

Canada Warbler Full-life-cycle Conservation Action Plan



Photos: Christian Artuso and David Disher

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EXECUTIVE SUMMARY

Following the assessment of the Canada Warbler by the Committee on the Status of Endangered Wildlife in Canada in 2008 and its subsequent listing as Threatened under Canada's Species At Risk Act in 2010, this plan was created with the vision of working towards "healthy and viable populations of Canada Warblers across the current range and extent of occurrence". The Canada Warbler was re-assessed as Special Concern in Canada in November 2020.

Workshops and meetings using the Conservation Standards framework united over 125 stakeholders from 50 organizations and 11 countries within the range of the Canada Warbler and identified the principle threats faced by the species and the best strategies to alleviate those threats.

The **principle threats** identified in at least some portion of the range (and often in both the nesting grounds and non-breeding grounds) were:

- Habitat loss through land conversion (especially through agriculture, mining and urban expansion) and, to a lesser extent, habitat degradation;
- Adverse forestry practices;
- Climate change and severe weather; and
- Pollutants.

These threats may be compounded or give rise to other complicating factors and be impactful in a cumulative manner.

The four **broad strategies** identified were:

- Adaptive management and legal instruments;
- Best Management Practices (BMPs), including a focus on sustainable economic alternatives;
- Research and monitoring; and
- Outreach and communications.

The **principle recommendations** made were:

- Address habitat loss throughout the species' range (cumulative evidence suggesting this is a driver of decline);
- Address range-wide impacts with international collaboration;
- Address differing regional impacts where appropriate (including habitat degradation as opposed to loss in some contexts);
- Coordinate efforts on the four broad strategies identified; and
- Maintain an international network of engaged partners.

INTRODUCTION

WHY AND HOW THIS PLAN WAS CREATED

Especially since being listed as “Threatened” on Schedule 1 of Canada’s Species At Risk Act (SARA) in 2010, the Canada Warbler has attracted special interest in avian conservation in the Americas. Even though the species is designated as Least Concern by Birdlife International (IUCN: International Union for the Conservation of Nature), the Canadian (federal) listing is especially significant in that approximately 80% of the species’ nesting range is in Canada. As a somewhat wide-ranging Nearctic-Neotropical migrant, this species also garnered international attention and in June, 2013, at the BirdLife International Global Congress in Ottawa, Canada, the Canada Warbler International Conservation Initiative (CWICI) was launched. This provided a platform for international collaboration and coordination, stimulated research across the species’ range, and lead to the development of this full-life-cycle conservation action plan.

The CWICI partners agreed to acquire and apply the best science possible to redress perceived population declines in this species and others that share its habitats (see “Population Decline” below). As part of this process, the detailed information presented in the three appendices was compiled and used to guide discussions. This includes the spatial models developed (Figures 2, 3 and 4). This work focused on filling knowledge gaps, especially in the non-breeding portions of the range where much less research on this species had been done. The partners chose a full-life-cycle approach to understand and apply the ecology of this species and the threats to its populations on the breeding grounds, wintering grounds and during migration. The partners also recognize that all on-the-ground actions and policies to recover this species must be respectful of local community values and include local community participation in management solutions. In order to adhere to these principles of inclusivity and comprehensiveness in a participatory process, wherever possible, we built this action plan using what was known at the time as the Open Standards for the Practice of Conservation (now renamed “Conservation Standards”; see: <http://cmp-openstandards.org>) approach and the Miradi Adaptive Management Software Program (<https://www.miradi.org>).

More information on CWICI and the Canada Warbler can be found at:

- <https://naturecanada.ca/discover-nature/endangered-species/canada-warbler/>
- <http://datazone.birdlife.org/species/factsheet/canada-warbler-cardellina-canadensis>
- https://wildlife-species.canada.ca/species-risk-registry/species/speciesDetails_e.cfm?sid=1008
- <https://wildlife-species.canada.ca/bird-status/oiseau-bird-eng.aspx?sY=2019&sl=e&sM=a&sB=CAWA>

The development of this full-life-cycle conservation action plan, followed the following timeline:

- June 2013:** CWICI formed at BirdLife International Global Congress in Ottawa, Canada; the Canadian Wildlife Service agrees to lead the initiative; Swarovski Optik announces 3-year sponsorship
- August 2013:** CWICI meeting at Partners in Flight V International Conference in Snowbird, Utah, U.S.A (24 participants from 8 countries); development of webpages, Griffin group, planning committee
- September 2014:** Workshop 1: Non-breeding grounds held in Bogotá, Colombia (24 participants from 11 countries)

- March 2015:** Workshop 2: Breeding-grounds workshop held in Ottawa, Canada (35 people from 2 countries and "Carlito", the CWICI mascot)
- August 2016:** Meeting to draft action plan in Washington D.C., U.S.A. during the North American Ornithological Conference; development of spatial distribution models for non-breeding grounds
- Winter 2018:** Series of webinars in English and Spanish following the Conservation Standards enabling further input and revision of the draft plan combining the breeding grounds and non-breeding grounds inputs
- August 2018:** Meeting and "progress report" in Vancouver, Canada during the 27th International Ornithological Congress
- 2018 – 2021:** Action Plan compiled and finalized

Organizations involved in this initiative in alphabetical order are:

American Bird Conservancy,	National Council for Air & Stream
Appalachian Landscape Conservation	Improvement,
Cooperative Network,	Nature Canada,
Appalachian Mountains Joint Venture,	New Jersey Audubon Society,
Asociación Calidris,	North Carolina Cooperative Fish & Wildlife
APECO: Asociación Peruana para la Conservación de	Research Unit,
de la Naturaleza,	North Carolina Wildlife Resources Commission,
Association of Fish & Wildlife Agencies,	Panama Audubon Society,
Audubon New York,	Partners in Flight,
Audubon North Carolina,	Pennsylvania Game Commission,
Audubon Pennsylvania,	Pronatura México,
Aves y Conservación – Birdlife en Ecuador,	QuébecOiseaux,
Birdlife International,	SalvaNATURA,
Bird (Studies) Canada,	SELVA,
Canadian Wildlife Service (Environment and	Sustainable Forestry Initiative,
Climate Change Canada),	Swarowski Optik,
Carnegie Museums of Pittsburgh,	The Nature Conservancy,
Cenicafé,	Union de Ornitólogos de Costa Rica,
Cornell Lab of Ornithology,	Universidad Nacional de Colombia,
Forest Products Association of Canada,	University of Alberta,
Fundación William H. Phelps,	University of Georgia,
Grandfather Mountain Stewardship	University of Maine,
Foundation,	University of Manitoba,
High Branch Conservation Services,	University of Massachusetts at Amherst,
Indiana University of Pennsylvania,	University of Saskatchewan,
Lac Seul First Nation,	University of Texas-Pan American,
Mass Audubon,	U.S. Fish and Wildlife Service,
Massachusetts Division of Fisheries & Wildlife,	U.S. Forest Service,
National Audubon Society,	Vermont Center for Ecostudies,
	Weyerhaeuser.

Over 125 individuals from 11 of the 13 countries where Canada Warbler occurs (Canada, U.S.A., Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Venezuela,

Ecuador and Peru), representing more than 50 organizations, participated in the workshops, meetings and webinars.

Participants

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COMPATIBILITY WITH OTHER INITIATIVES

There has been an exceptional amount of research and focus on the Canada Warbler in recent years and an increase in our knowledge regarding distribution, habitat, population status, ecology and threats on the breeding grounds, migratory pathways and non-breeding areas. Some of this focus has no doubt been inspired by the launch of CWICI in 2013. Recent research is cited in the introductory sections of this plan (below) as it applies to informed decision making; however, several broad-scale initiatives are worth special mention here, including:

- **COSEWIC status assessment and updates:**
COSEWIC is the body that assesses species for potential inclusion in SARA. COSEWIC status assessment reports are detailed and re-assessed every ten years. The 2008 status report can be viewed [here](#) and the current re-assessment report (to be completed in 2021, COSEWIC in prep.), including critical evaluation of current population status, was consulted, with permission, in the preparation of this action plan.
- **SARA process of identifying “Critical Habitat” and the Canadian Recovery Strategy:**
Recovery strategies are developed by teams of experts for species listed as either Threatened or Endangered under SARA Schedule 1 in Canada. The proposed recovery strategy can be viewed [here](#). As the Canada Warbler is a wide-ranging species, nesting from British Columbia to Nova Scotia in Canada, it posed a challenge for the typical process of critical habitat identification. Environment and Climate Change Canada partnered with the Boreal Avian Modelling Project (2021) to develop a framework (conceptual model) for the “Identification of critical habitat for wide-ranging migratory birds” and chose the Canada Warbler as a working example. This included a cluster analysis to identify “management units” from regional variability in habitat use, topography and climate variables. This analysis will be used to inform the development of a management plan for the species in Canada.
- **Development of regional Best Management Practices (BMPs) and site-specific plans:**
The Canada Warbler has already been the focus of BMP development and applied management guidelines in certain regions such as northeastern U.S.A. (Harding *et al.* 2017) and the Atlantic Northern Forest {the Canadian portion of Bird Conservation Region (BCR) 14 (Westwood *et al.* 2017)}. The Canada Warbler also forms part of the multi-species action plans for at least seven Canadian national parks.
- **The Canada Warbler Genoscape Project:**
The Canada Warbler was chosen as a focal species for a collaborative partnership between the Canadian Wildlife Service and the bird genoscape project (www.birdgenoscape.org). This will provide important information on population genetics and structure across the range (see Bossu and Ruegg 2019 for preliminary results).

This plan complements the aforementioned efforts, in particular by bringing a full-life-cycle lens to conservation and on-the-ground actions. It can and should be used to bridge national and regional efforts to improve the conservation outcomes of this species and others sharing its many habitats.

VISION AND GOAL

VISION

To have healthy and viable populations of Canada Warblers across the current range and extent of occurrence

GOAL

The participants chose to use the goal articulated in the Canadian Recovery Strategy, viz.:

To stop the decline of Canada Warblers by 2025, (losing no more than 10% over this time), have an increasing trend by 2035 and maintain the extent of occurrence with minimal loss of distribution

THE CANADA WARBLER FULL LIFE-CYCLE CONSERVATION ACTION PLAN

BACKGROUND

ABOUT THE CANADA WARBLER

The Canada Warbler (*Cardellina canadensis*) is an easily recognized wood-warbler (family Parulidae). Males have bright yellow underparts with slate-blue upperparts including wings and tail. They have a prominent and mostly white eye-ring (partially washed yellow in some plumages) and a black line from the lores, behind the eye and extending down to the “necklace” of black spots on the upper breast. Females and juveniles have similar markings to the males but their colour pattern is not as bright and contrasting. The song is a loud series of warbling notes that may begin with a chip note. This species was previously placed in the genus “*Wilsonia*” (now defunct as all species moved to *Cardellina* or *Setophaga*) but recent genetic analyses have shown that, along with Wilson's Warbler (*C. pusilla*), it is closely related to the Red-faced Warbler (*C. rubrifrons*), Red Warbler (*C. rubra*) and Pink-headed Warbler (*C. versicolor*) (Reitsma *et al.* 2020).

POPULATION DECLINE

The Canada Warbler has a large range (5,840,000 km²; BirdLife International 2019). The global population estimate, based primarily on the North American Breeding Bird Survey (BBS), is 2,597,361 (95% credible intervals: 2,028,500 – 3,242,734) individuals, which constitutes a loss of an estimated 4,205,252 (3,134,019 – 5,321,449) individuals (61.8%) since 1970 (Rosenberg *et al.* 2019). Survey-wide BBS data from 1966 to 2019 (Sauer *et al.* 2020) indicate a long-term decline of 1.3%/year (-2.08 – -0.61) in North America, although the rate of decline has slowed such that the trend from 2009 to 2019 is not statistically significant (-0.48, -1.35 – 0.59), suggesting current population stability.

There is now disagreement in interpretation of the BBS data: a General Additive Model (GAM) approach to analyzing BBS trend gives a 38% increase in Canada from 2008 to 2018 (COSEWIC in prep), which seems to contradict the Sauer *et al.* (2020) analysis that gives the 2009 – 2019 trend in Canada as -0.26 (-1.3 – 1.01). It has been suggested that the Canada Warbler may have benefitted from large-scale eastern spruce budworm (*Choristoneura fumiferana*) infestation in Québec beginning in 2006 (Natural Resources Canada 2018), especially from increased shrub growth following defoliation. This explanation nonetheless seems a poor fit for the observed patterns and unlikely to explain the putative overall (country-wide) increases, especially

considering the threats elsewhere. Another possible explanation is that these differences stem from artefacts of survey design or (changes in) analytical methods rather than actual biological range-wide increases. Alternatively, they could be a product of non-linear responses to reduced habitat availability. No ecological evidence has been presented to suggest that conditions improved for species like the Canada Warbler, Common Nighthawk, Olive-sided Flycatcher, Cerulean Warbler and others beginning approximately 2005 – 2010, although their trends all began to stabilize in the same period.

Analytical disagreements aside, the BBS-derived estimate of 57% population loss since 1970 (Pardieck *et al.* 2018) corresponds closely with the 62% estimate by Rosenberg *et al.* (2019). Regional differences in trend occur; for example, for the period 1966 – 2017, the steepest declines were estimated in the New England/mid-Atlantic Coast (-4.78%/year) and the Atlantic Northern Forest (-3.66%/year); with more modest significant declines in the Appalachian Mountains (-1.34%/year), Lower Great Lakes/St. Lawrence Plain (-1.79%/year) and Boreal Hardwood Transition (-2.11%/year); and non-significant trends in the Boreal Softwood Shield, Boreal Taiga Plains and Prairie Hardwood Transition (Smith *et al.* 2019).

Other lines of inquiry lend support to BBS-derived estimates of population decline. Data from the Monitoring Avian Productivity and Survivorship (MAPS) program suggest that breeding productivity has not declined (DeSante *et al.* 2015; Albert *et al.* 2016) but there was declining recruitment, low survival rates, and population declines especially in the eastern areas of the nesting grounds (Wilson *et al.* 2018). Repeat breeding bird atlases (typically at 20-year intervals) show declines in detection probabilities in various jurisdictions (for example, McLaren 2015; Stewart 2015; Peach *et al.* 2017; Robert *et al.* 2019). Abundance and trend maps from the eBird database (Fink *et al.* 2019), used by many birders and bird watchers in the Americas, are potentially informative and may eventually generate useful estimates throughout the species' range. Nonetheless, eBird derived abundance maps currently fail to distinguish between the breeding and non-breeding grounds of the Canada Warbler; for example, many areas shown as part of southern breeding range, such as in the Prairie Pothole region (BCR 11) (*cf.* Roberto-Charron 2018b), are incorrect. In addition, patterns of relative abundance are not consistent with more rigorous datasets such as BBS (Pardieck *et al.* 2018) and breeding bird atlases (*cf.* McLaren 2015; Stewart 2015; Peach *et al.* 2017; Robert *et al.* 2019), even though some formal survey data have been shared with eBird; for example, areas of high density are portrayed as low density and vice-versa, raising concerns that observational processes (rather than biological ones) are portrayed.

LEGAL AND NON-LEGAL STATUS (PROTECTION)

The Canada Warbler is currently afforded some legal protection in Canada under SARA, which includes provisions for the protection of "Critical Habitat". However, its recent re-assessment as Special Concern will mean that Critical Habitat is not formally designated. The Canada Warbler is also listed in provincial endangered species acts, including the Ontario Endangered Species Act (Special Concern), the Manitoba Endangered Species and Ecosystems Act (Threatened), the New Brunswick Species At Risk Act (Threatened), the Nova Scotia Endangered Species Act (Endangered) and receives some protection under various provincial and territorial wildlife acts. The Canada Warbler and its nests and eggs (but not habitat *per se*) receive protection under the Migratory Birds Convention Act in Canada and the Migratory Bird Treaty Act in the U.S.A. This species is not

included in the U.S. Endangered Species Act, being evaluated as Secure, despite being ranked as Imperiled (*sic*) in Illinois, Indiana, Ohio, and Oklahoma (COSEWIC in prep.). With its large range, despite the trends discussed above, the Canada Warbler is evaluated as Least Concern globally (Birdlife International 2019).

The Canada Warbler was listed under Appendix II of the international Convention on the Conservation of Migratory Species of Wild Animals (2015), although only a few of the countries in the range of the Canada Warbler are party to this convention (Peru, Ecuador, Panama, Costa Rica and Honduras). Appendix II lists migratory species that would benefit from international agreements for their conservation.

The Canada Warbler is also included in several non-legally-binding watchlists; for example, in North America within the Partners in Flight Landbird Conservation Plan (Rosenberg *et al.* 2016). Along the migratory pathway and wintering grounds, there are few formal protections specific to the Canada Warbler. Nonetheless, this species and other Neotropical migrants are encompassed by several national strategies and frameworks for the conservation of biodiversity, as well as protected area legislation (Table 1).

Table 1. Strategies and legal frameworks in the non-breeding range of the Canada Warbler

Country	Legal framework	Comments
Colombia	- National Strategy for the Conservation of Birds - National Plan for Migratory Species	No specific protection for Canada Warbler but migratory species are covered in general, and the Canada Warbler is a “species of concern”
Costa Rica	- None	Canada Warbler not mentioned in National Biodiversity Policy and National Red List
Ecuador	- National Constitution (art. 71 Nature Rights) - Law of Environmental Management - National Strategy for Biodiversity - National Program for the Conservation of Threatened Species	Canada Warbler not mentioned but biodiversity covered by national laws and strategies, as well as National System on Protected Areas; considered for protection in Colombia-Ecuador Binational Action Plan
El Salvador	- Wildlife Conservation Act - National Strategy for Biodiversity	Canada Warbler not mentioned but covered as part of the biodiversity of the country
Guatemala	- Policy, Strategy and Biological Diversity Action Plan - Law of Protected Areas	No specific legislation pertaining to Canada Warbler but legal framework on conservation of migratory species. In addition to protected areas, several private reserves provide habitat. The Forest Incentive Program of the Forest National Institute may be beneficial in supporting product alternatives that are compatible with conservation
Mexico	- State Biodiversity Strategies - State of Knowledge of Biodiversity in Mexican States	No specific mention of Canada Warbler but several state-level frameworks cover all species, both migrant and resident
Nicaragua	- Law 807 on Biological Diversity.	No specific legislation but law covers all biodiversity

Country	Legal framework	Comments
Peru	- None	There is no specific legislation for the species
Panama	- Resolution 0051 (2008) - Environmental Law 41 (1998) - Law 24 (1995): wildlife	No specific legislation for Canada Warbler but several laws and resolutions cover biodiversity
Venezuela	- Organic Law for the Environment - Wildlife Protection Act - Law of Biological Diversity	No specific legislation for Canada Warbler but several laws cover biodiversity

DISTRIBUTION AND HABITAT CONSIDERATIONS

The range of the Canada Warbler is depicted below (Figure 1) and habitat is discussed in three sections pertaining to the breeding grounds, non-breeding grounds and the migration pathways.



Figure 1. Breeding, migration, and wintering distribution of the Canada Warbler {adapted from BirdLife International (2019, with data from NatureServe), using data from Haché *et al.* (2014), and eBird (2014)}. Environment Canada 2016.

BREEDING GROUNDS

More than 80% of the breeding range of this aptly named wood-warbler is in Canada (COSEWIC in prep). The nesting range stretches from Nova Scotia to Northeastern British Columbia and the southern Yukon, and extending south in the Great Lakes Region and through the Appalachian

Mountains into northern Georgia, U.S.A. Canada Warbler habitat on the breeding grounds varies across the range, the species being found in a variety of forest types; generally mixed or deciduous woods (Haché *et al.* 2014, Reitsma *et al.* 2020). In the western part of the breeding range, for example in Alberta, the Canada Warbler is most commonly (not exclusively) found in old-growth deciduous forests, particularly near “incised streams” (Mahon *et al.* 2016; Ball *et al.* 2016). In central parts of the breeding range, such as Manitoba, it is mostly found in mature mixed woods, especially on slopes near watercourses and waterbodies (Roberto-Charron 2018b). In more eastern parts of the breeding range, it is found in boreal mixed-wood forests (e.g. Ontario and Québec), and further east, in Canada’s Maritime Provinces, in mature cedar swamps, regenerating mixed forests, partial cuts and shrublands (Environment Canada 2016). In the Appalachian chain, the breeding range is centered on a band 1300 – 1400 m ASL, with observations suggesting an association with understorey thickets of *Rhododendron* and *Kalmia* species (Chandler and Hepinstall-Cymerman 2016). Unifying habitat features that are selected across the range include a dense understorey with a deciduous shrub layer and the presence of nearby moist or wet areas (Reitsma *et al.* 2020). Landscape composition, patch size and forest age are important features, with the Canada Warbler being “nearly twice as persistent” in large patches of mature mixed forest (Grinde and Niemi 2016). Maximum entropy modelling in Nova Scotia suggested the six most important habitat features were proximity to water table, proximity to coniferous stand, (large) variation in canopy height, (large) distance to deciduous stand, (large) distance to stands with woody debris and (high) topographic complexity (Bale *et al.* 2020).

NON-BREEDING GROUNDS

The Canada Warbler winters mainly in northwestern South America, throughout the montane and pre-montane humid forests and cloud forests of Venezuela, Colombia, Ecuador and Peru. Smaller numbers overwinter north and south of this primary range; in Central America from southern Costa Rica to Panama, and in Bolivia (Appendix 2). Wintering is primarily classified as November to April (though some may arrive at overwintering sites in October and some depart in March) and occurs in a variety of forest types. The altitudinal range in the wintering grounds is 500 – 2,500 m ASL, especially 750 – 2,300 m ASL, with highest abundance at 1,000 – 2,200 m ASL, with no evidence of elevation and habitat-use differences between males and females (Céspedes and Bayly 2018; Bayly *et al.* 2019). In Costa Rica and Panama, the species can be found throughout the whole migration and wintering periods, albeit rare in winter. The wintering range of the Canada Warbler is much smaller than the breeding range and may, for this reason, represent greater vulnerability to habitat loss and disturbance.

Habitat use is no doubt complex in the wintering range but recent studies are beginning to shed light on this important part of the annual cycle. Generally speaking, the Canada Warbler is found in both mature and secondary forests, shade-grown coffee plantations, silvopastoral systems with different successional stages, and even mosaic habitats with treed copses and suburban gardens. Relative densities appear highest in mature forest (as compared to secondary forest and coffee plantations) and are positively correlated with canopy height (Céspedes and Bayly 2018). Although there is no current evidence of segregation by sex or age class, there are still concerns that different habitats in different parts of the range may produce different impacts on body condition. Studies in the Colombian Andes have shown that Canada Warblers can improve body condition in some shade coffee plantations (Colorado and Rodewald 2017) and that apparent survival was

similar in forests and in shade coffee, although in both habitats, condition and apparent survival decreased during the El Niño Southern Oscillation (González-Prieto *et al.* 2020).

In creating this plan and in order to establish an appropriate baseline to inform the non-breeding-grounds workshop, a spatial model of the species' migration (excluding the U.S.A.) and overwintering distribution was prepared using observations, mist-net captures, records in scientific literature and data from biological collections (Figures 2 – 4). These data were analyzed using altitudinal information, habitat, slope, 19 climatic variables, and the distribution of protected areas and Important Bird and Biodiversity Areas (IBAs). The spatial distribution model presents the spatial and seasonal dimensions, including relevant environmental factors, for targeted conservation of the species.

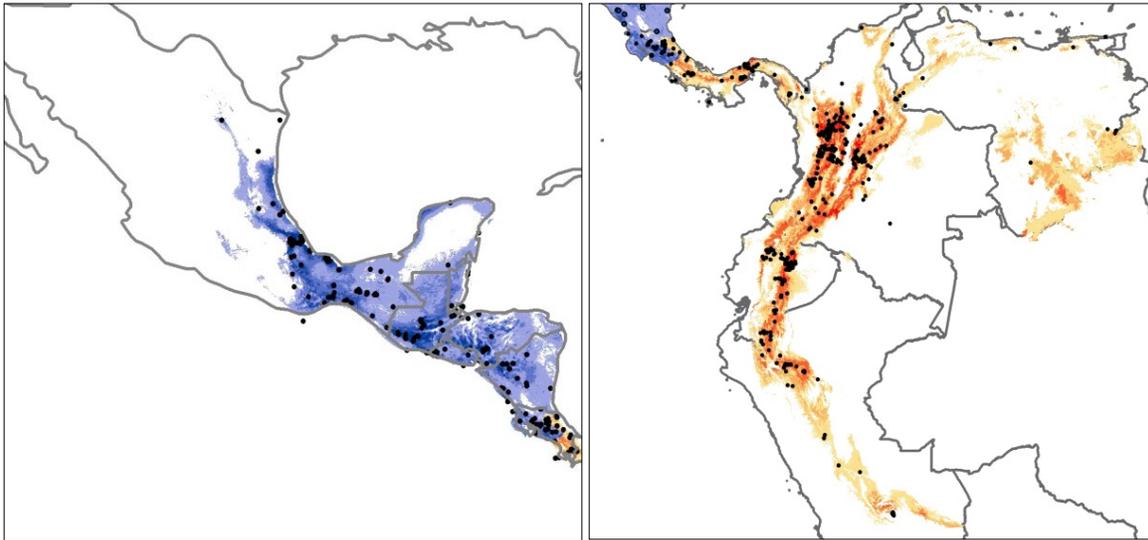


Figure 2. Canada Warbler spatial distribution model at passage sites (blue) and wintering sites (orange). Black dots represent the records used to generate the model.

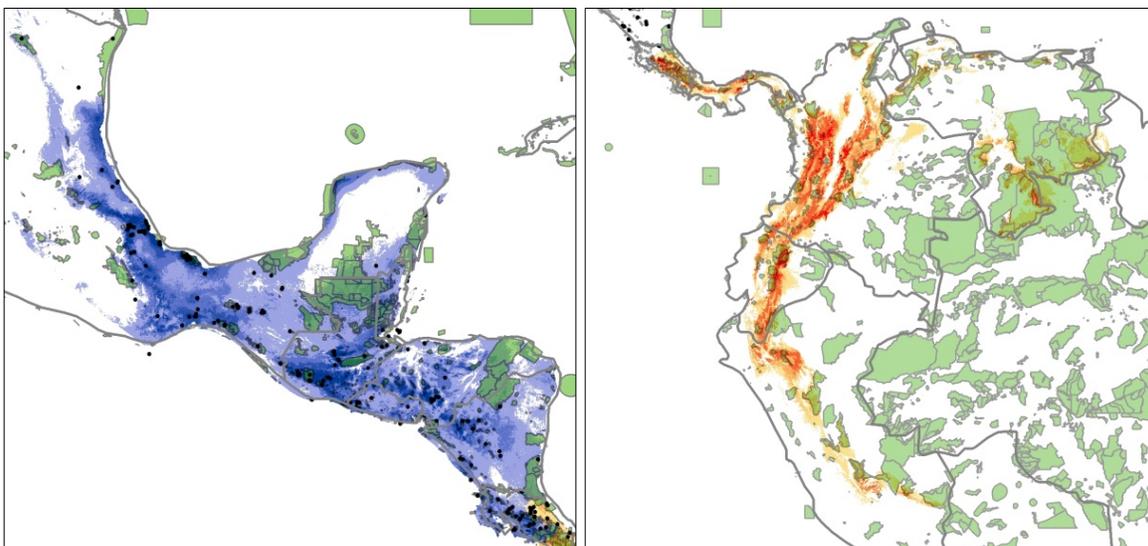


Figure 3. Canada Warbler spatial distribution model in protected areas at passage sites (blue) and wintering sites (orange). Black dots represent the records used to generate the model and green

polygons show protected areas. The spatial distribution model shows that there are 482 (70% of the distribution) protected areas occupying 103,000 km² at passage sites and 315 (47% of the distribution) occupying 212,000 km² in the wintering grounds.

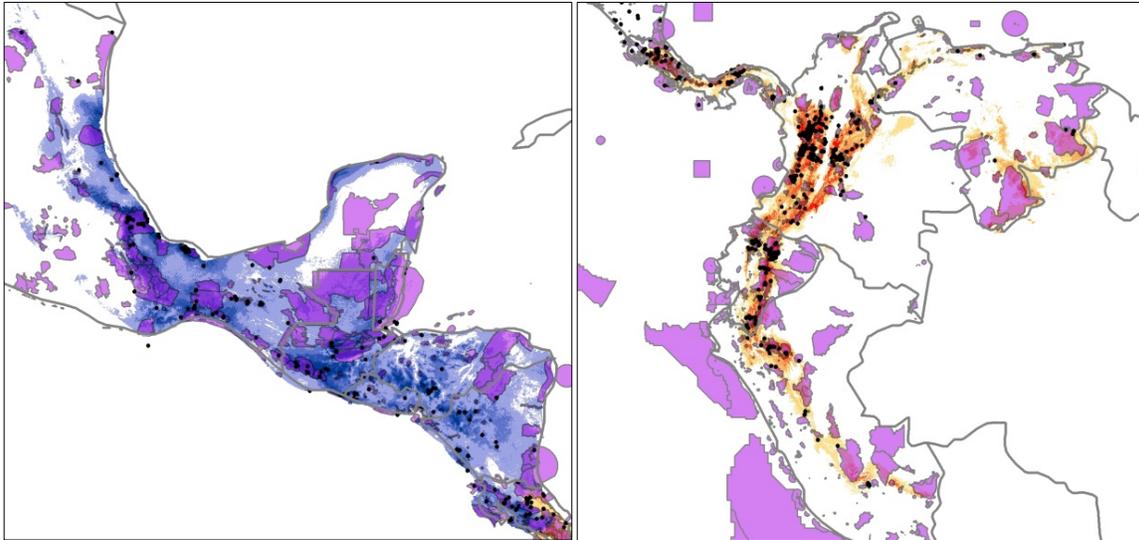


Figure 4. Canada Warbler spatial distribution model in IBAs at passage sites (blue) and wintering sites (orange). Black dots represent the records used to generate the model, and IBAs (including marine IBAs) are shown in pink polygons. Note that IBAs are not considered protected areas *per se* and their overlap with legal protection is generally small. The spatial distribution model shows that there are 196 IBAs (60% of the distribution) occupying 194,000 km² at stopover sites and 323 (53% of the distribution) occupying 214,000 km² in the wintering range. More detail on the methods used for Figures 2, 3 and 4 and data sources are found in Appendix 3.

MIGRATION AND MIGRATORY CONNECTIVITY

During migration, the Canada Warbler crosses Central America from southeast Mexico to Panama, with few records in the Caribbean. Fall (autumn) migration peaked in mid-October in the Darién Gap and ranged from 20 September until early November (Cárdenas Ortiz *et al.* 2017). Canada Warblers have been recorded between 0 – 500 m ASL at stopover sites (generally September – October and April – May). At stopover sites in Central America, Canada Warblers frequent a variety of natural forested areas, including secondary and mature forest, with open and closed canopies, dry, wet, gallery and coniferous forests (Bayly *et al.* 2019).

Banding data are somewhat meagre for this species but the 132 recoveries in the Canadian-U.S. bird-banding database show a general pattern of birds from the eastern portion of the breeding range migrating southwest around the Gulf of Mexico (Brewer *et al.* 2006). Direct tracking data are currently not available for such a small-bodied bird; however, recent research using geolocators and stable isotopes, accompanied by genetic information, are beginning to provide evidence of migratory connectivity in this species. There may be segregation of breeding populations of Canada Warbler within the complex topography of the wintering grounds, especially the three “arms” of the Andean chain in Colombia (González-Prieto 2017). Nonetheless, geocator studies across a staggering 43 degrees in longitude on the nesting grounds (From Alberta, Canada to New

Hampshire, U.S.A.) found no evidence of population specific segregation on migration and 18 of 25 birds (72%) overwintering in Colombia and 18% in Venezuela, but, interestingly none in Ecuador, Peru or eastern Venezuela (Roberto-Charron 2018a, Roberto-Charron *et al.* 2020). All of these birds migrated in fall (autumn) along a relatively narrow area around the western coast of the Gulf of Mexico and data showed that Colombia is a significant wintering area for these populations (72% of tagged birds) (Roberto-Charron *et al.* 2020). Stable isotope analyses lend support for a Central American migration route and suggest that most birds captured in the Darién Gap were from the eastern portion of the breeding range (Cárdenas Ortiz *et al.* 2017).

Stable isotope analyses suggest that birds from the Cauca Valley, Colombia (eastern slope of the western Andes) may originate in the central and western parts of the breeding range; birds from the eastern slope of the eastern Colombian Andes originate in the eastern and Appalachian parts of the breeding range; and birds from the Central Andes and the western slope of the eastern Andes originate in the eastern and central portions of the breeding range, with a notable exception in the birds from the “Santander” study site that may be of western origin (González-Prieto *et al.* 2017). Preliminary genetic analysis lends support for such population structure despite the lack of morphological differences (Ferrari *et al.* 2018), perhaps with four “ecotypes”, viz. North Carolina, Northeast, Québec and western boreal (Bossu and Ruegg 2019). In addition, the aforementioned clustering analysis suggests seven management units in Canada (Boreal Avian Modelling Project 2021). In conclusion, much remains to be learned about the population structure and the relative strength of migratory connectivity in this species.

OTHER ECOLOGICAL CONSIDERATIONS

Documenting the habitat types used by the species is of course insufficient to understand and safeguard populations of the Canada Warbler. There are complex ecological considerations that can influence usage of different habitat and generate differences in fecundity and/or survival. On the breeding grounds, the distribution of the Canada Warbler often appears clumped and this pattern is sometimes described as “neighbourhoods”, with males more likely to establish home ranges in proximity to conspecifics (Reitsma *et al.* 2020; Hunt *et al.* 2017; COSEWIC in prep). One behavioral mechanism in Canada Warbler territoriality that likely influences this distribution pattern is “song sharing” (Demko *et al.* 2016); however, the probability of pairing is lower for males in high-density areas (Hunt *et al.* 2017). Territory size ranges considerably (0.2 – 1 ha), as does home range (1 – 2 ha), and both are likely influenced by conspecific attraction and density dependence (Chace 2005; Machtans 2006; Hallworth *et al.* 2008a; Reitsma *et al.* 2020; Flockhart *et al.* 2016; Hunt 2017; Hunt *et al.* 2017; COSEWIC in prep). Conspecific attraction can bring male Canada Warblers into suboptimal habitat post-logging (Hunt 2017).

Likely due to its preference for a well-developed shrub layer, the Canada Warbler is able to nest along linear disturbances and in regenerating forestry cuts; however, males using such cuts were shown to be 16.6 times more likely to settle within 100 m of uncut forest than 300 m from uncut forest in Alberta (Hunt *et al.* 2017). Cut-overs only become suitable habitat for a limited period post-harvest, which differs across the range, likely due to rates of shrub regrowth; for example, from 6 – 20 years in northeastern forests to 20 – 30 years in western boreal region (Hobson and Schieck 1999; Lambert and Faccio 2005; Hunt *et al.* 2017), peaking about 20 years post-harvest in New Hampshire, but still occupied >30 years post-harvest (L. Reitsma, pers. comm. 2021). Stands regenerating after forest fires are also used for nesting but perhaps not to the same extent as

regeneration after logging (Hobson and Schieck 1999). In addition to the density of conspecifics, shrub density also contributes to smaller territory sizes and territories in forest interior sites are larger than those close to water. Nesting success was lower for birds in smaller territories suggesting a consequence of competition and the possibility of a negative density-dependent effect on productivity (Flockhart *et al.* 2016); however, Hallworth *et al.* (2008b) found that after-second-year males typically had smaller territories and were more successful, presumably because they held higher quality territories.

Although natural disturbances such as fire and some anthropogenic disturbances such as logging can create suitable habitat for the Canada Warbler, albeit for a limited time, other disturbances with more long-lasting impact on habitat are a deterrent. Within cutovers, the retention of legacy trees that serve as song perches can lengthen occupancy (Lambert and Faccio 2005, Hallworth *et al.* 2008b, Reitsma *et al.* 2008). The abundance of the Canada Warbler decreased with increasing disturbance around breeding-season banding sites (Wilson *et al.* 2018). Fragmentation of forests from agricultural incursion also has a negative impact on abundance (Robbins *et al.* 1989; Hobson and Bayne 2000; COSEWIC in prep). Disturbance and habitat fragmentation appear to be even more significant on the wintering grounds, where the human footprint index increased by 14% from 1993 to 2009 as opposed to 0.1% on the breeding grounds (Wilson *et al.* 2018).

There is recent data on non-breeding ecology of the species and some studies on landscape-level and micro-habitat-level associations (Appendix 2). On the wintering grounds, Canada Warblers feed in mixed-species flocks, including antwren flocks (Hespenheide 1980), and most commonly in the midstorey. Colorado and Rodewalde (2015) found that competitive interactions (rather than body size *per se*) influence distribution and flock composition in the Andes. Despite being present in a variety of habitats, there may be commonalities in the presence of a diverse and heterogeneous undergrowth, including shrubs, that are important for meeting the biophysical requirements of overwintering birds (Colorado and Rodewald 2017). It remains unclear if competitive exclusion between the sexes and/or age-classes is a factor in winter habitat use.

WORKSHOPS

Between 2014 and 2016, the partners of the Canada Warbler International Conservation Initiative (CWICI) participated in meetings, discussions and round tables to build the full life-cycle action plan. As part of these workshops, we collected information from across the range of the Canada Warbler, identified threats and contributing factors impacting the species and its habitats, and proposed strategies and actions to reduce the impact on the population. Workshops for the breeding grounds and non-breeding grounds used slightly different approaches (described below).

THE BREEDING-GROUNDS WORKSHOP

For the breeding-grounds workshop, we used a conceptual model based on the Conservation Standards (<http://cmp-openstandards.org/>). This model shows how direct and indirect threats relate to each other, and how they affect the species and habitats under consideration.

Threats on the breeding grounds, as identified in the workshop (Tables 2a, 2b and 2c), include those associated with habitat loss (both temporary and permanent) and fragmentation, as well as

pressures that may increase mortality and decrease productivity. Changes to habitat quality and availability, and prey availability, perhaps as a result of climate change, may be significant drivers associated with population loss, particularly in more southern regions of the breeding range, and may exacerbate the impact of other threats. Those threats ranked as “red” or high impact are discussed by category below and other threats are then discussed more generally. It is important to recognize that threats are not uniform across the breeding range; tables 2b and 2c capture some of the differences, at least east to west, although there are doubtless difference along a north/south axis as well. A key consideration that has the potential to hamper conservation efforts pertains to the significant knowledge gaps regarding habitat and prey availability, productivity and population size.

Table 2a. Threats following standard IUCN categories and numbering (at the time), with the specific wording chosen in parentheses, within the entire breeding range classified by scope, severity and irreversibility and ranked into four major threat categories: ≥ 8.5 = Very High (red); $6 - 8.4$ = High (yellow); $3.5 - 5.9$ = Medium (light green); $1 - 3.4$ = Low (dark green).

THREAT	Entire Breeding Range		Average of 11 Responses	
	Scope	Severity	Irreversibility	Rank
11. Climate change & severe weather	V. High	High	V. High	V. High
1.1 Housing & urban areas (urban expansion)	High	V. High	V. High	V. High
5.3 Logging & wood harvesting (adverse forestry practices)	V. High	V. High	Medium	V. High
2.1 Annual & perennial non-timber crops	High	V. High	High	High
3.2 Mining & quarrying	Medium	V. High	V. High	High
3.1 Oil & gas drilling	High	High	High	High
2.3 Livestock farming & ranching	High	High	High	High
9. Pollution	High	Medium	Medium	Medium
1. Residential & commercial development (window collisions)	Medium	High	Medium	Medium
8.2 Problematic native species/diseases (over-browsing by deer)	Medium	Medium	Medium	Medium
8.1 Invasive non-native/alien species/diseases	Medium	Medium	High	Medium
8.1 Invasive non-native/alien species/diseases (domestic and feral cats specifically)	Medium	Medium	Medium	Medium
8.2 Problematic native species/diseases (cowbird parasitism)	Low	Low	Medium	Low

1. Scope: The proportion of the target that can reasonably be expected to be affected by the threat within ten years, given the continuation of current circumstances and trends. For species, measured as the proportion of the target’s population. Very High: The threat is likely to be pervasive in its scope, affecting the target across all or most (71 – 100%) of its occurrence/population. High: The threat is likely to be widespread in its scope, affecting the target across much (31 – 70%) of its occurrence/population. Medium: The threat is likely to be restricted in its scope, affecting the target across some (11 – 30%) of its occurrence/population. Low: The threat is likely to be very narrow in its scope.
2. Severity: Within the scope, the level of damage to the target from the threat that can reasonably be expected given the continuation of current circumstances and trends. For species, measured as the degree of reduction of the target’s population within the scope. Very High: Within the

scope, the threat is likely to destroy or eliminate the target, or reduce its population by 71 – 100% within ten years or three generations. High: Within the scope, the threat is likely to seriously degrade/reduce the target or reduce its population by 31 – 70% within ten years or three generations. Medium: Within the scope, the threat is likely to moderately degrade/reduce the target or reduce its population by 11-30% within ten years or three generations. Low: Within the scope, the threat is likely to only slightly degrade/reduce the target or reduce its population by 1 – 10% within ten years or three generations.

3. Irreversibility: the degree to which the effects of a threat can be reversed and the target affected by the threat restored. It is assessed for the impact of the threat on the target, not the threat itself. Very High: The effects of the threat cannot be reversed, it is very unlikely the target can be restored, and/or it would take more than 100 years to achieve this (e.g., wetlands converted to a shopping center). High: The effects of the threat can technically be reversed and the target restored, but it is not practically affordable and/or it would take 21 – 100 years to achieve this (e.g., wetland converted to agriculture). Medium: The effects of the threat can be reversed and the target restored with a reasonable commitment of resources and/or within 6 – 20 years (e.g., ditching and draining of wetland). Low: The effects of the threat are easily reversible and the target can be easily restored at a relatively low cost and/or within 0–5 years (e.g., off-road vehicles trespassing in wetland).

Table 2b. Threats in the eastern portion of the breeding range (Ontario and East) classified by scope, severity and irreversibility and ranked into four major threat categories: ≥ 8.5 = Very High (red); 6 – 8.4 = High (yellow); 3.5 – 5.9 = Medium (light green); 1 – 3.4 = Low (dark green).

THREAT	Ontario and East			Average of 10 Responses	
	Scope	Severity	Irreversibility	Rank	
11. Climate change & severe weather	V. High	High	V. High	V. High	
5.3 Logging & wood harvesting (adverse forestry practices)	V. High	High	Medium	V. High	
1.1 Housing & urban areas (urban expansion)	High	High	V. High	V. High	
2.1 Annual & perennial non-timber crops	High	Medium	V. High	High	
9. Pollution	High	High	High	High	
8.2 Problematic native species/diseases (over-browsing by deer)	High	High	Medium	High	
3.2 Mining & quarrying	Low	High	High	High	
1. Residential & commercial development (window collisions)	High	High	Medium	High	
8.1 Invasive non-native/alien species/diseases	Medium	High	Medium	Medium	
8.1 Invasive non-native/alien species/diseases (domestic & feral cats specifically)	Medium	Medium	Medium	Medium	
2.3 Livestock farming and ranching	Medium	Medium	High	Medium	
3.1 Oil & gas drilling	Low	Medium	High	Medium	
8.2 Problematic native species/diseases (cowbird parasitism)	Medium	Medium	Medium	Medium	

Table 2c. Threats in the western portion of the breeding range (Manitoba and West) classified by scope, severity and irreversibility and ranked into four major threat categories: ≥ 8.5 = Very High (red); 6 – 8.4 = High (yellow); 3.5 – 5.9 = Medium (light green); 1 – 3.4 = Low (dark green).

THREAT	Manitoba and West			Average of 10 Responses		
	Scope	Severity	Irreversibility	Rank		
11. Climate change & severe weather	V. High	High	V. High	V. High		
5.3 Logging & wood harvesting (adverse forestry practices)	V. High	High	Medium	V. High		
1.1 Housing & urban areas (urban expansion)	High	High	V. High	V. High		
2.1 Annual & perennial non-timber crops	High	Medium	V. High	High		
9. Pollution	High	High	High	High		
8.2 Problematic native species/diseases (over-browsing by deer)	High	High	Medium	High		
3.2 Mining & quarrying	Low	High	V. High	High		
1. Residential & commercial development (window collisions)	Medium	High	Medium	High		
8.1 Invasive non-native/alien species/diseases	Medium	High	Medium	Medium		
8.1 Invasive non-native/alien species/diseases (domestic and feral cats specifically)	Medium	Medium	Medium	Medium		
2.3 Livestock farming and ranching	Medium	Medium	High	Medium		
3.1 Oil & gas drilling	Low	Medium	High	Medium		
8.2 Problematic native species/diseases (cowbird parasitism)	Medium	Medium	Medium	Medium		

THREAT: CLIMATE CHANGE (11. CLIMATE CHANGE & SEVERE WEATHER)

The influences of a changing climate are expected to have large impacts on songbirds and their prey (Stralberg *et al.* 2015). The boreal forest, which constitutes a large portion of the nesting range of the Canada Warbler, is predicted to experience major change (Price *et al.* 2013), with potential adverse effects on avian species assemblages (Cadieux *et al.* in prep). Whether such change will be net positive or net negative for any given species remains unclear; however, the COSEWIC threats calculator exercise assessed this threat as very high for the Canada Warbler (COSEWIC in prep). The primary impact on the Canada Warbler is expected to be related to distributional shifts and changes in habitat availability and quality; for example, the Canada Warbler was one of the species predicted to move into Alaska as a result of climate change weakening current biophysical barriers (Stralberg *et al.* 2017). Matthews *et al.* (2004) predicted decreases and range contraction for the Canada Warbler in eastern U.S.A as tree species such as balsam fir (*Abies balsamea*), striped maple (*Acer pensylvanicum*) and yellow birch (*Betula alleghaniensis*) were predicted to lose range under various climate change models. There are also concerns that this species will be negatively impacted by drier climate and even drought in some parts of its range; for example, Canada Warbler was one of several species associated with deciduous forests that was projected to decrease in the long-term under several global climate models (Stralberg *et al.* 2015).

We recognized during the workshops that climate change might already be a driver influencing populations; for example, by reducing prey availability, and that it might exacerbate the impact of

other threats such as decreased habitat suitability following disturbance. However, those threats are discussed separately in this section and in the non-breeding grounds workshop section.

THREAT: ADVERSE FORESTRY PRACTICES (5.3 LOGGING & WOOD HARVESTING)

Despite differences across the breeding range, stand-level structural diversity, including a dense shrub layer, complex understorey and ground cover, is thought to be important to Canada Warbler breeding success (Hallworth *et al.* 2008a; Reitsma *et al.* 2020). Deforestation and alteration, especially removal of the shrub layer, have been identified as major threats faced by the Canada Warbler on the breeding grounds. Nonetheless, the impacts of forestry operations are complex and potentially both negative (e.g., degradation of breeding habitat following a clear-cut or thinning) and positive (e.g., temporary habitat creation while regeneration occurs) (Hallworth *et al.* 2008a). Across Canada, it has been estimated that 740,000 hectares of forest are harvested each year, of which 680,000 hectares are clear cut and 60,000 hectares are selectively logged. In Alberta, the Canada Warbler is associated with old-growth boreal mixed forests (Bayne *et al.* 2016) and deciduous forests in relatively intact landscapes (greater amount of forest), leading to a prediction that forestry will reduce habitat availability over time (Ball *et al.* 2016).

The application of herbicides to remove the shrub layer as part of commercial and private enterprises has been identified as a concern to Canada Warbler breeding habitat, although the scale to which herbicides are used in this manner may be limited, at least on public lands. While the forests affected by herbicide are small in regards to the total amount of forest across Canada, there remains a general concern about the loss, alteration, and fragmentation of habitat (including forested wetlands), shrub management (including pre-commercial thinning and vegetation management along right of ways) and removal of residual trees from previously logged areas. These factors could influence the availability of Canada Warbler nesting habitat, possibly with population-level impacts.

Forestry certification mechanisms do offer some hope for beneficial management; however, existing forest certification standards in Canada do not include management for shrubs (A. deVries pers. comm. 2018). To date, best management practices regarding forestry (Harding *et al.* 2017; Westwood *et al.* 2017) and conservation planning scenarios (Westwood *et al.* 2020) have only been developed in the northeast (Atlantic) portion of the breeding range. Recommendations have stemmed from research in other areas; for example, retaining large stands of mature deciduous forest (residual patches) close to streams in Alberta (Ball *et al.* 2016) to using “light partial harvests” with unharvested legacy trees in West Virginia (Becker *et al.* 2012).

THREAT: URBAN EXPANSION (1.1 HOUSING & URBAN AREAS)

Urban and exurban expansion is already causing habitat loss in the southern portions of the nesting range of the Canada Warbler. This is only likely to increase in future. Habitat loss from urban development is coupled with other more subtle effects that may also play a role in population declines; for example, buildings and their associated roads fragment habitat. Some studies have shown limited impact of local-scale fragmentation on the Canada Warbler (Ball *et al.* 2016), whereas other studies have measured a negative impact on occupancy or density; for example, proximity to roads and disturbance decreased the density of the Canada Warbler within four national parks in eastern Canada (Westwood *et al.* 2019). These activities probably also increase the likelihood of collisions with human-made structures and may be accompanied by

noise, air and other forms of pollution (e.g., effluent), often with unmeasured impacts. In addition, important habitat for the Canada Warbler and its prey, including forested wetlands, is being lost as a result of agricultural expansion and livestock farming and ranching (Hobson *et al.* 2002).

THREAT: OTHER CONSIDERATIONS

Across its range, the habitat of the Canada Warbler, such as swamp forest in eastern Canada and boreal forest in western Canada, has been and continues to be lost to resource extraction (mining and oil and gas exploration) and agriculture (clearing for both cropping and ranching) (Hobson *et al.* 2002; COSEWIC in prep). In many cases, this leads to long-term habitat loss for the Canada Warbler. Resource extraction such as oil and gas drilling and mining and quarrying causes large-scale direct loss of habitat in some parts of Canada (immediate footprint of operations), but also creates further complications as a result of roads and other linear features, such as seismic lines, associated with industrial development.

Measures of Canada Warbler abundance along rights-of-way and small-scale linear disturbances are doubtless complicated by increased detectability (the detection radius of a singing Canada Warbler is likely to be increased in such an open context) and the fact that increased exposure to light in the lower story could produce a shrubby edge (as perhaps occurs along the streams that are typical nesting habitat for this species). In understanding the effect of fragmentation (as opposed to habitat loss), scale is undoubtedly important and this still constitutes a knowledge gap (cf. Becker *et al.* 2012; Bayne *et al.* 2016). This is likely equally important for consideration in forestry practices as well as in right-of-way development.

The populations of North American bird species dubbed “aerial insectivores” have experienced long-term declines. These species capture flying invertebrate prey and migrate long distances, i.e. they require flying invertebrates as a main food source year round (North American Bird Conservation Initiative 2016). This has led to speculation that reduced availability of insect prey is driving population declines (Nebel *et al.* 2010). The Canada Warbler is not considered to be an aerial insectivore *per se*, but it does feed on flying insects, to the extent that it earned the former moniker “Canadian flycatching warbler” (Reitsma *et al.* 2020). There are a multitude of suspected drivers for the declines in insects world-wide, including loss of habitat (through mechanisms including, but not limited to, wetland draining, peat extraction, agriculture, urban development, and oil and gas extraction). There is also concern regarding habitat acidification, pesticides and recent mismatches in avian breeding phenology with peak insect emergence as a result of climate change, (Environment Canada 2016).

In Canada, 100 – 350 million birds are killed by domestic cats and 16 - 42 million birds are killed by building collisions annually; in the U.S.A., 1.3 – 4 billion birds are killed by cats and 365 – 988 million birds are killed by building collisions annually (Blancher 2013; Loss *et al.* 2013, 2014, 2015a; Machtans *et al.* 2013). While it is unknown how vulnerable Canada Warblers are to predation by cats it is recognized that such predation likely occurs, especially in the migratory period at stopover sites and, perhaps to a lesser extent, in the southern parts of the nesting range in close proximity to human settlement. Canada Warblers are considered to be highly susceptible to collisions with buildings, to such a degree that these mortality events may exacerbate population declines (Loss *et al.* 2014). Even when collisions and predation attempts by domestic cats do not

cause direct mortality, they cause injury and are energetically costly and could result in a loss of fitness and productivity.

THE NON-BREEDING-GROUNDS WORKSHOP

The Conservation Standards were also applied to develop the non-breeding ground conceptual model and strategies. The threats categorized as having a high impact on the wintering grounds were those associated with fires to prepare land for agriculture; illegal and legal mining, energy production and forest harvesting. Other threats with high impact include building collisions (during migration) (Table 3).

Table 3. Threats within the non-breeding range grouped by category. Standard IUCN threat categories are used (Salafsky *et al.* 2008; Appendix 1), with assessment of the scope, severity and irreversibility of the threat. These three scores are combined into the rank (very high to low).

Threats	IUCN Category	Scope ¹	Severity ²	Irreversibility ³	Rank
Land Conversion: livestock & cropping	2. Agriculture and aquaculture <i>With exacerbating effect on:</i> 11.1 Habitat shifting & alteration 11.2 Droughts 11.3 Temperature extremes	V. High	High	V. High	V. High
Land Conversion: land-use change	1. Residential & commercial development 2. Agriculture & aquaculture 3. Energy production & mining 4. Transportation & service corridors	High	High	Medium	High
Land Conversion: urban & commercial expansion	1. Residential & commercial development	Medium	High	V. High	High
Land conversion: mining	3.2 Mining & quarrying	Medium	High	V. High	High
Forestry: Unsustainable & illegal logging	2.2 Wood & pulp plantations 5.3 Logging & wood harvesting	V. High	V. High	High	High
Agriculture: pollutants	2. Agriculture & aquaculture 9.2 Industrial & military effluents	High	High	High	High

1. Scope: The proportion of the target that can reasonably be expected to be affected by the threat within ten years, given the continuation of current circumstances and trends. For species, measured as the proportion of the target's population. Very High: The threat is likely to be pervasive in its scope, affecting the target across all or most (71 – 100%) of its occurrence/population. High: The threat is likely to be widespread in its scope, affecting the target across much (31 – 70%) of its occurrence/population. Medium: The threat is likely to be restricted in its scope, affecting the target across some (11 – 30%) of its occurrence/population. Low: The threat is likely to be very narrow in its scope.
2. Severity: Within the scope, the level of damage to the target from the threat that can reasonably be expected given the continuation of current circumstances and trends. For species, measured as the degree of reduction of the target's population within the scope. Very High: Within the scope, the threat is likely to destroy or eliminate the target, or reduce its population by 71 – 100% within ten years or three generations. High: Within the scope, the threat is likely to seriously degrade/reduce the target or reduce its population by 31 – 70% within ten years or three generations. Medium: Within the scope, the threat is likely to moderately degrade/reduce the target or reduce its population by 11-30% within ten years or three generations. Low: Within

the scope, the threat is likely to only slightly degrade/reduce the target or reduce its population by 1 – 10% within ten years or three generations.

3. Irreversibility: the degree to which the effects of a threat can be reversed and the target affected by the threat restored. It is assessed for the impact of the threat on the target, not the threat itself. Very High: The effects of the threat cannot be reversed, it is very unlikely the target can be restored, and/or it would take more than 100 years to achieve this (e.g., wetlands converted to a shopping center). High: The effects of the threat can technically be reversed and the target restored, but it is not practically affordable and/or it would take 21 – 100 years to achieve this (e.g., wetland converted to agriculture). Medium: The effects of the threat can be reversed and the target restored with a reasonable commitment of resources and/or within 6 – 20 years (e.g., ditching and draining of wetland). Low: The effects of the threat are easily reversible and the target can be easily restored at a relatively low cost and/or within 0–5 years (e.g., off-road vehicles trespassing in wetland).

THREAT: LAND CONVERSION (AGRICULTURE, MINING, URBAN EXPANSION)

The expansion of ranching and other forms of agriculture is arguably the main threat for the Canada Warbler on the non-breeding grounds. In the Andean region of northern South America, clearing for livestock has been a principle driver of land conversion (Dillon 1994; Etter *et al.* 2008; COSEWIC in prep). In Colombia, habitat lost may now be increasing as forested areas become accessible after the peace agreement. In Mexico and Costa Rica, pineapple and palm oil crops are the main sources of conversion. In Ecuador, the situation is complex with the introduction of monoculture plantations of palm oil, naranjilla (*Solanum quitoense*), and tamarillo (*Solanum betaceum*), among others. Some land-use changes are more subtle but doubtless impactful; for example, the relatively recent phenomenon of the replacement of shade-grown coffee with sun-grown coffee varieties in Venezuela, Colombia and perhaps elsewhere (Perfecto *et al.* 1996; Escobar 2013; González-Prieto 2018).

It is important to note the large-scale environmental and climactic influence of Andean forests in the continental and even global context. Forest clearing could exacerbate the effects of climate change, perhaps intensifying drought or temperature extremes as the water retention capacity of the land is diminished. It remains unclear how the Canada Warbler will be impacted by climate change working in concert with other threats such as the current rates of agricultural conversion.

In addition to agriculture, land-use changes are also occurring as a result of urban expansion (residential and commercial development), energy production and mining and the expansion of transportation and service corridors with their accompanying human footprint. The cumulative habitat loss from these mechanisms is thought to be the principle threat faced by this species.

In addition to direct habitat loss, the energy industry and urban expansion impact the Canada Warbler and other migratory species in other ways; for example, increasing the risk of collisions with glass, transmission lines and other anthropogenic structures during migration. The Panama-Colombia Electricity Interconnection Plan has the potential to impact migration at the very narrow isthmus that is a major migration route for many species travelling between North and South America, including the Canada Warbler (see Migratory Connectivity above). Other specific examples mentioned during discussion that could impact the Canada Warbler along its migration

pathway include wind farm development in the Isthmus of Tehuantepec and mining operations in the Sierra Madre in Chiapas, Mexico, or petroleum development in Petén and Izabal, Guatemala.

THREAT: FORESTRY

In the wintering grounds and some areas of the migration pathway of the Canada Warbler, illegal logging and wood extraction, as well as commercial operations, pose a real threat. This results in direct habitat loss and may greatly reduce habitat suitability in forested areas. Plantations for pulp do not appear to result in useable winter habitat for the Canada Warbler.

THREAT: POLLUTANTS

Beyond the loss of natural habitats, agricultural practices may influence the Canada Warbler and other biodiversity in indirect ways. Garbage and solid waste and contamination caused by the frequent use of agrochemicals and insecticides is likely to degrade habitat and reduce the prey availability, impacting body condition and winter survival. Likewise, mining operations also creates pollution and contamination problems.

In addition to all of the above, there is the compounding and as yet unknown effect of climate change on habitat distribution and quality. Climate change is already doubtless influencing plant phenological patterns, precipitation regimes, temperature patterns, the frequency and timing of tropical storms and hurricanes (more frequent in Central America and the Caribbean) and the intensification of climate phenomena including the coupled El Niño–Southern Oscillation and La Niña (González-Prieto 2018). Both seasonal dryness and El Niño have a negative impact on the body condition of Canada Warbler and the latter can exacerbate the former (González-Prieto *et al.* 2020).

COMBINED THREATS EXERCISE

Following the workshops, we synchronized the findings from both the breeding-grounds and non-breeding grounds workshops. This produced a total of 13 principle threat categories (Figure 5), which were prioritized based on the scoping exercise by regional experts. The threats identified as having high impact throughout the species' full life-cycle were related to loss and fragmentation of habitat such as the expansion of agriculture (unsustainable agricultural practices), urban and commercial development and other land-use change. Examples include the use of open-pit coffee varieties in the Andes. Another group of threats with high impact or potential impact were those associated with climate change, specifically those related to droughts, reduced availability of insect prey and habitat shifting and alteration. Nonetheless, there are still large knowledge gaps as to how these threats will impact the Canada Warbler.

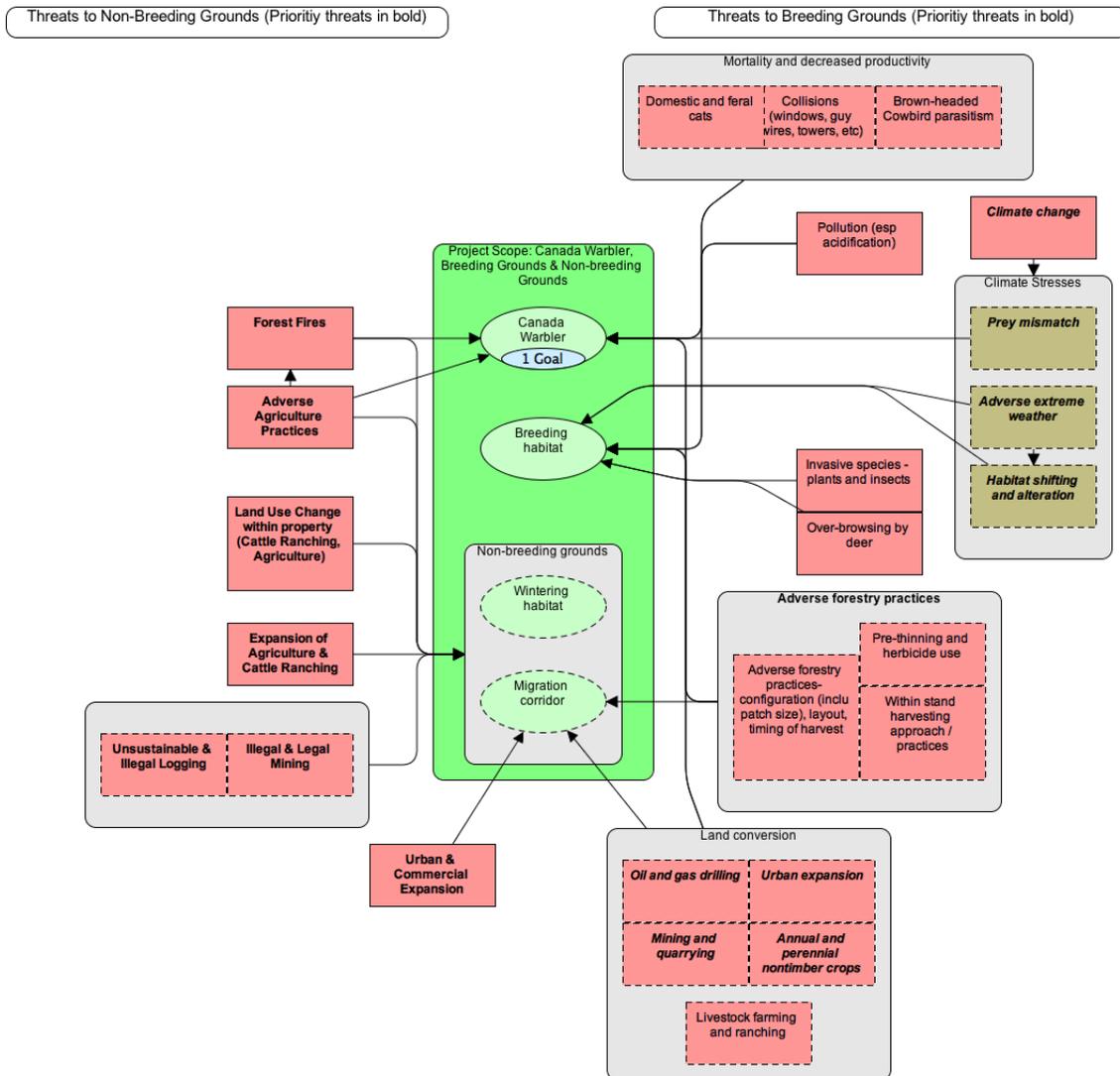


Figure 5. Threats to the Canada Warbler and its habitat on the breeding grounds, migratory pathway and wintering grounds (pink squares) produced as a synthesis of the threats identified in the workshops and how these relate to conservation targets (green rectangle). Some threats are grouped together (grey rectangles).

CONCEPTUAL MODELS AND STRATEGIES

Strategic approaches were identified to address the threats, especially those with the greatest impact or potential impact, on both the breeding grounds and the non-breeding grounds. Strategies were categorized as effective, “needs more information” (less effective) and ineffective. Effectiveness is related to the potential impact the proposed actions could have in mitigating the threats identified or restoring the status of the species and its habitats, and to the feasibility of the action.

The conceptual models (Figure 6 and 7) illustrate the relationships among the potential threats affecting the Canada Warbler and its habitats, the contributing factors (economic, cultural, political, legal, social, and/or institutional) and the strategies devised to address them. The models link the proposed strategies to the threats, research needs and knowledge gaps identified. For simplicity, research needs are indicated in the same format as direct threats in the figures. The conceptual models also include a ranking for the strategies, from effective to ineffective, based on the combined ratings for impact and feasibility (Tables 4 and 5).

STRATEGY: BREEDING GROUNDS

Strategies originally identified in the process of building the conceptual model for the breeding grounds are grouped below, for ease of discussion, into four main strategic approaches, viz.:

- Best Management Practices (BMPs)
- Adaptive management and the development of legal instruments
- Communications and outreach
- Research and monitoring

Naturally, some of the strategies identified fall into more than one category and/or require a multi-faceted approach. Some strategies comprise broader, long-term commitments whereas others may be more targeted. The kinds of resources or personnel and the level of management required may also vary. The strategies are discussed in turn for the breeding (Table 4, Figure 6) and non-breeding grounds (Table 5, Figure 7). The relationships between the strategies and the threats, and how these work towards the targets are best viewed in the conceptual models (Figures 6 and 7).

Table 4. Strategies to address threats to the Canada Warbler on its breeding grounds with an assessment of the potential impact and feasibility of each strategy. Effectiveness ranking from effective (green) to less effective represents a roll-up of the scores for impact and feasibility. Additional information on scores and ranking of proposed strategies can be found in Appendix 1.

Strategy	Effectiveness	Impact	Feasibility	Category
Develop BMPs (or test the effectiveness of existing one) and promote these in forestry management	Effective	High	High	BMPs
Create or support existing cooperative systems for small woodlot owner certification	Needs more information	Medium	High	BMPs
Develop tools and approaches for leveraging existing legal instruments for habitat protection	Needs more information	Medium	Medium	Adaptive management & legal tools
Integrate other species into this Canada Warbler action plan (and Canada Warbler into other place-based plans)	Needs more information	High	Medium	Adaptive management & legal tools
Conduct targeted communications and outreach in support of Canada Warbler conservation (especially when such conservation measures are controversial)	Needs more information	Medium	High	Communications and outreach
Conduct social marketing campaigns to educate the general public and policy makers	Needs more information	Medium	High	Communications and outreach

Conduct outreach and compliance promotion for the inclusion of Canada Warbler conservation in other land conversion initiatives	Needs more information	Medium	High	Communications and outreach
Enhance existing monitoring and mapping protocols	Needs more information	Medium	V. High	Research & Monitoring
Conduct research and monitoring to fill information needs on Canada Warbler conservation	Not specified	Not specified	Not specified	Research & Monitoring

BEST MANAGEMENT PRACTICES (BMPs)

The only strategy that was deemed effective on the breeding grounds was to “*Develop BMPs (or test the effectiveness of existing ones) and promote these in forestry management*”. Discussion highlighted both development and testing of context-specific BMPs, as well as the importance of promoting and refining existing BMPs (for example, *cf. Westwood et al. 2017*). BMPs seem particularly appropriate to mitigate the threats associated with habitat modification from forestry, but could also benefit conservation in regards to other threats such as mortality from collisions (e.g., municipal standards for new buildings).

In some cases, BMPs or guidelines already exist in relation to other species that utilize a similar habitat to the Canada Warbler {e.g., Golden-winged Warbler (*Vermivora chrysoptera*), at least in some parts of its range} and there are opportunities for a multi-species approach. Although work is already underway by the Boreal Avian Modelling Project (2021) to identify population management units, strategies to address the concerns associated with forestry operations would doubtless benefit from targeted research on key questions such as assessing range-wide differences in Canada Warbler habitat selection and reproductive success in different ecoregions. **This is especially important as the Canada Warbler has been shown to have differential habitat selection (Crosby et al. 2019).** Of course, the development of BMPs is only a first step and must be accompanied by opportunities for implementation, including the training of foresters and the establishment of links to certification standards. There should also be opportunities for BMP implementation on both private and public lands and the necessary supports in place; for example, cooperative systems for woodlot owners. The American Tree Farm System (<https://www.treefarmssystem.org/>) in the U.S.A. could perhaps provide a model for other areas. Woodlot associations exist in Canada but the participants felt that these lacked resources and capacity to lead in the development of such a system. Monitoring and adaptive management to ensure efficacy are also essential.

ADAPTIVE MANAGEMENT AND LEGAL INSTRUMENTS

Strategies (Figure 6, Table 4) discussed and grouped under this heading fell under the category of “needs more information” (in order to be effective). These include strategies to:

- Integrate other species into the Canada Warbler action plan (and Canada Warbler into other place-based plans). This may also include strategies such as:
 - Climate-change scenarios in protected-area plans & management plans
- Develop tools and approaches for leveraging existing legal instruments for habitat protection. This could include:
 - Adaptive management and legal instruments that protect habitat for the Canada Warbler and other biodiversity, including improved legal instruments to redress land conversion
 - Improved legal instruments to regulate air-born pollutants
 - Improved legal instruments to reduce anthropogenic causes of bird mortality

In addition to the above, adaptive management may also be especially applicable in addressing threats to the species and its habitat stemming from climate change, habitat loss, and prey availability. There are still immediate research needs in these areas that could inform management, as applied in an adaptive management framework. Likewise, an adaptive management approach could assist with the management of problematic native species, allowing

for incorporation of new information as different approaches are tested and monitored. The deer management strategy in place for Canadian National Parks has been identified as a successful adaptive-management model that could be followed by others. This model includes the need to identify problems, design appropriate solutions, and gain public acceptance for the need to maintain or restore the ecological integrity. In some cases, lethal means of control (by park staff and public hunting) are considered to be the best option for effective management (Nugent *et al.* 2011).

Adaptive management must of course be accompanied by effective legal measures that address the issue of habitat loss through land conversion. Over and above a protected-area strategy, this can include management options in working landscapes (management that is favorable to biodiversity including the Canada Warbler). This can be accompanied by compliance promotion mechanisms including tax reduction incentives or payment for ecological goods and services that should result in favorable outcomes for wildlife conservation.

COMMUNICATIONS AND OUTREACH

Strategies (Figure 6, Table 4) discussed and grouped under this heading fell under the category of “needs more information” (in order to be effective). These include:

- Conduct targeted communications and outreach in support of Canada Warbler conservation (especially when such conservation measures are controversial)
 - Link Canada Warbler conservation issues to other “high priority” species
 - Non-regulatory strategies to reduce anthropogenic causes of bird mortality
- Conduct social marketing campaigns to educate the general public and policy makers
 - Changing individual behaviors to mitigate mortality
- Conduct outreach and compliance promotion for the inclusion of Canada Warbler conservation in other land conversion initiatives

Communications and outreach actions associated with this plan encompass both general and specific recommendations. There are opportunities throughout the hemisphere for education on the plight of the Canada Warbler and other Neotropical migrants and the many threats they face. Such outreach can and should also place an emphasis on the problem of the broader impacts of climate change, both to human well-being and to biodiversity. Outreach around controversial and polarizing issues such as mortality from predation by domestic cats, as well as other “inconvenient” problems, such as building collisions, require many decades of work in the public sphere to be effective, both in terms of public support and in terms of overcoming inertia to bring about policy change. Linkages such as reduction in energy consumption with turning off lights to prevent collisions must also be found and promoted. Certification and consumer support as a trusted mechanism sustaining BMP implementation (sustainable forestry, shade-grown coffee, etc.) also requires communications and marketing.

RESEARCH AND MONITORING

Strategies (Figure 6, Table 4) discussed and grouped under this heading fell under the category of “needs more information” (in order to be effective) or “not specified”. These include:

- Enhance existing monitoring and mapping protocols

- Conduct research and monitoring to fill information needs on Canada Warbler conservation
 - Include climate change scenarios in Canada Warbler habitat modeling, protected areas planning and management plans

The Canada Warbler is reasonably well surveyed on the breeding grounds by the BBS and other initiatives; however, there remains uncertainty regarding the population level and current trend (see “Population Decline” above). Better monitoring data (e.g. better BBS coverage in under-surveyed parts of the range) would inform evaluation of the success of CWICI and this plan. There was discussion regarding the need for targeted surveying, especially on the wintering grounds (or at least the inclusion of this species in other monitoring programs), combined with research into other aspects such as migratory connectivity, to better inform conservation activities. A funding mechanism for this has yet to be identified. A rapid assessment tool for breeding performance on the nesting grounds is currently in development (Burns and Reitsma 2021).

RESEARCH NEEDS AND HOW THEY RELATE TO THE STRATEGIES

In addition to the strategies identified, the stakeholders identified key knowledge gaps and research questions that could better inform the strategies. These are discussed under nine subheadings below.

Climate Change

Long-distance migrants have to respond to local conditions when they arrive on the breeding grounds. It is unclear how climate change will affect the conditions they face during migration and what challenges this will present for productivity. Some areas of the range of the Canada Warbler may experience considerable drying (Stralberg *et al.* 2015; González-Prieto 2018) and this has been shown to impact the warblers on their wintering grounds (González-Prieto 2020). A knowledge gap remains on how to incorporate this information into habitat suitability models and in our understanding of Canada Warbler fecundity under changing climate scenarios. Improved understanding of the influence of climate change could perhaps inform the identification of high priority areas for conservation and management.

Specific recommendations related to climate change and the current knowledge gap include:

- Develop habitat suitability models that take into account the impact of drying / drought on Canada Warbler habitat,
- Identify high priority areas for conservation and management based upon predictive climatic models,
- Examine underlying environmental and ecological factors determining Canada Warbler breeding distribution and how it may be altered by climate change, including, establishing long-term monitoring sites to enable songbird capacity to respond to changing local conditions when they arrive on the breeding grounds,
- Examine changes in insect emergence as it relates to food availability for the Canada Warbler and other species,
- Develop and implement a communications strategy on climate change as a threat to birds and biodiversity and the need for the global community to decrease greenhouse gas emissions.

Forestry Management

We still lack a good understanding of the impact of habitat fragmentation on the Canada Warbler in different parts of its range and how different habitat mosaics created by urban expansion, different forms of agriculture, roads, rights-of-way and other linear developments, and other factors may influence forest species. Research on these impacts at multiple spatial scales, including factors such as dispersal, territoriality, conspecific attraction and potential ecological traps in different habitats (under the influence of the surrounding matrix) is required. Research findings of these topics must ultimately be tested and adopted in broad-scale forestry and agricultural planning.

Range-wide differences in Canada Warbler habitat selection (Reitsma *et al.* 2020) must influence recommendations for forestry. Nonetheless, habitat selection and differential reproductive success in different forest stand types or treatment types across the Canada Warbler range are poorly understood. We still do not understand to what degree forestry practices are impacting Canada Warbler populations overall. Some practices may be beneficial and others harmful (Hallworth *et al.* 2008a) and evaluation of such practices may differ at different temporal scales.

Specific recommendations related to forestry and the current knowledge gap include:

- Define and identify essential Canada Warbler habitat and document changes over time (see subsequent studies, for example, Céspedes and Bayly 2018 and González-Prieto *et al.* 2020),
- Apply appropriate measures to preserve/restore Canada Warbler breeding habitat,
- Document, assess, and determine the efficacy of existing BMPs in forestry and agriculture,
- Document all forestry and agricultural practices as they relate to creating or conserving Canada Warbler habitat on the breeding grounds (in all regions),
- Document all forestry and agricultural practices as they relate to the temporary and permanent loss of Canada Warbler habitat on the breeding grounds (in all regions),
- Determine the impact of previously unassessed forestry practices on Canada Warbler breeding habitat across the range,
- Manage Canada Warbler populations based upon responses to local/regional forest management,
- Summarize available information on habitat selection and reproductive success across stand types,
- Determine the impact of habitat loss and fragmentation on Canada Warbler breeding success and their threshold habitat needs at key sites throughout the breeding range.

Land Conversion

The extent to which industrial development and land conversion impact the Canada Warbler (over and above direct habitat loss) and its food supply on the breeding grounds is largely unknown. A first step would be to quantify the effects to try to determine if there are population-level impacts. This could include changes to settlement patterns, reproductive success, return rates, ability to communicate with conspecifics (e.g. in noisy environments) and conspecific attraction. It will doubtless be challenging to document the full impact of land conversion and associated issues such as the use of chemicals and impacts on food supply in the neighbouring habitat mosaic.

The impact of cattle grazing is largely unknown, although it likely reduces shrub cover at woodland edges, which would be detrimental to nesting and foraging activities. Additional research on the impact of ungulate grazing is also required to better inform management.

Specific recommendations related to land conversion and the current knowledge gap include:

- Determine the impact of oil and gas activities on Canada Warbler breeding habitat and behavior across the range,
- Determine the impact of mining and quarrying activities on Canada Warbler breeding habitat and behavior across the range,
- Determine the impact of agricultural land conversion practices, including cattle grazing, on Canada Warbler breeding habitat and behavior across the range.

Problematic Native Species

At least one study in Massachusetts showed a negative association between Canada Warbler abundance and White-tailed Deer abundance, where shrub layer was reduced by heavy browsing (DeGraaf *et al.* 1991). Nonetheless, it is not clear how much of a problem this poses for the Canada Warbler elsewhere and some participants expressed doubt that it presented a threat, except under exceptional circumstances. Reflecting this uncertainty, this threat was rated medium over the entire breeding range but high in some regions.

Food Availability

Determining prey availability (or changes in prey availability) in different ecosystems and habitats still presents a major challenge, as does deciphering what, if any, effect this is having on the Canada Warbler. Research on the causes of insect declines are urgently needed to inform broader conservation measures. Ongoing research associated with declining populations of insectivorous bird species (particularly aerial insectivores) should also benefit conservation initiatives for the Canada Warbler. Linkages with climate change also require investigation.

The specific recommendation related to food availability and the current knowledge gap is:

- Examine potential causes (for example, use of pesticides) for reductions in insect abundance and how this impacts the Canada Warbler.

Mortality and Reduced Productivity

Recent estimates of the total numbers of birds killed annually by domestic cats in the U.S.A. and Canada, as well as other causes of direct mortality such as building collisions (e.g., Calvert *et al.* 2013; Loss *et al.* 2015b), have shed light on the threats posed to migratory birds. Nonetheless, we still lack a good understanding of how different species are impacted and it is difficult to quantify the additional non-lethal effects of anthropogenic disturbance.

Specific recommendations related to mortality and productivity and the current knowledge gap include:

- Develop research projects to better understand anthropogenic sources of direct mortality and how they can be mitigated,
- Develop Best Management Practices addressing anthropogenic sources of direct mortality, and examine their efficacy following implementation in key areas,
- Determine if there are temporal and/or spatial hot spots for sources of mortality such as predation by domestic cats,

- Develop a communications plan regarding the impact of mortality from free-ranging cats and building collisions.

Additional research needs include information on the extent and causes of demographic variation in the Canada Warbler. For example, differential reproductive success in different forest stand types across the Canada Warbler range are poorly understood. Although there is near consensus among experts that population declines may be due to extensive habitat loss on the wintering grounds, this probably combines with other factors during nesting and migration. Additional research is needed to improve our understanding of habitat selection, demographics and connectivity of Canada Warbler populations to further focus conservation efforts. Some key areas are discussed below.

Habitat Selection

We have an imperfect understanding of what constitutes high-quality habitat for the Canada Warbler and how quality varies across the range. Evaluation of reproductive success in different habitat types and/or harvest treatments at multiple spatial scales would be greatly informative. Moisture regime appears to be an important consideration, influencing the development of the shrub layer, but we do not fully understand why sites near water are selected in some areas, or what trade-offs might exist between variables such as understory structure versus moisture. One hypothesis is that food supply is more reliable at sites near water.

Research on how conservation efforts for the Canada Warbler might affect other birds, and how current efforts for other species may benefit the Canada Warbler would also be informative.

Specific recommendations related to habitat selection and the current knowledge gap include:

- Synthesize all available research on factors that are driving population growth/decline throughout the annual cycle in order to identify ultimate drivers of population growth/decline,
- Develop a communications strategy addressing the need for Canada Warbler (and associated species) conservation on the breeding grounds.

Demographics, Trends and Population Size

Some parts of the Canada Warbler's range are remote and we lack certainty in our population size and trend estimates due to issues of coverage. Current efforts to improve coverage in the central and northern boreal forest, including using autonomous recording units (ARUs), will improve these estimates in due course. Investigation into questions such as roadside bias and coverage bias, as to how these influence trend estimates for species such as Canada Warbler, would also be beneficial.

We also have little demographic data for the Canada Warbler and it is difficult to assess limiting factors. In addition to research on the breeding grounds, studies to estimate over-wintering survival and density-dependence are required to allow for annual-life cycle demographic modelling. We have preliminary analyses from field studies and the Monitoring Avian Productivity and Survivorship (MAPS) and Monitoring Overwinter Survival (MOSI) programs; however, additional resources are needed to expand coverage. The rapid assessment tool for breeding performance on the nesting grounds could greatly improve our understanding (Burns and Reitsma 2021). These data will also allow us to generate estimates of habitat specific survival and reproductive rates and to identify areas of highest productivity. Because Canada Warbler habitat

can be dynamic, as succession progresses some areas could become population sources and others sinks; simply relying on abundance data (count data) may not allow us to properly assess these shifts. Finally, effective management requires an understanding of basic demographic parameters across populations; without these data it is difficult to assess the effectiveness of conservation actions.

Specific recommendations related to climate change and the current knowledge gap include:

- Develop and carry out one demographic research study per region to assess timing of breeding, age classes, survivorship, patch-size, clustering, and relative source-sink dynamics,
- Identify limiting factors at the proximate level by constructing demographic models (matrix model, integrated population model, Population Viability Analyses) using MAPS, MOSI and existing data from field studies and generate estimates of habitat specific survival, productivity and abundance.

Migratory Connectivity

To be able to link Canada Warbler population declines to specific threats we need to establish connectivity between breeding and wintering populations. Connectivity maps generated using stable-isotope or geolocator data are a first step in understanding this connection (at least for adult males on which geolocators are typically deployed). As technology advances, direct tracking may become possible for the Canada Warbler, building a more complete picture. This work may lead to the identification of key stopover sites and wintering areas, permitting targeted conservation.

Specific recommendations regarding migratory connectivity and current knowledge gaps include:

- Carry out research to identify migration routes, key stopover sites as well as core wintering areas (using methods such as nanotags, geolocators, stable isotope analyses and point counts on the wintering grounds). These activities should be aligned with work carried out on the wintering grounds.
- Develop a communications plan connecting breeding and non-breeding populations.

These recommendations have already generated significant progress in recent years.

STRATEGY: NON-BREEDING GROUNDS

Strategies identified through the participatory workshop to develop the conceptual model for the non-breeding grounds (Table 5, Figure 7) could be grouped into the same basic four groupings as per the breeding-grounds exercise, although many strategies exhibit cross-over between these categories, with the addition of strategies related to achieving “sustainable economic alternatives”, viz.:

- Best Management Practices (BMPs)
- Adaptive management and the development of legal instruments
- Communications and outreach
- Research and monitoring
- Sustainable economic alternatives

Five strategies were rated as effective through the combination of their impact and feasibility scores and one as “needs more information” (three strategies were not scored).

Table 5. Strategies to address threats to the Canada Warbler on its non-breeding grounds with an assessment of the potential impact and feasibility of each strategy. Effectiveness ranking from effective (green) to less effective represents a roll-up of the scores for impact and feasibility.

Strategy	Effectiveness	Impact	Feasibility	Category
Foster the improvement of local legislation for the conservation of the Canada Warbler	Effective	V. High	High	Adaptive management & legal instruments
Recover habitat through landscape management tools	Effective	V. High	High	Adaptive management & legal instruments
Foster lobbying to achieve engagement in planning processes	Effective	V. High	High	Communications
Promote a citizen science program for the Canada Warbler	Effective	High	High	Research & monitoring
Generate a sustainability-oriented market	Effective	High	High	Sustainable economic alternatives
Foster best management practices & production techniques	Needs more information	High	Medium	BMPs
Promote a program of incentives for the conservation of the Canada Warbler and its habitats	Not specified			Sustainable economic alternatives
Implement a communications strategy	Not specified			Communication & outreach
Generate an environmental education and awareness-raising program	Not specified			Communication & outreach

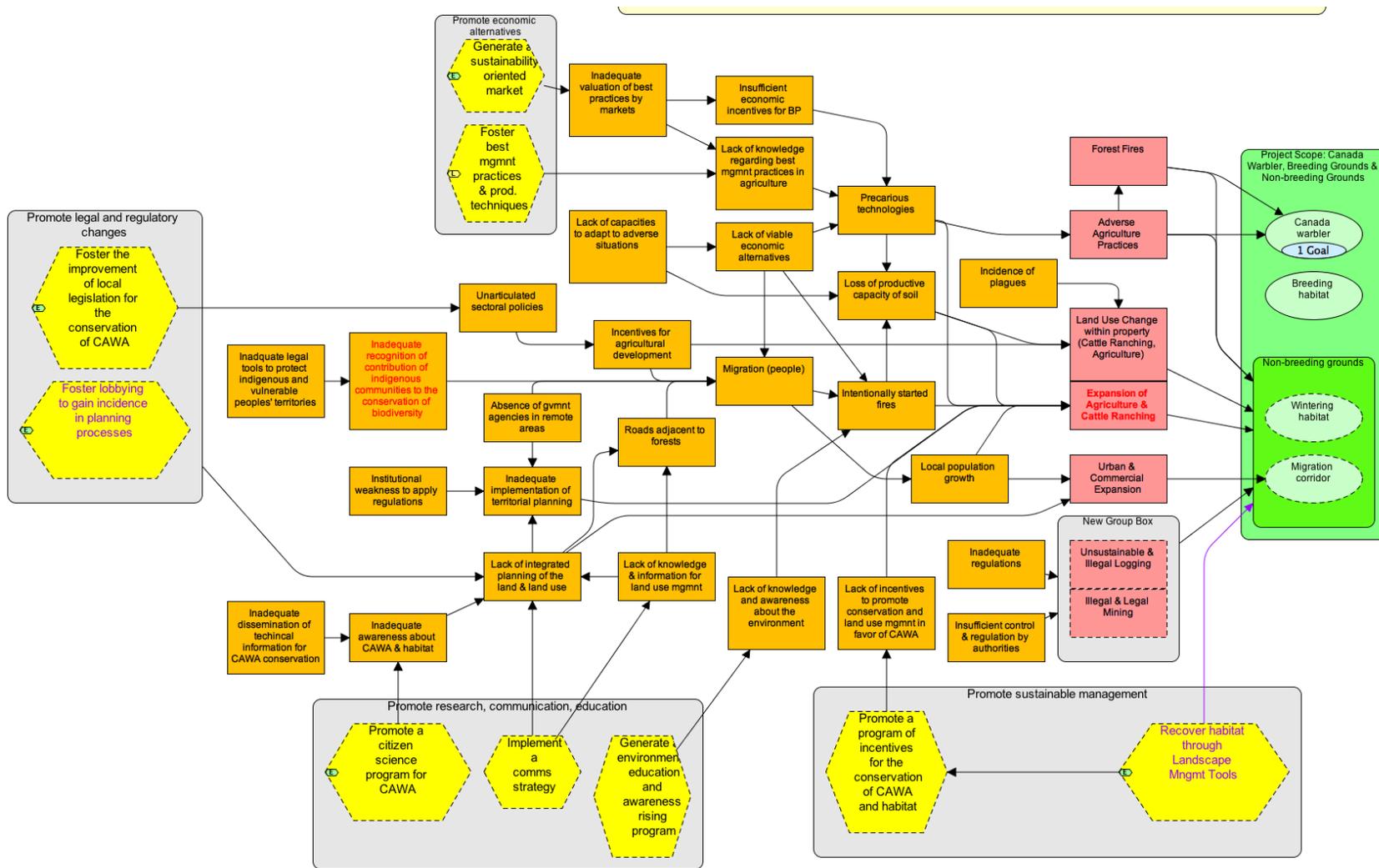


Figure 7. Conceptual model depicting the project scope and targets (green rectangle and green ovals), direct threats and research needs (pink rectangles), contributing factors (orange rectangles) and proposed strategies (yellow hexagons) on the non-breeding grounds.

BEST MANAGEMENT PRACTICES (BMPs)

One strategy identified for the non-breeding grounds, to “foster best management practices and production techniques” aligns well with the only strategy scored as effective on the breeding grounds, viz. to “develop BMPs (or test the effectiveness of existing one) and promote these in forestry management”. Nonetheless, the use of best management practices in the non-breeding grounds was scored as “needs more information” and discussions were more centered on BMPs in the context of food production in forested landscapes (such as shade-grown coffee) than on forestry *per se*. Though there has been much recent research, as discussed above, informing the use of shade-grown coffee for conservation purposes, knowledge gaps still exist that hamper context-specific BMP development. Participatory workshops and knowledge exchanges with regard to biodiversity and local food production and markets, could lead to better land management in the long term.

ADAPTIVE MANAGEMENT AND LEGAL INSTRUMENTS

Two strategies, scored as effective with very high impact, were identified, to:

- Foster the improvement of local legislation for the conservation of the Canada Warbler and
- Recover habitat through landscape management tools.

Adaptive management was covered in greater detail in the breeding grounds workshop than in the non-breeding-grounds discussions. Nonetheless, these strategies suggest that local legal tools and an adaptive management framework could realistically benefit conservation on the wintering grounds and along the migratory pathway.

In terms of influencing local/regional decision-making, conservation groups and even environmental agencies within government often lack the political wherewithal to influence sectors such as agriculture, forestry, mining and other industries. Advocating for ecosystem approaches under such conditions is difficult. In many cases, habitat loss has been exacerbated by the disconnect between environmental and agricultural policy; for example, government programs that in effect undo each other, such as agricultural incentives or tax benefits for settlement and habitat destruction versus incentives for habitat retention for conservation. Urban and commercial expansion also causes habitat loss and seldom occurs with biodiversity considerations factored into development plans. Unregulated activities such as illegal logging and mining further complicate the challenge of ecosystem preservation.

Building the capacity of local institutions and actors to implement this plan is therefore one of the most important factors in its success. Numerous methods to strengthen capacity include: building networks and multi-country alliances, improving local fundraising capacity, engaging technical staff in conservation activities, building relationships, and developing strategies to influence policy. The use of technical information in decision-making can empower local and national governments and allow for informed decision-making processes.

Actions:

- Building capacity for local partners to conserve ecosystems,

- Lobbying for the inclusion of conservation and environmental objectives in other sectoral policy (this could also include advocating for alternatives to current multi-national economic agreements that incentivize conversion of natural habitat to agricultural monoculture),
- Establishment of conservation agreements with landowners to implement management activities that contribute to the species' conservation,
- Implementing a program to build local capacity for fundraising,
- Developing a multinational initiative for the implementation of this plan.

COMMUNICATIONS AND OUTREACH

At least three of the strategies identified were focused on communications and outreach, viz. to:

- Foster lobbying to achieve engagement in planning processes,
- Implement a communications strategy, and
- Generate an environmental education and awareness-raising program.

Only the first of these strategies was scored as effective. The other two were not specified during the workshops. The key audience for such communications therefore must be governments and decision makers at local and regional levels. Current knowledge of the Canada Warbler's habitat use and distribution in countries where it overwinters or occurs as a passage migrant has the potential to support decision-making regarding agricultural, exurban, and commercial development. This of course depends on that knowledge being made available to planners, managers and decision-makers. For this reason, promoting environmental education, awareness and citizen-science programs were considered effective strategies to achieve the conservation of the species, at least when such knowledge was appropriately disseminated. Communication actions must of course align with the strategic directions discussed above.

Actions

- Promote meaningful dissemination and use of specific data products,
- Promote the inclusion of the agricultural and livestock-production sectors in citizen-science and education and awareness activities,
- Disseminate the action plan and species information among partners, stakeholders and beyond,
- Promoting the development of legal frameworks to support this plan,
- Strengthening communication channels between different stakeholders that contribute to the development of legal frameworks for the protection of migratory birds and biodiversity,
- Providing relevant information to governments to help them achieve international agreements,
- Encouraging countries that are party to the Convention of Migratory Species (CMS) to frame their activities under the CMS Americas Flyways Framework where appropriate.

RESEARCH AND MONITORING

A research and monitoring strategy to "promote a citizen science program for the Canada Warbler" was called for on the non-breeding grounds and scored as effective by the participants.

Citizen-science on the non-breeding grounds would complement existing efforts on the breeding grounds and could perhaps be used to address specific research gaps. Citizen-science programs should focus on improving local technical knowledge in a participatory manner and the effective application of citizen-science data in habitat planning and management situations.

More broadly, in order to verify the effectiveness of the conservation strategic approaches, it is necessary to promote a research program that helps fill knowledge gaps in terms of migration patterns and habitat use, response to habitat change, prey availability, response to changing climate scenarios, migratory connectivity, site fidelity, and the social structure of Canada Warbler populations.

There should be opportunities to incorporate active research into existing monitoring and to use bird-friendly operations (such as shade-grown coffee) for more in-depth research with an adaptive management feedback loop to improve operations. Research on populations within protected areas is also highly desirable. Ideally, such programs would be articulated in a publicly available, integrated information system. Sharing and high visibility of such research programs is likely to encourage further research.

Actions

- Promote the inclusion of the Canada Warbler within established citizen-science programs,
- Increase knowledge of the winter ecology of the Canada Warbler to help guide the species' conservation,
- Design and implement a monitoring program for the Canada Warbler during migration and wintering seasons,
- Promote the participation and use of a single database or data-management system to facilitate information exchange,
- Establish regional/trans-boundary agreements for research and conservation.

SUSTAINABLE ECONOMIC ALTERNATIVES

Two of the strategies identified spoke to generating sustainable economic alternatives through market mechanisms and incentives (state-sponsored), viz. to:

- Generate a sustainability-oriented market (scored as “effective”) and
- Promote a program of incentives for the conservation of the Canada Warbler and its habitats (not scored).

Sustainable production, as discussed in these workshops and applied by the participants, considers the application of agriculture and livestock practices and technologies, which:

- Promote the conservation of water, soil and air quality,
- Invest in the health of ecosystems,
- Protect biodiversity and ecosystems,
- Guarantee livelihoods.

Sustainable productive practices could reduce or mitigate some threats that the Canada Warbler faces during migration and on the wintering grounds. Many of these sites are currently subject to agricultural practices that degrade the natural habitat, including fires used for the preparation of

agricultural land. Frequent changes in land-use type occur due to losses of the productive capacity of the soil. This is exacerbated by insufficient knowledge of good production practices on the part of the producers, an insufficient assessment by the market of the agricultural products that come from sustainable practices and an increase in the local human population.

The impact of such threats, for the Canada Warbler and many other species, could be greatly reduced by:

- Promoting forest cover within food-production systems (agrosilvopastoral systems),
- Reducing chemical inputs,
- Good soil management,
- Efficient use of water,
- Generating markets for sustainable production.

Generating markets is a particularly important aspect to ensure the livelihood of local producers. Currently, agricultural edge is expanding and encroaching on forested areas. For local communities, having an economic incentive to retain such forests is as important as environmental incentives. Efforts to increase profit margins (both by lowering the costs of inputs and providing fair value for the produce) while retaining existing remnant forests (i.e. decreasing the rate of deforestation) will only work if producers see that they are making comparable or better profit. The long-term benefits of such an approach, such as maintaining the productive capacity of the soil, will also, ultimately, bear economic fruit.

Activities

- Assess the processing and certification systems currently available,
- Find mechanisms to promote participation in sustainable agricultural practices,
- Contribute to the creation of markets and support the identification of products, market research, certification, and distribution,
- Promote sustainable land use practices,
- Promote sustainable and efficient technologies.

RESEARCH NEEDS AND HOW THEY RELATE TO THE STRATEGIES

The Canada Warbler uses natural areas such as mature forests, as well as human-altered habitats such as shade-grown coffee plantations, canopied cacao plantations and other agrosilvopastoral systems. Nonetheless, studies have shown different extents of use of these habitats (*cf.* Colorado and Rodewald 2017; Céspedes and Bayly 2018) and there is concern that agrosilvopastoral lands may be suboptimal habitats that lead to relatively poor body condition over winter, perhaps due to decreased food availability (Colorado and Rodewald 2017; González-Prieto 2018). Before advocating for conservation solutions involving particular products or production methods, a better understanding of the benefits and disadvantages of such habitats to species such as the Canada Warbler is important.

In addition, more refined knowledge on habitat structure, as best suited to the Canada Warbler, in the wintering grounds; for example, the relative importance of epiphytes, canopy cover, tree composition, understory composition, would enlighten conservation efforts tied to lands in food production. Research on the best ways to reduce chemical inputs and other inputs while achieving quality yield is needed, both for the benefit of biodiversity but also to reduce costs to local

producers, given that such research can guide BMPs. This could also include research on low-toxicity inputs that may or may not offer a biodiversity-friendly compromise.

Some protected areas encompass natural habitat used by the Canada Warbler. This may offer reference habitat types against which to compare and evaluate agrosilvopastoral systems. Nonetheless, we do not understand the current significance of the protected areas network for the conservation of this species, nor what percentage of birds rely on protected areas and if this confers any advantage. Research on migratory connectivity may also inform conservation efforts by linking regions and habitats in the non-breeding grounds with populations (or management units) in the breeding grounds with a particular trend. The key research question on the wintering grounds and stopover sites is understanding where and how the birds can obtain the necessary resources for good physical condition that will translate into high survivorship and benefit productivity on the nesting grounds.

Overall, some of the key recommendations pertaining to research questions identified for the non-breeding grounds are:

- Improve knowledge of the species' distribution in passage and at wintering sites, as well as the phenology of migration through Central America,
- Determine the extent of migratory connectivity between different breeding, passage and wintering sites,
- Improve knowledge of the effects of habitat reduction and climate change on passage and wintering sites, and whether such factors are having population-level effects,
- Evaluate other climate change effects such as drought, extreme storms, etc.,
- Address information gaps to support the establishment of new protected areas that benefit the Canada Warbler and other migratory species,
- Study the social structure of populations on the wintering grounds and the interaction of the birds' sex and age-class with habitat types used,
- Improve knowledge of variation in the birds' physical conditions during the pre-migration period in different natural and human-altered habitats.

WHAT SUCCESS LOOKS LIKE

The culminating activity for the workshops and the full life-cycle plan is of course to plan for success. In order to better formulate the question of what success could look like and how the partners could translate the plan into a positive population-level effect for the Canada Warbler, we developed results chains using the Miradi software that illustrate a path to a positive impact for populations of the Canada Warbler as a conceptual model. The intention was to develop results chains for each of the strategies identified; however, resources and time permitted only two: Outreach and Communications (Figure 8) and the development of Best Management Practices and incentives on the non-breeding grounds (Figure 9).

Estrategia de Comunicación y divulgación de información técnica sobre la especie y su hábitat
Communication & Dissemination Strategy of Technical Information on the Species and its Habitat

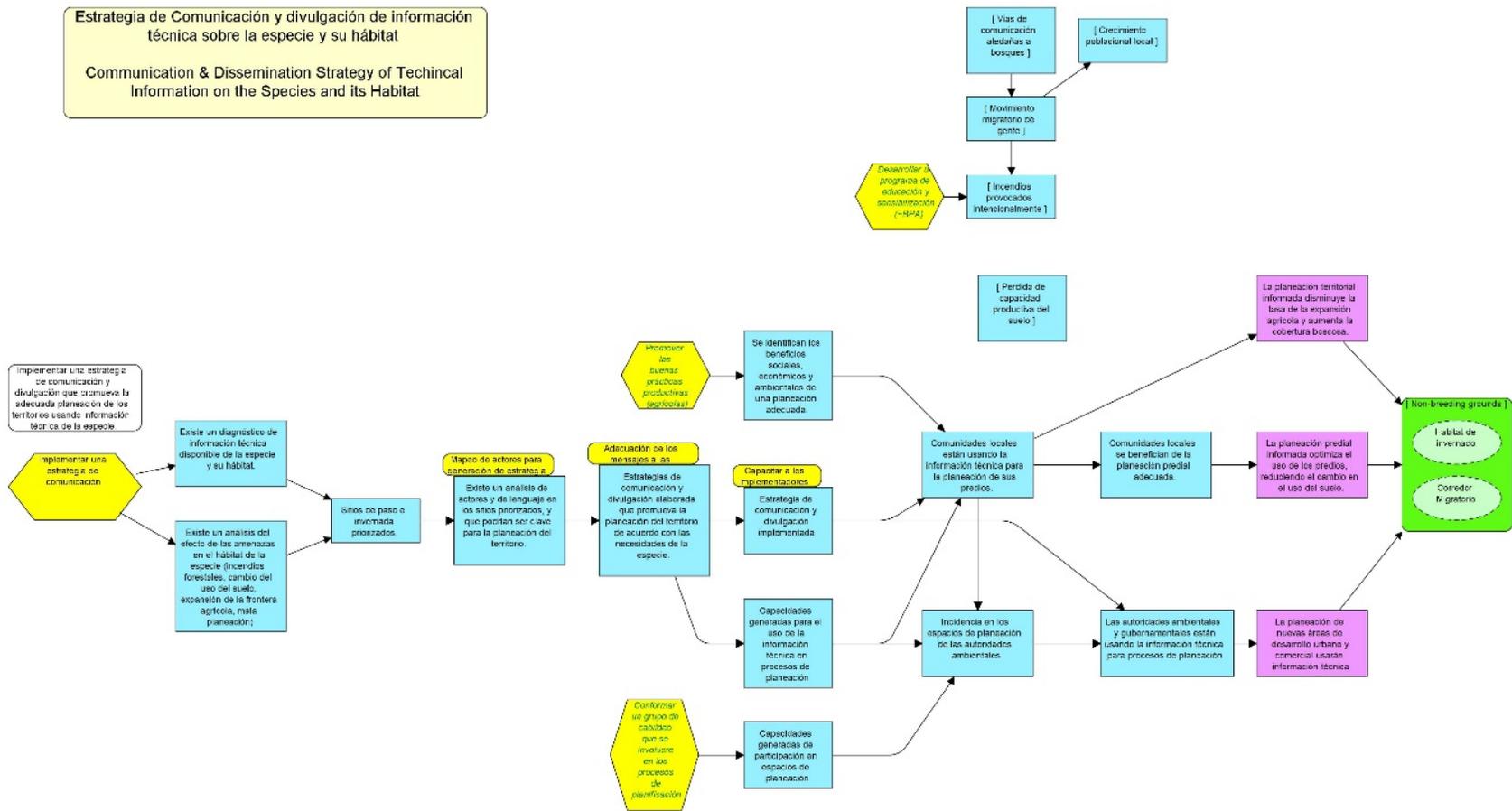


Figure 8. Conceptual model depicting the results chain for outreach and communications showing the relationship between proposed strategies (yellow hexagons) and results (blue rectangles) leading to specific objectives (purple rectangles) and the broad objective (green) for the Canada Warbler.

Estrategias de promoción de las buenas prácticas agrícolas y de los incentivos a la conservación de la Reineta de Canadá y su hábitat en las áreas de invernado y el corredor migratorio

Strategies to promote best agricultural practices and incentives for conservation of CAWA and its habitat within the NB areas

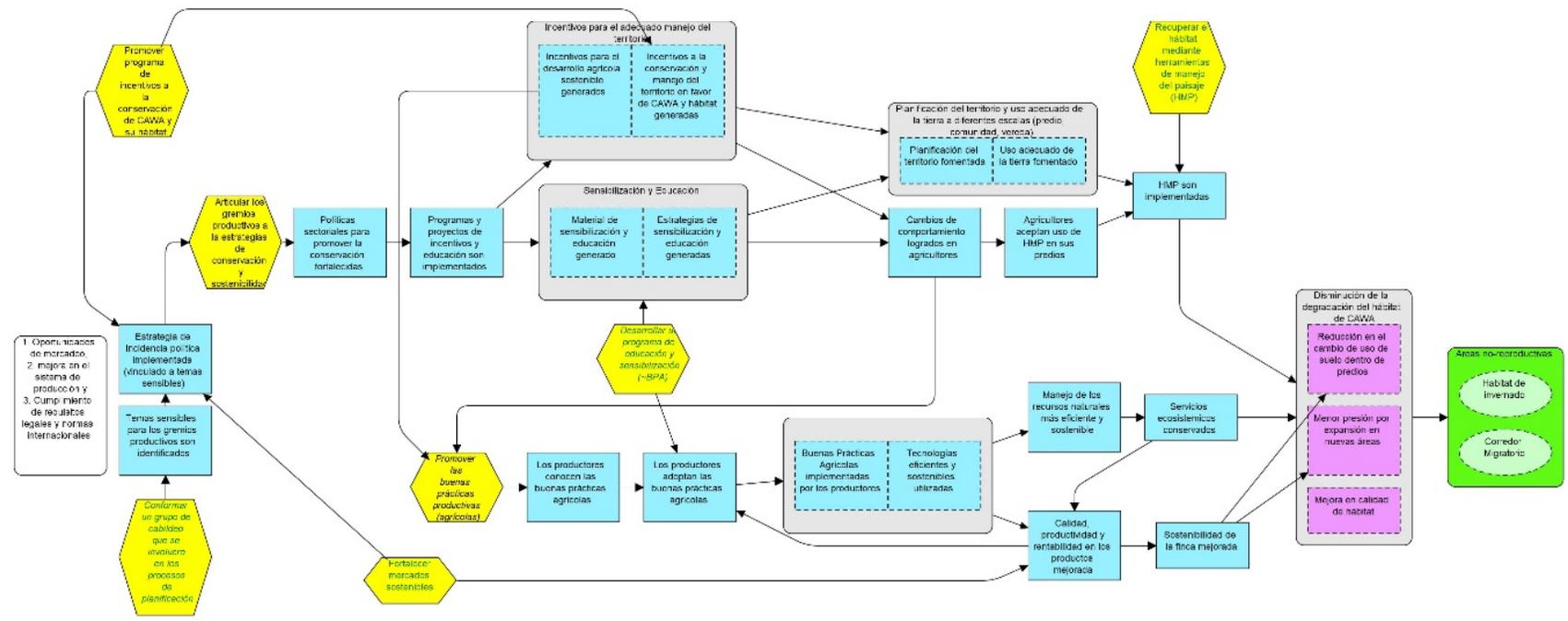


Figure 9. Conceptual model depicting the results chain for Best Management Practices and incentives on the non-breeding grounds showing the relationship between proposed strategies (yellow hexagons) and results (blue rectangle) leading to specific objectives (purple rectangles) and the broad objective (green) for the Canada Warbler.

The Outreach and Communications results chain (Figure 8) hinges on three specific objectives to achieve the vision of *healthy and viable populations of Canada Warblers across the current range and extent of occurrence*:

- Informed landscape planning reduces the scale of agricultural expansion and increases forest cover,
- Informed land-use planning optimizes the way land is used and reduces land-use change,
- Planning for new urban and commercial development uses pertinent technical information.

In order to achieve these, the strategies identified in this document must work towards (and be measured against) the specific outcomes (blue rectangles in Figure 8). These changes will nonetheless be incremental and certainly long-term. The linkage of achievements to the species population goal—*stop the decline of Canada Warblers by 2025, (losing no more than 10% over this time), have an increasing trend by 2035 and maintain the extent of occurrence with minimal loss of distribution*— is not direct. Nonetheless, these targets could be expressed in a manner to foster linkage and collaboration, as well as the positive “energy” obtained from reaching incremental milestones; for example, if 10% of the habitat that would have been converted in a given geography (based on current rates of conversion or predictive models) was retained before 2025 due to conservation efforts such as promoting meaningful land-use planning with biodiversity and ecosystem function considerations. As so much of this work is dependent upon opening meaningful lines of communication to reach and impact policy and decision makers, it is appropriate that these goals are expressed in the outreach and communications results chain.

The results chain for Best Management Practices (BMPs) and incentives on the non-breeding grounds (Figure 9) hinges on achieving a meaningful reduction in habitat degradation, specifically by:

- A reduction in (detrimental) land-use change,
- Reduced conversion pressure from anthropogenic expansion into new areas,
- Improved habitat quality.

The stakeholders gathered for these workshops recognized that the cost of any incentive program to compete with current (and ever-changing) market forces to achieve these targets in the short-term would be beyond the means of any conservation NGO in these countries. These objectives must forcibly too, therefore, be introduced incrementally and be supported by positive outreach and communications such that the benefits are understood by local communities and tested for efficacy (trust earned). All of the four (breeding grounds) and six (non-breeding grounds) strategies identified can be used in concert in striving for these goals.

CONCLUSIONS AND RECOMMENDATIONS

By way of conclusion, the following general considerations and recommendations were highlighted by the partners:

- **Habitat loss:** The combined knowledge exchange achieved through the process of gathering stakeholders and producing this plan points to impacts on Canada Warbler habitat as a driver of declines. Therefore, this action plan is focused not only on maintaining and recovering the

populations of Canada Warbler, but also the habitats used during the breeding, migration and wintering seasons.

- **Range-wide impacts:** Many of the threats identified affect the Canada Warbler throughout its range; for example, deforestation from sources such as mining, energy production, agriculture, urban and commercial expansion and others. There can and should therefore be opportunities for international collaboration pertaining to broad threats to migratory birds.
- **Regional impacts:** Some threats specific to the breeding grounds were also identified such as pre-commercial thinning in forestry operations. This is among the threats that pertain to degradation of habitat rather than habitat loss, which also includes some agricultural practices, the use of pesticides and herbicides and deliberately set fires, some of which are more significant on the non-breeding grounds and which will also require regionally specific strategies.
- **General strategies:** Despite the differences between the threats identified in the breeding and non-breeding grounds, the proposed strategies to address these threats (four for the breeding grounds and six for the non-breeding grounds) are similar (three strategies are shared). Four broad strategies follow from this work: adaptive management and legal instruments, Best Management Practices (BMPs), research and monitoring, and outreach and communications. Sustainable economic alternatives and habitat management fit well with the theme of BMPs and partnership building (empowering people to act across the species' range) is an essential component of the outreach and communication plan. Admittedly, some strategies may require greater priority in different countries / regions depending on the political and cultural landscape.
- **Role of CWICI:** The formation of an international initiative has facilitated the many excellent contributions and feedback on this action plan and enabled collaboration across eleven countries. Indeed, many of the most recent publications cited in this plan were inspired or supported by CWICI. If the implementation of this plan is to be successful, it will likewise require the participation and commitment of this same network of partners, linked under this initiative, and an iterative process to refine and measure the strategies enacted. We look forward to further collaboration and support in this objective.

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