Prairie Creek Mine All-Season Road: Birds Baseline



PRESENTED TO

Canadian Zinc Corporation

SEPTEMBER 29, 2021
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Tetra Tech Canada Inc.
Box 2244, 201, 4916 - 49 Street
Yellowknife, NT X1A 2P7 CANADA
Tel 867.920.2287 Fax 867.873.3324

Conformity Table – ECCC Comments*

Item	Requirement	Review Comment Reference	Section of Plan
1.	ECCC recommends that the Proponent provide the additional analysis of the 2017 migratory bird and avian species at risk baseline information prior to any vegetation clearing, in order to inform habitat loss and alteration effects. The analysis should follow ECCC's guidance. The Proponent should also conduct a power analysis using the baseline data in order to evaluate the efficacy of the current sampling design, and in order to inform the effects monitoring schedule.	#1	Sections 4.0, 5.0, 6.0 and 7.0
2.	ECCC recommends the Proponent compare Canada Warbler predicted densities estimates in the study area to the regional study area, and provide associated data model prediction uncertainty. This assessment should be consistent with ECCC guidance. ECCC recommends that the Proponent also provide a rationale for selecting a 10-km radius to compare Canada Warbler habitat availability in the region.	#2	Section 6.0
** Conformity Table per PropRespReq_12872 Wildlife*			

Conformity Table – Parks Canada Comments*

Item	Requirement	Review Comment Reference	Section of Plan
1.	*Analysis of bird habitat associations from ARU data:* For birds including species at risk, vegetation clearing for Phase 1 is a source of impacts. Analysis of habitat associations for all species from ARU is needed to determine if there are significant adverse effects that need to be mitigated with a route adjustment, for example. Although Table T3 states that the "2017 ARU survey provided data on bird species presence, abundance, and distribution (i.e., bird-habitat associations, where sufficient detections allow)", this analysis of baseline has not been provided and is not included in the WMMP. Please provide the results of the all-species analysis and any resulting project modifications and/or mitigations.	#36	Section 6.0 and 10.0
2.	*Canada Warbler Assessment, S2.4:* Please cite the R package used for QPAD analysis, as has been done for emmeans on page 4.	#48	Section 2.4
3.	*Canada Warbler Assessment, S2.4*: The sentence "Other variables were tested (e.g. latitude) but it was determined that sample size was not sufficient to include them" is unclear. Was latitude the only other variable included, or were other ecologically important variables such as elevation also tested? Were these variables correlated with one another (e.g. we might expect a correlation between Easting and elevation in this context); if so, how did you determine which variable to include? How did you determine that sample size was insufficient, and was this only the case for Canada Warbler, or for all bird species assessed (since the methods description appears generic)? Please further describe the variable selection methods used.	#49	Section 2.4
4.	*Canada Warbler Assessment, S2.4:* From a visual inspection of the data, it appears possible that there is an interaction between habitat and Easting. Was this potential interaction included in model 3, or simply the two dependent variables? Clarify whether model 3 included an interaction term	#50	Section 2.4
5.	*Canada Warbler Assessment, S2.4:* There is no description of how model assumptions were verified, to ensure that the sampling distributions tested were appropriate to the data. Please include a description of any model verifications performed.	#51	Section 2.4

Item	Requirement	Review Comment Reference	Section of Plan
6.	*Canada Warbler Assessment, S3.1:* The first sentence in this section differs from the results reported in the 2017 baseline report, which is itself inconsistent throughout: - Table 2 (p. 8) describes 11 individuals recorded at eight stations by human listening, with an additional two stations found by recognizer - Section 2.1.6 (p. 11) states "Canada Warbler were detected at 12.8% of the ARU survey stations (n=10; Table 2). Three stations recorded two individuals vocalizing and six survey stations recorded one individual (Table 2)." Please confirm the number of individual Canada Warblers recorded, and the number of stations.	#52	Sections 3.0 and 8.1.4
7.	*Canada Warbler Assessment, p. 8:* Provide justification for the statement that "The proposed ASR has no residual effect on Canada Warbler"; or amend to reflect the possibility of residual effects. Due to the possibility of a residual (adverse) effect, the Species At Risk Act requires monitoring of the effect.	#53	Section 9.0
** Conformity Table per Table 14 of Parks Canada “Comments on Management Plans and other Submissions under Water License PC2014L8-0006 and Land Use Permit PC2014F0013” dated December 14, 2020.*			

EXECUTIVE SUMMARY

Canadian Zinc Corporation (CZN) submitted a Developers Assessment Report to the Mackenzie Valley Review Board (MVRB) in 2015 for a proposed Prairie Creek Mine all-season road (the Project; EA1415-01; CZN 2015). Environment and Climate Change Canada (ECCC) and Parks Canada recommended that baseline migratory bird surveys, including bird species at risk, be conducted. Baseline wildlife surveys in 2017 included surveys of birds using autonomous recording units (ARUs) located along the proposed all-season road. The objectives of the surveys and of this report are to:

- Provide baseline data (species-specific density estimates and community-level metrics).
- Compare predicted bird species density in the area of the ASR to the region.
- Use power analyses to inform the design of future monitoring.
- Describe potential effects to Canada Warbler, which were not originally included in the DAR.

Results and analyses provided in support of the objectives include:

- A list of bird species detected at survey locations along the ASR generated using both human listening and automated recognition of ARU data.
- Bird species density estimated from count data using offsets. The analysis used the counts from the human-listening ARU data and was completed only for species that are reliably detected using auditory cues.
- A comparison of average density between the ASR footprint to the region to provide regional context to habitat losses as a result of the project.
- Estimation of bird species richness and diversity by habitat type, used to characterize the bird community as a whole.
- Simulation of power to detect change in species density and species richness over time and with varying number of survey locations.

Eighty ARUs were deployed along the 170 km proposed all-season road. Survey station locations were selected based on stratified random sampling of points from a systematic grid. The ARUs were programmed to record in 10-minute increments at the following times:

- Every hour starting one hour before sunset until one hour before sunrise (Yellow Rail and Common Nighthawk active period).
- Every hour starting one hour before sunrise until five hours after sunrise (forest birds active period).
- At noon and 3 p.m.

One ARU unit could not be re-located and recording data was therefore lost. A second unit malfunctioned, and no recordings were made.

Human listening was performed on recordings at all ARU survey stations. Three-minute long recordings were listened to at a minimum of three time intervals on three different days. Thus, a minimum of 27 audio minutes per survey station were processed for all diurnal species vocalizations. Human listening for nocturnal species was completed at survey stations where computer-automated recognizers identified potential Yellow Rail (*Coturnicops* *noveboracensis*) and Common Nighthawk (*Chordeiles minor*) vocalizations. Computer-automated species recognizers were also used to document the presence of bird species at risk at survey stations deployed within the species known range. Recognizer analyses were performed for Horned Grebe (*Podiceps auratus*), Yellow Rail, Red-necked Phalarope (*Phalaropus lobatus*), Common Nighthawk, Olive-sided Flycatcher (*Contopus cooperi*), Bank Swallow (*Riparia riparia*), Barn Swallow (*Hirundo rustica*), Canada Warbler (*Cardellina canadensis*), and Rusty Blackbird (*Euphagus carolinus*).

There were 87 bird species detected through human listening of the ARU recordings. Automated recognition detected species at additional stations where human listening had not. Five species listed under the Species at Risk Act were detected: Common Nighthawk, Bank Swallow, Olive-sided Flycatcher, Evening Grosbeak, and Canada Warbler.

To estimate bird density from the ARU count data, the QPAD approach was used (Solymos *et al.* 2013). The QPAD approach uses statistical offsets to correct for methodology and detectability differences across species and survey times and locations for species that typically sing. The offsets were then used in statistical models to estimate density from the original counts. Density by habitat was estimated for species that were detected in greater than 10 survey samples (38 species) using generalize linear mixed models (GLMM).

Species diversity was compared among habitats at two scales:

- Mean richness/diversity per survey, and
- Total richness/diversity across all surveys and stations.

Coniferous habitats had the highest richness followed by Open habitats (3.2 and 2.6 species detected per survey respectively). There was a strong geographic gradient with species richness highest in the eastern portions of the surveyed area and decreasing to the west. The total number of species detected during morning surveys (02:00 onward) and excluding waterbirds and diurnal birds of prey was 66. Analysis of total richness using rarefaction and extrapolation of species richness predicted that there were additional species present that were undetected, principally in Deciduous and Mixed habitats. The estimate of species richness when the extrapolated portion of the rarefaction curve reaches an asymptote is 70.9 (70.0 - 90.7: 95% confidence interval). Rarefaction curves for species richness were compared across habitats. More species were observed in Coniferous habitat (54, n = 36) than in Open habitats (49, n = 24) and many more than in Deciduous (38, n = 7) and Mixed (35, n = 11). Rarefaction and extrapolation indicates that Coniferous and Open habitats would have about the same number of species detections if there was equal sampling.

Species-specific density estimates were summarized to compare mean density within the project footprint (assumed to be 23 m in width), within 100 m of the road (representing the local area) and within 10 km of the road (representing the region). Most species have similar estimated mean densities within the footprint area and within the region. Canada Warbler, Fox Sparrow and Ovenbird have the largest apparent difference with estimated density higher in the footprint and the local area compared to the region (+29%, +15% and +11.5% respectively), though confidence in observed differences is low. In the absence of more precise estimates, a precautionary approach is followed for recommendations relating to potential project effects. For species where mean density is higher within the ASR footprint and adjacent areas relative to the region, the loss of habitat may be considered disproportionately higher relative to the region as a whole.

The ability to detect change over time in select bird community metrics and select species densities in future monitoring was evaluated using Monte Carlo simulation of power. The estimated number of survey stations required to achieve 80% power to detect -20% change varies widely by bird community and species metric. A -20% change in mean species richness, mean total abundance, Swainson's Thrush density (detected at 81% of stations) and Magnolia Warbler density (detected at 35% of stations) could be detected within 3-5 years with as few as 40 survey stations. Ovenbird was detected at close to the same number of stations (39%) as Magnolia Warbler though a -20% change would not be detected for up to eight years and with at least 60 survey stations. For selected species where it would take longer than ten monitoring years to detect a -20% effect size (Least Flycatcher, Olive-sided Flycatcher, and Canada Warbler), the power simulation was also conducted using -50% effect size and extended to 20 years. A -50% change in Least Flycatcher density (detected at 18% of stations) could be detected after seven monitoring years with 80 survey stations. A -50% change in Olive-sided Flycatcher and Canada Warbler densities (both detected at 14% of stations) are not predicted to be detected, even with 20 years of monitoring with up to 80 survey stations. These results are predictions and the true power to detect change would be known with additional data collection. The power analyses conducted here assumes the same sampling strategy would be used in future surveys as was used for the baseline. A different survey strategy that is focussed on species of management concern (i.e., listed species) or other non-listed indicator species may allow for detection of change in shorter time periods and with greater power. Future monitoring is described in the Wildlife Management and Monitoring Plan.

Potential effects to Canada Warbler that were considered included habitat loss and fragmentation, change to habitat effectiveness, change to abundance and occurrence, effects on local movement, risk of project-related mortality, effects to population cycles, predator-prey relationships, parasite relationships, and ability to recover. Canada Warbler density was found to be highest in deciduous forest. The majority of deciduous forest occurs in the eastern portion of the ASR, from the Silent Hills (around KP 95) to the Nahanni Butte access road. The area of deciduous forest within the footprint is approximately 63 ha, representing 10% of the footprint total area. The proportion of deciduous forest in the region (within 10 km) is lower, at 5%. This pattern indicates that losses within the footprint may have a disproportionate effect on Canada Warbler habitat relative to the average of all other areas within 10 km of the ASR. The total loss of deciduous forest however is small (0.3% of the amount present in the region). The proposed ASR is predicted to have no residual effect on Canada Warbler.

Potential project effects and mitigations to avoid and minimize impacts to birds and bird habitat are described in the Developers Assessment Report and the Wildlife Management and Monitoring Plan. The main strategies to minimizing impacts to birds include minimization of the footprint, restoration of temporary cleared areas as early as possible, dust suppression (if needed) to avoid degradation, and clearing outside the bird nesting period. No further modifications to the existing effects assessment and/or mitigations have been made based on the results of the baseline bird survey. The results of the baseline bird survey will support future monitoring of breeding bird species richness, relative abundance, and distribution during road operations.

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LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Canadian Zinc Corporation and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Canadian Zinc Corporation, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user.

1.0 INTRODUCTION

Canadian Zinc Corporation (CZN) submitted a Developers Assessment Report (DAR) to the Mackenzie Valley Review Board (MVRB) in 2015 for a proposed Prairie Creek Mine all-season road (the Project; EA1415-01; CZN 2015). Environment and Climate Change Canada (ECCC) and Parks Canada recommended that baseline migratory bird surveys, including bird species at risk, be conducted. Baseline wildlife surveys in 2017 included surveys of birds using autonomous recording units (ARUs) located along the proposed all-season road. The purpose of the bird surveys was to evaluate occurrence, relative abundance, and distribution of migratory birds along the proposed all-season road (ASR). Results were initially reported in a baseline field report (Tetra Tech Canada Inc. 2018) that provided a summary of the bird data including presentation of relative abundance. In the time since the initial reporting of results, additional analysis of the bird data was completed, including species-specific density estimates and estimates of species richness and diversity. A separate report describing potential effects of the ASR on Canada Warbler was also prepared (Tetra Tech Canada Inc. 2019). This current report is intended to amalgamate the information presented in the baseline field report and the Canada Warbler report and present the additional analyses and summaries of the collected bird data in a unified baseline report on birds in relation to the Project.

The objectives of this report are to:

- Provide baseline data (species-specific density estimates and community-level metrics);
- Compare predicted bird species density in the are of the ASR to the region;
- Use power analyses to inform the design of future monitoring; and
- Describe potential effects to Canada Warbler, which were not originally included in the DAR.

ARUs are becoming a common approach for surveys of birds (review by Shonfield and Bayne 2017). ARUs are an especially useful survey approach for remote areas that are difficult or costly to visit for repeated surveys. Two approaches to process ARU recordings are human listing (identification of birds by a human listener during playback of recordings) and using computer-automated recognition. Human listening has the benefit of being able to estimate the number individual birds vocalizing during a defined time-period but is time-consuming and not all recordings can typically be processed. Automated recognition has the benefit of being able to process large numbers of recordings though counts of individual birds can typically not be done and the development of recognizers for many species is time-consuming. Both approaches were used to process recordings from ARUs along the ASR. Computer-automated recognition was specifically used to identify bird species at risk. Species at risk are usually at very low levels of abundance; automated recognition allows for processing of all recordings at a site, thus increasing the potential for detection. The data from human listening combined with automated recognition of species at risk were used to generate a list of bird species detected at survey locations along the ASR.

Bird survey counts are an incomplete measure of bird abundance as they do not account for the probability of detecting a species. Measures of bird abundance or density (number per unit area) are preferable to count data as it allows for comparisons among species, comparison to other datasets, and provides greater accuracy for area-based summaries. Bird species density was estimated from the count data using offsets following the QPAD approach (Solymos et al. 2013). The analysis used the counts from the human-listening ARU data and was completed only for species that are reliably detected using auditory cues.

Bird species occur at varying densities across the landscape due at least in part to the distribution of different bird habitats. Species-specific density estimates by habitat type allow for the prediction of average density across all habitat types within a defined area. A comparison of average density between the ASR footprint to the region provides context to habitat losses as a result of the project. For example, if average density is higher within the ASR footprint and adjacent areas relative to the region, then the loss of habitat may be considered disproportionately high relative to the region. Estimates of average density within 100 m of the ASR footprint were calculated and compared to average density estimates within 10 km of the road (representing the region) for all species where density was estimated.

The analyses described above are focused on species-level characteristics. To characterize the bird community as a whole, species richness and diversity by habitat type were estimated. This allows for detection of potential effects of the road on the bird community over time.

The general aim of power analysis is to predict the power of an experimental design or the sample size required to achieve an acceptable level of power. The ARU bird data was used to simulate power across varying sample sizes (number of stations) and varying number of monitoring years. The results of the power analysis will be used to inform the design of future monitoring.

2.0 METHODS

2.1 Sampling Design and ARU Deployment

Eighty ARUs (Wildlife Acoustics Songmeter SM2, SM3, and SM4) were deployed along the 170 km proposed all-season road (Appendix A, Figure A-1). Survey station locations were selected based on stratified random sampling of points from a systematic grid. Points were placed at 600 m intervals on the proposed road centreline to represent all possible survey stations and were manually adjusted at road bends to avoid potential overlap of ARU detection areas.

Approximately 115 km of the proposed 170 km road length were considered to be accessible by ground or helicopter. These accessible areas (n = 10, ranging in length from 2.0 to 22.5 km) were overlaid on the systematic grid and treated as strata. Survey stations were then selected in the accessible areas by random draw with the number of stations in each accessible area proportionate to the length of each accessible area. This stratification approach ensured spatial representation, subject to the constraints of access. Sampling intensity was adjusted in some accessible areas to reduce sampling in strata with very common habitats and allow additional sampling in strata with uncommon habitats. Open wetlands and waterbodies (habitats appropriate for Yellow Rail and other species at risk) on or immediately near the proposed road alignment are uncommon. Some stations were non-randomly located at select wetlands and lake shorelines to ensure these habitat types could be surveyed. During deployment, survey stations determined to be inaccessible (e.g., large creek crossing, heavy snow cover at deployment, or other logistical constraints) were relocated. This included marginal adjustments of nine stations from their pre-selected location (approximately 10-25 m away) and relocation to a new random draw survey station (n = 3 stations). The 80 ARUs were deployed in late May and retrieved in mid-August (Appendix B)[1].

The ARUs were programmed to record wildlife vocalizations at predetermined intervals each day until: 1) ARUs were retrieved; 2) batteries expired; and/or 3) memory cards were full. Units were programmed to record in 10-minute increments at the following times:

[1] Work was completed under Government of Northwest Territories Wildlife Research Permit WL500512 and Parks Canada Research and Collection Permit NAH-2017-24258.

- Every hour starting one hour before sunset until one hour before sunrise (Yellow Rail and Common Nighthawk active period).
- Every hour starting one hour before sunrise until five hours after sunrise (forest birds active period).
- At noon and 3 PM (to opportunistically detect birds that may be active during the daytime).

One ARU unit could not be re-located and recording data was therefore lost. A second unit malfunctioned, and no recordings were made.

2.2 Habitat Classification

The habitat at each station was determined using the 30 m resolution Land Cover of Canada, part of the North American Land Change Monitoring System (NALCMS) (CCRS 2015) (Table 2-1). The dominant land cover class within 250 m of the survey station centre was selected as the habitat representing the sampled area.

Table 2-1. The Number of Bird Survey Stations by Habitat Type

Land Cover of Canada Class Name	Habitat (4-Class)	Number of ARU Survey Stations [1]
Temperate or sub-polar needleleaf forest	Coniferous	31
Sub-polar taiga needleleaf forest	Coniferous	5
Temperate or sub-polar broadleaf deciduous	Deciduous	7
Mixed Forest	Mixed	11
Temperate or sub-polar shrubland	Open	14
Temperate or sub-polar grassland	Open	6
Sub-polar or polar grassland-lichen-moss	Open	1
Barren Lands	Open	3

[1] Does not include the sites with lost or malfunctioned units.

2.3 ARU Data Processing and Analysis

Alberta Biodiversity Monitoring Institute’s Bioacoustic Unit (Bioacoustic Unit) processed the ARU sound files using human listening and a computer-automated recognizer to identify species and abundance. Human listening was performed on all ARU survey stations. Three-minute long recordings were listened to at a minimum of three time intervals (i.e., on or around 3:30 a.m., 4:30 a.m., and 7:30 a.m.) on three different days (i.e., June 5, 11, and 15). Thus, a minimum of nine samples for a total of 27 audio minutes per survey station were processed for all diurnal species vocalizations. Human listening for nocturnal species was completed at survey stations where computer-automated recognizers identified potential Yellow Rail and Common Nighthawk vocalizations. Three-minute long recordings were listened to at survey stations determined to potentially include these nocturnal species at a minimum of three-time intervals (i.e. on or around 10:00 p.m., 12:30 p.m., and 2:00 a.m.) on three different days (i.e. June 5, 11, and 19). During the human listening, all vocalizations were recorded to species, as well as the number of individual’s calling.

Computer-automated species recognizers were also used to document the presence of bird species at risk at survey stations deployed within the species known range (Table 2-2). Recognizer analyses were performed for Horned Grebe (*Podiceps auratus*), Yellow Rail (*Coturnicops noveboracensis*), Red-necked Phalarope (*Phalaropus lobatus*), Common Nighthawk (*Chordeiles minor*), Olive-sided Flycatcher (*Contopus cooperi*), Bank Swallow (*Riparia riparia*), Barn Swallow (*Hirundo rustica*), Canada Warbler (*Cardellina canadensis*), and Rusty Blackbird (*Euphagus carolinus*). Recognizers for Trumpeter Swan, Harlequin Duck, Short-eared Owl, and

Peregrine Falcon were not developed, as recommended by the Bioacoustic Unit, as sufficient quantity of vocalization recordings are unavailable to currently develop recognizers for these species.

Table 2-2: Species and Survey Stations Processed by Computer-automated Recognizer

Species	Survey Stations Processed (all-season road KPs)
Horned Grebe	ARUs within the boreal forest zone (KP 39 to 170; n=62)
Yellow Rail	ARUs within the boreal forest zone (KP 39 to 170; n=62)
Red-necked Phalarope	ARUs within the boreal forest zone (KP 39 to 170; n=62)
Common Nighthawk	All ARUs (km 0-170; n=80)
Olive-sided Flycatcher	All ARUs (km 0-170; n=80)
Bank Swallow	All ARUs (km 0-170; n=80)
Barn Swallow	All ARUs (km 0-170; n=80)
Canada Warbler	All ARUs (km 0-170; n=80)
Rusty Blackbird	All ARUs (km 0-170; n=80)

2.4 Density Estimation

Bird survey counts are an incomplete measure of bird abundance as they do not account for the probability of detecting a species. Measures of bird abundance or density (number per unit area) are preferable to count data as it allows for comparisons among species and to other datasets and better supports monitoring and conservation objectives. To estimate density from the ARU count data, the QPAD approach was used (Solymos et al. 2013). The QPAD approach uses statistical offsets to correct for methodology and detectability differences across species and survey times and locations. The offsets can then be used in statistical models to estimate density from the original counts. The parameter estimates used to calculate offsets were developed from the Boreal Avian Modelling (BAM) project database that includes over 230,000 survey events (for QPAD version 3) across the Boreal region of North America (Solymos 2016). One of the benefits of using the QPAD approach is it provides a methodology to correct for imperfect detection and estimate density that otherwise would be very complex or impossible, especially in smaller datasets. The QPAD approach was developed using a database of human-conducted point counts. Use of the QPAD approach with ARU data assumes that human listening data from ARUs have the same range of bird detection as a human conducting point counts.

QPAD provides estimates for two components of detectability: availability for detection (p; based on singing rate) and detectability (q; based on perceptibility as a function of distance). The QPAD model parameter estimates for *p* and *q* can be retrieved from the QPAD database according to predictor variables (Table 2-2). The specific combination of best predictor variables depends on the species.

Table 2-3. Predictor Variables in QPAD used to Estimate Offsets

Parameter	Predictor Variable [1]	Description and Source Data
Availability (p)	Julian Day	The number of days between the date of survey and the start of the year.
	Time Since Local Sunrise	The time of survey since local sunrise, in hours. Source: National Research Council Sunrise/Sunset Calculator.
	Days Since Local Spring	Survey date minus date of average last spring frost. Source: Climate Atlas of Canada (Prairie Climate Centre 2019).
Detectability (q)	Tree Cover	Proportion tree cover at survey station. MODIS vegetation cover (Townshend et al. 2019).
	Land Cover (4-class and 2-class)	The 19 Land Cover of Canada classes as two separate variables: a 4-class variable (DecidMixed, Conif, Open, and Wet) and a 2-class variable (Forest, and OpenWet). Source: CCRS et al. (2015).

[1] The QPAD model also uses quadratic terms (x^2) of the first three variables.

The QPAD estimates are provided as a package for use in the statistical computing environment R (R Core Group 2019; R version 3.6.1 was used for the density estimates). The methods used to retrieve the estimates for the all-season road data were exactly as specified in Solymos (2016). The QPAD approach was developed for boreal birds considered to be singing species and that can mostly be detected by auditory cues. QPAD version 3 has parameter estimates for 141 species.

QPAD calculates an offset for each detection given the availability and detectability parameters retrieved from the QPAD database. The offsets together with raw count data can then be used in a model to estimate bird species density. Bird species density by habitat (land cover type) was considered to be of primary interest as species distribution is typically correlated with vegetation characteristics and it can be used to map species distribution across a landscape. The eight Land Cover of Canada classes mapped in the vicinity of the road (Table 2-1) were collapsed in to four habitat types and used as model variables.

Bird species density was also expected to vary with location along the road since the road lies in a long east-west orientation, with elevation generally increasing further west. East-west location (standardized UTM Easting) was therefore selected as a second candidate variable. Standardized UTM Northing and elevation were also considered for inclusion. Elevation was highly correlated with UTM Easting and was discarded from further consideration. UTM Northing was included as a model variable for several test species and in all cases a model could not be fit when included with both habitat and UTM Easting. Since the UTM Easting gradient is larger than the UTM Northing gradient and the distribution of some species was expected to be influenced by the east-west transition from boreal to montane, UTM Easting was selected for inclusion and UTM Northing was discarded from further consideration. An interaction term of habitat * UTM Easting was also tested, but again a model could not be fit.

Generalized Linear Mixed Models (GLMMs) were used to estimate density for each species that was detected in greater than 10 samples (~1%). Habitat and Easting were considered fixed effects and survey station was included as a random effect to account for pseudoreplication since there are repeated measures for each station. Three candidate models were evaluated:

1. Intercept only (with no effects; null model)
2. Habitat
3. Habitat + Easting.

A model with an interaction between habitat and easting was tested for several abundant species but models could not be fit and was not pursued further. Each of the three models was evaluated using four sampling distributions: Poisson, zero-inflated Poisson, negative binomial, and zero-inflated binomial. The 12 possible model and sampling distribution combinations were compared using Akaike's Information Criterion corrected for small samples (AICc). The habitat model (i.e., model 2 or 3 listed above) with the lowest AICc was selected as the top model. The appropriateness of each best model was evaluated using diagnostic plots of residuals generated using the R package DHARMa (Hartig 2019). The amount of variance explained by the top model (goodness-of-fit) was estimated by a specific formulation of R^2 for mixed-models (Nakagawa and Schielzeth 2013) using the function *r.squaredGLMM* in the R package *MuMIn* (Barton 2020). The R^2 values reported were estimated using the "trigamma method".

Mean species density (males per hectare (ha)) with 95% confidence interval (CI) was estimated for each habitat. When the best model included Easting, the effect of Easting was held constant to provide mean density by habitat for the entire area (the conditional mean). Means and confidence intervals were calculated using the R package 'emmeans' (version 1.3.3; Brooks et al. 2017).

2.5 Diversity Estimation

Species diversity was compared among habitats at two scales:

- Mean diversity (alpha diversity), the mean number of species per survey station; and
- Total diversity (gamma diversity), the total number of species across all survey stations.

Mean diversity was estimated using a GLMM with a Poisson distribution. Habitat, Easting, and Elevation were selected as candidate geographic variables though Elevation was discarded due to significant correlation with Easting. Julian Day, Days Since Local Spring, and Time Since Sunrise were selected as candidate variables to account for differences in survey timing; Days Since Local Spring was discarded due to high correlation with Julian Day. Models with all combinations of variables were compared and the model with the lowest AICc was selected as the top model and the most appropriate to estimate diversity. Survey station was included as a random effect in all models since there are repeated measures for each station. Mean species richness (number of species per station) with 95% confidence interval was estimated for each habitat using the R package 'emmeans'.

Measurements of total species diversity are strongly influenced by sampling effort as more surveys will generally detect species until there are no new species to detect. Comparison of species diversity among habitats or strata with unequal survey effort is therefore biased. However, samples with unequal survey effort can be compared using rarefaction. Rarefaction curves are related to species accumulation curves. Species accumulation curves represent the cumulative number of species detected in a survey area for a single ordering of samples as they are successively pooled (i.e., sampling effort increases). When the number of pooled stations is small, the addition of each new station adds many new species. As the data for more stations are pooled, the number of new species declines until a point when there are no new species to add. If species accumulation curves are repeated by reordering the stations, a smooth curve can be produced by averaging the number of species at each sample size for all accumulation curves. This is a rarefaction curve. The curve allows for the estimate of species richness for any number of samples.

Rarefaction can also be used with other measures of diversity. When diversity indices are expressed as the effective number of species, they are often referred to as Hill numbers. Hill numbers are a mathematically unified family of diversity indices. Hill number 0 is equivalent to species richness, Hill number 1 is equivalent to Shannon diversity, and Hill number 2 is equivalent to Simpson diversity (Chao et al. 2014). Shannon diversity incorporates species richness and the relative abundance of each species and each species is weighted relative to its frequency. Simpson diversity also incorporates species richness and relative abundance, though common species are weighted more heavily than uncommon species. The three measures of diversity can be thought of as existing along a continuum of decreasing sensitivity to uncommon species. These measures are applicable to both alpha and gamma diversity.

Rarefaction curves and estimates of asymptotic diversity (the point at which no new species are expected to be observed) were generated using the R package 'iNext' (version 2.0.20; Hsieh et al. 2016).

For all diversity analyses, only morning survey records (02:00 onward) from the human listening data were included as human listening at other times of day (noon to midnight) were not done for every station. Waterbirds and diurnal birds of prey were removed from the diversity analysis as we felt they were not reliably surveyed using auditory cues. The diversity analysis included only the human listening data; the automated recognizer data could not be included because of differences in sampling between the two approaches

2.6 Comparison of Predicted Species Density in Footprint Area to Region

Species-specific density estimates were summarized to compare predicted mean density within 100 m of the road (representing the road footprint and the immediately adjacent area) and within 10 km of the road (representing the region). The 10 km distance for the region was selected arbitrarily but was considered large enough to adequately characterize the landscape surrounding the road and small enough to be ecologically relevant (i.e., does not extend into other Ecological Regions).

Mean species density for each study area was calculated by multiplying species-specific density estimates for each habitat by the total area of each habitat within each study area, then summing across habitats, and finally dividing by the total area of each study area. This produced a prediction of average density across study areas that reflects the relative availability of different habitats. The associated 95% confidence intervals were calculated in the same way.

2.7 Analysis of Power to Detect Change

The data collected in 2017 represents the baseline bird conditions, prior to development of the Project (and includes overlapping portions of the regenerating 1980s winter road). The data can be compared to future data collected using the same protocol and analytical methods to identify changes to the bird community and individual bird species in the time periods before and after development of the Project. Power analysis can be used to estimate how the ability to detect change varies with differing sampling intensity. The results of this analysis will be used to inform the design of the monitoring program. The analysis of power was conducted for the following metrics:

1. Change in mean survey species richness and mean survey abundance (of all species combined), as measures to characterize the bird community.
2. Change in density of Olive-sided Flycatcher and Canada Warbler, to represent listed species that have low rates of detection relative to most other detected species.
3. Change in density of Least Flycatcher, Magnolia Warbler, Ovenbird and Swainson's Thrush, to represent non-listed species with various rates of detection.

Power is defined as the probability of rejecting the null hypothesis when it is false. Power depends on sample size, effect size (rate of change), the variability in the response variable and significance level (alpha). The general aim of power analysis is to predict the power of an experimental design or the sample size required to achieve an acceptable level of power (80% is conventionally deemed adequate). Monte Carlo simulation of power is an approach that can accommodate a wide variety of modeling approaches (Johnson *et al.* 2015; Green and McLeod 2016), such as the mixed models used to analyze the ARU bird data. The R package 'simr' (version 1.0.5; Green and McLeod 2016) provides functions to simulate power across varying levels of sample size using existing data. The 2017 bird data from ARU human listening was used to simulate power across varying sample sizes (number of stations) and varying number of monitoring years. The simulation used the mixed effects models described in Sections 2.4 and 2.5.

The simulation of power was conducted using an effect size of -20% change from one monitoring year to the next for each of the metrics (species richness, abundance and species-specific density) and additionally using an effect size of -50% change for species where a -20% change could not be detected within 10 years. Significance level (alpha) was set at 0.1 instead of the often-used 0.05. The lower significance threshold is a conservative approach in that it assumes it would be preferable to risk concluding that there is a change when there really is not (false positive) and minimize the potential of concluding there is no decline when there really is one (false negative).

3.0 SPECIES DETECTIONS

There were 87 bird species detected through human listening of the ARU recordings (Table 3-1). The most commonly found species were Swainson's Thrush (detected at 63 stations), Tennessee Warbler (54 stations), Chipping Sparrow (50 stations) White-throated Sparrow (49 stations) (Table 3-1). These bird species are representative of coniferous and mixed-forest habitats, including open woodlands throughout the road length (Fisher and Acorn 1998, Sibley 2016).

Table 3-1. Bird Species Detected Using Autonomous Recording Units

English Name [1, 2]	COSEWIC [3]	SARA [4]	NWT [5]	Human Listening		Additional Stations Identified by Recognizer [8]	Proportion of Survey Stations Detected (%)
				Total Detections [6]	Station Incidence [7]		
Canada Goose	-	-	Secure	2	2	-	2.6%
Trumpeter Swan	Not At Risk	-	Secure	6	4	-	5.1%
American Wigeon	-	-	Secure	2	2	-	2.6%
Green-winged Teal	-	-	Secure	3	2	-	2.6%
Ruffed Grouse *	-	-	Secure	45	18	-	23.1%
Spruce Grouse *	-	-	Secure	4	2	-	2.6%
Pied-billed Grebe *	-	-	Undetermined	5	4	-	5.1%
Common Nighthawk	Special Concern	Threatened	At Risk	120	27	21	61.5%
Sora	-	-	Secure	10	7	0	9.0%
American Coot	Not At Risk	-	Secure	2	2	-	2.6%
Sandhill Crane *	-	-	Secure	1	1	-	1.3%
Wilson's Snipe *	-	-	Secure	14	6	-	7.7%
Spotted Sandpiper	-	-	Secure	18	12	-	15.4%
Solitary Sandpiper	-	-	Secure	6	6	-	7.7%
Common Loon *	Not At Risk	-	Secure	1	1	-	1.3%
American Bittern *	-	-	Sensitive	1	1	-	1.3%
Red-tailed Hawk *	Not At Risk	-	Secure	1	1	-	1.3%
Great Horned Owl *	-	-	Secure	1	1	-	1.3%
Barred Owl	-	-	Undetermined	2	2	-	2.6%
Great Gray Owl	Not At Risk	-	Secure	3	2	-	2.6%
Boreal Owl *	Not At Risk	-	Secure	2	1	-	1.3%
Yellow-bellied Sapsucker	-	-	Secure	8	5	-	6.4%
Black-backed Woodpecker *	-	-	Secure	1	1	-	1.3%
Hairy Woodpecker *	-	-	Secure	1	1	-	1.3%
Northern Flicker *	-	-	Secure	8	7	-	9.0%
Pileated Woodpecker *	-	-	Secure	2	2	-	2.6%

English Name [1, 2]	COSEWIC [3]	SARA [4]	NWT [5]	Human Listening		Additional Stations Identified by Recognizer [8]	Proportion of Survey Stations Detected (%)
				Total Detections [6]	Station Incidence [7]		
Merlin *	Not At Risk	-	Secure	1	1	-	1.3%
Olive-sided Flycatcher *	Special Concern	Threatened	At Risk	15	9	2	14.1%
Western Wood-Pewee *	-	-	Secure	1	1	-	1.3%
Yellow-bellied Flycatcher *	-	-	Secure	19	9	-	11.5%
Alder Flycatcher *	-	-	Secure	84	18	-	23.1%
Least Flycatcher *	-	-	Secure	38	14	-	17.9%
Say's Phoebe *	-	-	Undetermined	1	1	-	1.3%
Blue-headed Vireo *	-	-	Secure	1	1	-	1.3%
Warbling Vireo *	-	-	Secure	19	11	-	14.1%
Red-eyed Vireo *	-	-	Secure	36	11	-	14.1%
Canada Jay *	-	-	Secure	14	13	-	16.7%
Common Raven *	-	-	Secure	9	7	-	9.0%
Bank Swallow *	Threatened	Threatened	At Risk	3	3	0	3.8%
Black-capped Chickadee *	-	-	Secure	2	2	-	2.6%
Boreal Chickadee *	-	-	Secure	8	7	-	9.0%
Red-breasted Nuthatch *	-	-	Secure	6	4	-	5.1%
Winter Wren *	-	-	Secure	3	3	-	3.8%
Ruby-crowned Kinglet *	-	-	Secure	62	27	-	34.6%
Mountain Bluebird *	-	-	Undetermined	1	1	-	1.3%
Townsend's Solitaire *	-	-	Secure	2	2	-	2.6%
Gray-cheeked Thrush *	-	-	Secure	21	9	-	11.5%
Swainson's Thrush *	-	-	Secure	884	63	-	80.8%
Hermit Thrush *	-	-	Secure	278	39	-	50.0%
American Robin *	-	-	Secure	63	22	-	28.2%
Varied Thrush *	-	-	Undetermined	16	8	-	10.3%
Bohemian Waxwing *	-	-	Secure	1	1	-	1.3%
Cedar Waxwing *	-	-	Secure	2	1	-	1.3%
Evening Grosbeak *	Special Concern	Special Concern	Secure	1	1	-	1.3%
Common Redpoll *	-	-	Secure	2	2	-	2.6%
White-winged Crossbill *	-	-	Secure	25	21	-	26.9%
Pine Siskin *	-	-	Secure	12	12	-	15.4%
Chipping Sparrow *	-	-	Secure	210	50	-	64.1%
Clay-colored Sparrow *	-	-	Secure	4	4	-	5.1%
Fox Sparrow *	-	-	Secure	12	7	-	9.0%

English Name [1, 2]	COSEWIC [3]	SARA [4]	NWT [5]	Human Listening		Additional Stations Identified by Recognizer [8]	Proportion of Survey Stations Detected (%)
				Total Detections [6]	Station Incidence [7]		
American Tree Sparrow *	-	-	Secure	3	3	-	3.8%
Dark-eyed Junco *	-	-	Secure	136	36	-	46.2%
White-crowned Sparrow *	-	-	Secure	54	13	-	16.7%
White-throated Sparrow *	-	-	Secure	534	49	-	62.8%
LeConte's Sparrow *	-	-	Secure	37	5	-	6.4%
Savannah Sparrow *	-	-	Secure	2	2	-	2.6%
Lincoln's Sparrow *	-	-	Secure	205	30	-	38.5%
Swamp Sparrow *	-	-	Secure	30	8	-	10.3%
Ovenbird *	-	-	Secure	272	30	-	38.5%
Northern Waterthrush *	-	-	Secure	11	7	-	9.0%
Black-and-white Warbler	-	-	Secure	14	10	-	12.8%
Tennessee Warbler *	-	-	Secure	443	54	-	69.2%
Orange-crowned Warbler	-	-	Secure	31	10	-	12.8%
Nashville Warbler *	-	-	-	1	1	-	1.3%
Common Yellowthroat *	-	-	Secure	57	17	-	21.8%
American Redstart *	-	-	Secure	59	11	-	14.1%
Cape May Warbler *	-	-	Secure	5	4	-	5.1%
Magnolia Warbler *	-	-	Secure	107	27	-	34.6%
Bay-breasted Warbler *	-	-	Secure	34	12	-	15.4%
Yellow Warbler *	-	-	Secure	19	5	-	6.4%
Blackpoll Warbler *	-	-	Secure	7	2	-	2.6%
Palm Warbler *	-	-	Secure	8	6	-	7.7%
Yellow-rumped Warbler	-	-	Secure	147	47	-	60.3%
Canada Warbler *	Threatened	Threatened	At Risk	17	9	2	14.1%
Wilson's Warbler *	-	-	Secure	6	6	-	7.7%
Western Tanager *	-	-	Secure	7	5	-	6.4%
Rose-breasted Grosbeak *	-	-	Secure	6	4	-	5.1%

[1] Species are listed in phylogenetic order.
[2] Species marked with * are those in the QPAD database and abundance offsets can be estimated.
[3] Committee on the Status of Endangered Wildlife in Canada.
[4] Species at Risk Act.
[5] NWT List of Species at Risk
[6] The sum of all detections over all samples at all stations.
[7] Station incidence is the number of stations that a species was detected at.
[8] Species with "-" did not have automated recognition completed.

Some of the least commonly detected species favour wetland and lakeshore habitats, such as the Sandhill Crane, American Bittern, and Common Loon (all detected at only 1 station), and the American Widgeon, Green-winged Teal, and American Coot (all detected at two stations; Fisher and Acorn 1998, Sibley 2016). Wetlands, ponds, and lakes infrequently occur on and immediately adjacent to the proposed all-season road. Therefore, it is expected that fewer wetland species were detected.

Also, among the least common were species that are typically found in open and semi-open habitats, such as the Say's Phoebe (detected at 1 station) (Fisher and Acorn 1998, Sibley 2016). A Say's Phoebe was detected in an open rock/rubble habitat at KP 17. Other infrequently detected species include the Blue-headed Vireo, Bohemian Waxwing, and the Western Wood-pewee (all detected at one station), which prefer open mixed-wood forests and woodlands, and habitat edges around lakes/wetlands/burns, respectively (Fisher and Acorn 1998, Sibley 2016).

Relatively non-vocal species were also rarely detected, as found in previous studies (Alquezar and Machado 2015, Haselmayer and Quinn 2000). Infrequently vocal species such as the Red-tailed Hawk and the Merlin were only recorded once each. The ARU monitoring program used in this study is not ideally suited for these species. Few detections of these species should not be interpreted as presence of few individuals. Few detections of nocturnal raptors, such as the Great Grey Owl, Barred Owl, Boreal Owl, and Great-horned Owl were recorded. This is most likely because night-time recordings were only analyzed by human listening for stations where the recognizers detected potential Common Nighthawk or Yellow Rail hits, limiting the probability of detection for these nocturnal raptor species.

4.0 SPECIES DENSITY

Density by habitat could be estimated for 38 of the 39 species that were detected in greater than 10 samples (could not fit a model for Canada Jay) (Table 4-1; see Appendix C for the parameter estimates of the best model). Effects plots are shown in Figures 4-1 to 4-37. For species where the best model included Easting, then expected density by habitat depends on the location along the proposed all-season road and two plots are shown: one for the effect of habitat when Easting is held constant, and a second for Easting when the effect of habitat is held constant. Location along road (as measured by UTM Easting) was an important factor for 13 of the 38 species modelled. The confidence intervals are large for most of the less common species and the pattern of differences among habitats have low confidence.

The data for most of species (34 of 38) fit a poisson distribution. Diagnostic plots (residuals against predicted and Q-Q plots; data not presented) indicated that the relevant model was appropriate for most species. The marginal R^2 (the proportion of variance explained by the fixed effects) ranged widely, from .008 to 0.988 (Appendix C, Table C.2). Habitat and elevation (where it was included in the top model for a species) explained little or no variability (<5%) in estimated density for 12 of the 38 species. R^2 value close to 1 are suspiciously high and likely an artifact of overfitting (too many covariates for the number of observations). A similar pattern exists for the conditional R^2 (the proportion of variance explained by both the fixed and random effects). For those species with poor model fit, a larger sample size and or additional environmental variables to explain variation may be needed.

Each ARU survey station was assigned one of four habitat classes derived from the Land Cover of Canada mapping to represent the dominant habitat sampled (within 250 m) at each survey station. The benefit of using geographic (mapped) habitat variables is that the model for each species can be applied to the geographic data to produce species distribution maps. The area sampled by each ARU however does not necessarily represent a pure sample of each habitat. The surveyed areas are naturally heterogeneous and other habitats are present to varying degrees. Furthermore, the ARU detection radius is variable and some species may be detected at great distances, with some of those in a different habitat. It is also possible that the 250 m distance for the assignment of the dominant habitat is too large and does not reflect the dominant habitat in the area sampled by the ARU.

These factors influence the accuracy and precision of the habitat estimates. There may be other approaches to characterizing habitat that may improve model fit. For example, continuous habitat variables could be used in place of categorical. For example, coniferous forest could be expressed as proportion of coniferous forest within a specified radius. It is recommended that other covariate options be considered after the next year of data collection.

Table 4-1. Estimates of Species Density (males/ha with 95% confidence intervals) for Species that Occurred in Greater than 10 samples (~1%)

Species	Sample Incidence (n=935) [1]	Model Family [2]	Variables in Best Model	Coniferous	Mixed	Deciduous	Open
Ruffed Grouse	37	P	Habitat + Easting	0.010 (0.003-0.035)	0.008 (0.002-0.041)	0.010 (0.002-0.059)	0.002 (0.000-0.013)
Wilson's Snipe	12	P	Habitat	<.001 (<.001-0.010)	ND [3]	ND	<.001 (<.001-0.009)
Spotted Sandpiper	18	P	Habitat	0.006 (0.001-0.026)	ND	ND	0.013 (0.004-0.048)
Olive-sided Flycatcher	15	P	Habitat	<.001 (<.001-0.026)	ND	<.001 (<.001-0.075)	<.001 (<.001-0.028)
Yellow-bellied Flycatcher	14	NB	Habitat	<.001 (<.001-0.012)	0.001 (<.001-0.102)	ND	<.001 (<.001-0.039)
Alder Flycatcher	71	P	Habitat	0.005 (0.001-0.027)	ND	0.019 (0.002-0.226)	0.016 (0.003-0.092)
Least Flycatcher	34	P	Habitat	0.002 (0.000-0.019)	0.027 (0.004-0.177)	0.003 (0.000-0.059)	0.004 (0.001-0.027)
Warbling Vireo	17	P	Habitat + Easting	0.002 (0.000-0.019)	0.010 (0.002-0.052)	0.003 (0.000-0.031)	0.004 (0.001-0.023)
Red-eyed Vireo	31	P	Habitat + Easting	0.002 (0.000-0.015)	0.007 (0.000-0.099)	0.002 (0.000-0.068)	<.001 (0.000-0.007)
Ruby-crowned Kinglet	60	P	Habitat + Easting	0.056 (0.028-0.109)	0.019 (0.005-0.069)	0.013 (0.003-0.062)	0.014 (0.005-0.039)
Gray-cheeked Thrush	21	P	Habitat	0.002 (0.000-0.062)	ND	0.001 (0.000-0.084)	<.001 (0.000-0.021)
Swainson's Thrush	623	P	Habitat + Easting	0.768 (0.579-1.019)	0.775 (0.478-1.256)	0.449 (0.240-0.842)	0.293 (0.196-0.438)
Hermit Thrush	222	P	Habitat + Easting	0.075 (0.040-0.142)	0.011 (0.003-0.038)	0.018 (0.004-0.077)	0.018 (0.007-0.047)
American Robin	59	P	Habitat	0.029 (0.012-0.070)	0.003 (0.000-0.035)	0.010 (0.001-0.072)	0.017 (0.005-0.053)
Varied Thrush	14	P	Habitat	0.005 (0.000-0.080)	0.001 (0.000-0.051)	0.002 (0.000-0.083)	ND
White-winged Crossbill	25	P	Habitat	0.040 (0.025-0.063)	0.021 (0.007-0.066)	0.011 (0.002-0.076)	0.006 (0.002-0.020)
Pine Siskin	12	P	Habitat + Easting	0.014 (0.006-0.031)	0.010 (0.002-0.039)	0.007 (0.001-0.046)	0.009 (0.003-0.029)
Chipping Sparrow	174	P	Habitat	0.261 (0.188-0.362)	0.080 (0.038-0.170)	0.023 (0.006-0.085)	0.083 (0.051-0.136)
Fox Sparrow	12	P	Habitat	0.001 (0.000-0.013)	ND	0.012 (0.001-0.213)	0.004 (0.000-0.055)
Dark-eyed Junco	107	ZIP	Habitat	0.199 (0.106-0.373)	0.038 (0.010-0.138)	ND	0.068 (0.030-0.152)
White-crowned Sparrow	44	P	Habitat	0.001 (0.000-0.014)	ND	ND	0.019 (0.002-0.153)
White-throated Sparrow	385	P	Habitat + Easting	0.235 (0.141-0.391)	0.071 (0.027-0.189)	0.219 (0.077-0.621)	0.282 (0.150-0.530)
LeConte's Sparrow	22	P	Habitat	<.001 (<.001-0.005)	<.001 (<.001-0.026)	<.001 (<.001-<.001)	<.001 (<.001-0.004)
Lincoln's Sparrow	165	P	Habitat + Easting	0.055 (0.023-0.136)	0.006 (0.001-0.041)	0.011 (0.002-0.078)	0.064 (0.025-0.167)
Swamp Sparrow	26	P	Habitat	0.002 (0.000-0.045)	ND	ND	0.001 (0.000-0.033)
Ovenbird	177	P	Habitat + Easting	0.006 (0.002-0.019)	0.041 (0.011-0.150)	0.022 (0.004-0.134)	0.003 (0.000-0.020)

Species	Sample Incidence (n=935) [1]	Model Family [2]	Variables in Best Model	Coniferous	Mixed	Deciduous	Open
Northern Waterthrush	11	P	Habitat	<.001 (<.001-0.037)	ND	0.001 (<.001-0.379)	<.001 (<.001-0.054)
Black-and-white Warbler	14	P	Habitat + Easting	<.001 (<.001-0.022)	<.001 (<.001-0.030)	<.001 (<.001-0.037)	<.001 (<.001-0.021)
Tennessee Warbler	277	ZIP	Habitat + Easting	0.469 (0.337-0.651)	0.715 (0.457-1.121)	0.218 (0.114-0.416)	0.333 (0.222-0.500)
Orange-crowned Warbler	26	P	Habitat	<.001 (<.001-0.008)	ND	ND	<.001 (<.001-0.010)
Common Yellowthroat	55	P	Habitat + Easting	0.010 (0.003-0.036)	0.005 (0.001-0.034)	0.002 (0.000-0.021)	0.014 (0.004-0.052)
American Redstart	41	P	Habitat + Easting	<.001 (<.001-0.016)	<.001 (<.001-0.023)	<.001 (<.001-0.068)	<.001 (<.001-0.015)
Magnolia Warbler	90	P	Habitat + Easting	0.007 (0.002-0.020)	0.017 (0.006-0.047)	0.040 (0.014-0.113)	0.048 (0.020-0.117)
Bay-breasted Warbler	27	P	Habitat + Easting	0.003 (0.000-0.026)	0.002 (0.000-0.036)	0.001 (0.000-0.019)	0.000 (0.000-0.007)
Yellow Warbler	14	P	Habitat	<.001 (<.001-<.001)	<.001 (<.001-<.001)	<.001 (<.001-0.080)	<.001 (<.001-0.025)
Yellow-rumped Warbler	133	P	Habitat	0.141 (0.094-0.211)	0.137 (0.067-0.280)	0.057 (0.019-0.166)	0.054 (0.030-0.097)
Canada Warbler	9	P	Habitat	ND	0.126 (0.021-0.763)	0.837 (0.280-2.505)	0.088 (0.021-0.372)

[1] The number of samples that a species was detected in. The total number of samples used in the density analyses was 935.

[2] P = poisson, NB = negative binomial, ZIP = zero-inflated poisson.

[3] ND = not detected.

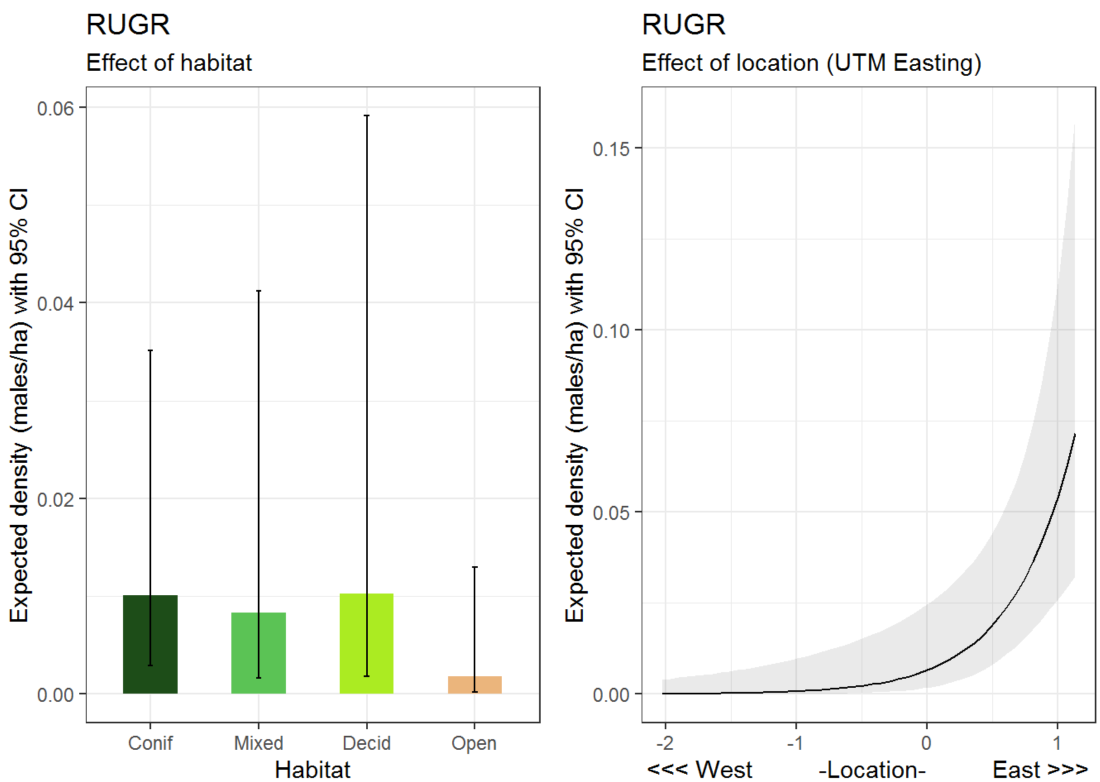

Figure 4-1. Ruffed Grouse Density Estimates

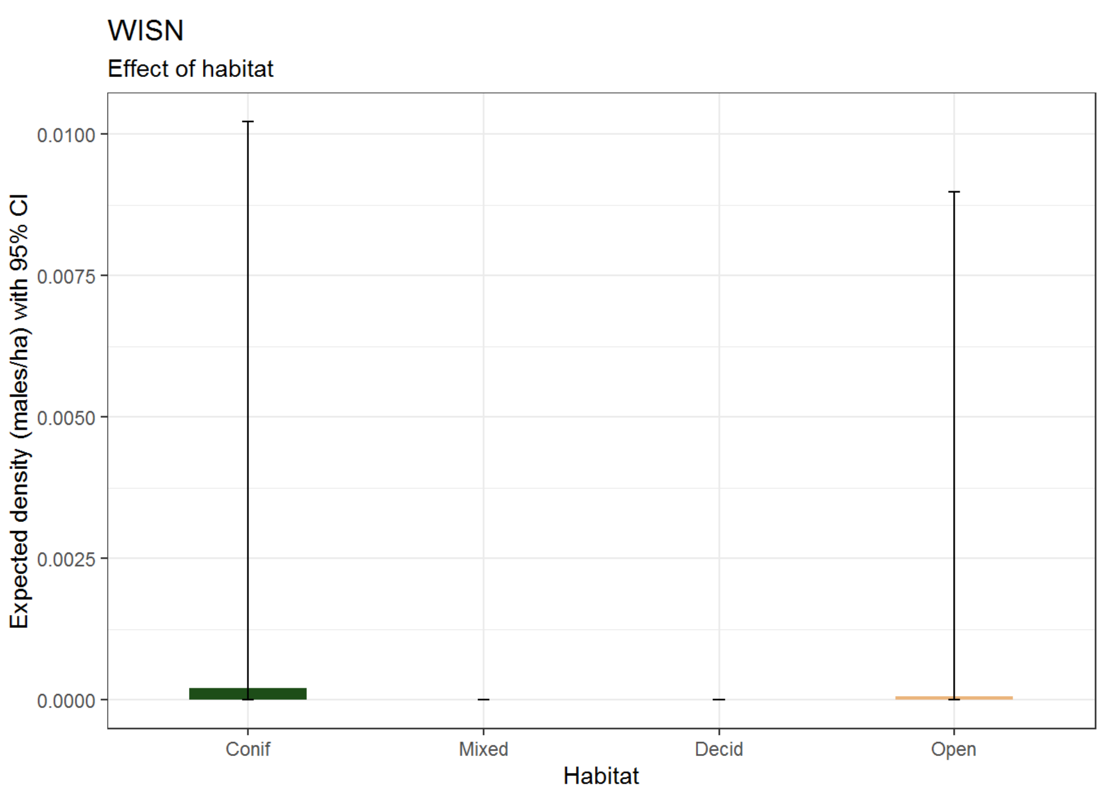

Figure 4-2. Wilson's Snipe Density Estimates

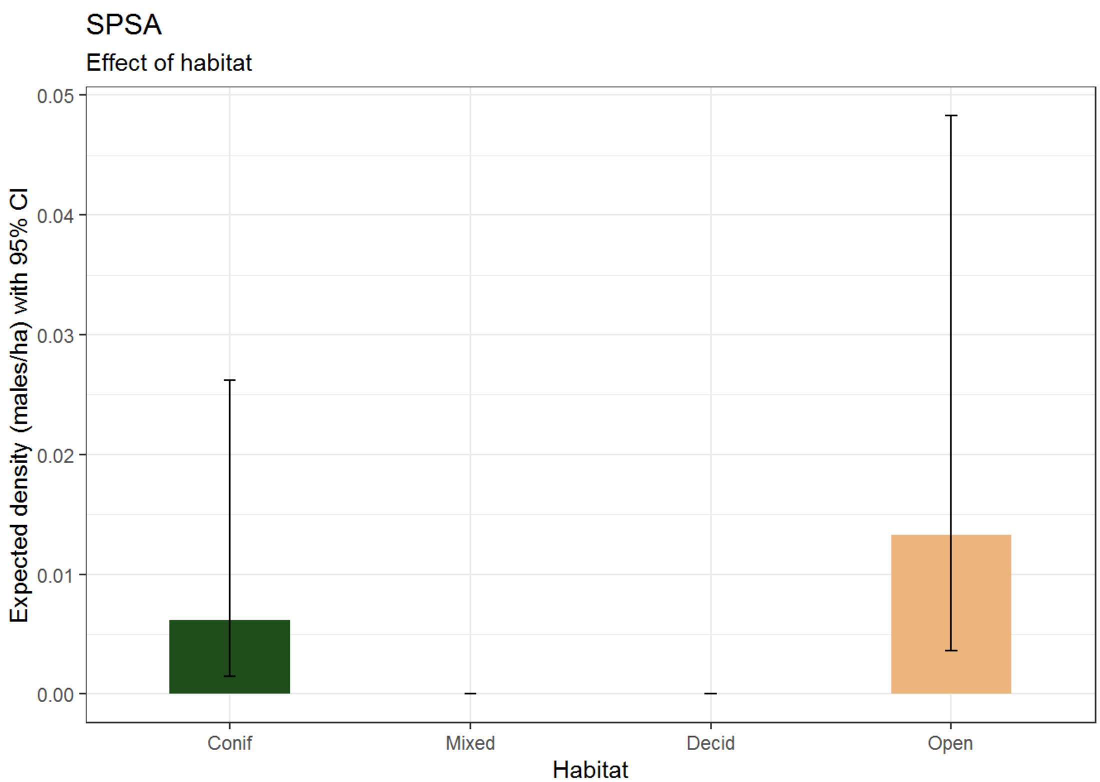

Figure 4-3. Spotted Sandpiper Density Estimates

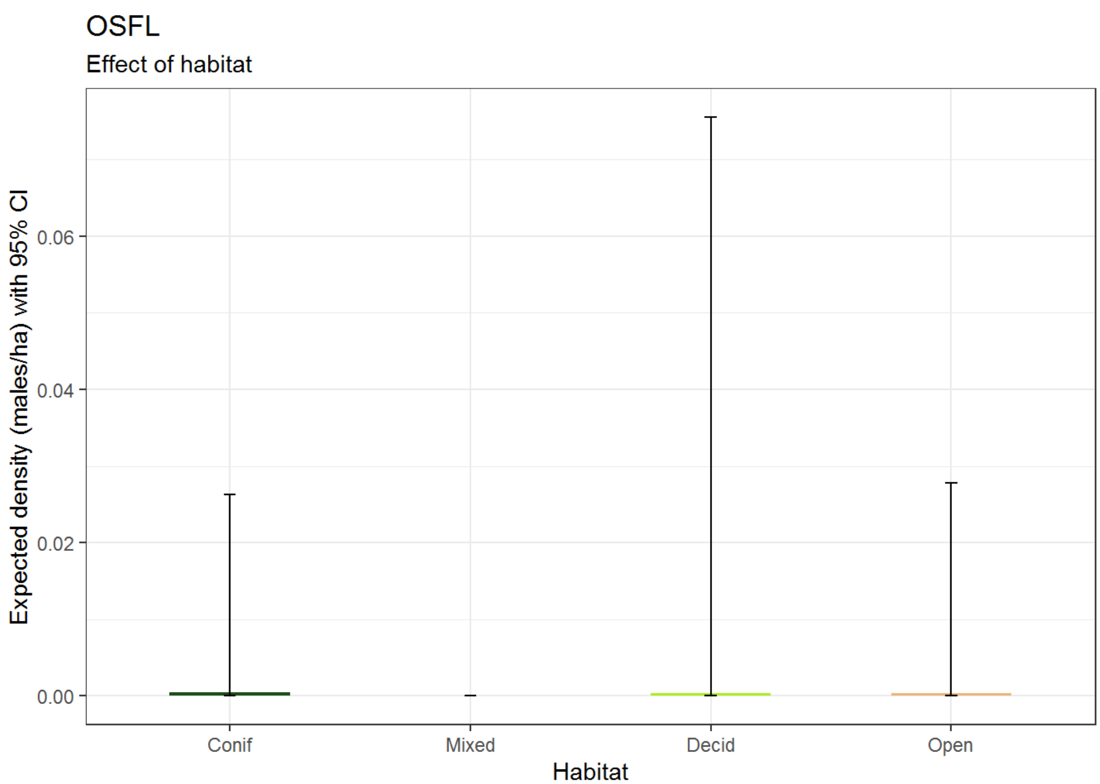

Figure 4-4. Olive-sided Flycatcher Density Estimates

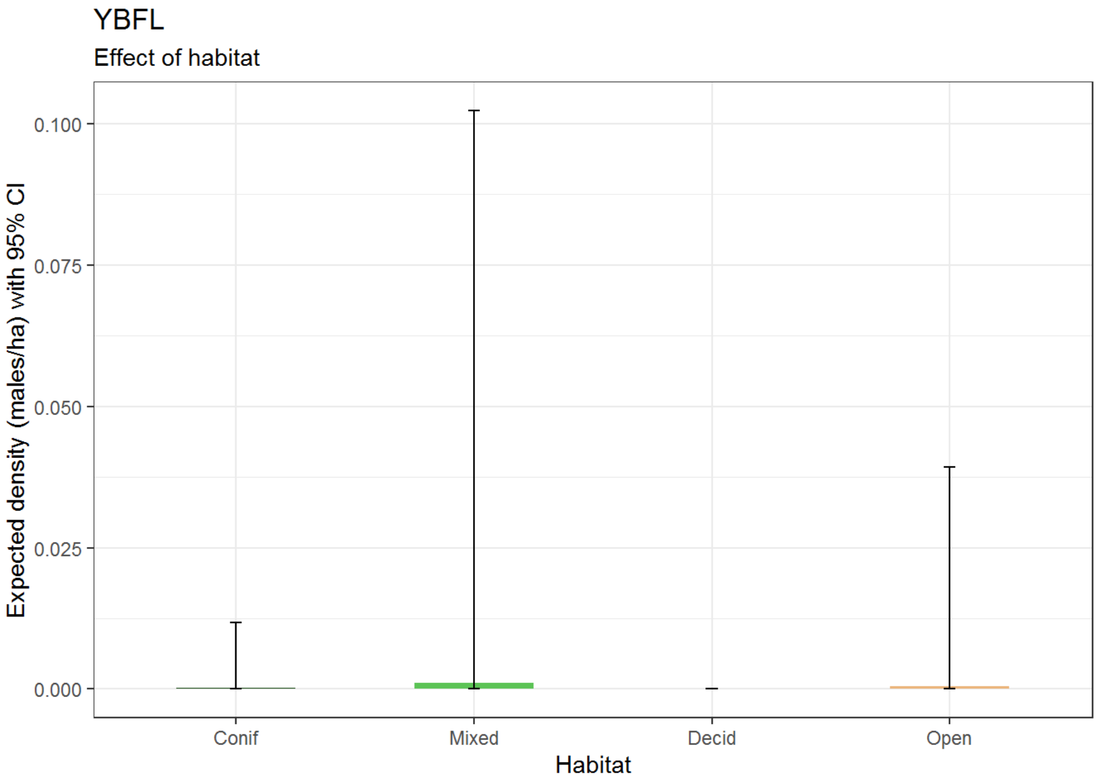

Figure 4-5. Yellow-bellied Flycatcher Density Estimates

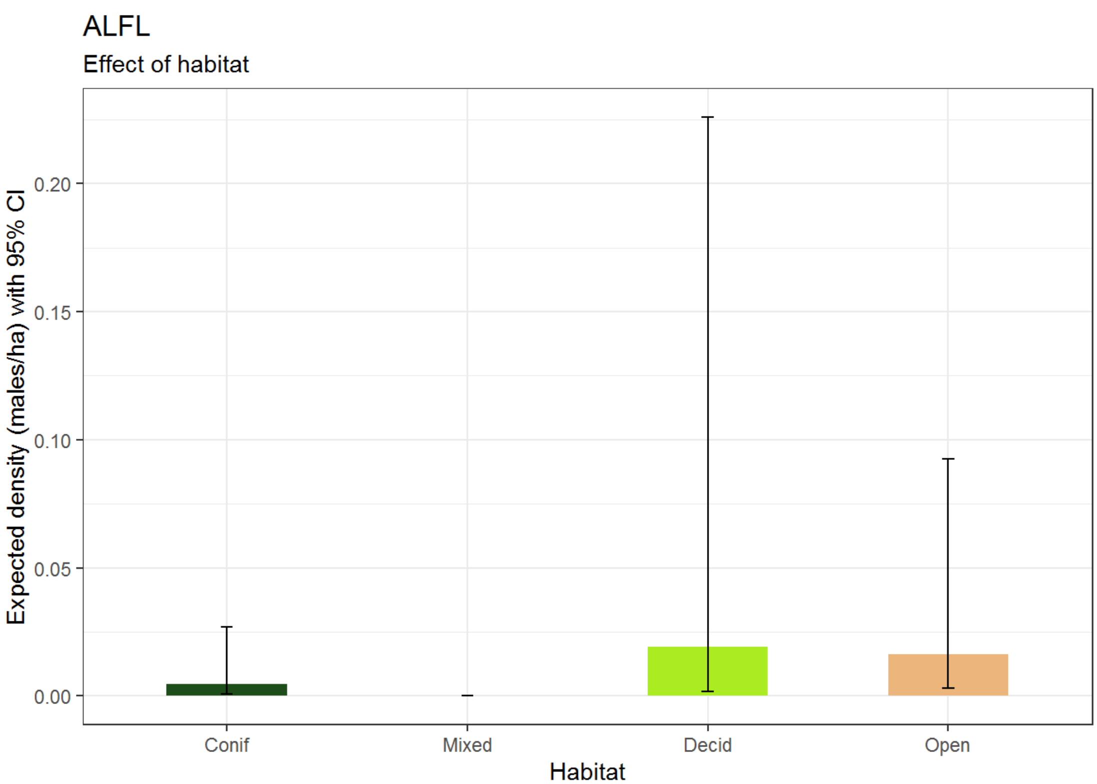

Figure 4-6. Alder Flycatcher Density Estimates

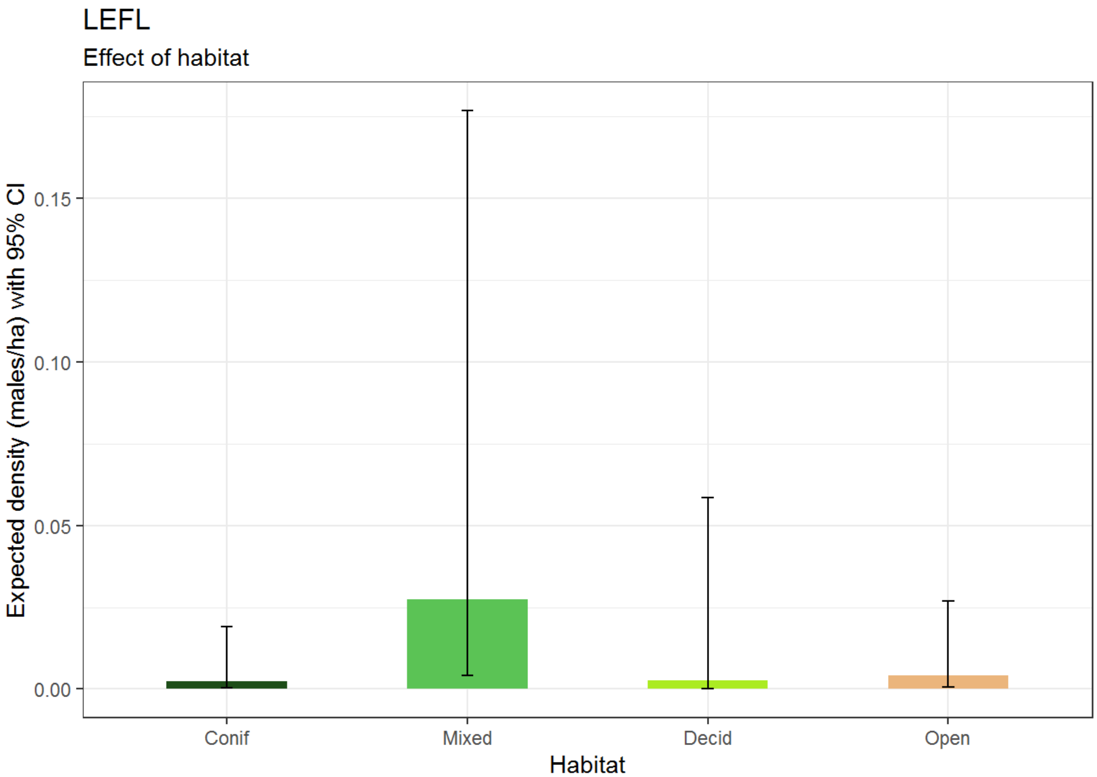

Figure 4-7. Least Flycatcher Density Estimates

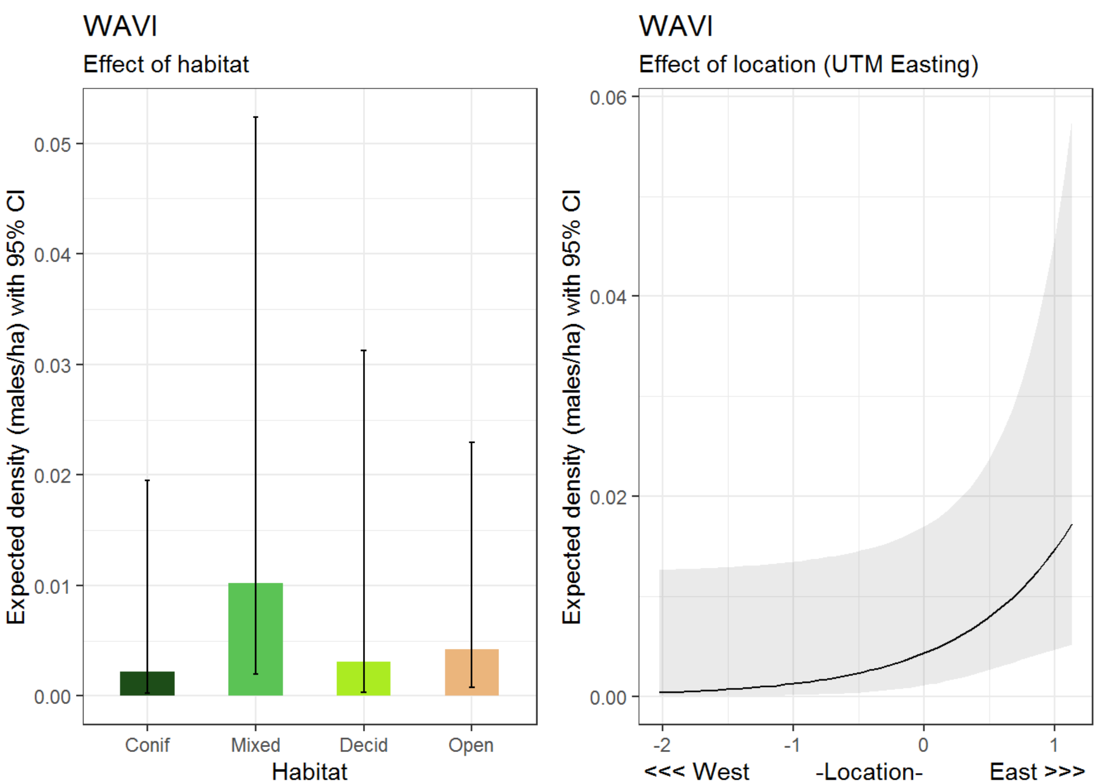

Figure 4-8. Warbling Vireo Density Estimates

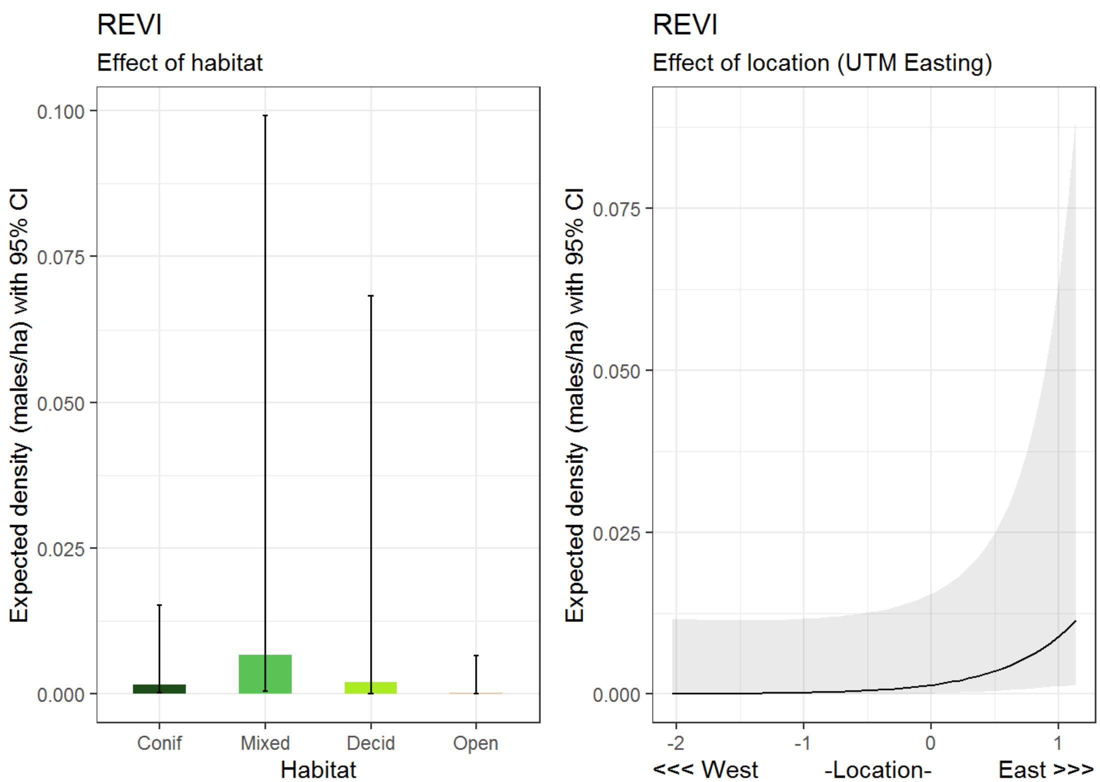

Figure 4-9. Red-eyed Vireo Density Estimates

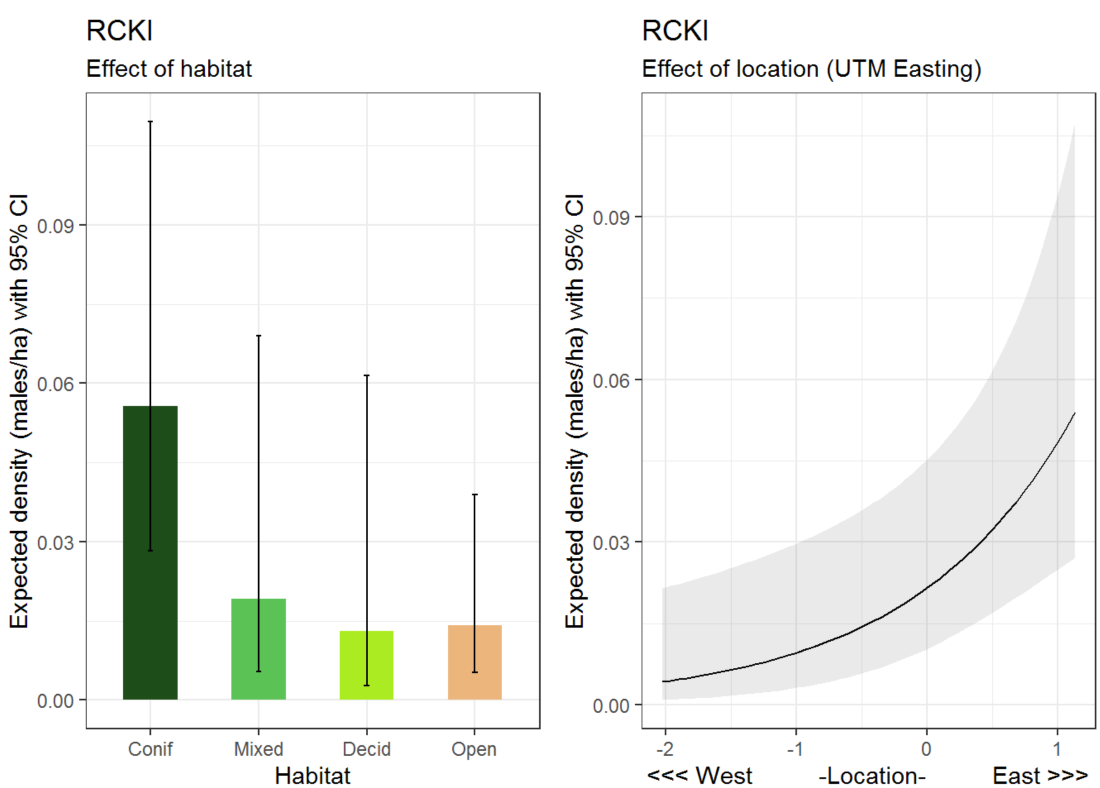

Figure 4-10. Ruby-crowned Kinglet Density Estimates

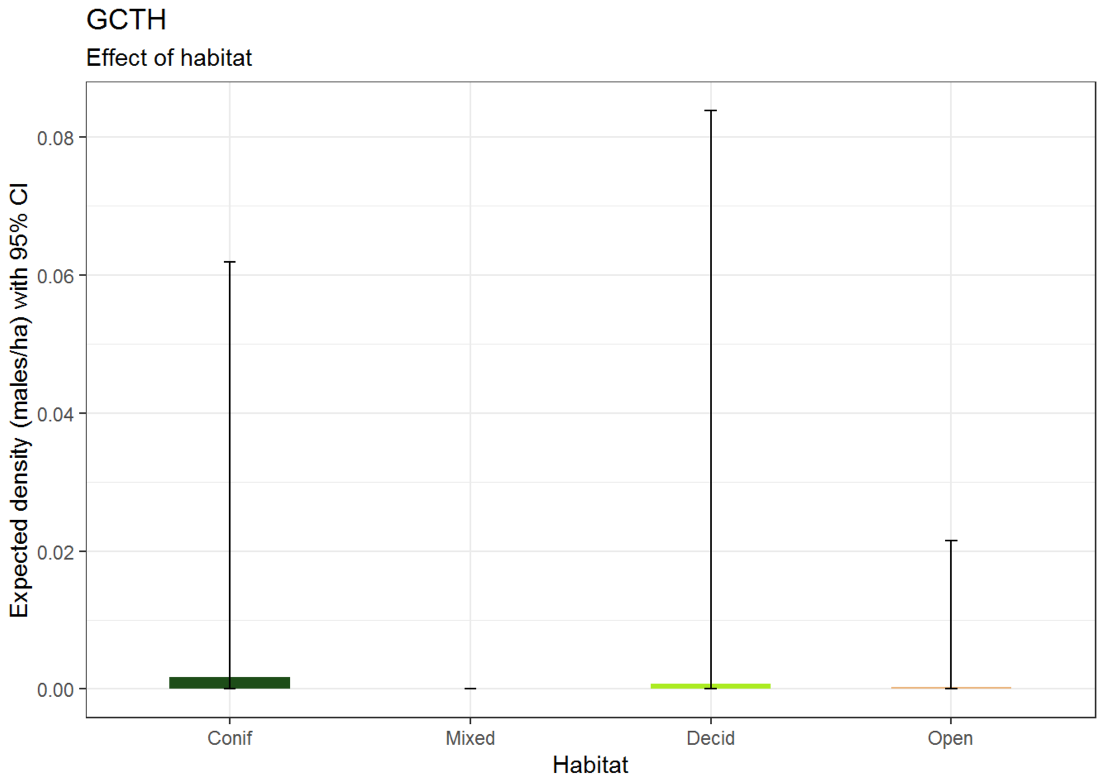

Figure 4-11. Gray-cheeked Thrush Density Estimates

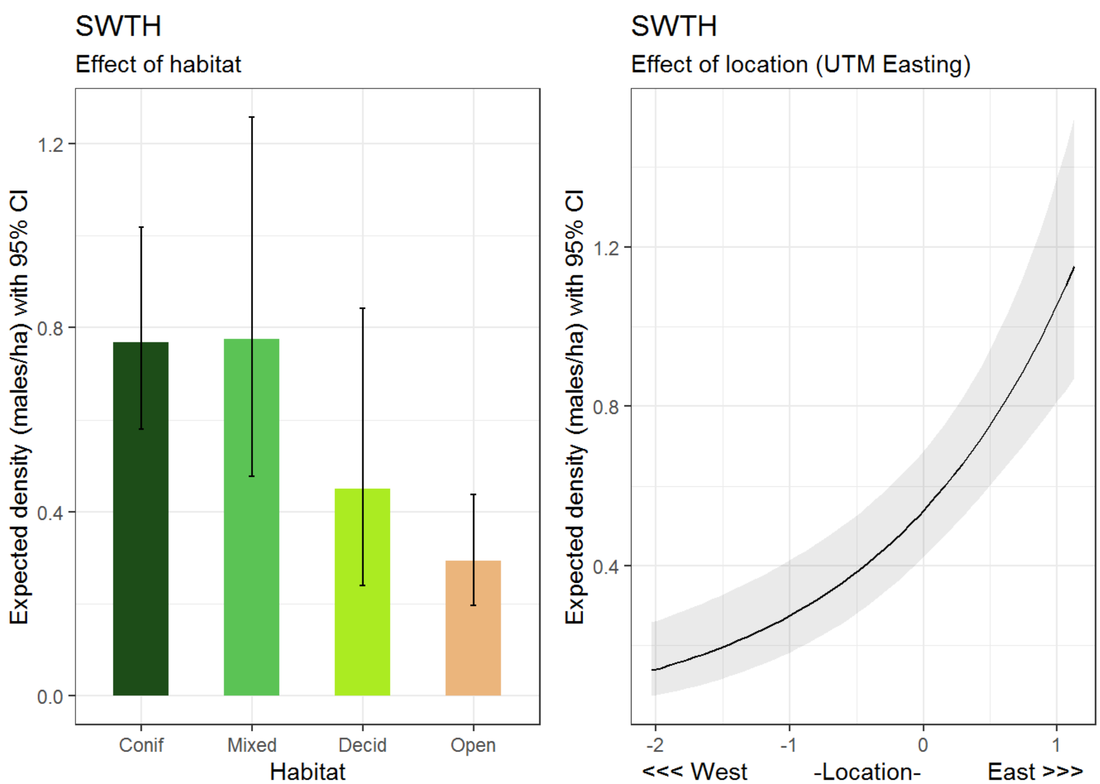

Figure 4-12. Swainson's Thrush Density Estimates

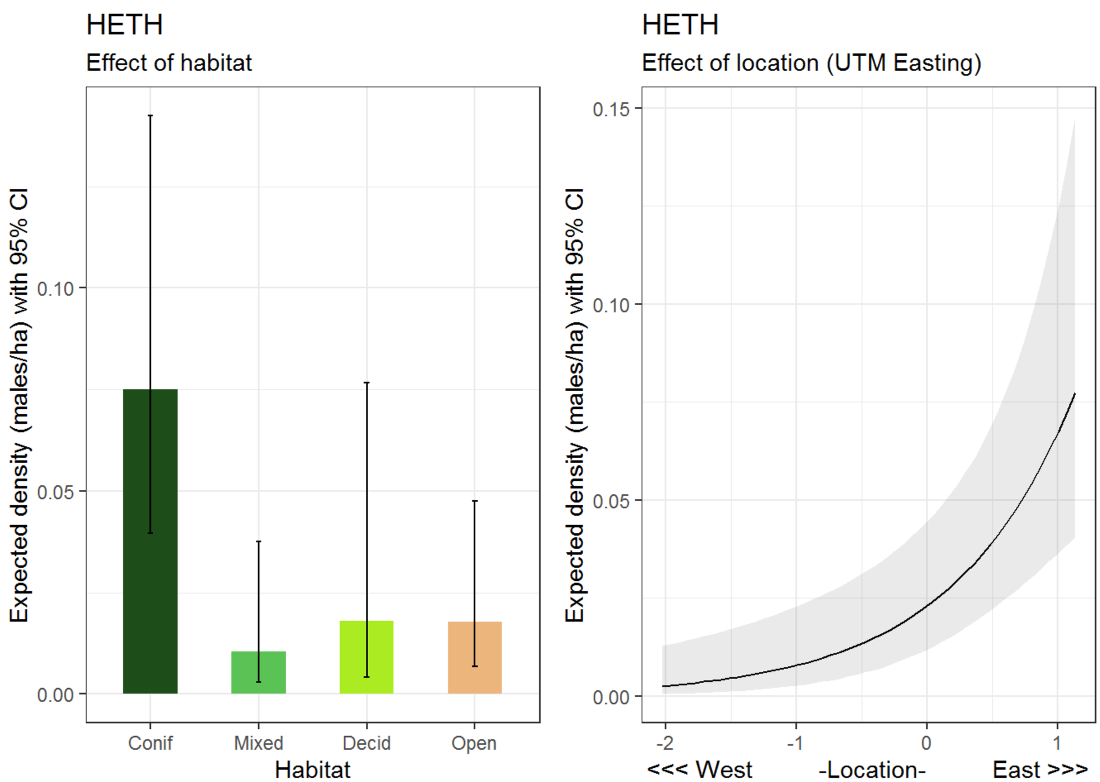

Figure 4-13. Hermit Thrush Density Estimates

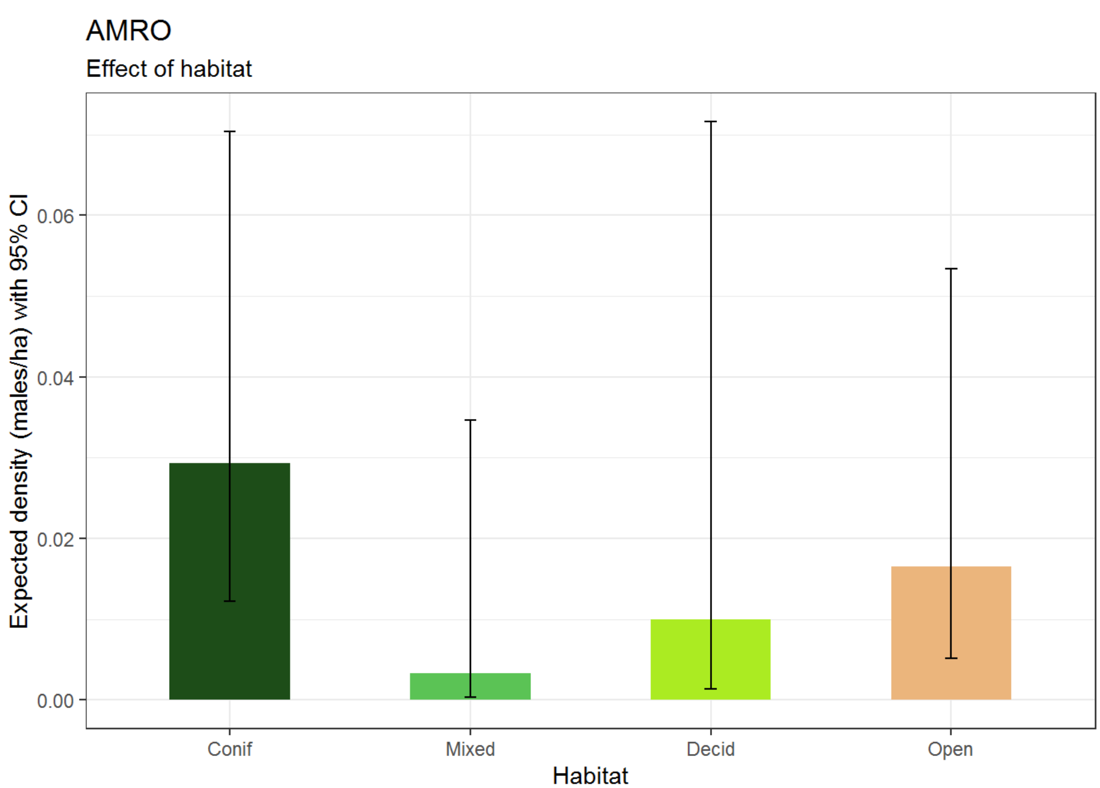

Figure 4-14. American Robin Density Estimates

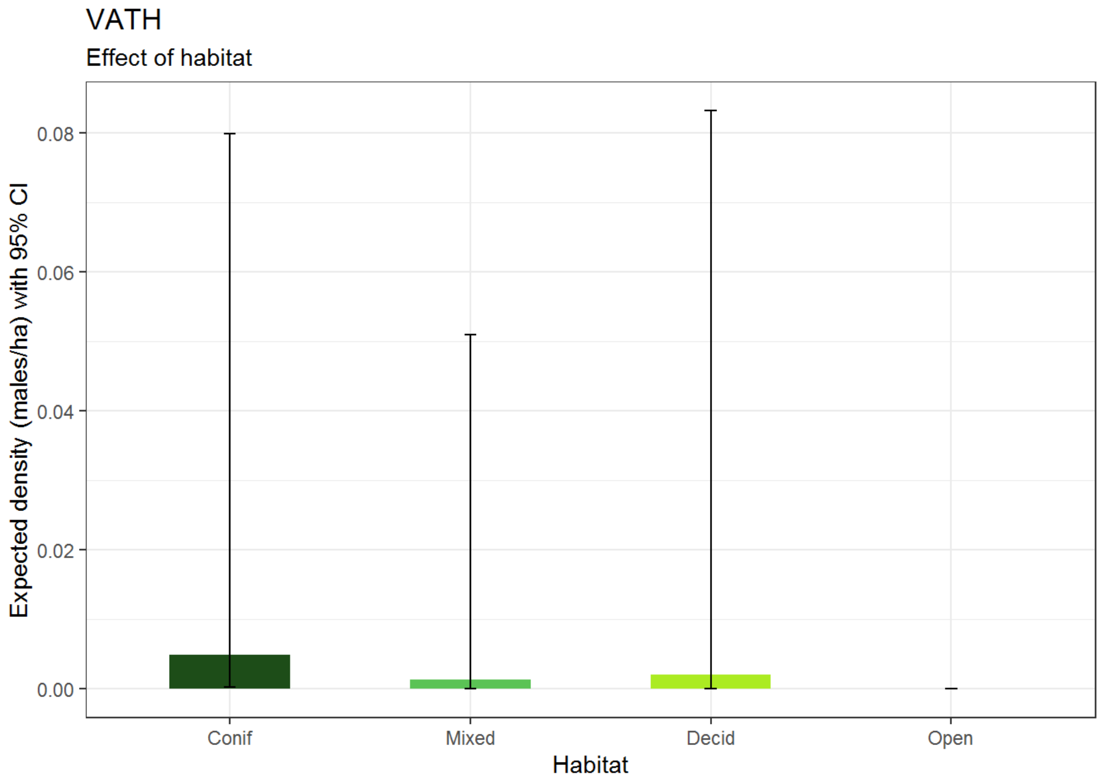

Figure 4-15. Varied Thrush Density Estimates

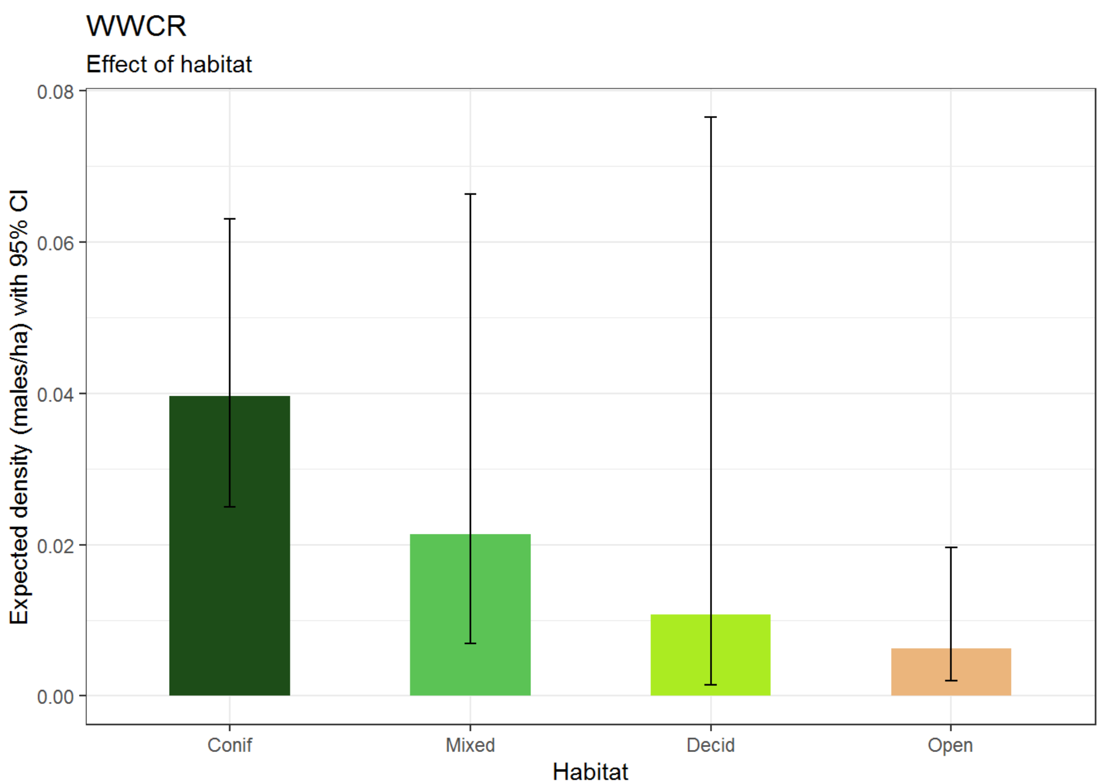

Figure 4-16. White-Winged Crossbill Density Estimates

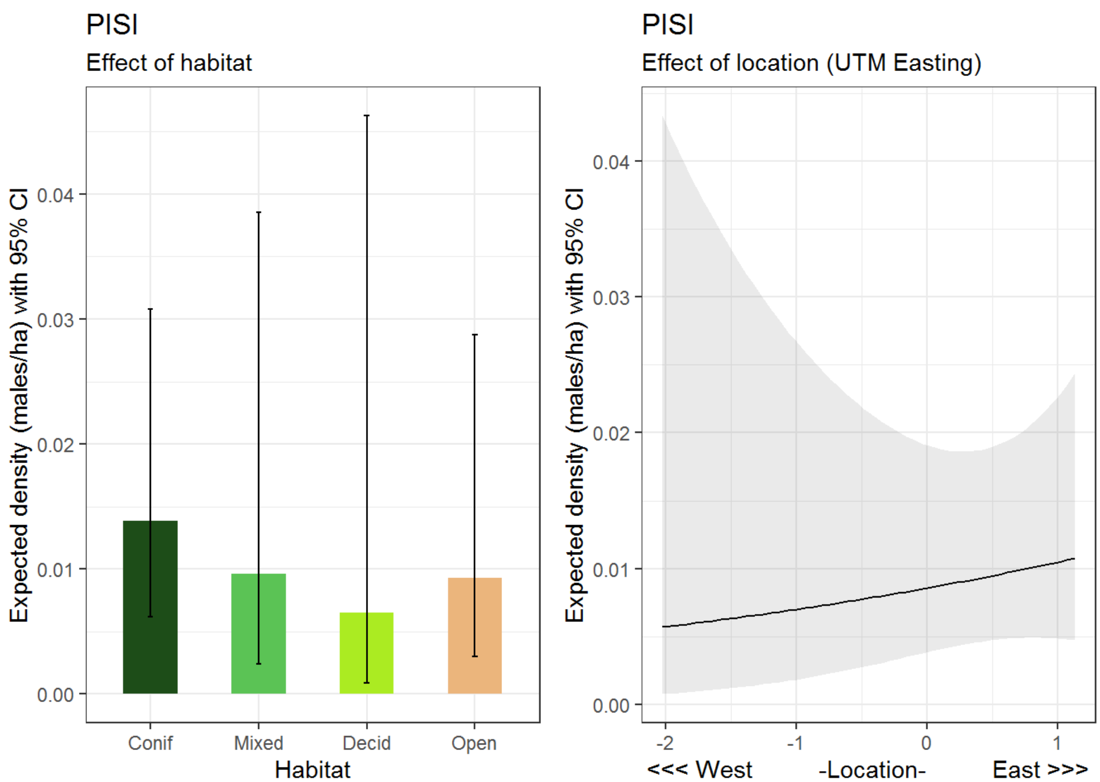

Figure 4-17. Pine Siskin Density Estimates

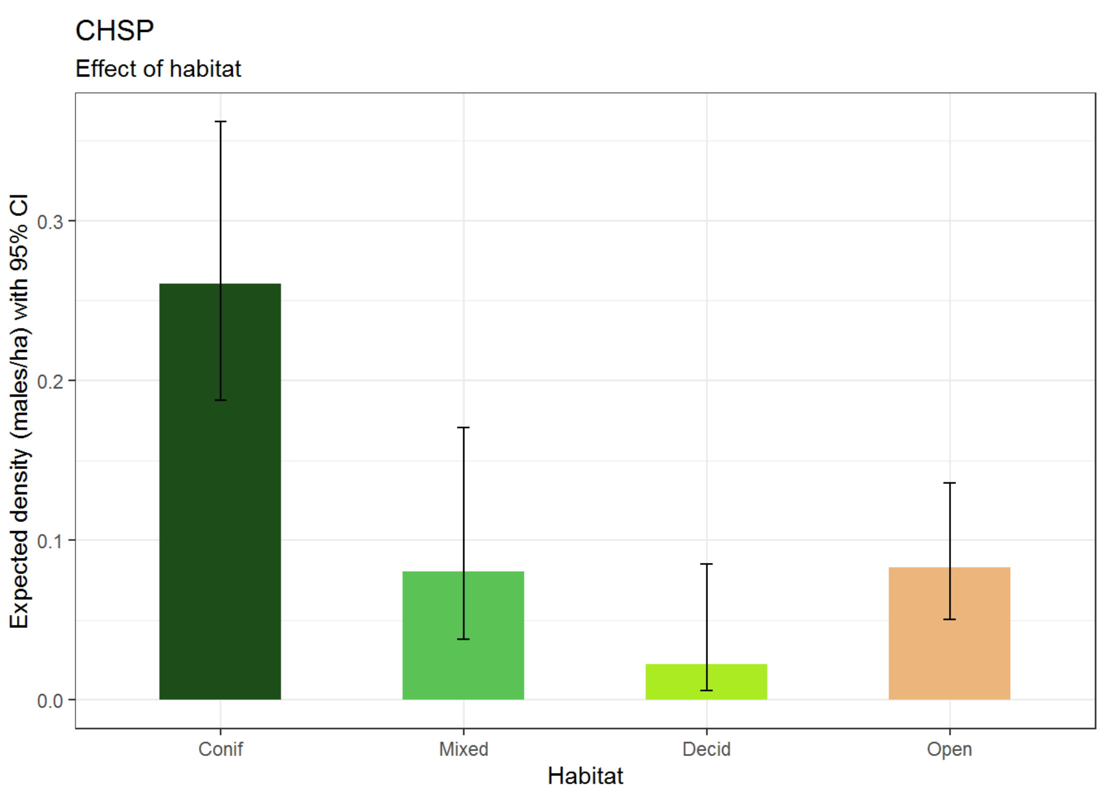

Figure 4-18. Chipping Sparrow Density Estimates

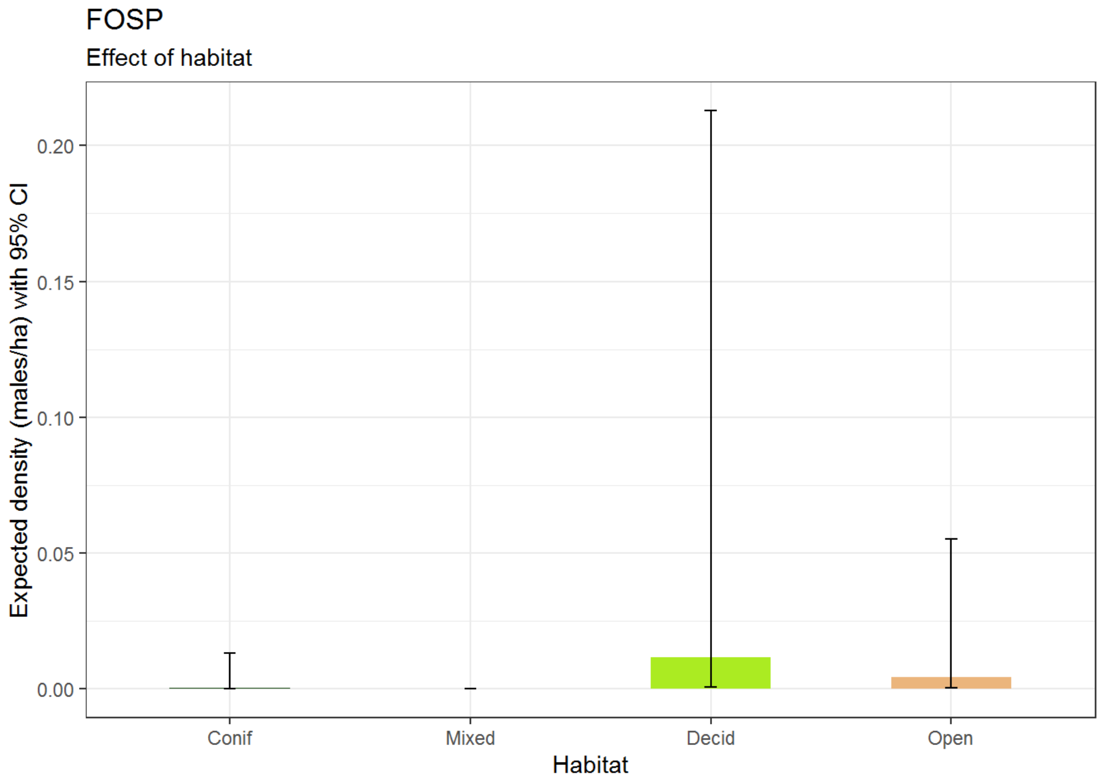

Figure 4-19. Fox Sparrow Density Estimates

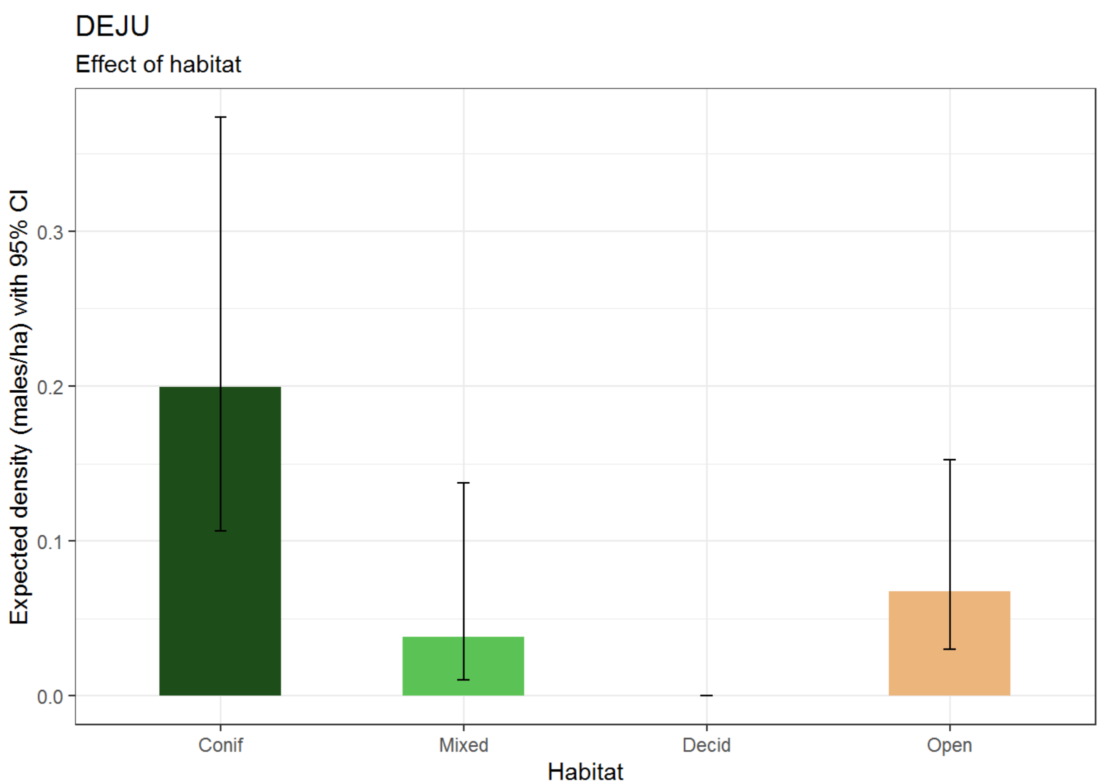

Figure 4-20. Dark-Eyed Junco Density Estimates

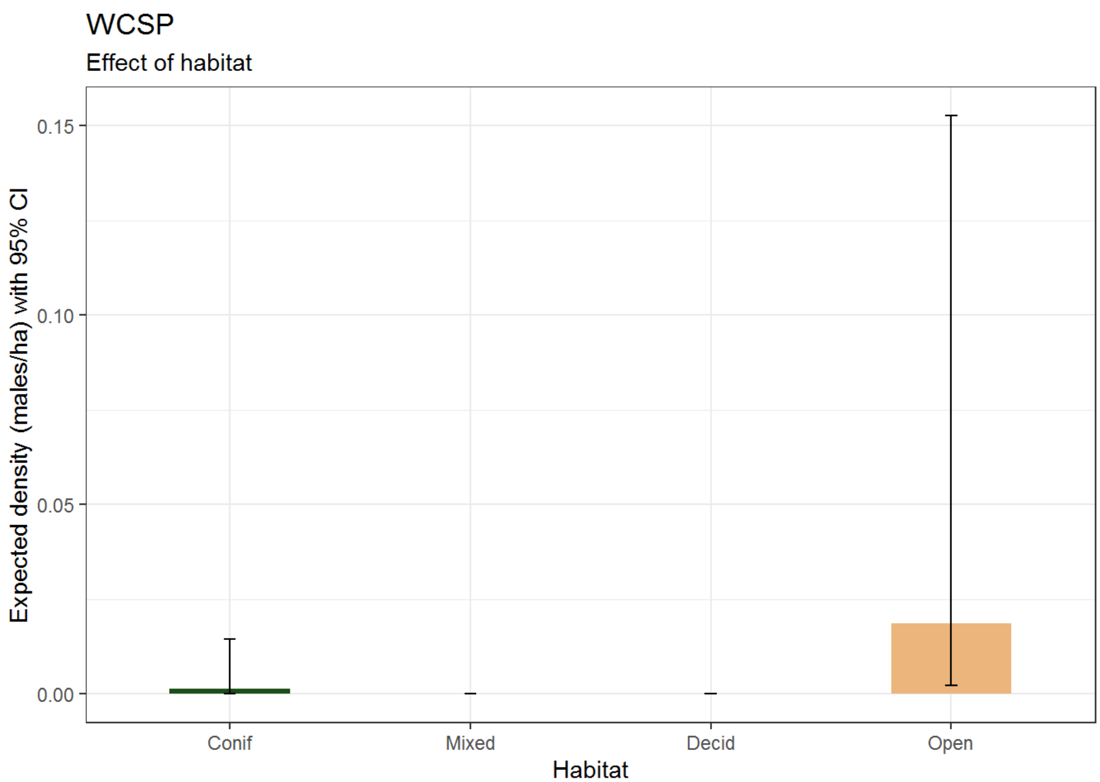

Figure 4-21. White-Crowned Sparrow Density Estimates

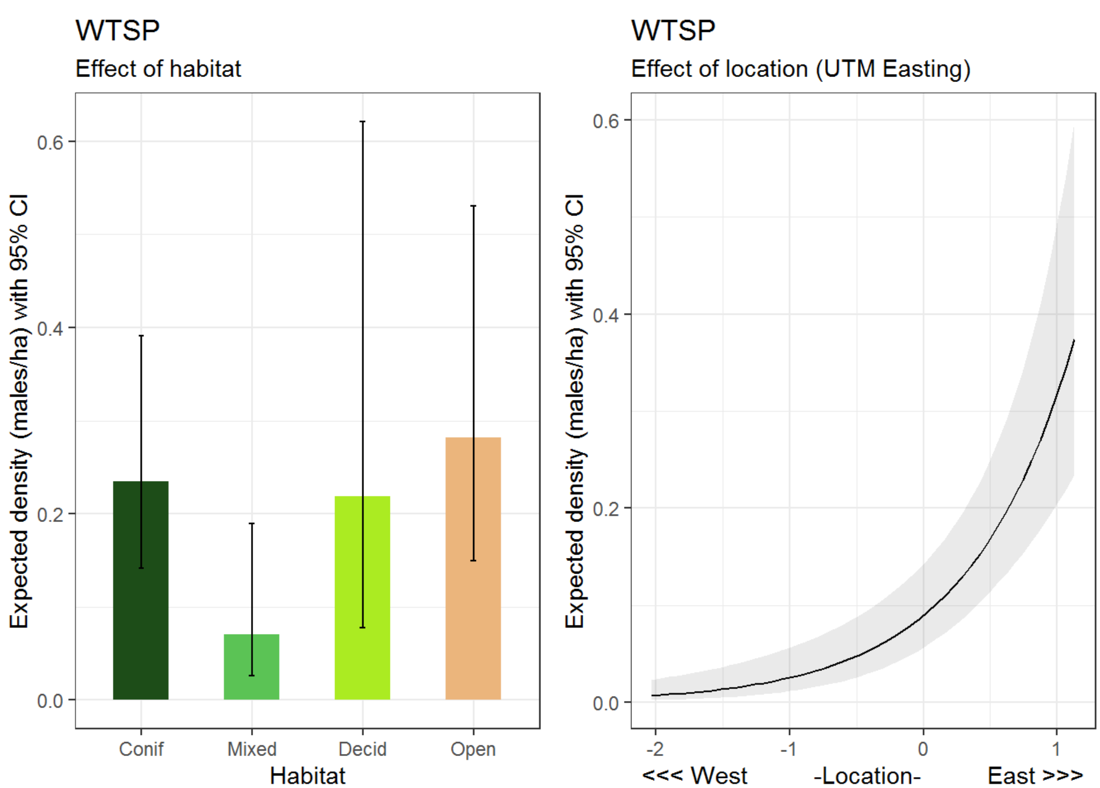

Figure 4-22. White-Throated Sparrow Density Estimates

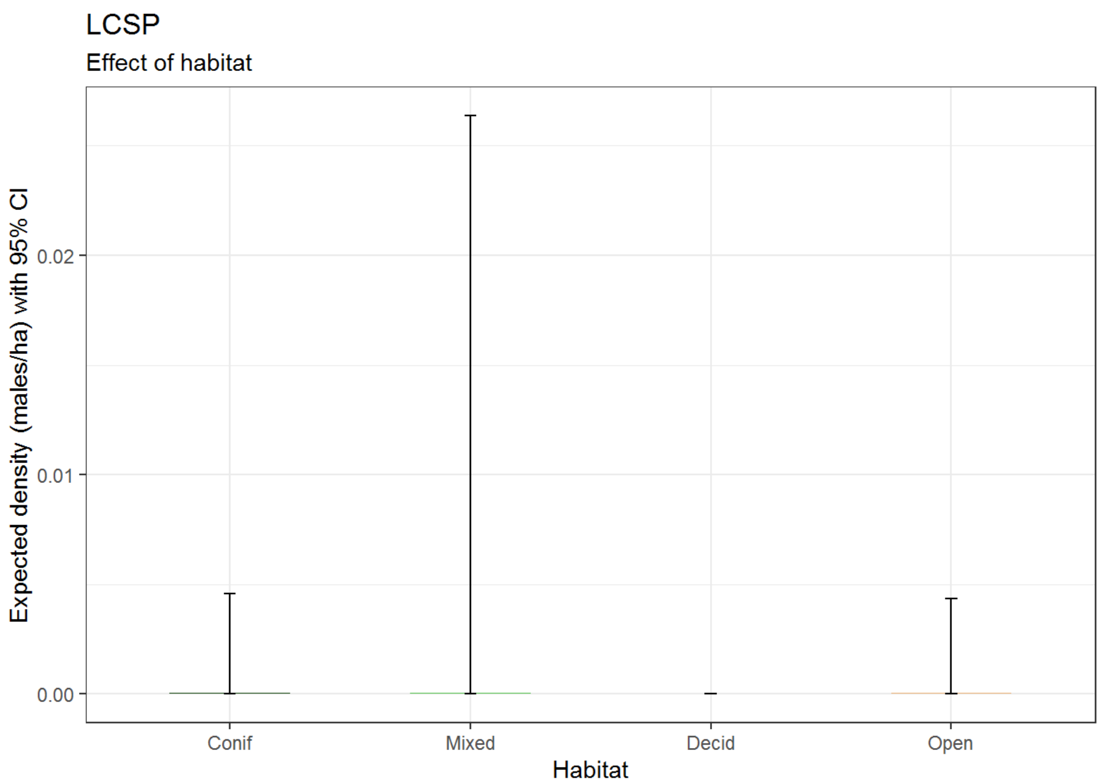

Figure 4-23. LeConte's Sparrow Density Estimates

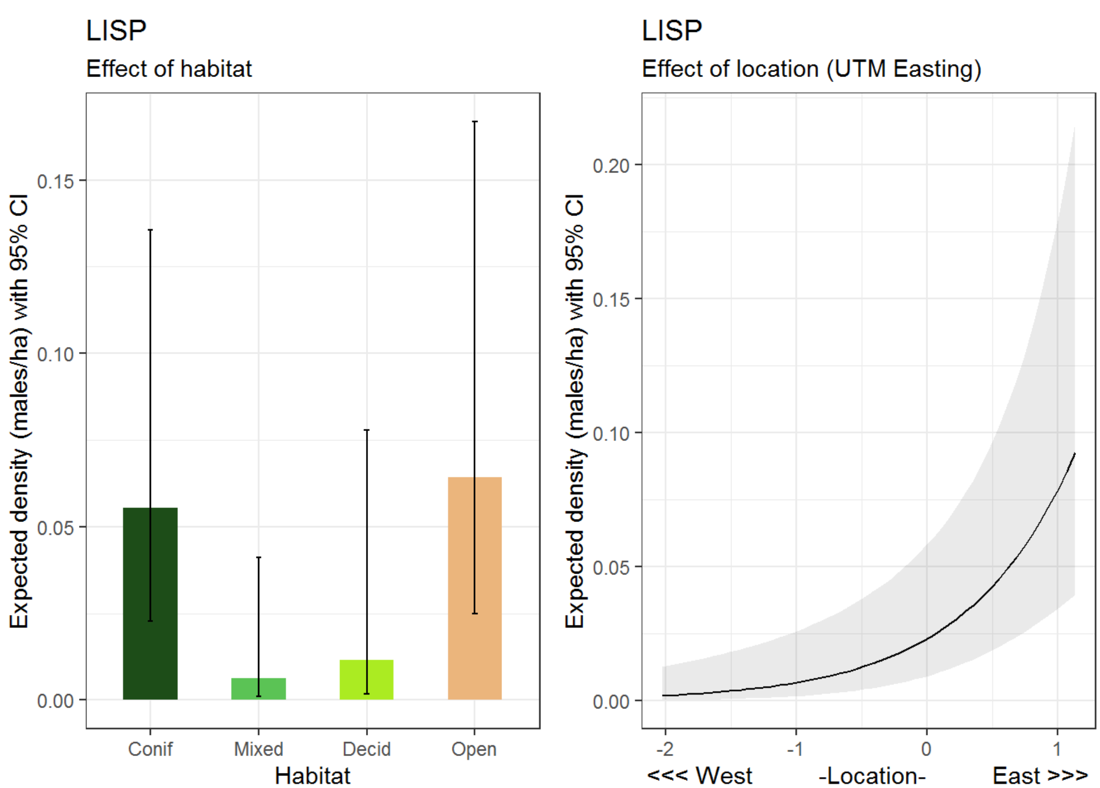

Figure 4-24. Lincoln's Sparrow Density Estimates

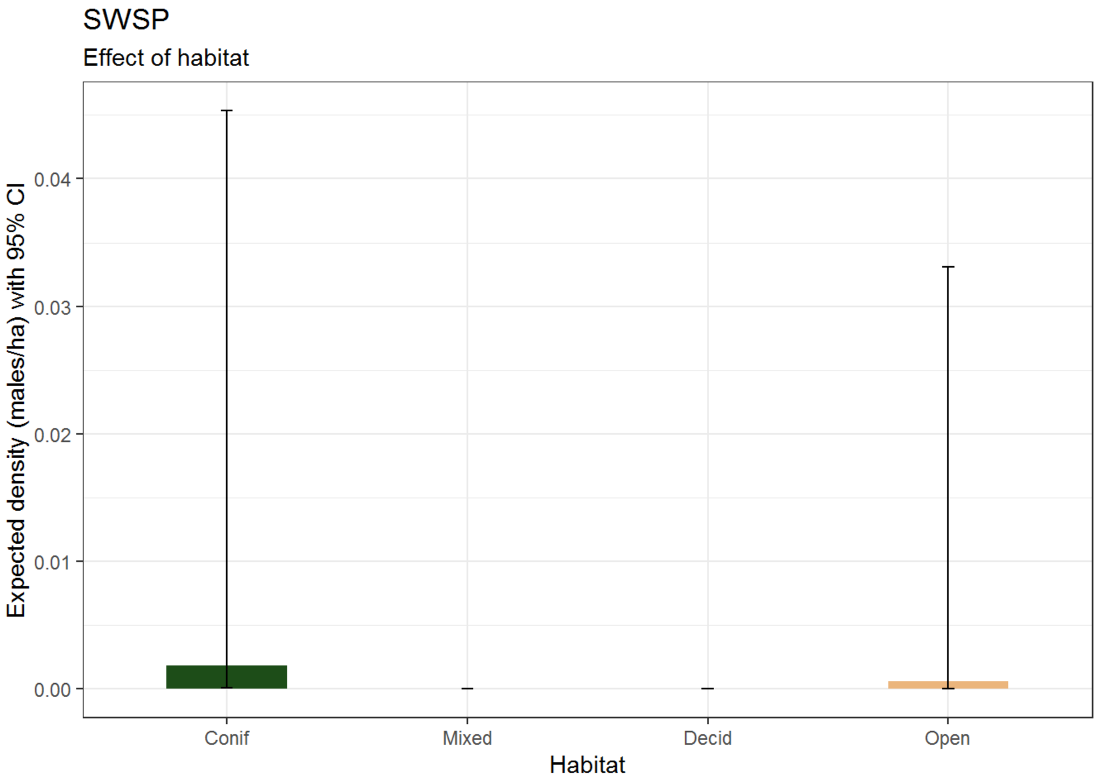

Figure 4-25. Swamp Sparrow Density Estimates

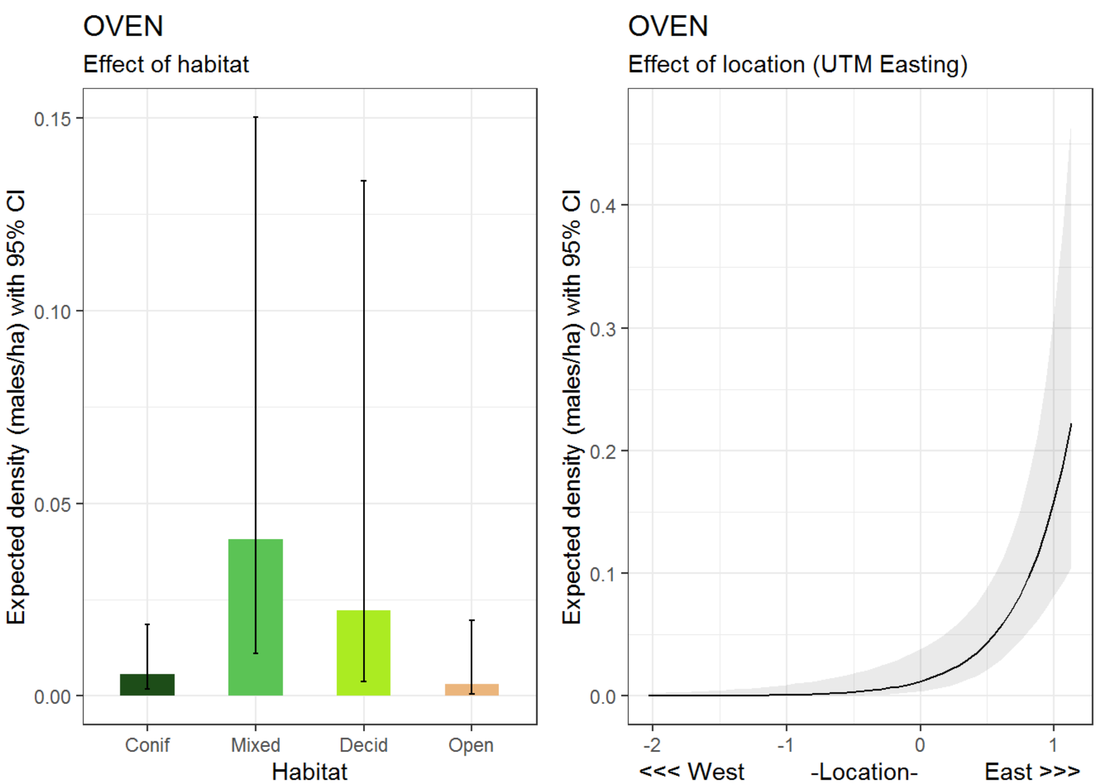

Figure 4-26. Ovenbird Density Estimates

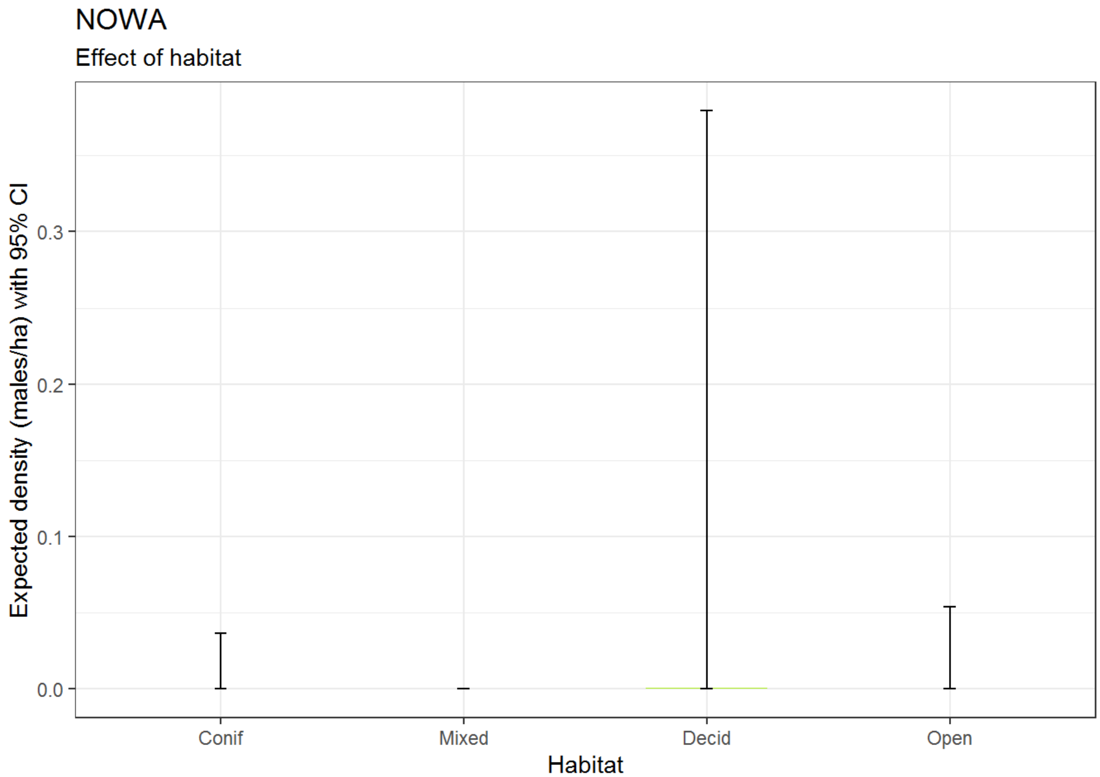

Figure 4-27. Northern Waterthrush Density Estimates

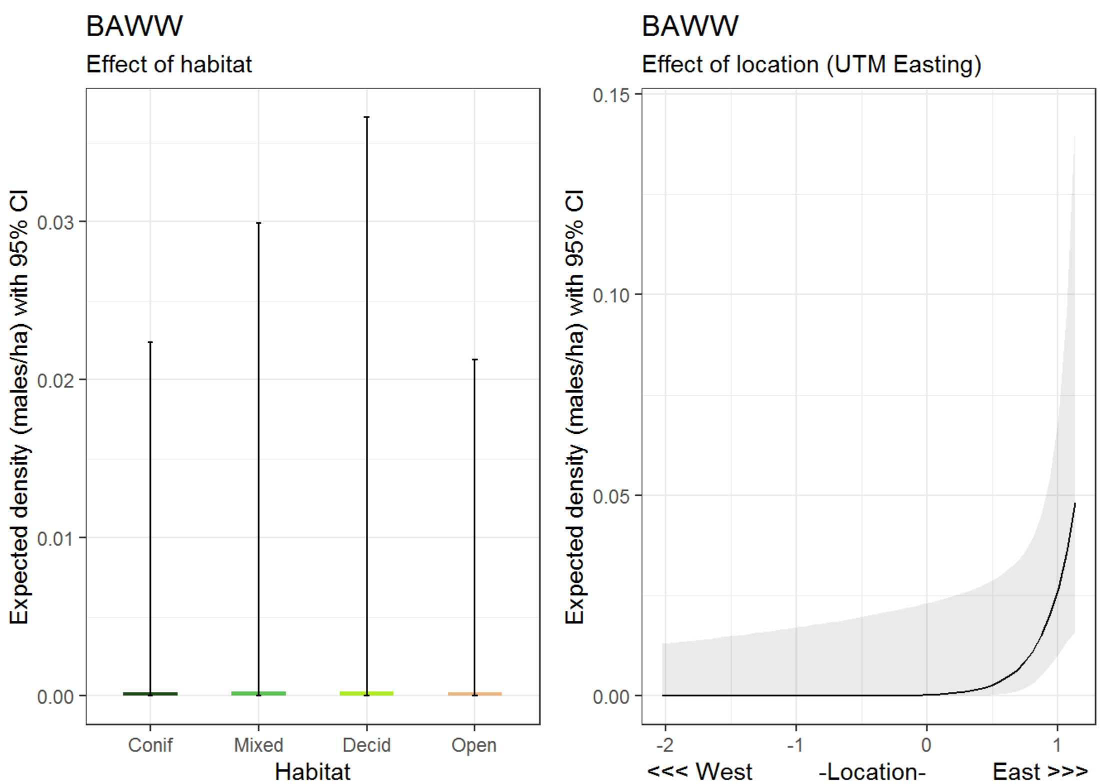

Figure 4-28. Black-and-white Warbler Density Estimates

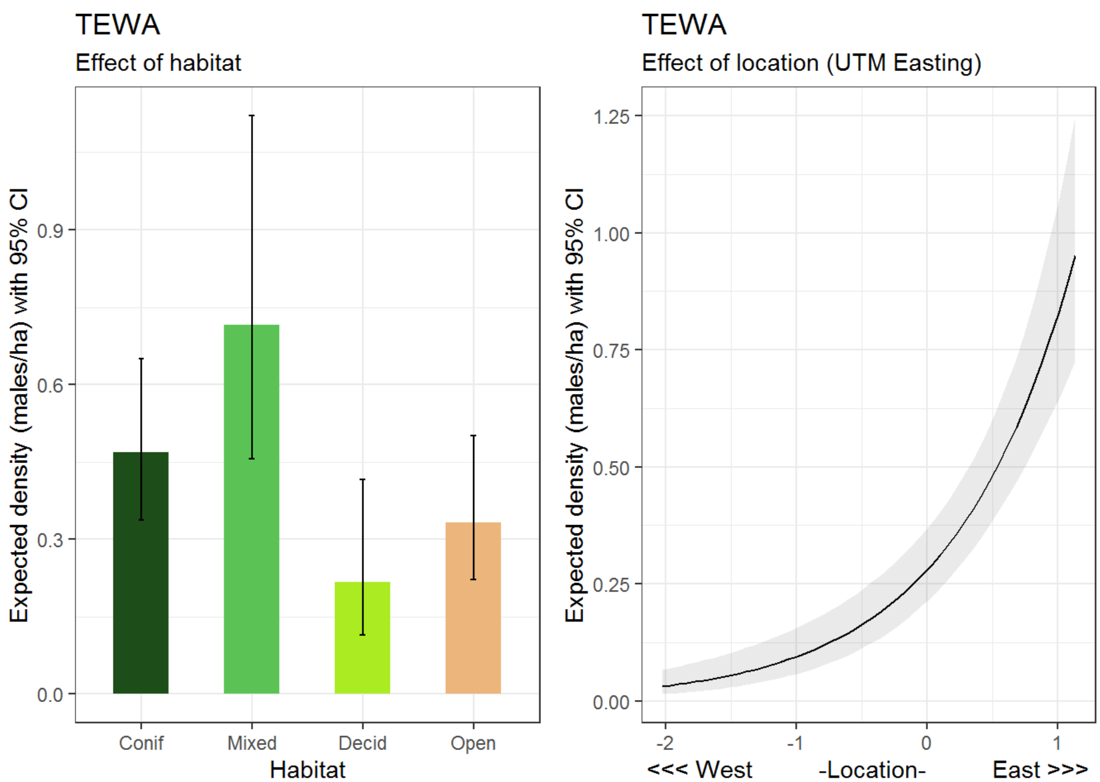

Figure 4-29. Tennessee Warbler Density Estimates

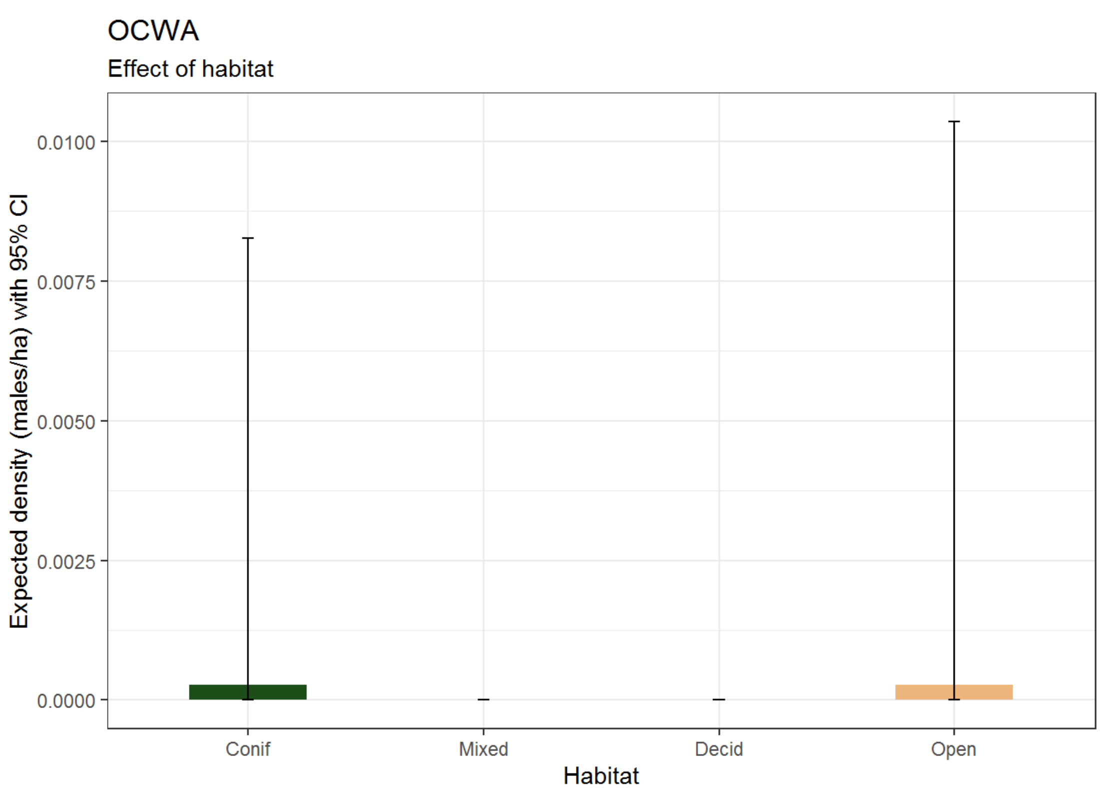

Figure 4-30. Orange-crowned Warbler Density Estimates

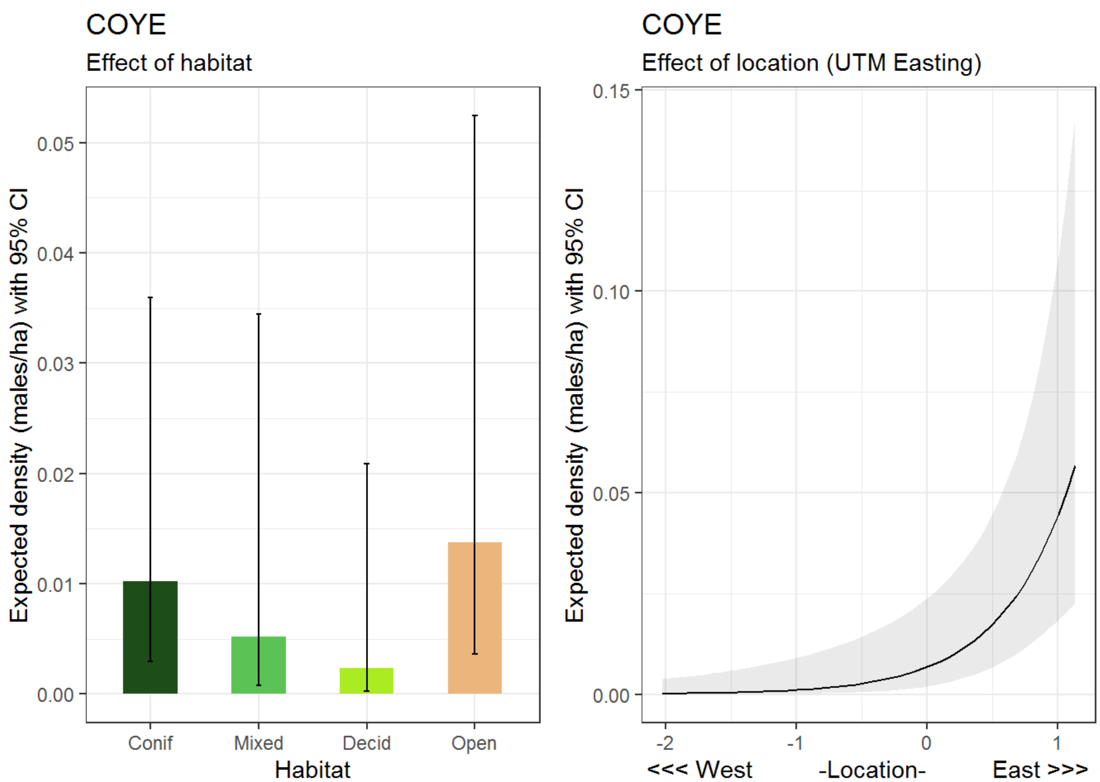

Figure 4-31. Common Yellowthroat Density Estimates

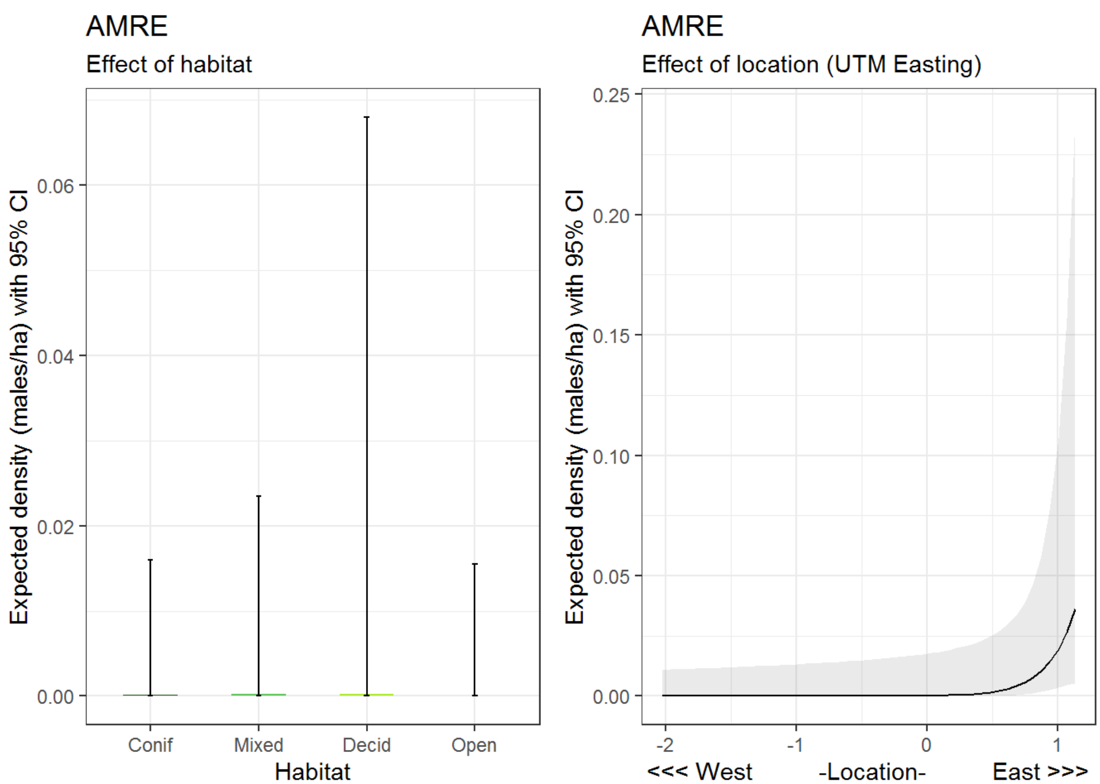

Figure 4-32. American Redstart Density Estimates

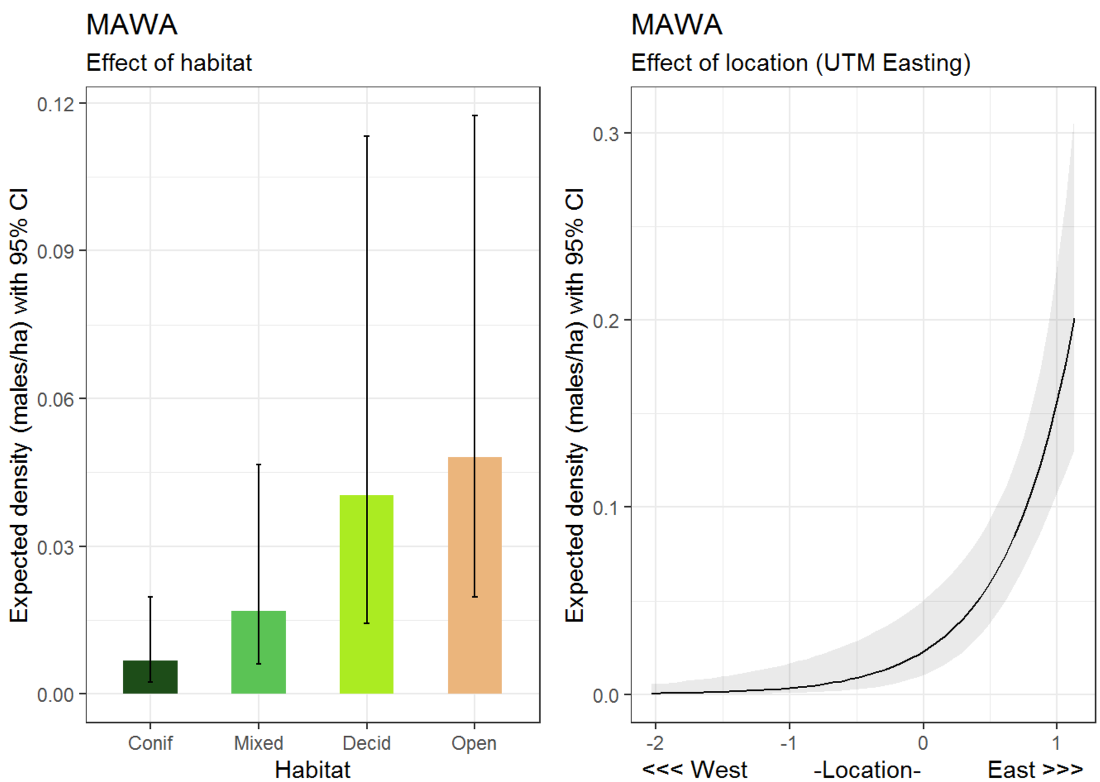

Figure 4-33. Magnolia Warbler Density Estimates

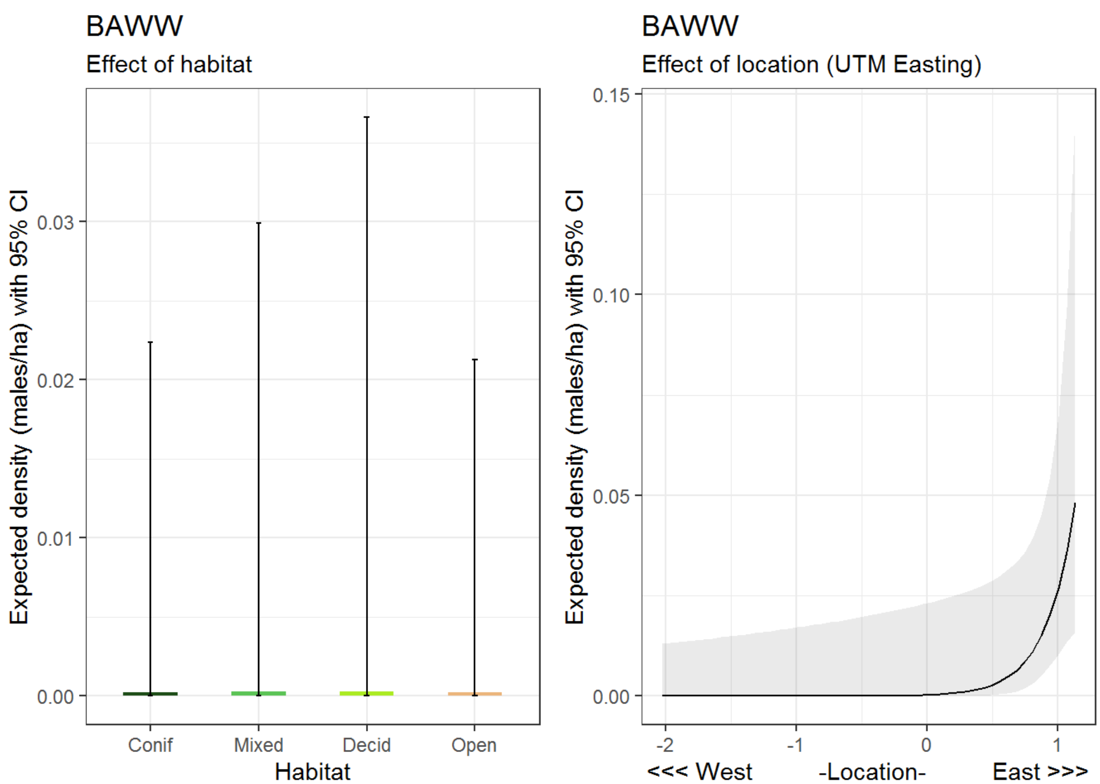

Figure 4-34. Bay-breasted Warbler Density Estimates

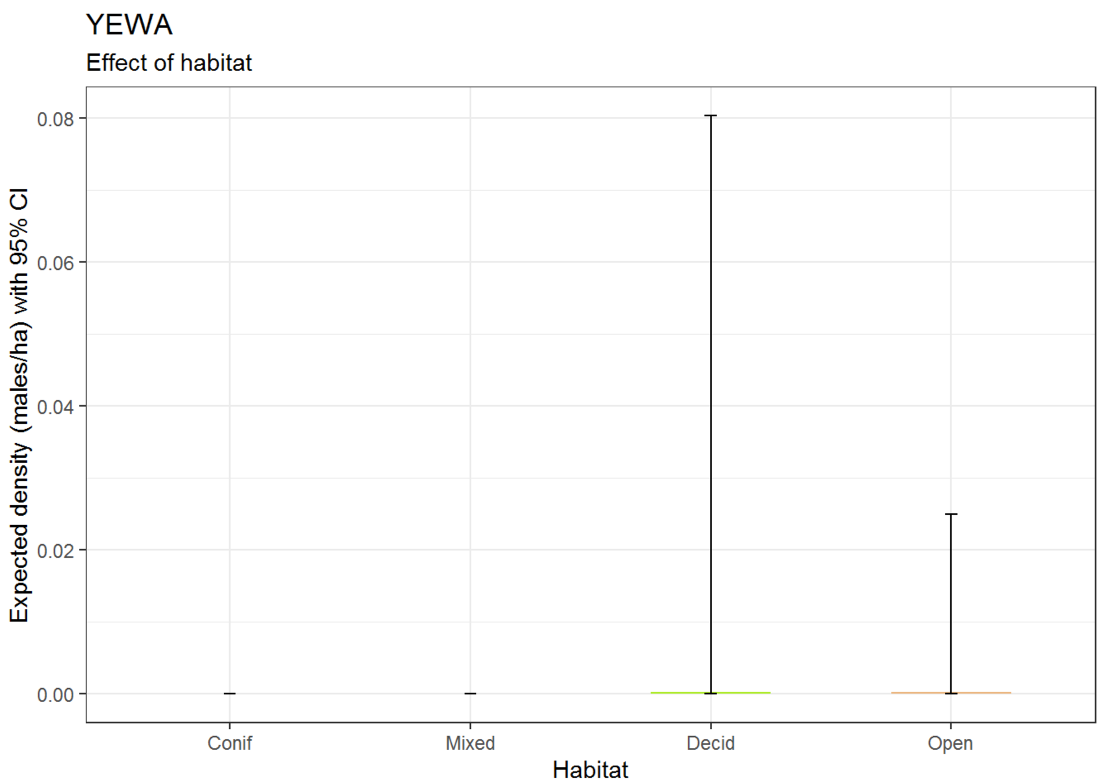

Figure 4-35. Yellow Warbler Density Estimates

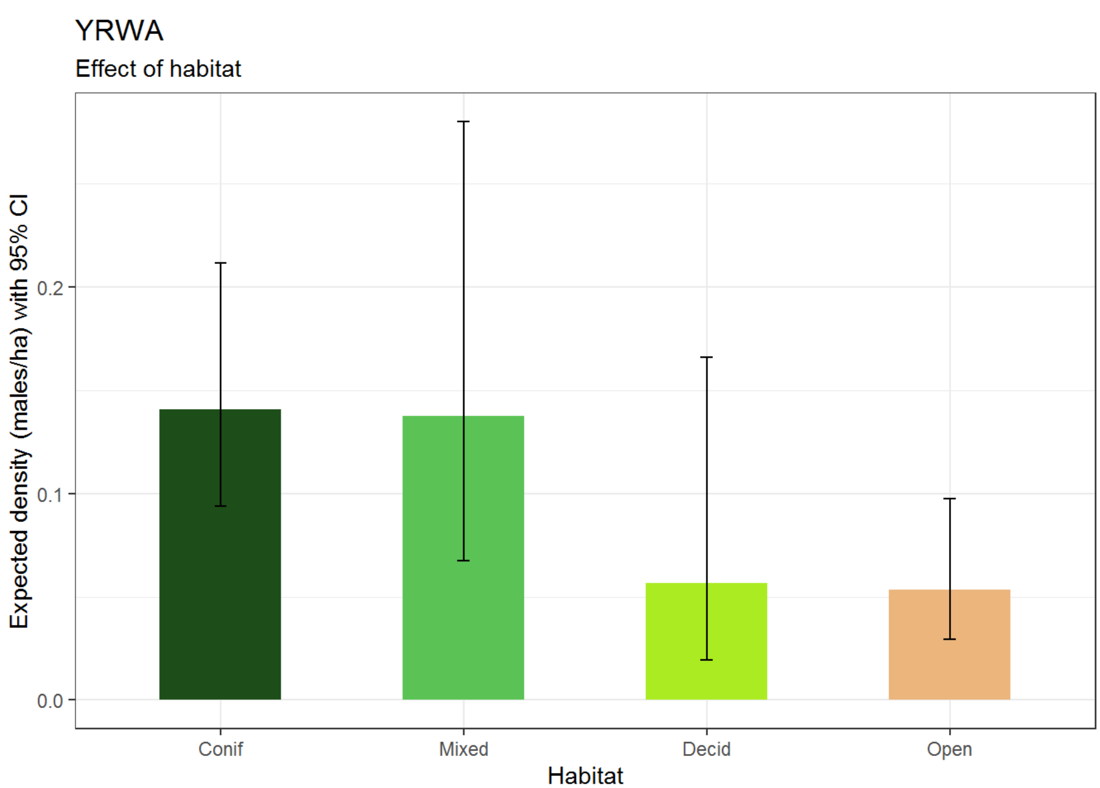

Figure 4-36. Yellow-rumped Warbler Density Estimates

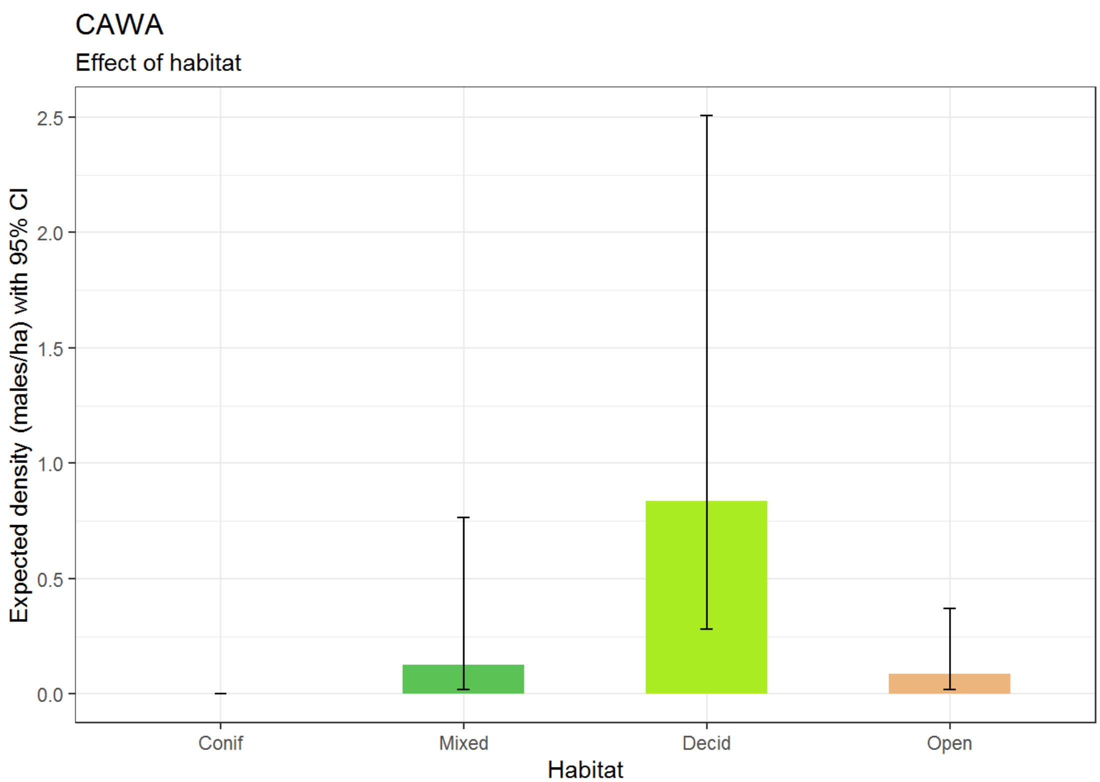

Figure 4-37. Canada Warbler Density Estimates

5.0 SPECIES DIVERSITY

5.1 Mean Species Richness

The top model to estimate mean species richness included Habitat, Easting, Julian Day, and Time Since Sunrise (see Appendix D for summary of the model output). Coniferous had the highest richness, followed by Open (Figure 5-1 and Table 5-1). There is a strong geographical gradient with species richness highest in the eastern portions of the surveyed area and decreasing to the west (Figure 5-1).

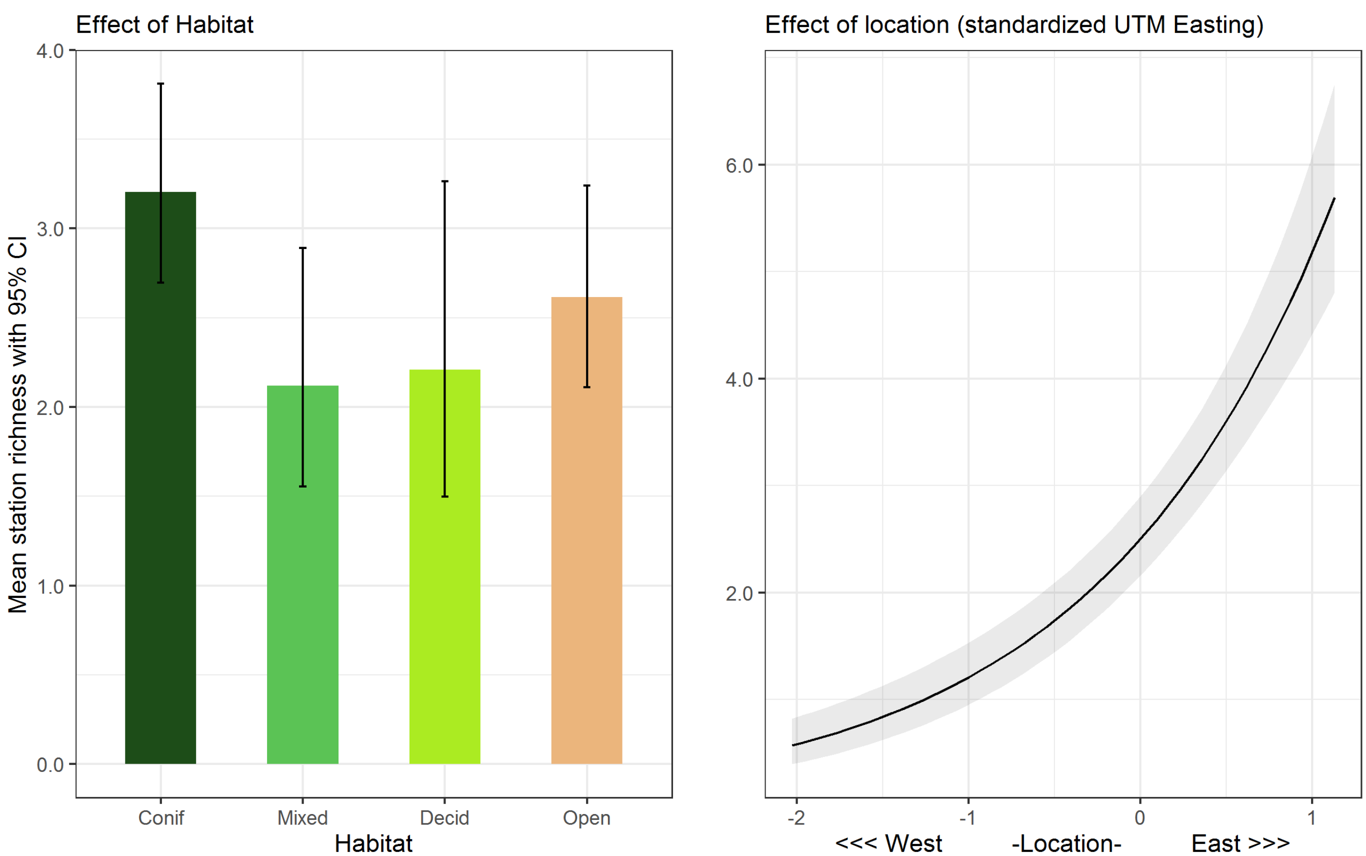

Figure 5-1. The Effects of Habitat and Location on Species Richness.
Each plot shows estimates of mean station richness when the other variable is held constant.

Table 5-1. Estimated Mean Species Richness by Habitat Per 3-Minute Sample

Habitat	Mean Species Richness (95% CI)
Coniferous	3.2 (2.7 - 3.8)
Mixed	2.1 (1.6 - 2.9)
Deciduous	2.2 (1.5 - 3.3)
Open	2.6 (2.1 - 3.2)

The marginal R^2 (the proportion of variance explained by fixed effects) was 0.407 (Appendix D, Table D.2) indicating 40.1% of the variability in density is explained by habitat and elevation.

5.2 Total Diversity

The total number of species detected during morning surveys (02:00 onward) and excluding waterbirds and diurnal birds of prey was 66. Analysis using rarefaction and extrapolation of species richness (Figure 5-2) predicts that there were additional species present that were undetected. The estimate of species richness when the extrapolated portion of the rarefaction curve reaches an asymptote is 70.9 (70.0 - 90.7 95% CI).

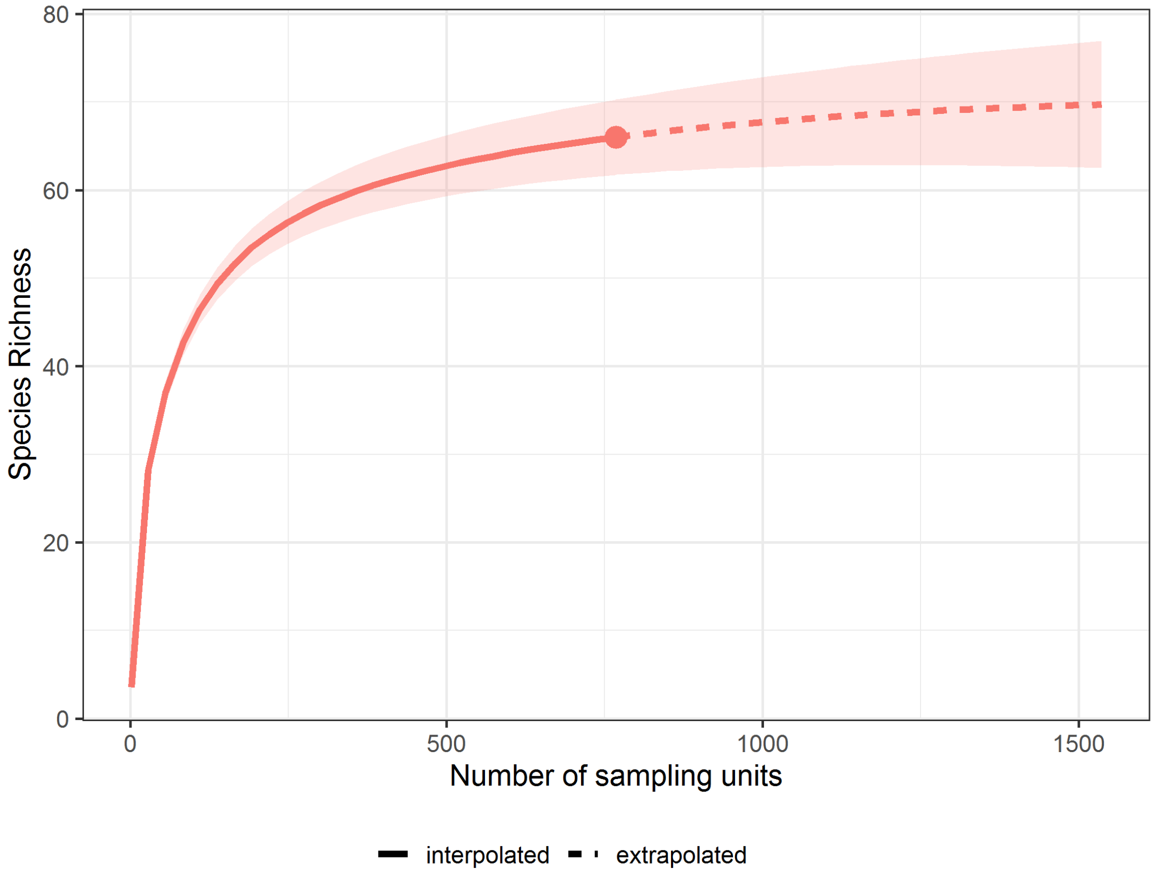

Figure 5-2. Estimated Species Richness with 95% Confidence Intervals at Various Levels of Sampling Intensity using Rarefaction.

Rarefaction curves for species richness, Shannon diversity, and Simpson diversity were compared across habitats (Figure 5-3 and Table 5-2). More species were observed in Coniferous habitat (54, n = 36) than in Open habitats (49, n = 24) and many more than in Deciduous (38, n = 7) and Mixed (35, n = 11). Rarefaction and extrapolation indicates that Coniferous and Open habitats would have about the same number of species detections if there was equal sampling (Figure 5-4). Shannon and Simpson diversity indices show a somewhat different pattern than species richness: Open has much higher diversity than all other habitats. This can be interpreted as this habitat type having more even occurrence of a larger number of species across sites when compared to other habitats. This pattern is the same for both observed and estimated measures.

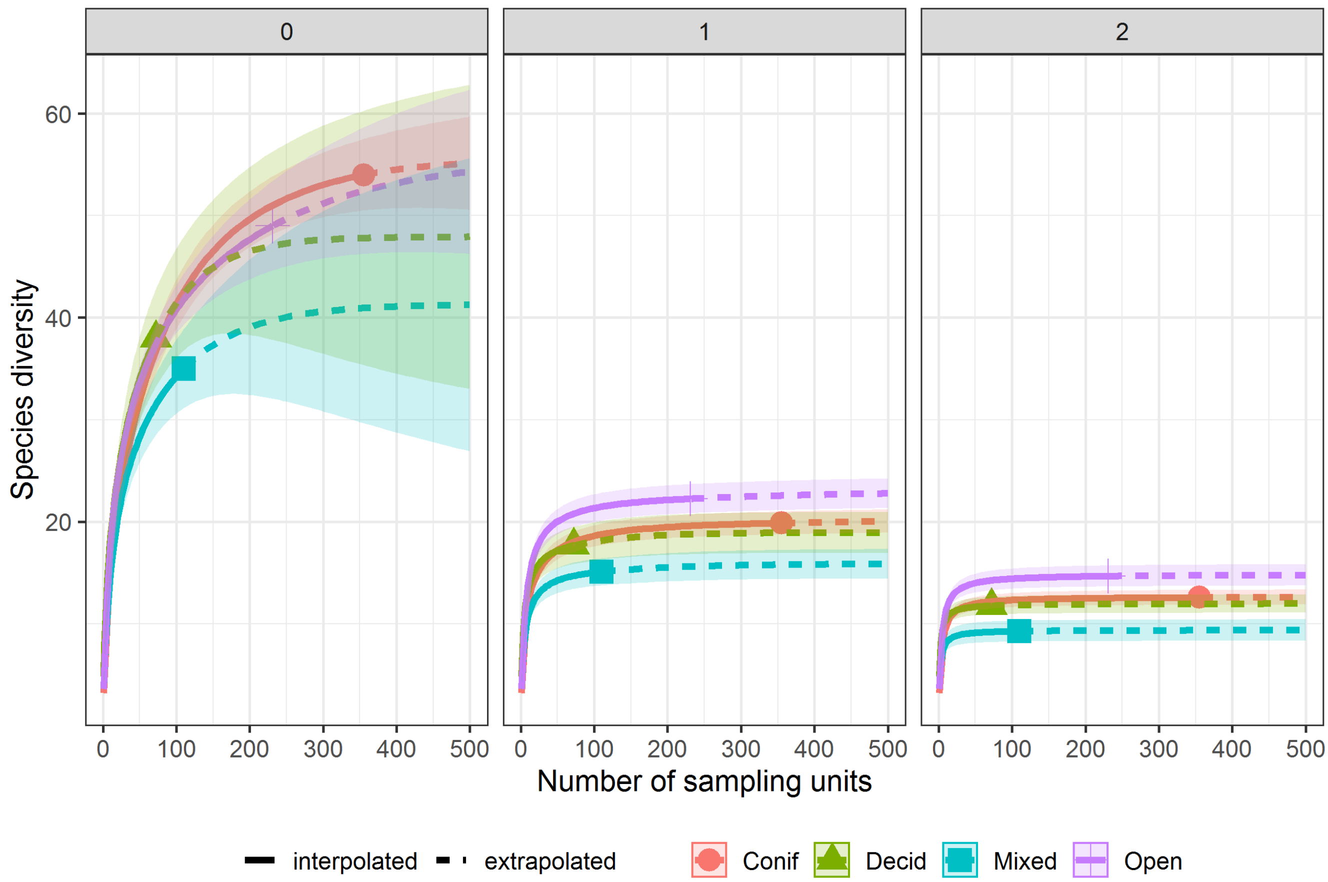

Figure 5-3. Species Diversity According to Hill Number using Rarefaction, with 95% confidence intervals. Hill number 0 (first panel) is species richness. Hill numbers 1 and 2 are Shannon diversity and Simpson diversity respectively, both expressed as effective number of species. Higher Hill numbers have decreasing sensitivity to rare species.

Table 5-2. Observed and Estimated Measures of Species Diversity

Diversity Measure	Method	Diversity (95% confidence intervals)			
		Coniferous	Mixed	Deciduous	Open
Richness	Observed	54	35	38	49
	Estimated	55.6 (54.2-64.4)	41.3 (36.4-64.7)	47.9 (40.5-77.2)	55.7 (50.5-78.3)
Shannon Diversity	Observed	19.9	15.1	17.7	22.3
	Estimated	20.4 (19.9-21.7)	15.9 (15.1-17.4)	18.9 (17.7-21.0)	23.0 (22.3-24.5)
Simpson Diversity	Observed	12.6	9.3	11.8	14.7
	Estimated	12.7 (12.6-13.5)	9.4 (9.3-10.4)	12.0 (11.8-13.2)	14.9 (14.7-16.1)

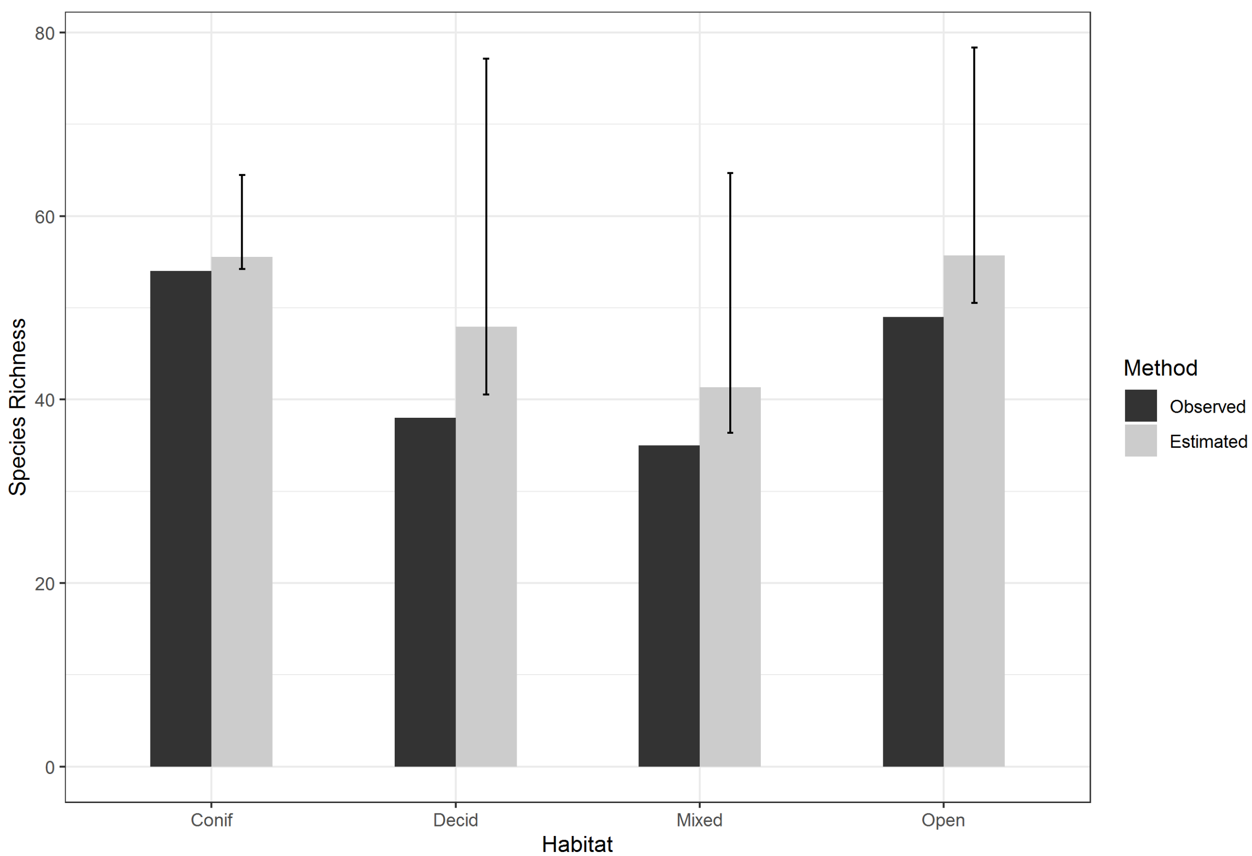

Figure 5-4. Comparison of Observed Total Richness with the Asymptotic Estimate of Richness using Rarefaction

6.0 COMPARISON OF FOOTPRINT AREA TO REGION

Most species have similar estimated mean densities within the footprint, in the local area (within 100 m of the road), and the region (within 10 km of the road) (Figure 6-1). Canada Warbler (CAWA), Fox Sparrow (FOSP) and Ovenbird (MAWA) have the largest apparent difference with estimated density higher in the footprint and the local area compared to the region (+29%, +15% and +11.5% respectively). Confidence intervals are not shown in Figure 6-1 though were calculated and are provided in Appendix E [2]. The confidence intervals for each study area overlap the means of the other study area for all species. While this cannot be used to determine significant differences, it does indicate that confidence in observed differences is low. In the absence of more precise estimates, a precautionary approach is followed for recommendations relating to potential project effects. For species where mean density is higher within the ASR footprint and adjacent areas relative to the region, the loss of habitat may be considered disproportionately higher relative to the region as a whole. The reverse scenario also applies. For species where mean density is lower within the ASR footprint and adjacent areas compared to the region, the loss of habitat may be considered disproportionately lower, as species density is higher in areas away from the ASR.

[2] The confidence intervals are not shown in Figure 6-1 for clarity: their large range would require a scale on the y-axis that would inhibit the ability to observe differences in the mean values among the three study areas.

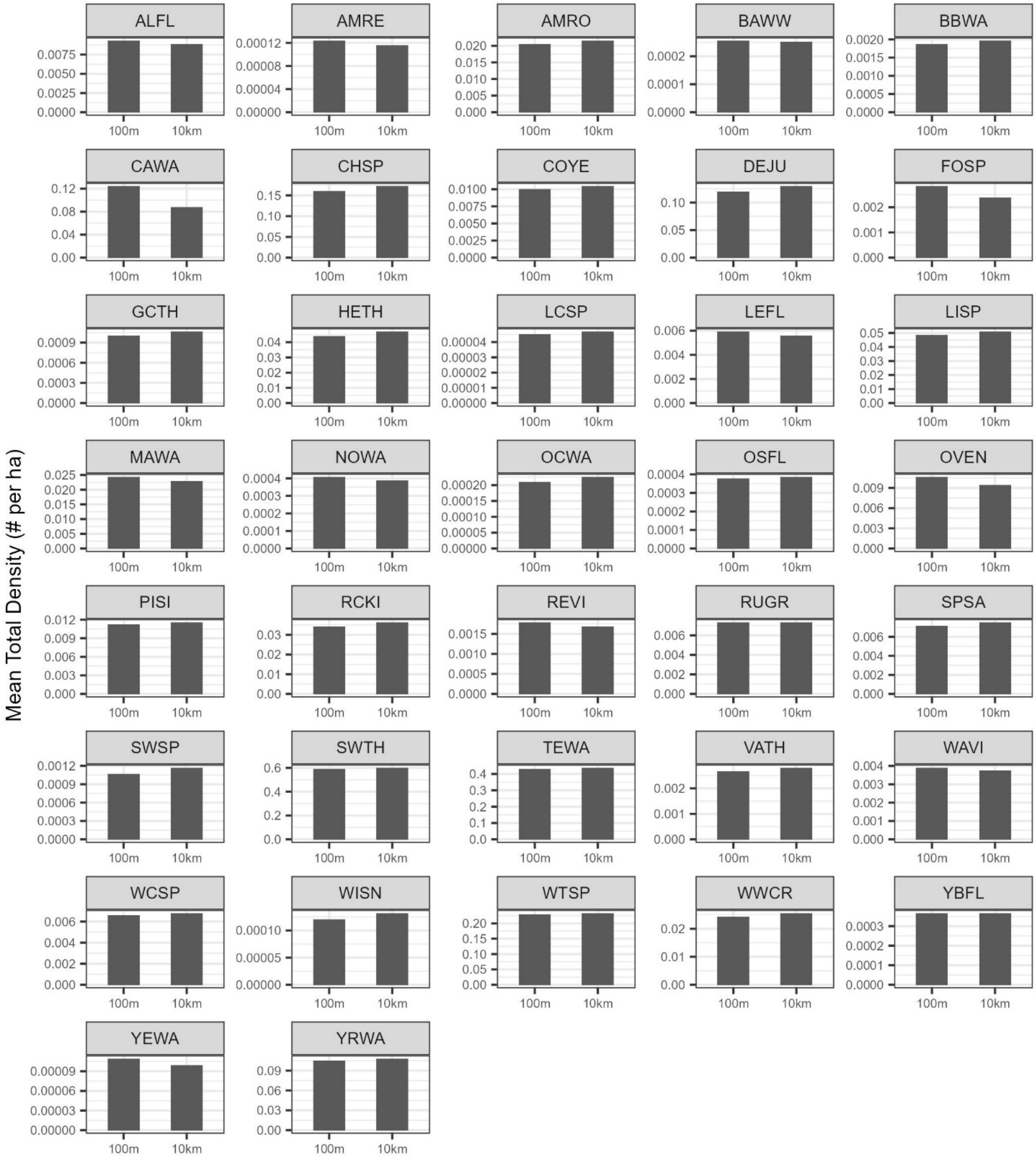

Figure 6-1. Predicted Mean Species Density (number per hectare) for the Footprint Area (within 100m of the road) and the Region (within 10 km of the road).

See Appendix E for confidence intervals and common names for species code.

7.0 ANALYSIS OF POWER TO DETECT CHANGE

The estimated number of survey stations required to achieve 80% power to detect -20% change varies widely by bird community and species metric (Figures 7-1 to 7-6). A -20% change in mean species richness, mean total abundance, Swainson's Thrush density (detected at 81% of stations) and Magnolia Warbler density (detected at 35% of stations) could be detected within 3-5 years with as few as 40 survey stations. Ovenbird (Figure 7-5) was detected at close to the same number of stations (39%) as Magnolia Warbler though a -20% change would not be detected for up to eight years and with at least 60 survey stations. For selected species where it would take longer than ten monitoring years to detect -20% effect size (Least Flycatcher, Olive-sided Flycatcher, and Canada Warbler, the power simulation was also conducted using -50% effect size and extended to 20 years. A -50% change in Least Flycatcher density (detected at 18% of stations) could be detected after seven monitoring years with 80 survey stations. A -50% change in Olive-sided Flycatcher and Canada Warbler densities (both detected at 14% of stations) are not predicted to be detected, even with 20 years of monitoring with up to 80 survey stations.

These results are predictions and the true power to detect change would be known with additional data collection. The power analyses conducted here assumes the same sampling strategy would be used in future surveys as was used for the baseline. A different survey strategy that is focussed on species of management concern (i.e., listed species) or other non-listed indicator species may allow for detection of change in shorter time periods and with greater power. Future monitoring is described in the Wildlife Management and Monitoring Plan.

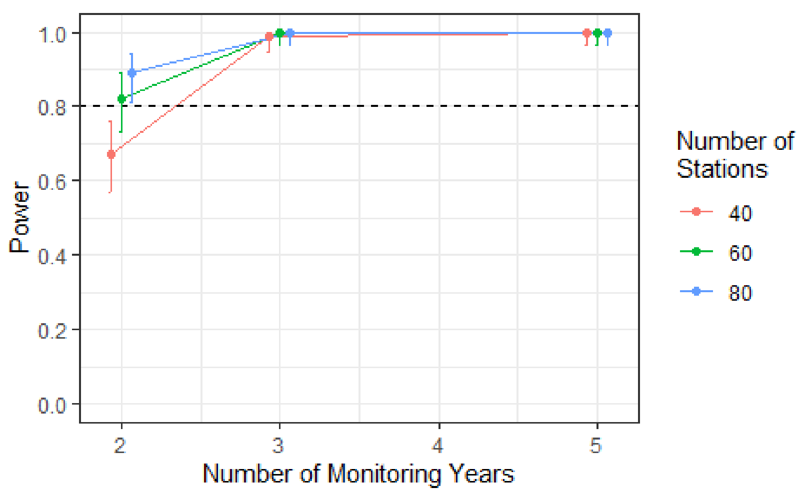

Figure 7-1. Predicted Power to Detect -20% Change in Mean Survey Species Richness.

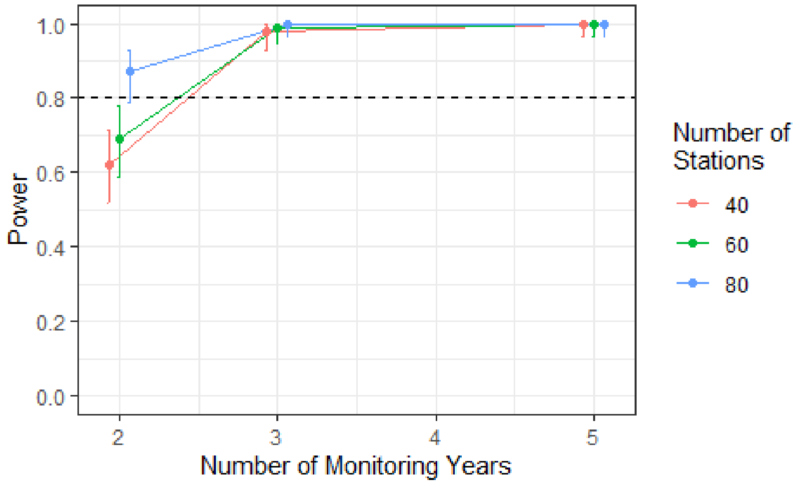

Figure 7-2. Predicted Power to Detect -20% Change in Mean Survey Abundance.

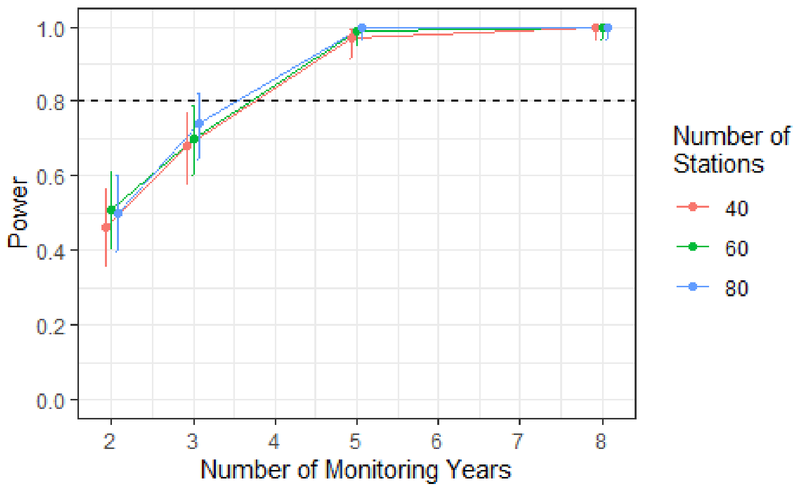

Figure 7-3. Predicted Power to Detect -20% Change in Density of Magnolia Warbler.

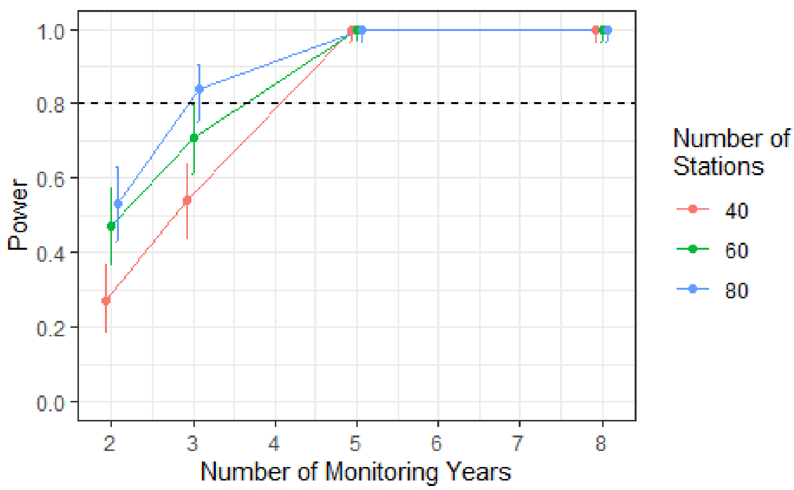

Figure 7-4. Predicted Power to Detect -20% Change in Density of Swainson's Thrush.

TETRA TECH

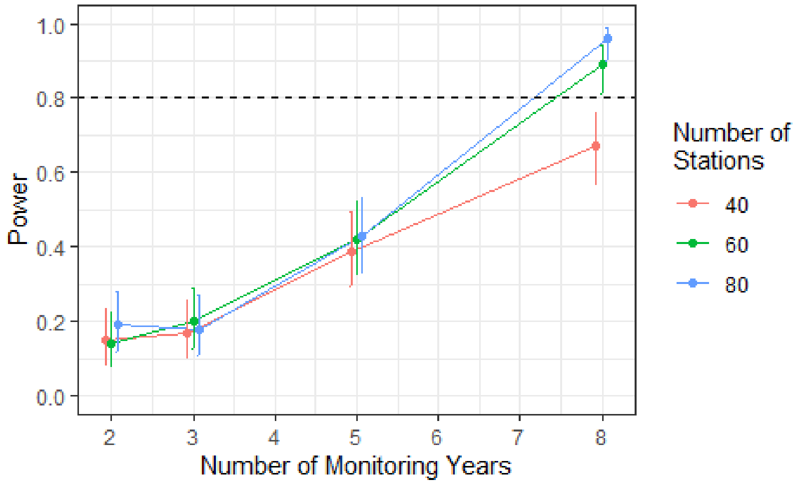

Figure 7-5. Predicted Power to Detect -20% Change in Density of Ovenbird.

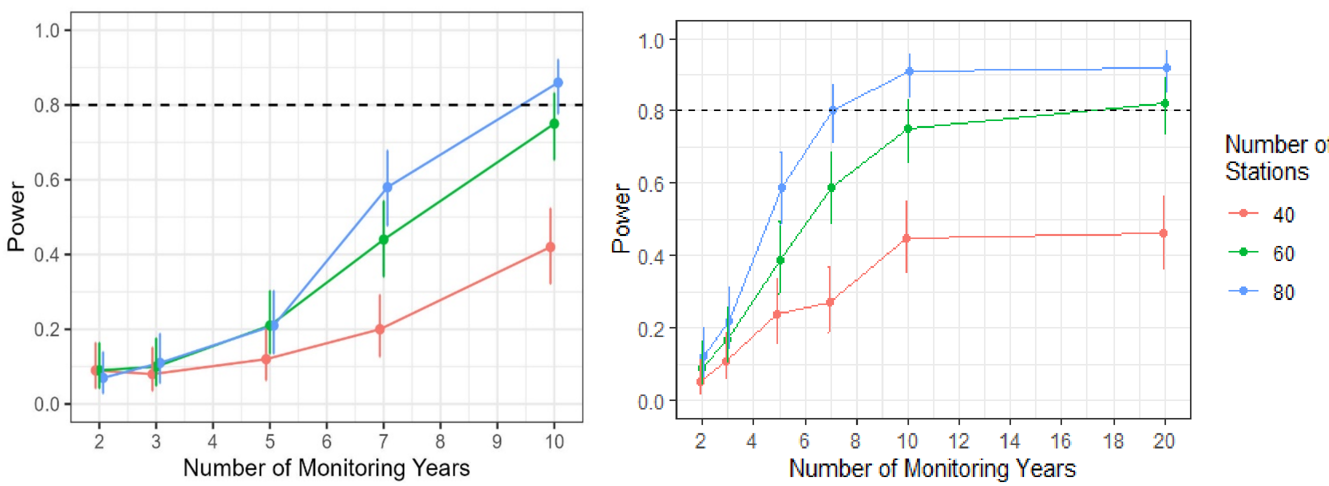

Figure 7-6. Power to Detect -20% Change (left) and -50% Change (right) in Density of Least Flycatcher.

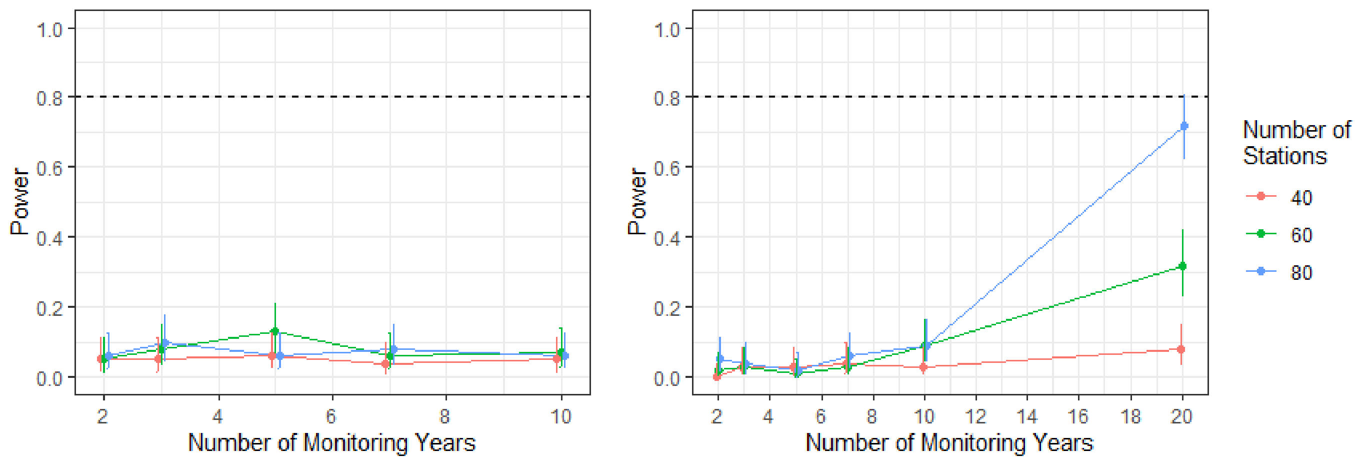

Figure 7-7. Power to Detect -20% Change (left) and -50% Change (right) in Density of Olive-Sided Flycatcher.

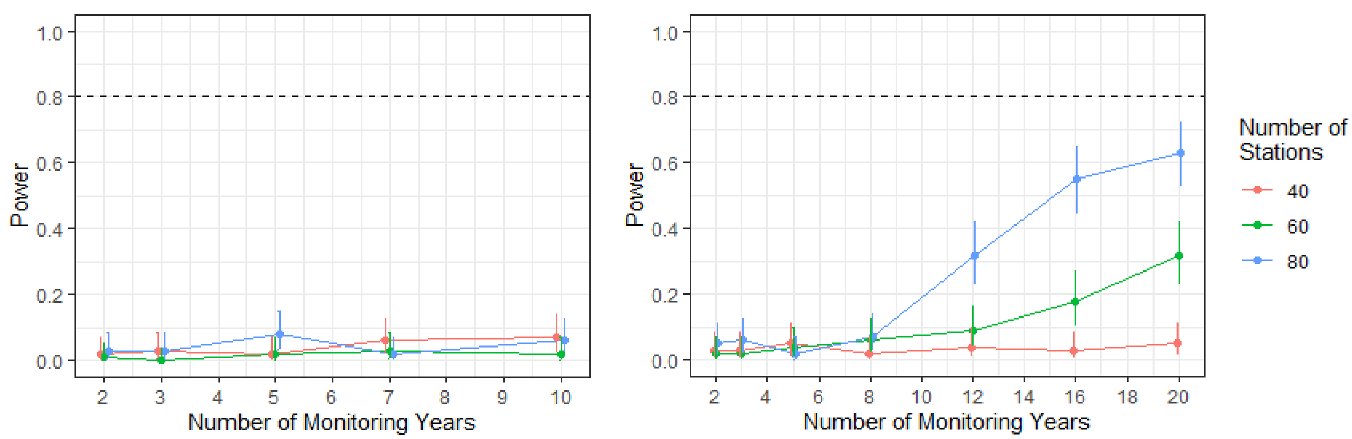

Figure 7-8. Power to Detect -20% Change (left) and -50% Change (right) in Density of Canada Warbler.

8.0 SPECIES AT RISK OCCURRENCE

8.1 Detected During Surveys

8.1.1 Common Nighthawk

Sixty-two percent of the ARU survey stations (58 stations) detected Common Nighthawk. Human listening identified 33 individual Common Nighthawks at 27 survey stations. Common Nighthawk were detected at 21 additional survey stations using the computer-automated recognizer (Table 3-1; relative abundance was not measured by the recognizer). Two thirds of the stations (17) recorded a single individual and one third recorded two individuals together (8). Territories are known to vary in size depending on habitat suitability and nest site availability, ranging from <1 to 28 hectares (Environment Canada 2016). Nine survey stations recorded wingbooms indicating breeding males marking their territories (Roth & Jones 2000). Common Nighthawk were present at stations throughout the boreal forest zone (Figure A-1). Thirty-two percent of detections were between KP 39-63 and 34% between KP 112-143. In addition, a single survey station at KP 7 along Prairie Creek also detected Common Nighthawk. Individuals were detected in a variety of habitats, though most-commonly detected in open/sparse coniferous forests (25%) and shrub habitats (14%).

8.1.2 Olive-sided Flycatcher

Olive-sided flycatcher were detected at nine stations in 15 surveys using human listening and two additional stations using automated recognition (14.1% of all stations; Table 3-1). All surveys recorded only one individual vocalizing during the same survey. Olive-sided Flycatchers inhabit open coniferous forests (Altman and Sallabanks 2012). The dominant habitat at stations detecting Olive-sided Flycatchers was open coniferous forest (55.6%; Figure A-1).

8.1.3 Bank Swallow

Bank swallows are found along lakes and rivers with steep banks and in open areas such as meadows (Fisher and Acorn 1998, Sibley 2016). Three Bank Swallows were detected, one individual each at three ARU survey stations (detected at 3.8% of all survey stations; Table 3-1). The surveys stations were in three different habitat types: exposed land, treed/shrub wetland, and open coniferous forest. Stations at CZN-057-092 and CZN-095-153 were near open water (a polje and Fishtrap Creek), but station CZN-112-180 was not (Appendix A, Figure A-1). No Bank Swallows were detected at the survey stations near the Liard River.

8.1.4 Evening Grosbeak

Evening Grosbeak was detected at one location along Sundog Creek (CZN-039-063) in open grassland/shrubland habitat with coniferous forest nearby. Breeding habitat for Evening Grosbeak generally includes open, mature mixed forests, where fir species and/or white spruce are dominant, and spruce budworm is abundant. (COSEWIC 2016).

8.1.5 Canada Warbler

Canada Warbler were detected at nine survey stations using human listening and two additional stations using automated recognition (14.1% of all stations; Table 3-1). Three stations recorded two individuals vocalizing during the same survey. When repeated detections at the same survey station are accounted for, a conservative estimate of the number of individual Canada Warblers detected is 14 across all stations. Canada Warbler is typically found in mixed and deciduous forest with shrubby understory (Fisher and Acorn 1998, Sibley 2016). This species was detected at all three survey stations deployed in the Silent Hills (KP 100), an extensive area of deciduous forest, as well as near Tall Shrub habitats along the eastern slopes of the Nahanni Range from KP 140 to the Liard River (Appendix A, Figure A-2).

8.2 Present in Region, Not Detected During Surveys

The following are species at risk that are known to or expected to occur in the region but were not detected during surveys.

8.2.1 Horned Grebe

Horned Grebes are typically found in wetlands, ponds, and lakes in the boreal forest zone (Fisher and Acorn 1998, Sibley 2016). Yip et al. (2017) report Wildlife Acoustics SM3 ARU models can detect 4 kilohertz (kHz) calls (estimated calling frequency of Horned Grebes; Stedman 2018) at 388 m distance in coniferous habitat. All graminoid and shrub wetlands and 53% of waterbodies within 388 m of the proposed all-season road were assumed to be sampled by the ARUs. No Horned Grebe were detected at any ARU survey station, including the 14 ARUs placed within 388 m of suitable habitat (Figure 1; Table 2).

8.2.2 Yellow Rail

Yellow Rail are typically found in sedge marshes and some grassy meadows (Fisher and Acorn 1998, Sibley 2016). The effective ARU detection distance for the quiet and secretive Yellow Rail is ≤175 m (Drake et al 2016). All graminoid and shrub wetlands and 63% of waterbodies within 175 m of the proposed all-season road were assumed to be sampled by the ARUs. No Yellow Rails were detected at any of the ARUs, including the 10 ARU survey stations within 175 m of suitable habitat (Figure 1; Table 2). Though present on the landscape, wetlands and waterbodies represent only a small fraction of available habitat along the proposed all-season road.

8.2.3 Red-necked Phalarope

Red-necked Phalaropes are typically found in ponds and large sloughs during the breeding season (Fisher and Acorn 1998, Sibley 2016). Red-necked Phalarope vocalizations are typically between 1-5 kHz (Rubega et al. 2000). According to Yip *et al*. (2017), a Wildlife Acoustics SM3 ARU can detect a 5 kHz call from 313 m away in coniferous habitat. All graminoid and shrub wetlands and 63% of waterbodies within 313 m of the road were assumed to be sampled by the ARUs. No Red-necked Phalaropes were detected at any ARU survey stations, including the 14 placed within 313 m of wetlands and waterbodies (Figure 1; Table 2).

8.2.4 Short-eared Owl

Short-eared Owls hunt over grasslands, fields, and marshes, and nest on the ground, often in tall grass or under small shrubs (Environment Canada 2018, Fisher and Acorn 1998, Sibley 2016). Open habitat types (e.g. low shrub, herb, bryoid) suitable for Short-eared Owl nesting and hunting are available however they are scattered in patches of open habitat within a forest-dominated landscape (Figure 1). No Short-eared Owls were detected in this study. Short-eared Owls are a relatively non-vocal species, and no computer-automated recognizer was available, limiting the detection potential for this species along the proposed all-season road.

8.2.5 Barn Swallow

Like Bank Swallows, Barn Swallows feed over rivers and in open meadows, though they also feed over marshes and prefer to nest in structures such as bridges and buildings (Fisher and Acorn 1998, Sibley 2016). No Barn Swallows were detected in the ARU recordings.

8.2.6 Rusty Blackbird

Rusty Blackbirds are typically found near ponds, bogs, and wetlands, and nest in spruce trees in the boreal forest (Fisher and Acorn 1998, Sibley 2016). Despite presence of a few waterbodies and wetlands along the proposed all-season road, no Rusty Blackbirds were detected.

9.0 CANADA WARBLER EFFECTS ASSESSMENT

Effects on Canada Warbler were not originally included in the DAR. Effects on Canada Warbler were assessed following the same methods outlined in the DAR and further described in an Information Request (April 2016). The assessment of effects considers the direction/magnitude, geographic extent, duration, frequency of occurrence, reversibility, and certainty of predicted effects.

Canada Warblers occupy cool, moist deciduous or mixed-wood forests with dense shrubby understories, often on steep slopes, and forested wetlands (COSEWIC 2008; Environment Canada 2016; Government of Northwest Territories 2013; Reitsma et al. 2009). Canada Warblers nest on or near the ground in wet, mossy areas with dense herb or shrub cover, often building the nest in fallen tree root masses, stumps, or moss hummocks (Reitsma et al. 2009). Of the four habitat types described along the proposed ASR, the density of Canada Warbler was estimated to be highest in deciduous forests. Though a new nest is typically built every year, nest site fidelity is known to occur (Reitsma et al. 2009).

Canada Warblers spend little time in their breeding range and are often the last warbler species to appear and the first to leave (Environment Canada 2016; Reitsma et al. 2009). Canada Warblers typically appear on their breeding range in late May or early June and depart for their overwintering grounds between mid-July and mid-September (Reitsma et al. 2009). The proposed ASR may interact with Canada Warbler during this 3.5-month period when the species is present.

Effects of Habitat Loss and Fragmentation

The proposed ASR alignment follows that of the 1980’s road, to the extent possible. However, construction of the proposed ASR and associated camps, borrow sources, and access roads will result in the direct loss and fragmentation of Canada Warbler habitat. Canada Warbler density was found to be highest in deciduous forest (Figure 4-37). The majority of deciduous forest occurs in the eastern portion of the ASR, from the Silent Hills (around KP 95) to the Nahanni Butte access road. The area of deciduous forest within the footprint is approximately 63 ha, representing 10% of the footprint total area. The proportion of deciduous forest in the region (within 10 km) is lower, at 5%. This pattern indicates that losses within the footprint may have a disproportionate effect on Canada Warbler habitat relative to the average of all other areas within 10 km of the ASR. The total loss of deciduous forest however is small (0.3% of the amount present in the region). The significance of effects with respect to habitat loss and fragmentation is considered low, and reversible once the road alignment regenerates.

Effects on Habitat Effectiveness

Habitat effectiveness refers to the ability or quality of the habitat to support Canada Warbler, and includes Project-related indirect habitat loss such as habitat alteration. Canada Warbler habitat depends on the following: dense deciduous shrub understories, complex forest floors (e.g., with downed trees, hummocks), availability of perch trees, and interior forests (i.e., not forest edges), and access to insect prey (Environment Canada 2016). In the western boreal forest, Canada Warbler are reported to be most abundant in old-growth deciduous stands and in stands with increasing canopy height and canopy cover (Hunt et al. 2017, Haché et al. 2014, and Ball et al. 2016).

Habitat composition, complexity, and the availability of perch trees will be lost within the footprint. The creation of a forest edge may decrease habitat effectiveness of adjacent areas, as some research suggests that Canada Warblers are not typically found in forest edge habitat (Environment Canada 2016), though this is refuted by other studies (Reitsma et al. 2009). For areas outside the footprint, the proposed ASR is considered to have an adverse, but low magnitude effect on habitat effectiveness within a small geographical extent and is reversible once the footprint regenerates to forest. The significance of potential changes to habitat effectiveness is considered low and reversible at Project closure.

Effects on Abundance and Occurrence

In the context of potential road-related effects, changes in abundance and occurrence is a measure of Canada Warbler's: 1) sensitivity to disturbance (i.e., avoidance behaviour); 2) vulnerability to road mortality; and, 3) available habitat and habitat quality. Clearing occurs in the winter when Canada Warbler are absent but road operations will occur throughout the year. Canada Warbler are relatively tolerant of human disturbances, even disturbances that are close to nest sites (Milosevich and Olson 1981), with the exception of activities that result in direct habitat loss (e.g., logging; Cooper et al. 1997).

Loss of Canada Warbler habitat may result in decreased abundance and occurrence. In a northern Alberta landscape, male Canada Warbler densities were found to decrease with increasing amounts of forest harvesting, and territorial males were less likely to have home ranges in postharvest than in unharvested stands (Hunt et al. 2017). Similar effects may be possible for the ASR, however the ASR is a linear corridor and Ball et. al (2016) reported little evidence that local-scale fragmentation (i.e., edges created by linear features) influenced Canada Warbler abundance.

Mitigation to minimize traffic-related disturbances (i.e., low traffic volumes, low traffic speeds) identified in the DAR, remain appropriate, as well as avoiding vegetation clearing when Canada Warbler are present in the breeding season. Potential Project-related effects to Canada Warbler abundance and occurrence are considered adverse but low in magnitude and geographic extent, moderate in duration and frequency, and readily reversible. Overall significance to abundance and occurrence effects are considered low.

Effects on Local Movement

Local movements are defined as daily movements to access available resources within a breeding territory. Canada Warblers may change their local movement patterns and behaviour by intense and chronic disturbances and habitat loss. Any changes to their movements are directly related to their tolerance to disturbances (as discussed above) and the intensity of Project-activities. Adverse effects of noise on birds have been well-described for highways (e.g., Halfwerk et al. 2011) and industrial environments (Bayne et al. 2008). The ASR will have low traffic volumes; Canada Warbler (where present) will be subjected to vehicle noise infrequently and for short duration. Potential effects to Canada Warbler local movements resulting from the proposed ASR are considered adverse but low in magnitude and geographic extent, moderate in duration and frequency, and readily reversible. The significance of effects on local movements is considered low.

Risk of Project-Related Mortality

The risk of Project-related mortality is dependent upon on the inherent behaviour of Canada Warbler, their abundance along the access road, and seasonal use of the surrounding area as well as traffic volumes and traffic speeds. Clearing occurs in the winter when Canada Warbler are absent and thus will not result in mortality. Traffic and equipment operations when Canada Warbler are present (roughly 3.5 month period) pose the greatest mortality risk. Mortality due to vehicle/equipment collisions is possible, but unlikely to occur since Canada Warbler may remain in forest interiors and thus few individuals are expected in the road right-of-way and traffic volume and speeds are low (60 km/hr speed limit). There is the possibility of higher rates of nest failure if Canada Warbler nest near the road but subsequently abandon an established nest containing either eggs or young due to disturbance; the magnitude and probability of this effect is not known. Mitigation already outlined in the DAR regarding low traffic speeds and volumes remain appropriate. Potential Project-related effects to Canada Warbler mortality are considered adverse but low in magnitude and frequency, local in geographic extent, moderate in duration, and readily reversible upon cessation of traffic. The overall significance is considered low.

Effects to Population Cycles

Canada Warblers are not known to undergo population cycles.

Effects on Predator-Prey Relationships

Species that nest on or near the ground, such as Canada Warbler, are particularly sensitive to nest predation from a number of predators, including Red Fox, Common Raven, and mustelids. Project-related activities that may attract nest predators (e.g., poor waste management and handling) have the potential to increase encounter and predation rates. Additionally, creation of the roadway itself may attract predators to hunt and travel along it. Mitigation already outlined in the DAR regarding adherence to a waste management plan, no littering, and no feeding wildlife policies remain appropriate for Canada Warbler. Potential effects to predator-prey relationships are adverse but low in magnitude, geographical extent, and frequency, moderate in duration, and reversible at Project closure.

Effects on Parasitic Relationships

The Brown-headed Cowbird (*Molothrus ater*) is known to parasitize Canada Warbler nests (Environment Canada 2016). Brown-headed Cowbirds were recorded at Yohin Lake in 1976, in Nahanni Butte in 2013, and in Nahanni National Park in 2001, 2002, and 2013 (eBird 2019). Brown-headed Cowbirds prefer open grassland and forest edges to extensive forest habitats (Lowther 1993). Although the proposed ASR frequently follows the existing 1980's winter alignment, a small amount of forest edge will be created within Canada Warbler habitat. Previous research has demonstrated an increase in severity of Brown-headed Cowbird parasitism in fragmented forests compared to extensive forests (Cooper et al. 1997). Therefore, construction of the proposed ASR may increase the probability of Brown-headed Cowbird parasitism on Canada Warbler nests. Potential effects to parasitic relationships are adverse but low in magnitude, geographical extent, and frequency, moderate in duration, and reversible at Project closure.

Effects on the Ability to Recover

Conservation of habitat deemed important for Canada Warbler is identified as a high priority in Environment Canada's recovery strategy for the species (Environment Canada 2016). The ASR will result in an incremental loss of suitable Canada Warbler habitat. The loss, however, is very small (0.3% of deciduous habitat in the region). The predicted effects on the ability of the species to recover are considered negative in direction, low in magnitude and geographical extent, and moderate in duration and frequency. The significance of the effect is predicted to be low.

The proposed ASR is predicted to have no residual effect on Canada Warbler. CZN committed to monitoring birds during operation of the proposed ASR to verify impact predictions.

10.0 MITIGATION RECOMMENDATIONS

Project effects and mitigations to avoid and minimize impacts to birds and bird habitat are described in the Developers Assessment Report and the Wildlife Management and Monitoring Plan and include strategies related to:

- Habitat loss and alteration;
- Wildlife mortality and harm; and,
- Wildlife disturbances (i.e., changes to local wildlife abundance, movement).

The ASR will result in the loss of high-quality habitat for some species. Avoidance of all high-quality bird habitat is impossible given the varying habitat requirements of different bird species and other wildlife. The main strategy to minimizing impacts to birds is minimization of the footprint, restoration of cleared areas as early as possible, dust suppression (if needed) to avoid degradation, and clearing outside the bird nesting period. No further modifications to the existing effects assessment and/or mitigations have been made based on the results of the 2017 bird survey. The results of the 2017 bird survey will support future monitoring of breeding bird species richness, relative abundance, and distribution during road operations.

11.0 CLOSURE

We trust this document meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully Submitted,
Tetra Tech Canada Inc.

Prepared by:
Jeff Matheson, M.Sc., P.Biol., R.P.Bio
Senior Biologist
Environment and Water Practice
Direct Line: 604.608.8908
Jeff.matheson@tetratech.com

Reviewed by:
Karla Langlois, B.Sc., P.Biol.
Biologist
Environment and Water Practice
Direct Line: 867.675.0254
Karla.Langlois@tetratech.com

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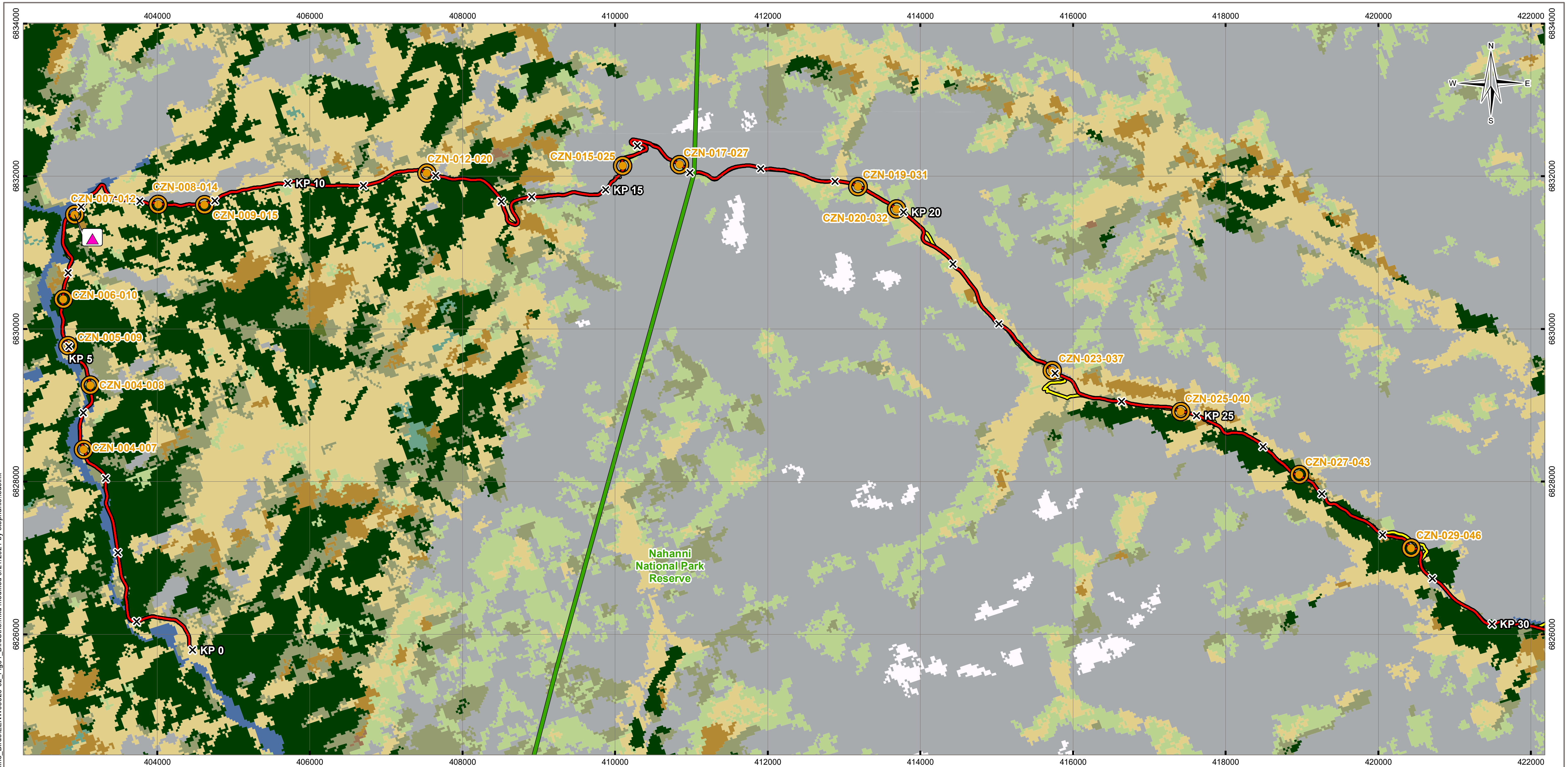
APPENDIX A

MAPS



LEGEND

- Bird Survey Station
- 100 m Detection Radius

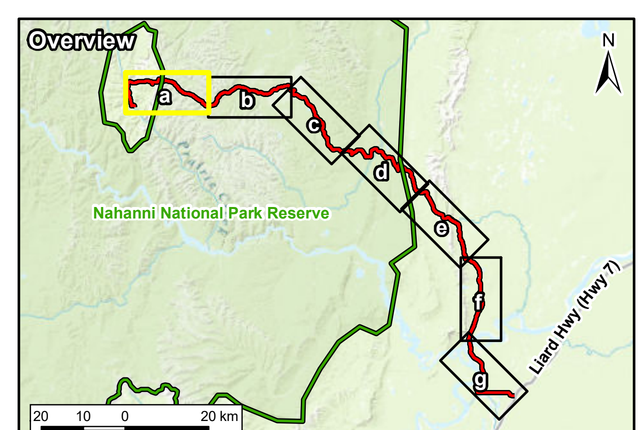
Species At Risk

- Bank Swallow
- Canada Warbler
- Common Nighthawk
- Evening Grosbeak
- Olive-sided Flycatcher
- Trumpeter Swan

- All-Season Road Kilometre Marker
- Proposed All-Season Road (June 2021)
- Proposed Pioneer Winter Road (Phase 1)[1]
- Nahanni National Park Reserve Boundary

Land Cover

- Temperate or sub-polar needleleaf forest
- Sub-polar taiga needleleaf forest
- Mixed forest
- Temperate or sub-polar shrubland
- Temperate or sub-polar grassland
- Sub-polar or polar shrubland-lichen-moss
- Sub-polar or polar grassland-lichen-moss
- Wetland
- Barren land
- Water
- Snow and ice



NOTES

1. Pioneer Winter Road only visible where it differs from the All-Season Road.

Base data sources:
2019 Kilometre Markers and 2021 Winter Road and All-Season Road alignments from AllNorth.
Land Cover from NALCMS 2010.
Nahanni National Park Reserve of Canada.

STATUS
ISSUED FOR USE

BIRDS BASELINE REPORT PRAIRIE CREEK ALL-SEASON ROAD

Bird Survey Stations

PROJECTION	DATUM
UTM Zone 10	NAD83

Scale: 1:50,000
1 0.5 0 1
Kilometres

CLIENT: CANADIAN ZINC CORPORATION

TETRA TECH

FILE NO.
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OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MRV	JM	0

DATE	PROJECT NO.
September 21, 2021	ENW.EENW03326-02

Figure 1a

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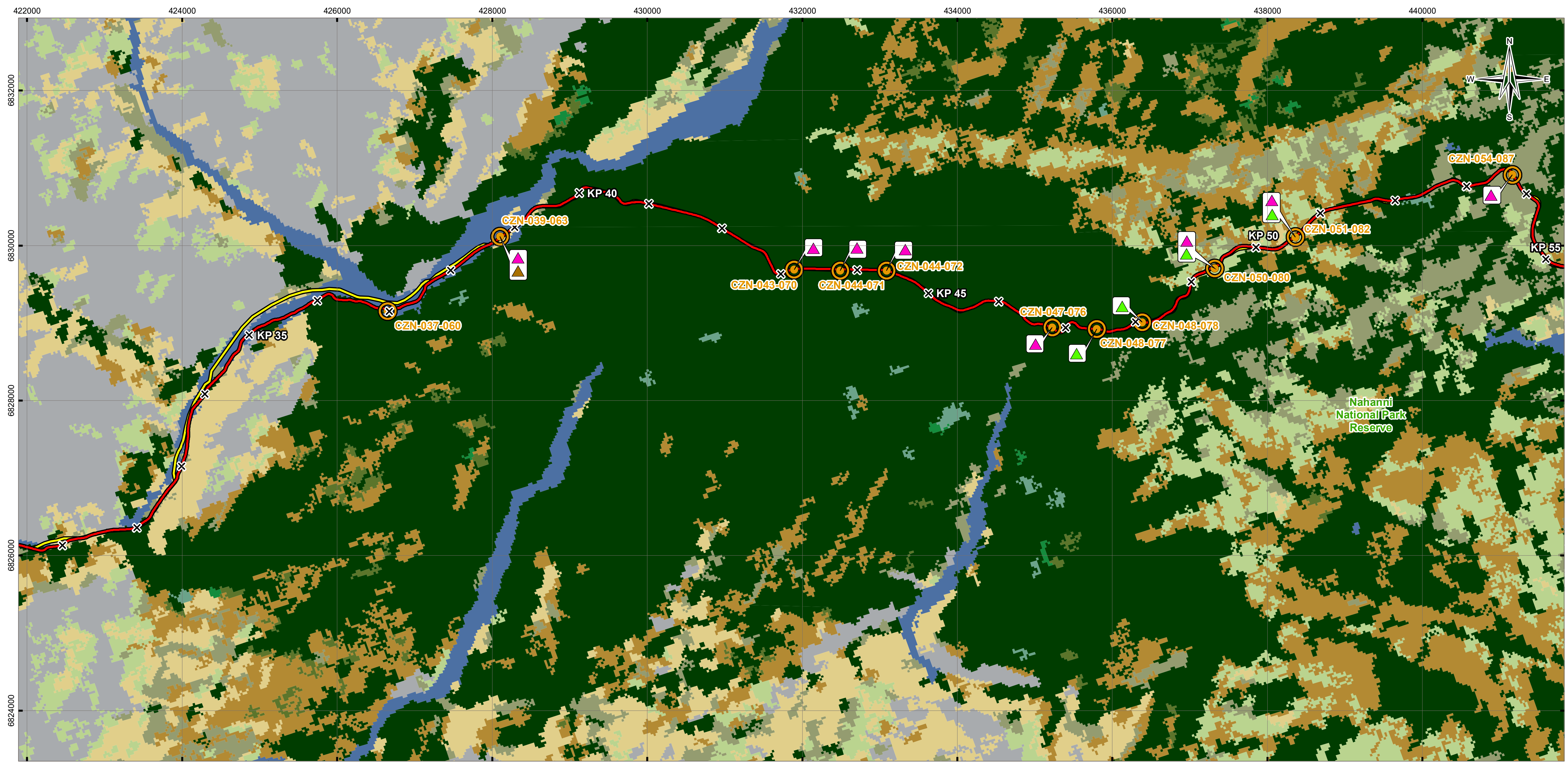

LEGEND

- Bird Survey Station
- 100 m Detection Radius

Species At Risk

- Bank Swallow
- Canada Warbler
- Common Nighthawk
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Land Cover

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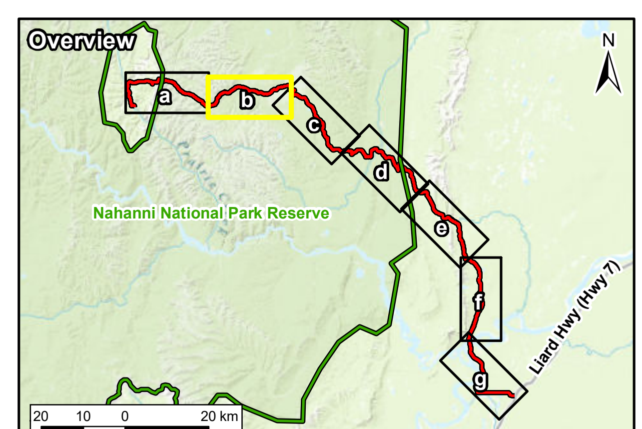
- Mixed forest
- Temperate or sub-polar shrubland
- Temperate or sub-polar grassland
- Sub-polar or polar grassland-lichen-moss
- Wetland
- Barren land
- Water



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Nahanni National Park Reserve of Canada.

STATUS
ISSUED FOR USE

BIRDS BASELINE REPORT PRAIRIE CREEK ALL-SEASON ROAD

Bird Survey Stations

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:50,000 (Kilometres)

FILE NO.
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OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MRV	JM	0

DATE	PROJECT NO.
September 21, 2021	ENW.EENW03326-02

TETRA TECH

Figure 1b

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LEGEND

- Bird Survey Station
- 100 m Detection Radius

Species At Risk

- Bank Swallow
- Canada Warbler
- Common Nighthawk
- Evening Grosbeak
- Olive-sided Flycatcher
- Trumpeter Swan

- All-Season Road Kilometre Marker
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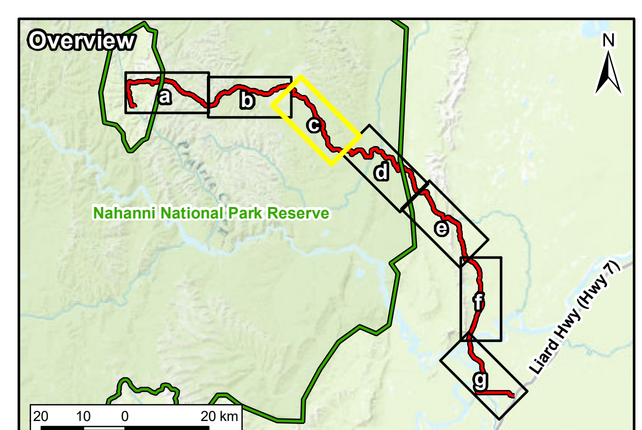
- Temperate or sub-polar grassland
- Sub-polar or polar grassland-lichen-moss
- Wetland
- Barren land
- Water



NOTES

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Base data sources:
2019 Kilometre Markers and 2021 Winter Road and All-Season Road alignments from AllNorth.
Land Cover from NALCMS 2010.
Nahanni National Park Reserve of Canada.

STATUS
ISSUED FOR USE

BIRDS BASELINE REPORT PRAIRIE CREEK ALL-SEASON ROAD

Bird Survey Stations

PROJECTION UTM Zone 10 | **DATUM** NAD83 | **CLIENT** CANADIAN ZINC CORPORATION

Scale: 1:50,000 (1 – 0.5 – 0 – 1 Kilometres)

FILE NO. EENW03326-02_Fig01_BirdStns.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MRV	JM	0

DATE September 21, 2021 | **PROJECT NO.** ENW.EENW03326-02

Figure 1c

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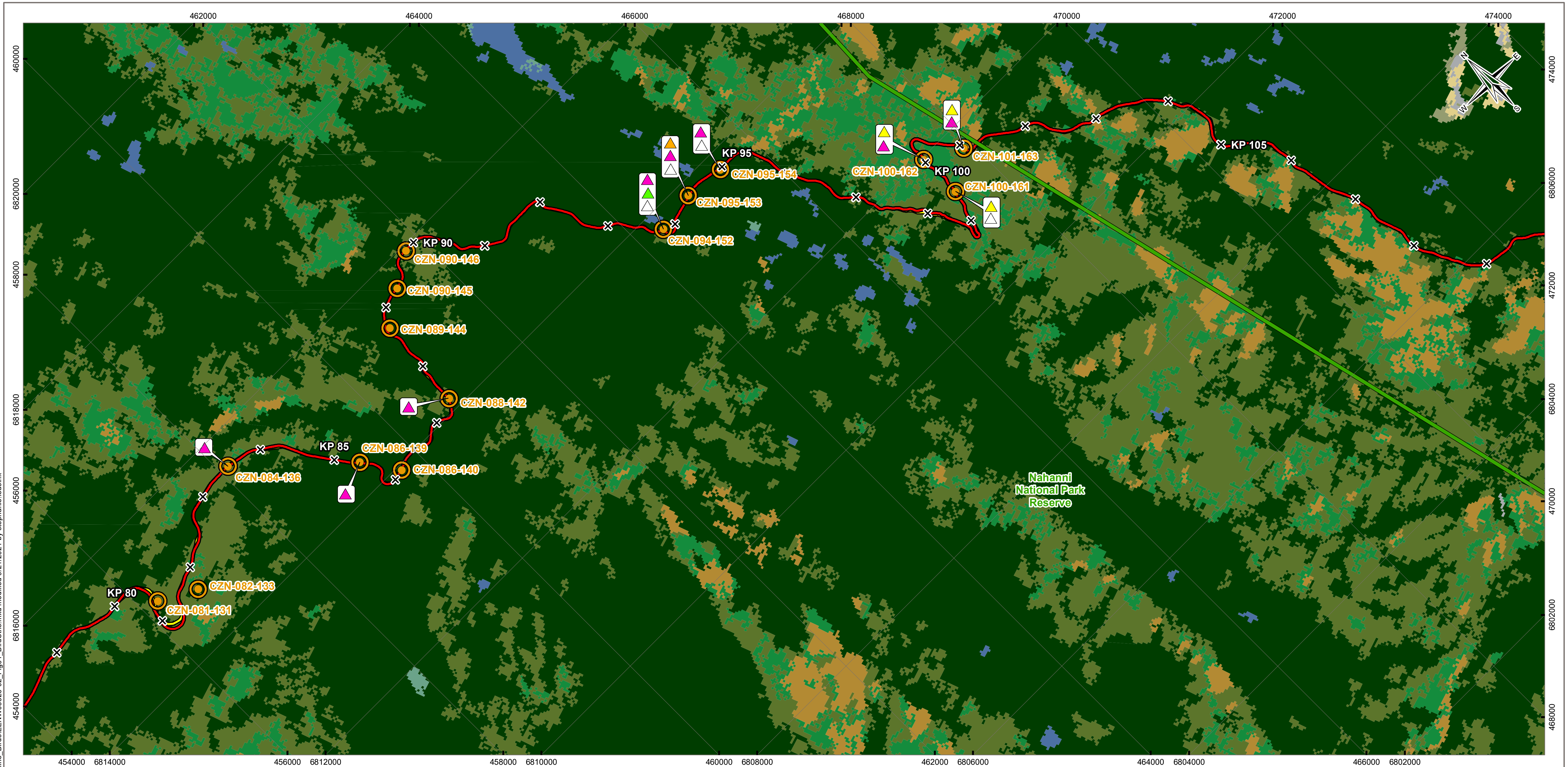

LEGEND

- Bird Survey Station
- 100 m Detection Radius

Species At Risk

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- Canada Warbler
- Common Nighthawk
- Evening Grosbeak
- Olive-sided Flycatcher
- Trumpeter Swan

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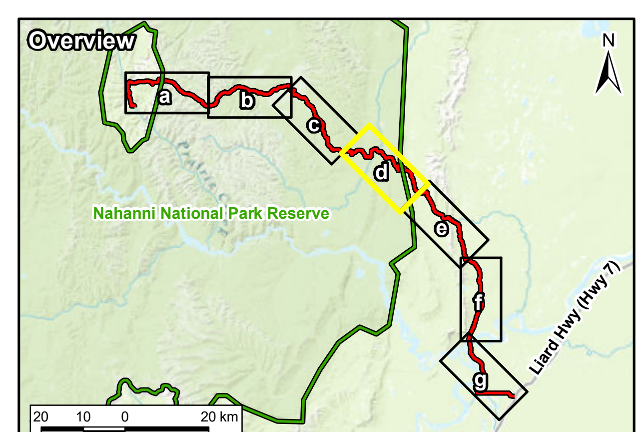
- Mixed forest
- Temperate or sub-polar shrubland
- Temperate or sub-polar grassland
- Wetland
- Barren land
- Water



NOTES

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Base data sources:
2019 Kilometre Markers and 2021 Winter Road and All-Season Road alignments from AllNorth.
Land Cover from NALCMS 2010.
Nahanni National Park Reserve of Canada.

STATUS
ISSUED FOR USE

BIRDS BASELINE REPORT PRAIRIE CREEK ALL-SEASON ROAD

Bird Survey Stations

PROJECTION UTM Zone 10 | **DATUM** NAD83 | **CLIENT** Canadian Zinc Corporation

Scale: 1:50,000 (Kilometres)

FILE NO. EENW03326-02_Fig01_BirdStns.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MRV	JM	0

DATE September 21, 2021 | **PROJECT NO.** ENW.EENW03326-02

TETRA TECH

Figure 1d

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LEGEND

- Bird Survey Station
- 100 m Detection Radius

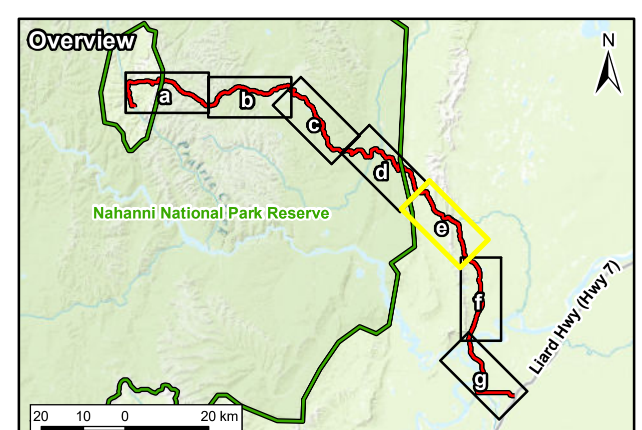
Species At Risk

- Bank Swallow
- Canada Warbler
- Common Nighthawk
- Evening Grosbeak
- Olive-sided Flycatcher
- Trumpeter Swan

- All-Season Road Kilometre Marker
- Proposed All-Season Road (June 2021)
- Proposed Pioneer Winter Road (Phase 1)[1]
- Nahanni National Park Reserve Boundary

Land Cover

- Temperate or sub-polar needleleaf forest
- Sub-polar taiga needleleaf forest
- Temperate or sub-polar broadleaf deciduous forest
- Mixed forest
- Temperate or sub-polar shrubland
- Temperate or sub-polar grassland
- Sub-polar or polar grassland-lichen-moss
- Wetland
- Barren land
- Water



NOTES

1. Pioneer Winter Road only visible where it differs from the All-Season Road.

Base data sources:
2019 Kilometre Markers and 2021 Winter Road and All-Season Road alignments from AllNorth.
Land Cover from NALCMS 2010.
Nahanni National Park Reserve of Canada.

STATUS
ISSUED FOR USE

BIRDS BASELINE REPORT
PRAIRIE CREEK ALL-SEASON ROAD

Bird Survey Stations

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:50,000 (Kilometres)

FILE NO.
EENW03326-02_Fig01_BirdStns.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MRV	JM	0

DATE	PROJECT NO.
September 21, 2021	ENW.EENW03326-02

TETRA TECH

Figure 1e

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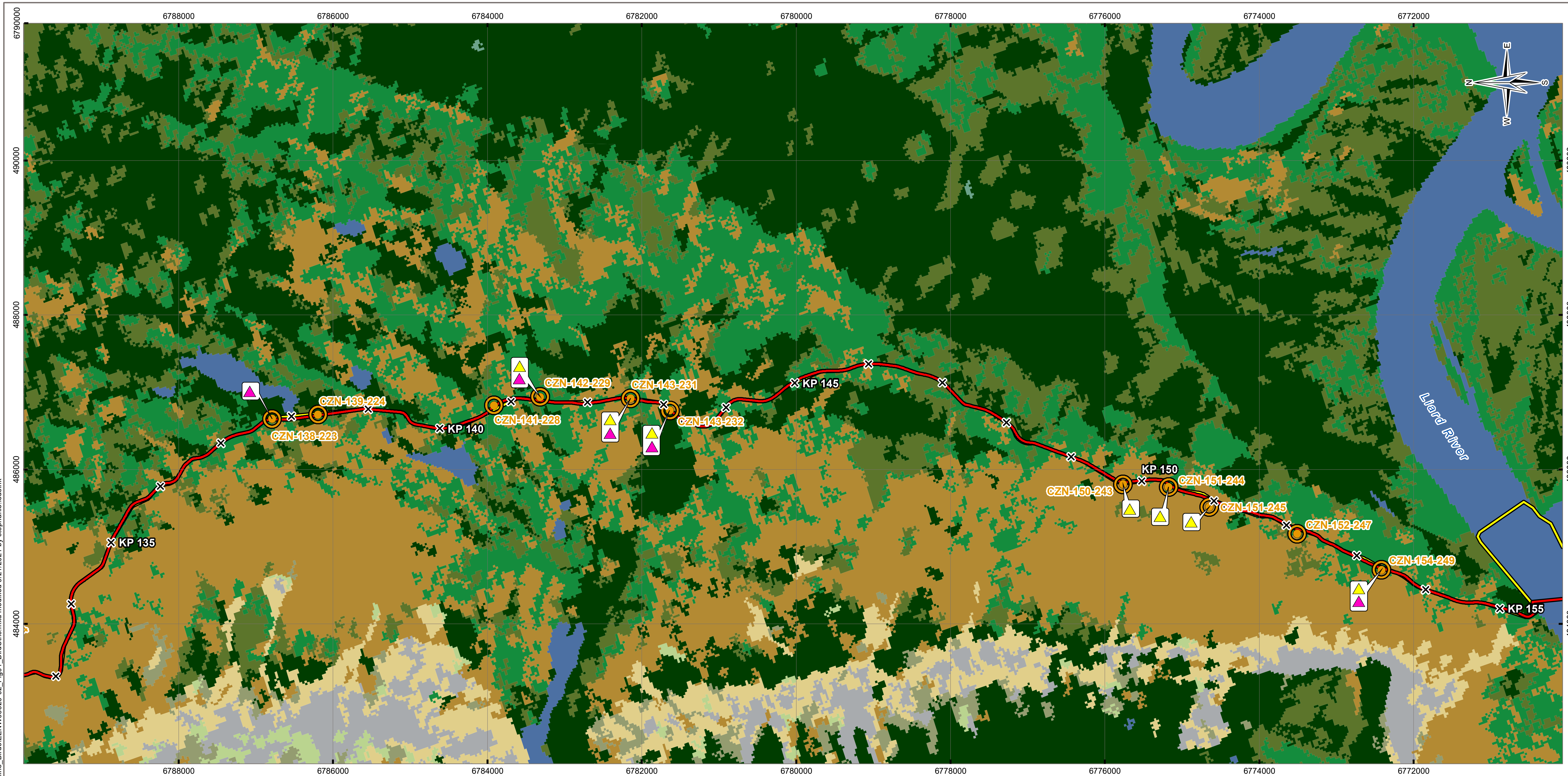

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LEGEND

- Bird Survey Station
- 100 m Detection Radius

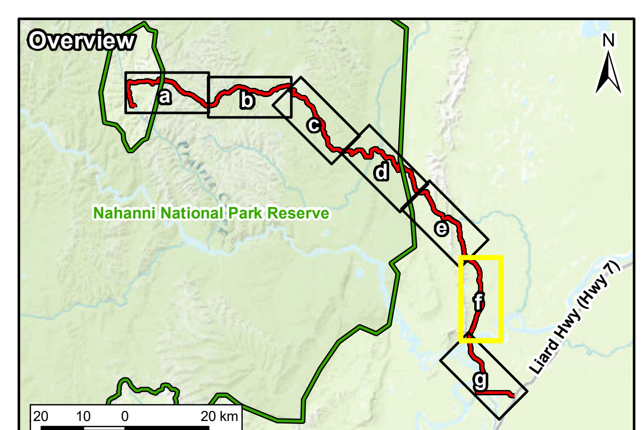
Species At Risk

- Bank Swallow
- Canada Warbler
- Common Nighthawk
- Evening Grosbeak
- Olive-sided Flycatcher
- Trumpeter Swan

- All-Season Road Kilometre Marker
- Proposed All-Season Road (June 2021)
- Proposed Pioneer Winter Road (Phase 1)[1]
- Nahanni National Park Reserve Boundary

Land Cover

- Temperate or sub-polar needleleaf forest
- Sub-polar taiga needleleaf forest
- Temperate or sub-polar broadleaf deciduous forest
- Mixed forest
- Temperate or sub-polar shrubland
- Temperate or sub-polar grassland
- Sub-polar or polar grassland-lichen-moss
- Wetland
- Barren land
- Water



NOTES

1. Pioneer Winter Road only visible where it differs from the All-Season Road.

Base data sources:
2019 Kilometre Markers and 2021 Winter Road and All-Season Road alignments from AllNorth.
Land Cover from NALCMS 2010.
Nahanni National Park Reserve of Canada.

STATUS
ISSUED FOR USE

BIRDS BASELINE REPORT PRAIRIE CREEK ALL-SEASON ROAD

Bird Survey Stations

PROJECTION UTM Zone 10				DATUM NAD83	CLIENT CANADIAN ZINC CORPORATION
Scale: 1:50,000 (1 0.5 0 1 Kilometres)					TETRA TECH
FILE NO. EENW03326-02_Fig01_BirdStns.mxd					
OFFICE Tt-VANC	DWN SL	CKD MRV	APVD JM	REV 0	**Figure 1f**
DATE September 21, 2021	PROJECT NO. ENW.EENW03326-02				

LEGEND

- Bird Survey Station
- 100 m Detection Radius

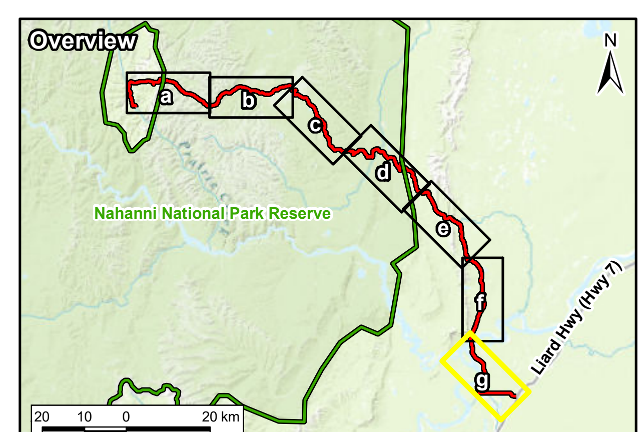
Species At Risk

- Bank Swallow
- Canada Warbler
- Common Nighthawk
- Evening Grosbeak
- Olive-sided Flycatcher
- Trumpeter Swan

- All-Season Road Kilometre Marker
- Proposed All-Season Road (June 2021)
- Proposed Pioneer Winter Road (Phase 1)[1]
- Nahanni National Park Reserve Boundary

Land Cover

- Temperate or sub-polar needleleaf forest
- Sub-polar taiga needleleaf forest
- Temperate or sub-polar broadleaf deciduous forest
- Mixed forest
- Temperate or sub-polar shrubland
- Temperate or sub-polar grassland
- Wetland
- Barren land
- Urban and built-up
- Water



NOTES

1. Pioneer Winter Road only visible where it differs from the All-Season Road.

Base data sources:
2019 Kilometre Markers and 2021 Winter Road and All-Season Road alignments from AllNorth.
Land Cover from NALCMS 2010.
Nahanni National Park Reserve of Canada.

STATUS
ISSUED FOR USE

BIRDS BASELINE REPORT
PRAIRIE CREEK ALL-SEASON ROAD

Bird Survey Stations

PROJECTION UTM Zone 10

DATUM NAD83

Scale: 1:50,000 (Kilometres)

CLIENT CANADIAN ZINC CORPORATION

TETRA TECH

FILE NO. EENW03326-02_Fig01_BirdStns.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	MRV	JM	0

DATE September 21, 2021

PROJECT NO. ENW.EENW03326-02

Figure 1g

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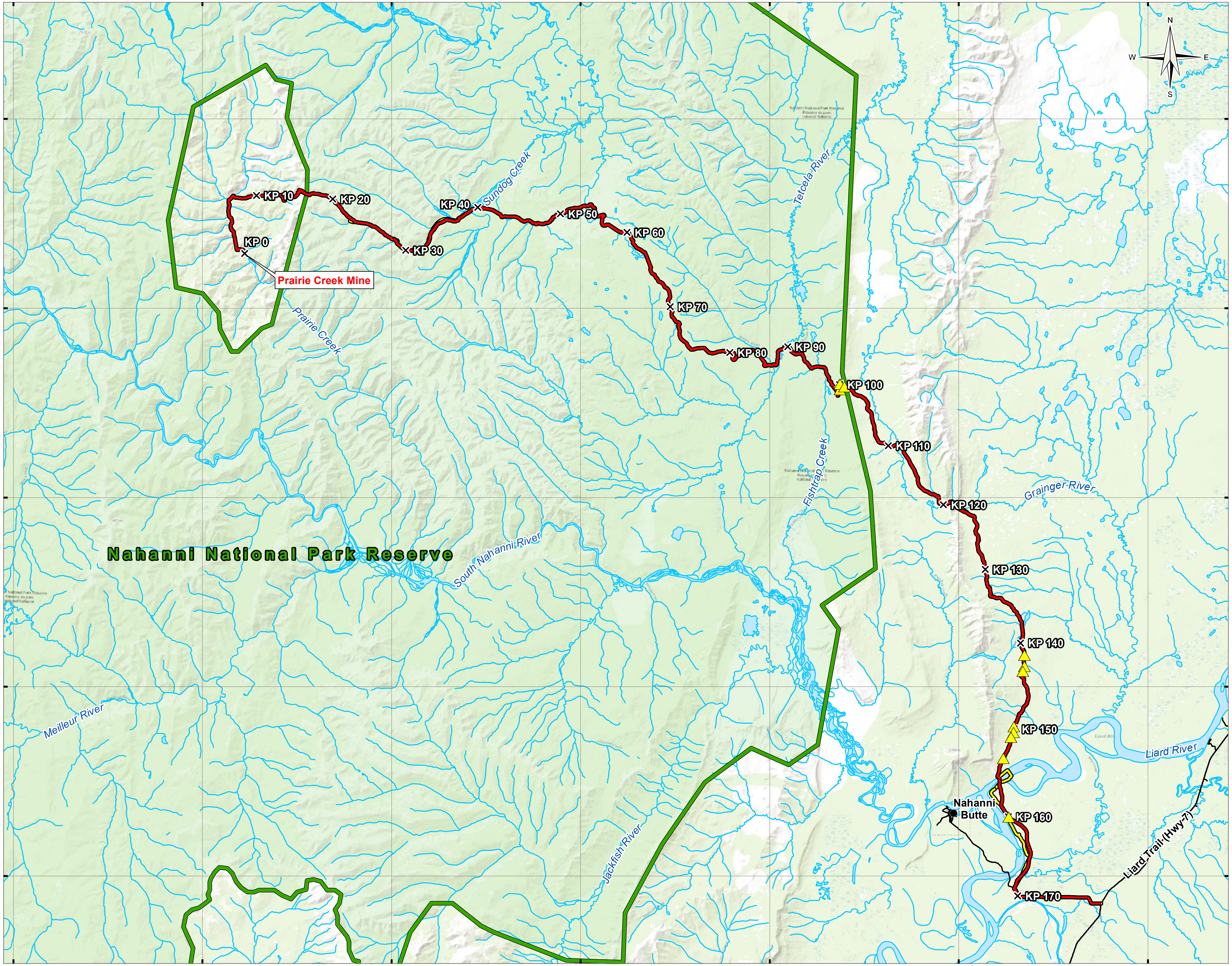

LEGEND

- Canada Warbler Observation
- All-Season Road Kilometre Marker
- Proposed All-Season Road (June 2021)
- Proposed Pioneer Winter Road (Phase 1)[1]

Base Data

- Community
- Existing Road
- Watercourse
- Waterbody
- Nahanni National Park Reserve Boundary

NOTES

1. Pioneer Winter Road only visible where it differs from the All-Season Road.

Base data source:
2019 Kilometre Markers and 2021 Winter Road and All-Season Road alignments from AllNorth.
Nahanni National Park Reserve of Canada
Existing roads from CanVec (1:50,000)
Watercourses from CanVec (1:250,000)

STATUS
ISSUED FOR USE

BIRDS BASELINE REPORT PRAIRIE CREEK ALL-SEASON ROAD

Canada Warbler Observations

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:400,000
5 2.5 0 5
Kilometres

FILE NO.
EENW03326-02_Fig02_Warblers.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	SL	YL	JM	0

DATE	PROJECT NO.
September 21, 2021	ENW.EENW03326-02

TETRA TECH

Figure 2

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APPENDIX B

ARU SITE DATA

Table B.1 List of ARU Survey Station Locations

Station	UTM Zone	UTM Easting	UTM Northing	Deployment Date	Retrieval Date	Observed Habitat at Station Centre	Dominant Habitat (Land Cover of Canada) Within 250m	Dominant Habitat (4-class) within 250m	Sub-Dominant Habitat (4-class) within 250m
004-007	10V	403035	6828420	2017-05-25	2017-08-12	Tall Shrub, Rock/Rubble	Grassland	Open	Open
004-008	10V	403122	6829264	2017-05-25	2017-08-12	Open coniferous/tall shrub	Sub-polar taiga needleleaf forest	Coniferous	-
005-009	10V	402831	6829781	2017-05-25	2017-08-12	Rock/Rubble, herb, open coniferous, dry stream bed	Grassland	Open	Coniferous
006-010	10V	402769	6830389	2017-05-25	2017-08-12	Open coniferous	Needleleaf forest	Coniferous	Coniferous
007-012	10V	402917	6831497	2017-05-25	2017-08-12	Shrub Low, Coniferous Sparse	Needleleaf forest	Coniferous	Open
008-014	10V	404012	6831632	2017-05-25	2017-08-12	Coniferous Sparse	Needleleaf forest	Coniferous	-
009-015	10V	404620	6831625	2017-05-25	2017-08-12	Coniferous Sparse	Needleleaf forest	Coniferous	-
012-020	10V	407531	6832040	2017-05-25	2017-08-12	Coniferous sparse, near river but slope steep	Grassland	Open	Coniferous
015-025	10V	410099	6832137	2017-05-25	2017-08-12	Herb	Barren Lands	Open	-
017-027	10V	410844	6832153	2017-05-25	2017-08-14	Herb	Barren Lands	Open	-
019-031	10V	413182	6831865	2017-05-25	2017-08-14	Low Shrub	Barren Lands	Open	-
020-032	10V	413687	6831570	2017-05-25	2017-08-14	Low Shrub	Grassland-lichen-moss	Open	-
023-037	10V	415727	6829455	2017-05-25	2017-08-14	Shrub Low	Grassland	Open	Coniferous
025-040	10V	417413	6828918	2017-05-25	2017-08-14	Shrub Low	Grassland	Open	-
027-043	10V	418966	6828091	2017-05-25	2017-08-15	Coniferous Open	Needleleaf forest	Coniferous	-
029-046	10V	420430	6827129	2017-05-25	2017-08-15	Coniferous Sparse	Needleleaf forest	Coniferous	-
037-060	10V	426651	6829154	2017-05-25	2017-08-15	Coniferous Open	Needleleaf forest	Coniferous	Coniferous
039-063	10V	428101	6830115	2017-05-25	2017-08-13	Exposed Land, Shrub Low	Grassland	Open	Coniferous
043-070	10V	431894	6829689	2017-05-24	2017-08-15	Coniferous Dense	Needleleaf forest	Coniferous	-
044-071	10V	432490	6829677	2017-05-24	2017-08-15	Coniferous Open	Needleleaf forest	Coniferous	-
044-072	10V	433088	6829677	2017-05-24	2017-08-15	Coniferous Open	Needleleaf forest	Coniferous	-
047-076	10V	435224	6828944	2017-05-24	2017-08-15	Coniferous Open	Needleleaf forest	Coniferous	-
048-077	10V	435799	6828923	2017-05-24	2017-08-15	Coniferous Open	Needleleaf forest	Coniferous	-
048-078	10V	436385	6829009	2017-05-24	2017-08-15	Coniferous Open, Wetland	Needleleaf forest	Coniferous	-

Station	UTM Zone	UTM Easting	UTM Northing	Deployment Date	Retrieval Date	Observed Habitat at Station Centre	Dominant Habitat (Land Cover of Canada) Within 250m	Dominant Habitat (4-class) within 250m	Sub-Dominant Habitat (4-class) within 250m
						- Shrub			
050-080	10V	437320	6829705	2017-05-24	2017-08-15	Shrub Tall	Shrubland	Shrubland	Coniferous
051-082	10V	438361	6830109	2017-05-24	2017-08-15	Shrub Tall	Shrubland	Shrubland	Open
054-087	10V	441160	6830912	2017-05-26	2017-08-08 to 2017-08-15	Coniferous Sparse, Shrub Low	Sub-polar taiga Needleleaf forest	Coniferous	-
057-092	10V	442245	6829161	2017-05-26	2017-08-08 to 2017-08-15	Coniferous Open, Shrub Tall	Needleleaf forest	Coniferous	-
058-094	10V	443127	6828702	2017-05-26	2017-08-08 to 2017-08-15	Coniferous Open, Shrub Low	Sub-polar taiga Needleleaf forest	Coniferous	Coniferous
059-095	10V	443622	6828367	2017-05-26	2017-08-08 to 2017-08-15	Coniferous Open	Sub-polar taiga Needleleaf forest	Coniferous	Coniferous
060-097	10V	444735	6828032	2017-05-26	2017-08-08 to 2017-08-15	Shrub Low	Sub-polar taiga Needleleaf forest	Coniferous	Open
062-100	10V	445695	6826677	2017-05-26	2017-08-08 to 2017-08-15	Coniferous Open, Exposed Land, Shrub Low	Needleleaf forest	Coniferous	-
062-101	10V	446129	6826279	2017-05-26	2017-08-08 to 2017-08-15	Coniferous Open, Shrub Low	Needleleaf forest	Coniferous	-
063-102	10V	446607	6825945	2017-05-26	2017-08-08 to 2017-08-15	Coniferous Open, Exposed Land, Shrub Low	Needleleaf forest	Coniferous	-
081-131	10V	456225	6814981	2017-05-26	Not retrieved	Coniferous Dense	Needleleaf forest	Coniferous	Mixed
082-133	10V	456708	6814716	2017-05-26	2017-08-08 to 2017-08-15	Coniferous Open	Mixed Forest	Mixed	Coniferous
084-136	10V	458124	6815578	2017-05-26	2017-08-08 to 2017-08-15	Mixedwood Dense	Mixed Forest	Mixed	Coniferous
086-139	10V	459383	6814393	2017-05-26	2017-08-08 to 2017-08-15	Coniferous Dense	Needleleaf forest	Coniferous	-
086-140	10V	459698	6813933	2017-05-26	2017-08-08 to 2017-08-15	Mixedwood Dense	Needleleaf forest	Coniferous	Coniferous
088-142	10V	460800	6814156	2017-05-26	2017-08-08 to 2017-08-15	Mixedwood Dense	Needleleaf forest	Coniferous	Coniferous
089-144	10V	460904	6815356	2017-05-27	2017-08-11	Coniferous Open	Needleleaf forest	Coniferous	-
090-145	10V	461340	6815657	2017-05-27	2017-08-11	Coniferous Dense	Needleleaf forest	Coniferous	Coniferous
090-146	10V	461769	6815923	2017-05-27	2017-08-08 to 2017-08-15	Mixedwood Dense	Mixed Forest	Mixed	Mixed
094-152	10V	464354	6813739	2017-05-27	2017-08-08 to 2017-08-15	Shrub Low, Wetland	Needleleaf forest	Coniferous	Coniferous
095-153	10V	464896	6813821	2017-05-27	2017-08-08 to 2017-08-15	Wetland, Coniferous	Needleleaf forest	Coniferous	-

Station	UTM Zone	UTM Easting	UTM Northing	Deployment Date	Retrieval Date	Observed Habitat at Station Centre	Dominant Habitat (Land Cover of Canada) Within 250m	Dominant Habitat (4-class) within 250m	Sub-Dominant Habitat (4-class) within 250m
095-154	10V	465434	6813763	2017-05-27	2017-08-08 to 2017-08-15	Wetland, Coniferous	Needleleaf forest	Coniferous	-
100-161	10V	467410	6811382	2017-05-27	2017-08-08 to 2017-08-15	Broadleaf open, Tall Shrub	Mixed Forest	Mixed	Deciduous
100-162	10V	467411	6811973	2017-05-27	2017-08-08 to 2017-08-15	Broadleaf Dense	Broadleaf deciduous	Deciduous	Mixed
101-163	10V	467887	6811706	2017-05-27	2017-08-08 to 2017-08-15	Broadleaf Dense	Mixed Forest	Mixed	Open
112-180	10V	473924	6805654	2017-05-27	2017-08-08 to 2017-08-15	Moss	Needleleaf forest	Coniferous	Deciduous
112-181	10V	474244	6805161	2017-05-27	2017-08-08 to 2017-08-15	Pine Moderately Open	Needleleaf forest	Coniferous	-
118-190	10V	476627	6800615	2017-05-27	2017-08-08 to 2017-08-15	Bryoids, Coniferous Dense	Needleleaf forest	Coniferous	Coniferous
118-191	10V	477159	6800340	2017-05-27	2017-08-08 to 2017-08-15	Mixedwood Open, Shrub Tall	Mixed Forest	Mixed	Deciduous
119-192	10V	477660	6800128	2017-05-27	2017-08-08 to 2017-08-15	Mixedwood Dense, Rock/Rubble, Shrub Tall	Mixed Forest	Mixed	Deciduous
122-196	10V	479371	6799509	2017-05-27	2017-08-10	Coniferous Sparse, Shrub Low	Shrubland	Shrubland	-
122-197	10V	479882	6799195	2017-05-27	2017-08-08 to 2017-08-15	Herb, Shrub Low	Shrubland	Shrubland	Open
123-198	10V	480336	6798819	2017-05-27	2017-08-08 to 2017-08-15	Herb, Shrub Low	Shrubland	Shrubland	Open
126-203	10V	481851	6796560	2017-05-28	2017-08-10	Shrub Tall	Shrubland	Shrubland	Mixed
126-204	10V	481946	6796021	2017-05-28	2017-08-08 to 2017-08-15	Shrub Tall	Shrubland	Shrubland	Coniferous
129-208	10V	482480	6793796	2017-05-28	2017-08-10	Low Shrub	Mixed Forest	Mixed	Deciduous
131-211	10V	482913	6792065	2017-05-28	2017-08-08 to 2017-08-15	Shrub Low, Shrub Tall, Wetland - Shrub	Shrubland	Shrubland	-
131-212	10V	482943	6791470	2017-05-28	2017-08-08 to 2017-08-15	Coniferous Open, Shrub Tall	Broadleaf deciduous	Deciduous	Open
132-214	10V	483269	6790371	2017-05-28	2017-08-11	Shrub Tall	Shrubland	Shrubland	Open
132-231	10V	483006	6790910	2017-05-28	2017-08-11	Coniferous Open, Shrub Low	Shrubland	Shrubland	Deciduous
138-223	10V	486655	6786790	2017-05-28	2017-08-11	Mixedwood Open	Mixed Forest	Mixed	Open
139-224	10V	486712	6786194	2017-05-28	2017-08-08 to 2017-08-15	Coniferous Open, Tall Shrub	Needleleaf forest	Coniferous	Open
141-228*	10V	486831	6783915	2017-05-28	2017-08-08 to	Broadleaf open	Broadleaf deciduous	Deciduous	Mixed

Station	UTM Zone	UTM Easting	UTM Northing	Deployment Date	Retrieval Date	Observed Habitat at Station Centre	Dominant Habitat (Land Cover of Canada) Within 250m	Dominant Habitat (4-class) within 250m	Sub-Dominant Habitat (4-class) within 250m
					2017-08-15				
142-229	10V	486941	6783317	2017-05-28	2017-08-08 to 2017-08-15	Broadleaf Dense	Broadleaf deciduous	Deciduous	Coniferous
143-231	10V	486921	6782146	2017-05-28	2017-08-08 to 2017-08-15	Broadleaf Dense, Broadleaf Open	Broadleaf deciduous	Deciduous	Mixed
143-232	10V	486765	6781636	2017-05-28	2017-08-08 to 2017-08-15	Broadleaf Dense	Broadleaf deciduous	Deciduous	Open
150-243	10V	485808	6775767	2017-05-29	2017-08-08 to 2017-08-15	Broadleaf Dense	Shrubland	Shrubland	Deciduous
151-244	10V	485774	6775175	2017-05-29	2017-08-10	Broadleaf Dense	Shrubland	Shrubland	Deciduous
151-245	10V	485516	6774648	2017-05-29	2017-08-10	Broadleaf Dense, Shrub Low	Shrubland	Shrubland	Open
152-247	10V	485168	6773510	2017-05-29	2017-08-10	Coniferous Open, Coniferous Sparse, Shrub Tall, Wetland - Shrub, Wetland - Treed	Shrubland	Shrubland	Deciduous
154-249	10V	484702	6772418	2017-05-29	2017-08-08	Broadleaf Dense, Wetland - Shrub	Broadleaf deciduous	Deciduous	Deciduous
159-258	10V	484626	6767206	2017-05-30	2017-08-09	Broadleaf Dense	Mixed Forest	Mixed	Deciduous
160-260	10V	485265	6766218	2017-05-30	2017-08-08	Broadleaf Dense	Broadleaf deciduous	Deciduous	Deciduous
162-262	10V	486260	6765540	2017-05-30	2017-08-08	Forest	Mixed Forest	Mixed	Mixed
163-265	10V	487183	6764270	2017-05-30	2017-08-08	Mixedwood Open	Needleleaf forest	Coniferous	Mixed
165-269	10V	487555	6762185	2017-05-30	2017-08-08	Coniferous Open, Wetland - Shrub	Needleleaf forest	Coniferous	Coniferous

* ARU at station 141-228 malfunctioned and no recordings were made.

APPENDIX C

DENSITY MODEL SUMMARIES

Table C.1 Summary of model estimates and parameters of the top habitat model for each species.

Species Code	Effect	Component	Group	Term	Estimate	Std. Error	Statistic	p-value
ALFL	fixed	cond	NA	(Intercept)	-5.769	0.888	-6.500	0.000
ALFL	fixed	cond	NA	HabitatDecid	1.404	1.285	1.093	0.274
ALFL	fixed	cond	NA	HabitatMixed	-18.341	6424.322	-0.003	0.998
ALFL	fixed	cond	NA	HabitatOpen	1.244	0.844	1.474	0.141
ALFL	ran_pars	cond	SiteStation	sd__(Intercept)	2.406	NA	NA	NA
AMRE	fixed	cond	NA	(Intercept)	-8.802	2.489	-3.536	0.000
AMRE	fixed	cond	NA	HabitatDecid	0.861	1.713	0.502	0.615
AMRE	fixed	cond	NA	HabitatMixed	0.624	1.656	0.377	0.706
AMRE	fixed	cond	NA	HabitatOpen	-0.413	1.561	-0.265	0.791
AMRE	fixed	cond	NA	xEasting	4.778	2.369	2.017	0.044
AMRE	ran_pars	cond	SiteStation	sd__(Intercept)	2.426	NA	NA	NA
AMRO	fixed	cond	NA	(Intercept)	-3.873	0.446	-8.678	0.000
AMRO	fixed	cond	NA	HabitatDecid	-1.082	1.026	-1.055	0.291
AMRO	fixed	cond	NA	HabitatMixed	-2.187	1.202	-1.820	0.069
AMRO	fixed	cond	NA	HabitatOpen	-0.574	0.588	-0.975	0.329
AMRO	ran_pars	cond	SiteStation	sd__(Intercept)	1.446	NA	NA	NA
BAWW	fixed	cond	NA	(Intercept)	-7.922	2.252	-3.519	0.000
BAWW	fixed	cond	NA	HabitatDecid	0.200	1.080	0.186	0.853
BAWW	fixed	cond	NA	HabitatMixed	0.155	1.154	0.134	0.893
BAWW	fixed	cond	NA	HabitatOpen	0.018	1.008	0.017	0.986
BAWW	fixed	cond	NA	xEasting	4.486	2.161	2.075	0.038
BAWW	ran_pars	cond	SiteStation	sd__(Intercept)	0.884	NA	NA	NA
BBWA	fixed	cond	NA	(Intercept)	-4.699	1.065	-4.414	0.000
BBWA	fixed	cond	NA	HabitatDecid	-1.566	1.345	-1.164	0.244
BBWA	fixed	cond	NA	HabitatMixed	-0.226	1.081	-0.209	0.834
BBWA	fixed	cond	NA	HabitatOpen	-2.500	1.269	-1.970	0.049
BBWA	fixed	cond	NA	xEasting	3.030	1.057	2.868	0.004
BBWA	ran_pars	cond	SiteStation	sd__(Intercept)	1.876	NA	NA	NA
CAWA	fixed	cond	NA	(Intercept)	-25.673	13921.679	-0.002	0.999
CAWA	fixed	cond	NA	HabitatDecid	23.307	13921.679	0.002	0.999
CAWA	fixed	cond	NA	HabitatMixed	21.104	13921.679	0.002	0.999
CAWA	fixed	cond	NA	HabitatOpen	20.826	13921.679	0.001	0.999
CAWA	ran_pars	cond	SiteStation	sd__(Intercept)	1.171	NA	NA	NA

Species Code	Effect	Component	Group	Term	Estimate	Std. Error	Statistic	p-value
CHSP	fixed	cond	NA	(Intercept)	-1.345	0.168	-8.021	0.000
CHSP	fixed	cond	NA	HabitatDecid	-2.439	0.686	-3.554	0.000
CHSP	fixed	cond	NA	HabitatMixed	-1.175	0.407	-2.884	0.004
CHSP	fixed	cond	NA	HabitatOpen	-1.145	0.287	-3.996	0.000
CHSP	ran_pars	cond	SiteStation	sd__(Intercept)	0.765	NA	NA	NA
COYE	fixed	cond	NA	(Intercept)	-4.949	0.634	-7.810	0.000
COYE	fixed	cond	NA	HabitatDecid	-1.466	1.059	-1.384	0.166
COYE	fixed	cond	NA	HabitatMixed	-0.678	0.892	-0.760	0.447
COYE	fixed	cond	NA	HabitatOpen	0.293	0.719	0.408	0.684
COYE	fixed	cond	NA	xEasting	1.879	0.550	3.415	0.001
COYE	ran_pars	cond	SiteStation	sd__(Intercept)	1.362	NA	NA	NA
DEJU	fixed	cond	NA	(Intercept)	-1.314	0.320	-4.102	0.000
DEJU	fixed	cond	NA	HabitatDecid	-20.099	5204.900	-0.004	0.997
DEJU	fixed	cond	NA	HabitatMixed	-1.659	0.642	-2.584	0.010
DEJU	fixed	cond	NA	HabitatOpen	-1.081	0.402	-2.687	0.007
DEJU	fixed	zi	NA	(Intercept)	-0.673	0.508	-1.325	0.185
DEJU	ran_pars	cond	SiteStation	sd__(Intercept)	1.071	NA	NA	NA
FOSP	fixed	cond	NA	(Intercept)	-8.171	1.611	-5.073	0.000
FOSP	fixed	cond	NA	HabitatDecid	3.040	1.560	1.949	0.051
FOSP	fixed	cond	NA	HabitatMixed	-17.631	15216.424	-0.001	0.999
FOSP	fixed	cond	NA	HabitatOpen	2.064	1.336	1.545	0.122
FOSP	ran_pars	cond	SiteStation	sd__(Intercept)	1.983	NA	NA	NA
GCTH	fixed	cond	NA	(Intercept)	-6.615	1.811	-3.652	0.000
GCTH	fixed	cond	NA	HabitatDecid	-0.801	1.960	-0.409	0.683
GCTH	fixed	cond	NA	HabitatMixed	-19.008	11073.404	-0.002	0.999
GCTH	fixed	cond	NA	HabitatOpen	-1.815	1.499	-1.211	0.226
GCTH	ran_pars	cond	SiteStation	sd__(Intercept)	3.391	NA	NA	NA
HETH	fixed	cond	NA	(Intercept)	-2.561	0.328	-7.815	0.000
HETH	fixed	cond	NA	HabitatDecid	-1.429	0.798	-1.790	0.074
HETH	fixed	cond	NA	HabitatMixed	-1.961	0.710	-2.761	0.006
HETH	fixed	cond	NA	HabitatOpen	-1.435	0.565	-2.541	0.011
HETH	fixed	cond	NA	xEasting	1.070	0.289	3.699	0.000
HETH	ran_pars	cond	SiteStation	sd__(Intercept)	1.493	NA	NA	NA
LCSP	fixed	cond	NA	(Intercept)	-9.999	2.327	-4.297	0.000
LCSP	fixed	cond	NA	HabitatDecid	-16.257	11692.461	-0.001	0.999
LCSP	fixed	cond	NA	HabitatMixed	0.419	3.043	0.138	0.890
LCSP	fixed	cond	NA	HabitatOpen	-0.065	2.325	-0.028	0.978
LCSP	ran_pars	cond	SiteStation	sd__(Intercept)	6.588	NA	NA	NA
LEFL	fixed	cond	NA	(Intercept)	-5.822	1.040	-5.598	0.000

Species Code	Effect	Component	Group	Term	Estimate	Std. Error	Statistic	p-value
LEFL	fixed	cond	NA	HabitatDecid	0.097	1.578	0.061	0.951
LEFL	fixed	cond	NA	HabitatMixed	2.406	1.103	2.182	0.029
LEFL	fixed	cond	NA	HabitatOpen	0.497	0.953	0.521	0.602
LEFL	ran_pars	cond	SiteStation	sd__(Intercept)	2.162	NA	NA	NA
LISP	fixed	cond	NA	(Intercept)	-2.860	0.458	-6.243	0.000
LISP	fixed	cond	NA	HabitatDecid	-1.576	1.020	-1.545	0.122
LISP	fixed	cond	NA	HabitatMixed	-2.170	0.972	-2.233	0.026
LISP	fixed	cond	NA	HabitatOpen	0.149	0.609	0.245	0.806
LISP	fixed	cond	NA	xEasting	1.220	0.318	3.838	0.000
LISP	ran_pars	cond	SiteStation	sd__(Intercept)	1.778	NA	NA	NA
MAWA	fixed	cond	NA	(Intercept)	-4.782	0.533	-8.979	0.000
MAWA	fixed	cond	NA	HabitatDecid	1.773	0.574	3.092	0.002
MAWA	fixed	cond	NA	HabitatMixed	0.899	0.604	1.489	0.137
MAWA	fixed	cond	NA	HabitatOpen	1.948	0.531	3.669	0.000
MAWA	fixed	cond	NA	xEasting	1.923	0.433	4.440	0.000
MAWA	ran_pars	cond	SiteStation	sd__(Intercept)	0.466	NA	NA	NA
NOWA	fixed	cond	NA	(Intercept)	-8.413	2.359	-3.566	0.000
NOWA	fixed	cond	NA	HabitatDecid	1.001	2.032	0.493	0.622
NOWA	fixed	cond	NA	HabitatMixed	-18.047	14157.458	-0.001	0.999
NOWA	fixed	cond	NA	HabitatOpen	0.214	1.465	0.146	0.884
NOWA	ran_pars	cond	SiteStation	sd__(Intercept)	3.789	NA	NA	NA
OCWA	fixed	cond	NA	(Intercept)	-7.841	1.750	-4.481	0.000
OCWA	fixed	cond	NA	HabitatDecid	-17.247	9901.413	-0.002	0.999
OCWA	fixed	cond	NA	HabitatMixed	-29.040	3155514.704	0.000	1.000
OCWA	fixed	cond	NA	HabitatOpen	-0.004	1.466	-0.003	0.998
OCWA	ran_pars	cond	SiteStation	sd__(Intercept)	5.199	NA	NA	NA
OSFL	fixed	cond	NA	(Intercept)	-8.501	2.062	-4.123	0.000
OSFL	fixed	cond	NA	HabitatDecid	-0.137	2.147	-0.064	0.949
OSFL	fixed	cond	NA	HabitatMixed	-18.554	13916.824	-0.001	0.999
OSFL	fixed	cond	NA	HabitatOpen	-0.190	1.427	-0.133	0.894
OSFL	ran_pars	cond	SiteStation	sd__(Intercept)	4.123	NA	NA	NA
OVEN	fixed	cond	NA	(Intercept)	-5.082	0.588	-8.643	0.000
OVEN	fixed	cond	NA	HabitatDecid	1.343	0.888	1.512	0.131
OVEN	fixed	cond	NA	HabitatMixed	1.951	0.733	2.661	0.008
OVEN	fixed	cond	NA	HabitatOpen	-0.642	0.858	-0.748	0.454
OVEN	fixed	cond	NA	xEasting	2.580	0.642	4.020	0.000
OVEN	ran_pars	cond	SiteStation	sd__(Intercept)	1.630	NA	NA	NA
PISI	fixed	cond	NA	(Intercept)	-2.228	0.408	-5.458	0.000
PISI	fixed	cond	NA	HabitatDecid	-0.957	1.138	-0.841	0.400

Species Code	Effect	Component	Group	Term	Estimate	Std. Error	Statistic	p-value
PISI	fixed	cond	NA	HabitatMixed	-0.503	0.853	-0.590	0.555
PISI	fixed	cond	NA	HabitatOpen	-0.494	0.731	-0.675	0.500
PISI	fixed	cond	NA	xEasting	0.202	0.379	0.533	0.594
PISI	ran_pars	cond	SiteStation	sd__(Intercept)	0.000	NA	NA	NA
RCKI	fixed	cond	NA	(Intercept)	-3.249	0.346	-9.397	0.000
RCKI	fixed	cond	NA	HabitatDecid	-1.450	0.816	-1.776	0.076
RCKI	fixed	cond	NA	HabitatMixed	-1.061	0.683	-1.555	0.120
RCKI	fixed	cond	NA	HabitatOpen	-1.363	0.557	-2.445	0.014
RCKI	fixed	cond	NA	xEasting	0.811	0.286	2.835	0.005
RCKI	ran_pars	cond	SiteStation	sd__(Intercept)	1.105	NA	NA	NA
REVI	fixed	cond	NA	(Intercept)	-6.943	1.148	-6.050	0.000
REVI	fixed	cond	NA	HabitatDecid	0.231	1.604	0.144	0.886
REVI	fixed	cond	NA	HabitatMixed	1.452	1.285	1.130	0.258
REVI	fixed	cond	NA	HabitatOpen	-2.311	1.756	-1.316	0.188
REVI	fixed	cond	NA	xEasting	1.846	1.023	1.804	0.071
REVI	ran_pars	cond	SiteStation	sd__(Intercept)	2.400	NA	NA	NA
RUGR	fixed	cond	NA	(Intercept)	-5.105	0.624	-8.185	0.000
RUGR	fixed	cond	NA	HabitatDecid	0.016	0.818	0.019	0.985
RUGR	fixed	cond	NA	HabitatMixed	-0.201	0.748	-0.269	0.788
RUGR	fixed	cond	NA	HabitatOpen	-1.730	0.843	-2.052	0.040
RUGR	fixed	cond	NA	xEasting	2.104	0.657	3.203	0.001
RUGR	ran_pars	cond	SiteStation	sd__(Intercept)	1.134	NA	NA	NA
SPSA	fixed	cond	NA	(Intercept)	-5.244	0.736	-7.126	0.000
SPSA	fixed	cond	NA	HabitatDecid	-22.125	56767.284	0.000	1.000
SPSA	fixed	cond	NA	HabitatMixed	-18.996	9998.515	-0.002	0.998
SPSA	fixed	cond	NA	HabitatOpen	0.763	0.725	1.053	0.292
SPSA	ran_pars	cond	SiteStation	sd__(Intercept)	1.512	NA	NA	NA
SWSP	fixed	cond	NA	(Intercept)	-8.554	1.790	-4.779	0.000
SWSP	fixed	cond	NA	HabitatDecid	-19.009	22252.494	-0.001	0.999
SWSP	fixed	cond	NA	HabitatMixed	-17.812	10378.347	-0.002	0.999
SWSP	fixed	cond	NA	HabitatOpen	-0.054	1.586	-0.034	0.973
SWSP	ran_pars	cond	SiteStation	sd__(Intercept)	5.307	NA	NA	NA
SWTH	fixed	cond	NA	(Intercept)	-0.445	0.145	-3.078	0.002
SWTH	fixed	cond	NA	HabitatDecid	-0.536	0.359	-1.494	0.135
SWTH	fixed	cond	NA	HabitatMixed	0.008	0.292	0.029	0.977
SWTH	fixed	cond	NA	HabitatOpen	-0.964	0.248	-3.882	0.000
SWTH	fixed	cond	NA	xEasting	0.673	0.123	5.484	0.000
SWTH	ran_pars	cond	SiteStation	sd__(Intercept)	0.722	NA	NA	NA
TEWA	fixed	cond	NA	(Intercept)	-0.635	0.167	-3.801	0.000

Species Code	Effect	Component	Group	Term	Estimate	Std. Error	Statistic	p-value
TEWA	fixed	cond	NA	HabitatDecid	-0.767	0.345	-2.223	0.026
TEWA	fixed	cond	NA	HabitatMixed	0.423	0.265	1.598	0.110
TEWA	fixed	cond	NA	HabitatOpen	-0.342	0.242	-1.409	0.159
TEWA	fixed	cond	NA	xEasting	1.053	0.139	7.602	0.000
TEWA	fixed	zi	NA	(Intercept)	-0.615	0.186	-3.312	0.001
TEWA	ran_pars	cond	SiteStation	sd__(Intercept)	0.563	NA	NA	NA
VATH	fixed	cond	NA	(Intercept)	-6.060	1.426	-4.249	0.000
VATH	fixed	cond	NA	HabitatDecid	-0.875	1.606	-0.545	0.586
VATH	fixed	cond	NA	HabitatMixed	-1.250	1.509	-0.828	0.407
VATH	fixed	cond	NA	HabitatOpen	-21.030	13607.803	-0.002	0.999
VATH	ran_pars	cond	SiteStation	sd__(Intercept)	2.273	NA	NA	NA
WAVI	fixed	cond	NA	(Intercept)	-6.134	1.105	-5.549	0.000
WAVI	fixed	cond	NA	HabitatDecid	0.342	1.459	0.234	0.815
WAVI	fixed	cond	NA	HabitatMixed	1.527	1.238	1.233	0.217
WAVI	fixed	cond	NA	HabitatOpen	0.653	1.215	0.537	0.591
WAVI	fixed	cond	NA	xEasting	1.229	0.641	1.918	0.055
WAVI	ran_pars	cond	SiteStation	sd__(Intercept)	1.172	NA	NA	NA
WCSP	fixed	cond	NA	(Intercept)	-7.199	1.167	-6.171	0.000
WCSP	fixed	cond	NA	HabitatDecid	-21.161	49087.958	0.000	1.000
WCSP	fixed	cond	NA	HabitatMixed	-17.742	7479.670	-0.002	0.998
WCSP	fixed	cond	NA	HabitatOpen	2.542	0.992	2.563	0.010
WCSP	ran_pars	cond	SiteStation	sd__(Intercept)	2.682	NA	NA	NA
WISN	fixed	cond	NA	(Intercept)	-9.566	1.972	-4.851	0.000
WISN	fixed	cond	NA	HabitatDecid	-23.899	278354.533	0.000	1.000
WISN	fixed	cond	NA	HabitatMixed	-18.251	14250.518	-0.001	0.999
WISN	fixed	cond	NA	HabitatOpen	-1.237	2.151	-0.575	0.565
WISN	ran_pars	cond	SiteStation	sd__(Intercept)	5.464	NA	NA	NA
WTSP	fixed	cond	NA	(Intercept)	-2.141	0.260	-8.239	0.000
WTSP	fixed	cond	NA	HabitatDecid	-0.071	0.591	-0.120	0.905
WTSP	fixed	cond	NA	HabitatMixed	-1.199	0.551	-2.175	0.030
WTSP	fixed	cond	NA	HabitatOpen	0.181	0.401	0.451	0.652
WTSP	fixed	cond	NA	xEasting	1.266	0.228	5.542	0.000
WTSP	ran_pars	cond	SiteStation	sd__(Intercept)	1.210	NA	NA	NA
WWCR	fixed	cond	NA	(Intercept)	-2.080	0.236	-8.826	0.000
WWCR	fixed	cond	NA	HabitatDecid	-1.304	1.027	-1.270	0.204
WWCR	fixed	cond	NA	HabitatMixed	-0.619	0.624	-0.992	0.321
WWCR	fixed	cond	NA	HabitatOpen	-1.835	0.624	-2.943	0.003
WWCR	ran_pars	cond	SiteStation	sd__(Intercept)	0.000	NA	NA	NA
YEWA	fixed	cond	NA	(Intercept)	-27.435	13726.582	-0.002	0.998

Species Code	Effect	Component	Group	Term	Estimate	Std. Error	Statistic	p-value
YEWA	fixed	cond	NA	HabitatDecid	19.276	13726.582	0.001	0.999
YEWA	fixed	cond	NA	HabitatMixed	-9.156	2318153.744	0.000	1.000
YEWA	fixed	cond	NA	HabitatOpen	19.237	13726.582	0.001	0.999
YEWA	ran_pars	cond	SiteStation	sd__(Intercept)	4.905	NA	NA	NA
YRWA	fixed	cond	NA	(Intercept)	-1.685	0.208	-8.119	0.000
YRWA	fixed	cond	NA	HabitatDecid	-0.908	0.566	-1.603	0.109
YRWA	fixed	cond	NA	HabitatMixed	-0.024	0.404	-0.059	0.953
YRWA	fixed	cond	NA	HabitatOpen	-0.966	0.342	-2.822	0.005
YRWA	ran_pars	cond	SiteStation	sd__(Intercept)	0.852	NA	NA	NA
YBFL	fixed	cond	NA	(Intercept)	-8.348	2.076	-4.021	0.000
YBFL	fixed	cond	NA	HabitatDecid	-17.349	12587.066	-0.001	0.999
YBFL	fixed	cond	NA	HabitatMixed	1.648	1.791	0.920	0.358
YBFL	fixed	cond	NA	HabitatOpen	0.835	1.635	0.511	0.610
YBFL	ran_pars	cond	SiteStation	sd__(Intercept)	4.337	NA	NA	NA

Table C.2 Goodness-of-fit of the top density model for each species.

Species Code	Marginal R^2	Conditional R^2	Station Incidence (n=78)	Sample Incidence (n=935)
SWTH	0.163	0.301	63	623
WTSP	0.136	0.264	49	385
TEWA	0.246	0.326	54	277
HETH	0.023	0.066	39	222
OVEN	0.699	0.896	30	177
CHSP	0.026	0.05	50	174
LISP	0.092	0.301	30	165
YRWA	0.008	0.034	47	133
DEJU	0.545	0.565	36	107
MAWA	0.152	0.158	27	90
ALFL	0.815	0.922	18	71
RCKI	0.001	0.004	27	60
AMRO	0.001	0.005	22	59
COYE	0.016	0.026	17	55
WCSP	0.914	1	13	44
AMRE	0.812	1	11	41
RUGR	0.006	0.007	18	37
LEFL	0.013	0.102	14	34
REVI	0.511	1	11	31
BBWA	0.741	1	12	27
OCWA	0.811	1	10	26
SWSP	0.688	1	8	26
WWCR	0.003	0.003	21	25
LCSP	0.359	1	5	22
GCTH	0.784	0.999	9	21
SPSA	0.036	0.037	12	18
WAVI	0.001	0.001	11	17
OSFL	0.71	0.998	9	15
CAWA	0.988	1	9	14
VATH	0.945	1	8	14
YEWA	0.831	1	5	14
YBFL	0.604	0.988	9	14
BAWW	0.063	0.066	10	14
FOSP	0.917	0.999	7	12
WISN	0.721	1	6	12
PISI	0.001	0.001	12	12
NOWA	0.739	0.998	7	11

APPENDIX D

SPECIES RICHNESS MODEL SUMMARY

Table D.1 Summary of model estimates and parameters of the top species richness habitat model.

Effect	Group	Term	Estimate	Std. Error	Statistic	P-value
fixed	NA	(Intercept)	0.925	0.103	8.973	0.000
fixed	NA	HabitatMixed	-0.364	0.168	-2.159	0.031
fixed	NA	HabitatDecid	-0.172	0.209	-0.823	0.411
fixed	NA	HabitatOpen	-0.069	0.135	-0.511	0.609
fixed	NA	xEasting	0.680	0.069	9.906	0.000
ran_pars	SiteStation	sd__(Intercept)	0.419038	NA	NA	NA
ran_pars	TSSR	sd__(Intercept)	0.242814	NA	NA	NA
ran_pars	JDAY	sd__(Intercept)	0.051029	NA	NA	NA

Table D.2 Goodness-of-fit of the top species richness habitat model.

Marginal R^2	Conditional R^2
0.407	0.641

APPENDIX E

COMPARISON OF MEAN SPECIES DENSITY

Table E-1. Estimated Mean Species Density (number per hectare) Within 100m of the Road and Within 10 km of the Road

Code	Common Name	Footprint and Area (Within 100 m of Road)		Region (Within 10 km of Road)		Relative Difference in Mean Density (Footprint and Area to Region)
		Density (#/ha)	95% Confidence Interval	Density (#/ha)	95% Confidence Interval	
ALFL	Alder Flycatcher	0.0093	0.0015-0.0638	0.0088	0.0015-0.0561	+5.0
AMRE	American Redstart	0.0001	0-0.0218	0.0001	0-0.0195	+6.5
AMRO	American Robin	0.0204	0.0075-0.0609	0.0215	0.0081-0.0613	-5.6
BAWW	Black-and-white Warbler	0.0003	0-0.0243	0.0003	0-0.0236	+1.1
BBWA	Bay-breasted Warbler	0.0019	0.0002-0.0201	0.0020	0.0002-0.0201	-5.5
CAWA	Canada Warbler	0.1241	0.0363-0.451	0.0872	0.0242-0.3356	+29.2
CHSP	Chipping Sparrow	0.1603	0.1092-0.2412	0.1719	0.1182-0.2544	-7.6
COYE	Common Yellowthroat	0.0100	0.0026-0.0395	0.0104	0.0028-0.0402	-4.2
DEJU	Dark-eyed Junco	0.1194	0.0607-0.2396	0.1294	0.0661-0.2576	-8.7
FOSP	Fox Sparrow	0.0028	0.0002-0.0444	0.0024	0.0002-0.0364	+15.1
GCTH	Gray-cheeked Thrush	0.0010	0-0.044	0.0011	0-0.0437	-6.1
HETH	Hermit Thrush	0.0439	0.0215-0.0938	0.0469	0.0233-0.0975	-7.2
LCSP	LeConte's Sparrow	0.0000	0-0.0066	0.0000	0-0.0065	-3.7
LEFL	Least Flycatcher	0.0059	0.0009-0.0438	0.0056	0.0008-0.0399	+5.9
LISP	Lincoln's Sparrow	0.0482	0.0188-0.1288	0.0509	0.02-0.1327	-5.4
MAWA	Magnolia Warbler	0.0243	0.0094-0.0627	0.0229	0.009-0.059	+5.1
NOWA	Northern Waterthrush	0.0004	0-0.0712	0.0004	0-0.0572	+5.1
OCWA	Orange-crowned Warbler	0.0002	0-0.0072	0.0002	0-0.0076	-7.2
OSFL	Olive-sided Flycatcher	0.0004	0-0.0285	0.0004	0-0.0267	-2.3
OVEN	Ovenbird	0.0106	0.0026-0.0455	0.0094	0.0024-0.0388	+11.5
PISI	Pine Siskin	0.0112	0.0042-0.0326	0.0115	0.0045-0.0318	-3.1
RCKI	Ruby-crowned Kinglet	0.0342	0.0158-0.0778	0.0362	0.0171-0.08	-6.4
REVI	Red-eyed Vireo	0.0018	0.0001-0.0275	0.0017	0.0001-0.024	+5.7
RUGR	Ruffed Grouse	0.0073	0.0018-0.0312	0.0073	0.0019-0.0299	+0.4

Code	Common Name	Footprint and Area (Within 100 m of Road)		Region (Within 10 km of Road)		Relative Difference in Mean Density (Footprint and Area to Region)
		Density (#/ha)	95% Confidence Interval	Density (#/ha)	95% Confidence Interval	
SPSA	Spotted Sandpiper	0.0071	0.0018-0.0275	0.0075	0.0019-0.0292	-5.3
SWSP	Swamp Sparrow	0.0011	0-0.0317	0.0012	0-0.0342	-9.6
SWTH	Swainson's Thrush	0.5880	0.4134-0.8462	0.5987	0.4271-0.847	-1.9
TEWA	Tennessee Warbler	0.4302	0.2931-0.6354	0.4367	0.3003-0.6379	-1.5
VATH	Varied Thrush	0.0027	0.0001-0.0517	0.0028	0.0002-0.0515	-5.8
WAVI	Warbling Vireo	0.0039	0.0006-0.0256	0.0037	0.0006-0.0246	+3.5
WCSP	White-crowned Sparrow	0.0066	0.0008-0.0549	0.0068	0.0008-0.0566	-2.5
WISN	Wilson's Snipe	0.0001	0-0.0076	0.0001	0-0.0082	-9.8
WTSP	White-throated Sparrow	0.2292	0.1244-0.4339	0.2324	0.1288-0.4278	-1.4
WWCR	White-winged Crossbill	0.0242	0.0134-0.051	0.0255	0.0145-0.0501	-5.7
YBFL	Yellow-bellied Flycatcher	0.0004	0-0.0299	0.0004	0-0.0293	+0.5
YEWA	Yellow Warbler	0.0001	0-0.0157	0.0001	0-0.0124	+8.4
YRWA	Yellow-rumped Warbler	0.1047	0.0631-0.179	0.1078	0.0663-0.1793	-3.1