1.52 million mature individuals assuming a male:female ratio of 1:1, which may not be the case)

Quantitative Analysis:

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years]. A quantitative analysis was not done for this species.	Not applicable

Threats (actual or imminent, to populations or habitats):

- Loss and degradation of breeding habitat
- Climate change
- Loss and degradation of wintering habitats

See 7.0 Threats.

Rescue Effect (immigration from outside Alberta)

Status of outside population(s)? *See 8.0 Status Designations (8.2 Other Areas).* Although Canada warblers are generally declining across their range, numbers in Saskatchewan are increasing and range expansion is occurring in British Columbia.	Not applicable
Is immigration known or possible? *See 6.0 Population Size and Trends (6.3 Rescue Potential).*	Yes
Would immigrants be adapted to survive in Alberta? *See 6.0 Population Size and Trends (6.3 Rescue Potential).*	Yes
Is there sufficient habitat for immigrants in Alberta? *See 6.0 Population Size and Trends (6.3 Rescue Potential).* Declines in the number of Alberta birds are hypothesized to be caused, at least in part, by declines in habitat quality and quantity in Alberta; therefore, immigrants might not find sufficient habitat in Alberta. In areas where short-term gains in habitat are occurring (e.g., Calling Lake), local increases in population could be a result of immigration (or of local recruitment).	Unlikely
Is rescue from outside populations likely? *See 6.0 Population Size and Trends (6.3 Rescue Potential).* Immigrants could reach Alberta and would be adapted to the local habitat, but if current management practices continue, there will not be sufficient habitat to support a significant rescue effect. If land-use practices were to allow an increase in suitable habitat that would support immigrants, then rescue could occur.	Possible, but not likely

Current Status (See 8.0 Status Designations)**:**

Provincial: *Sensitive* (general status)

National: *Threatened* under *Species at Risk Act* but recommended in 2020 for downlisting to *Special Concern* by COSEWC

Elsewhere: BC—S3S4B (*Vulnerable*); SK—S4B (*Apparently Secure*) to S5B((Secure), depending on the source; MB—*Threatened*; eastern US—S1 (*Critically Imperiled*) to S5 (Secure).

Authors of technical summary: Robin Gutsell, Jeff Ball and Jocelyn Gregoire

List of Titles in the Alberta Wildlife Status Report Series (as of March 2022)

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